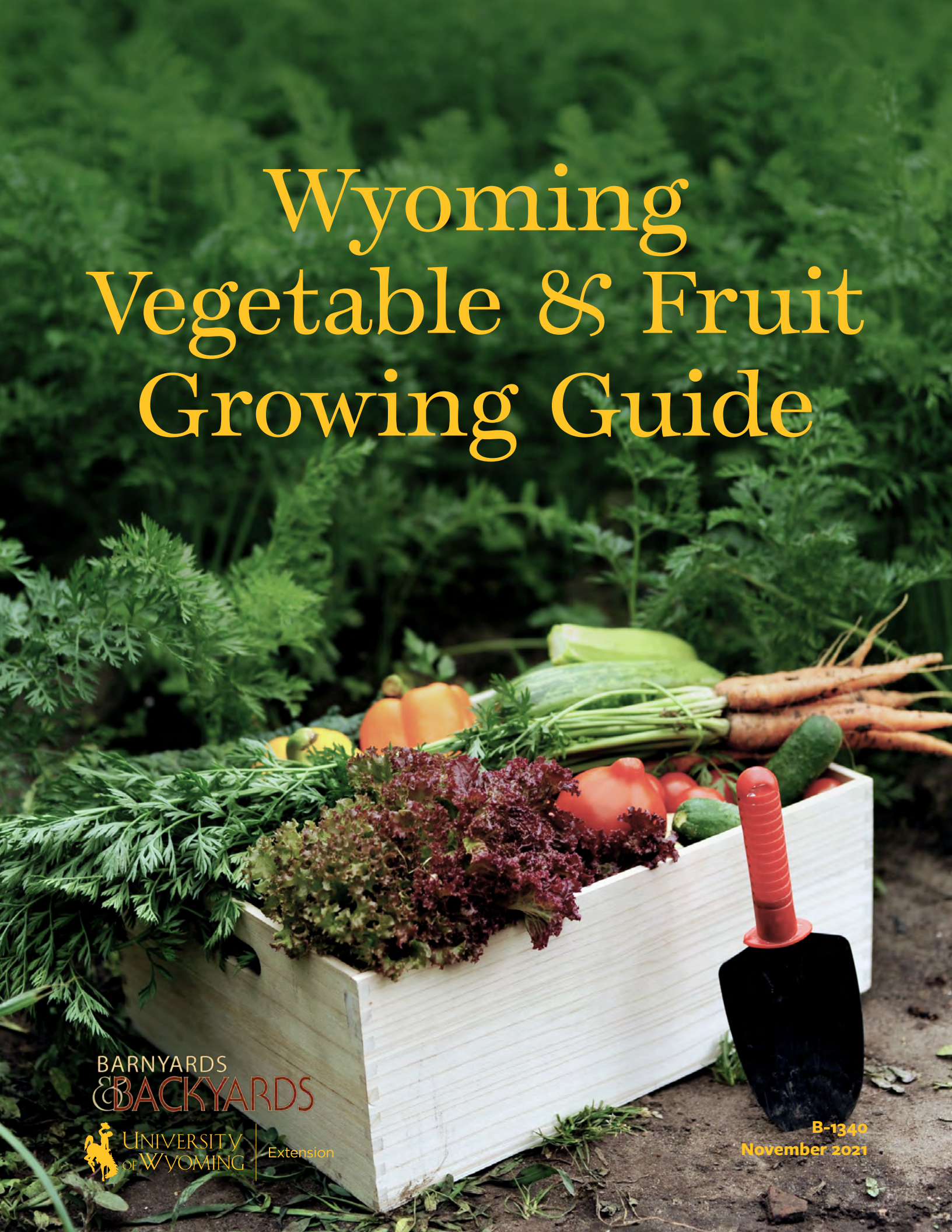
Wyoming Vegetable & Fruit Growing Guide



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UNIVERSITY OF WYOMING | Extension

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Authors
Brian Sebade, University of Wyoming Extension
Scott Schell, University of Wyoming Extension
Bill Stump, University of Wyoming Extension
Jenny Thompson, University of Wyoming Extension
Chris Hilgert, University of Wyoming Extension
Karen Panter, University of Wyoming Extension
Caitlin Youngquist, University of Wyoming Extension

Review and Additional Contributions
Jeremiah Vardiman, University of Wyoming Extension
Jeff Edwards, University of Wyoming Extension
Janet Milek
Donna Hoffman, University of Wyoming Extension

Acknowledgments
Wyoming Department of Agriculture–Specialty Crops Block Grant Program

Editors
Jenny Thompson, University of Wyoming Extension
Steve Miller, University of Wyoming Extension
Katie Shockley, University of Wyoming Extension

Designer
Tanya Engel, University of Wyoming Extension

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INTRODUCTION TO GROWING FRUITS AND VEGETABLES IN WYOMING

Growing fruits and vegetables can be a very rewarding experience; however, growing fruits, vegetables, and herbs can be challenging in many parts of Wyoming. This guide is our attempt to provide basic, Wyoming-centered information on various common issues in our state involving climate, water, soils, insects, diseases, and wildlife so if you are beginning or improving a vegetable or fruit growing effort, you will have the knowledge to help you succeed. The guide also provides the basics on particular crops and their possible insect or disease challenges to help you get started growing each crop and to help you troubleshoot. There is always something new to learn and new situations to deal with when growing edible crops. We hope this guide is a handy resource whether you are growing crops for sale or to feed family and friends. Be sure to visit our website at barnyardsandbackyards.com if you are looking for more information on these topics. You will find links to brief articles, publications, and videos on a wide variety of subjects. Happy growing!

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CHAPTER 1

POTENTIAL CHALLENGES

As mentioned in the introduction, growing edible crops in Wyoming can be a challenging experience in parts of the state. Some of the challenges include:

- Soil issues
- Water supply
- Short growing seasons
- Wildlife
- Pests
- Diseases, and
- In some areas, wind.

We briefly outline some of these challenges here for folks new to growing in Wyoming, not to discourage you, but to make you aware of some of the keys for successful growing. The more you know, the more likely you are to be successful. We will go into many of these issues in more detail later in the guide.

SOIL ISSUES

Soil is fundamental to success when growing food. If you haven't grown crops in an area before, sending a sample of your soil in for testing is a great way to determine what you have and if improvements are needed to successfully grow vegetables and fruits.

Vegetable crops and some fruit crops grow best in soils with good levels of organic matter. Unfortunately, many western soils don't contain much organic matter (which comes from decomposed plant material) because of our short growing seasons and scarce rainfall. These conditions aren't favorable to the growth of an abundance of vegetation that will die down and create organic matter over time. Many areas have organic matter levels of 1 percent or less.

Low fertility, low water retention, compaction, and poor drainage are common problems we see in

Wyoming soils. Organic matter helps address these issues. As organic materials degrade during the growing season, they release valuable nutrients plants can utilize. If the soil is heavy clay, adding organic matter (such as compost) loosens the soil, which helps relieve compaction problems and improves drainage. Soil structure is improved. Many organic materials retain significant amounts of water and improve moisture-holding capacity in very sandy soils. Organic matter is truly a wonder material for soil. See the Soils section, page 13, of this guide for more information to determine what type of soil you have and how to improve it.

WATER SUPPLY

Most of our state does not receive adequate precipitation for raising vegetables and fruits. Consider how you plan to irrigate the plants. Running a water line(s) so there is a handy tap near the growing area will make watering easier. Many folks with growing areas that aren't too large water by hand using a hose. Others prefer to automate their watering by using a timer along with a drip irrigation or soaker hose system. The irrigation section of this guide provides more detail on methods used to irrigate crops. Mulching irrigated vegetable crops can help conserve the water that is applied.

The quality of your water source is another issue in Wyoming. If your water source is a well that hasn't been used for irrigation before, consider getting the water tested by a lab to see if there are any issues.

SHORT GROWING SEASONS

Growing seasons are short in many areas of the state. Residents in these areas, and even folks living in areas having warmer temperatures and longer growing seasons, may want to extend their growing seasons for longer-seasoned vegetables, for "warm-season" crops such as tomatoes or corn, or to produce more produce during the year.

Season extenders help do this. These can include everything from starting plants indoors from seed to using row covers, hot caps, cold frames, low tunnels, or greenhouses, high tunnels, or geodesic domes. Regardless of the structure type, using a structure to extend the growing season is referred to as enclosed space production.

Selecting vegetable varieties with short maturation times is another strategy that helps growers succeed in our short, sometimes cool, growing seasons. When deciding between vegetable varieties, try choosing those that take the least number of days to mature.

The chart, page 4, gives a rough idea of the growing season in your area. These are averages–each year is different, and you should watch the weather and be ready to protect crops at any time during the growing season. The chart lists the probabilities of the temperature dropping to 32 F (frost) or 28 F (hard freeze) for the last (Spring) or first (Fall) time at the locations listed. For example, you may want to wait until June 14 if you live in Laramie, or May 21 if in Powell, to put out frost sensitive crops in the spring. Keep in mind topography plays a significant role in Wyoming–for example, if your growing area lies at the bottom of a hill, those at the top of the hill may not experience a freeze while your land may (cold air sinks). Also remember that each year the weather is different and some crops can be planted out earlier with protection.

Hail can be a threat to gardens in many parts of the state. Covering plants with row covers, tarps or other coverings placed over hoops can provide protection from smaller or soft hail. There are other techniques that can be used. Read the Summer 2014 *Barnyards & Backyards* article "Hail and Gardens," https://bit.ly/hail-gardens, for information on some of these techniques. Most techniques have their limits, however, and with large diameter hail severe hailstorms can take out most methods—at that point growers can determine if there is anything to salvage and remember that each year is different.

continues page 6

PROBABILITIES OF LAST SPRING OR FIRST FALL TEMPERATURE OCCURRING

Based upon 1981 to 2017 data (PRISM Climate Group, Oregon State University)

	Probability of Last Spring Temperature						Probability of First Fall Temperature					
	Spring: 28F			Spring: 32F			Fall: 28F			Fall: 32F		
	90%	50%	10%	90%	50%	10%	90%	50%	10%	90%	50%	10%
Afton	9-May	27-May	13-Jun	26-May	15-Jun	4-Jul	6-Oct	21-Sep	5-Sep	22-Sep	8-Sep	25-Aug
Albin	18-Apr	2-May	16-May	2-May	15-May	28-May	25-Oct	10-Oct	25-Sep	12-Oct	28-Sep	13-Sep
Alpine	28-Apr	11-May	23-May	16-May	4-Jun	22-Jun	16-Oct	28-Sep	10-Sep	28-Sep	14-Sep	31-Aug
Baggs	25-Apr	6-May	17-May	11-May	29-May	16-Jun	15-Oct	30-Sep	15-Sep	3-Oct	21-Sep	8-Sep
Bar Nunn	19-Apr	2-May	15-May	2-May	11-May	20-May	23-Oct	7-Oct	21-Sep	11-Oct	27-Sep	14-Sep
Bear River	30-Apr	19-May	6-Jun	19-May	3-Jun	18-Jun	10-Oct	25-Sep	10-Sep	2-Oct	17-Sep	2-Sep
Big Horn	17-Apr	2-May	17-May	3-May	z16-May	28-May	23-Oct	6-Oct	19-Sep	7-Oct	25-Sep	12-Sep
Big Piney / Marbelton	15-May	3-Jun	21-Jun	1-Jun	19-Jun	7-Jul	25-Sep	10-Sep	26-Aug	15-Sep	29-Aug	13-Aug
Boulder	21-May	7-Jun	24-Jun	8-Jun	25-Jun	11-Jul	21-Sep	5-Sep	21-Aug	13-Sep	27-Aug	9-Aug
Buffalo	14-Apr	30-Apr	15-May	2-May	12-May	23-May	25-Oct	7-Oct	19-Sep	14-Oct	29-Sep	14-Sep
Burlington	9-Apr	23-Apr	7-May	25-Apr	7-May	20-May	25-Oct	9-Oct	24-Sep	16-Oct	30-Sep	15-Sep
Burns	18-Apr	2-May	16-May	3-May	15-May	27-May	24-Oct	9-Oct	24-Sep	11-Oct	27-Sep	13-Sep
Carpenter	18-Apr	2-May	15-May	3-May	15-May	26-May	24-Oct	9-Oct	24-Sep	11-Oct	27-Sep	13-Sep
Casper	17-Apr	2-May	16-May	1-May	10-May	20-May	22-Oct	6-Oct	19-Sep	12-Oct	28-Sep	13-Sep
Centennial	5-May	21-May	5-Jun	26-May	8-Jun	21-Jun	6-Oct	21-Sep	6-Sep	22-Sep	10-Sep	30-Aug
Cheyenne	20-Apr	3-May	17-May	2-May	14-May	26-May	24-Oct	8-Oct	23-Sep	15-Oct	30-Sep	14-Sep
Chugwater	21-Apr	4-May	17-May	2-May	15-May	29-May	22-Oct	6-Oct	20-Sep	8-Oct	24-Sep	11-Sep
Clearmont	17-Apr	2-May	18-May	5-May	16-May	27-May	20-Oct	4-Oct	18-Sep	7-Oct	25-Sep	13-Sep
Cody	12-Apr	28-Apr	13-May	28-Apr	11-May	24-May	26-Oct	9-Oct	22-Sep	15-Oct	30-Sep	16-Sep
Cokeville	28-Apr	17-May	5-Jun	16-May	6-Jun	26-Jun	3-Oct	18-Sep	4-Sep	22-Sep	6-Sep	21-Aug
Cora	25-May	13-Jun	1-Jul	13-Jun	2-Jul	20-Jul	19-Sep	2-Sep	16-Aug	9-Sep	23-Aug	5-Aug
Daniel	27-May	17-Jun	7-Jul	15-Jun	2-Jul	19-Jul	17-Sep	31-Aug	15-Aug	5-Sep	20-Aug	4-Aug
Dayton	20-Apr	4-May	18-May	3-May	15-May	27-May	21-Oct	4-Oct	18-Sep	4-Oct	20-Sep	7-Sep
Douglas	20-Apr	3-May	16-May	2-May	14-May	25-May	22-Oct	5-Oct	18-Sep	6-Oct	24-Sep	13-Sep
Dubois	5-May	23-May	10-Jun	28-May	16-Jun	4-Jul	7-Oct	21-Sep	5-Sep	19-Sep	4-Sep	21-Aug
Elk Mountain	28-Apr	10-May	23-May	12-May	29-May	16-Jun	15-Oct	28-Sep	11-Sep	26-Sep	15-Sep	4-Sep
Encampment	29-Apr	15-May	31-May	25-May	5-Jun	17-Jun	14-Oct	29-Sep	14-Sep	24-Sep	15-Sep	6-Sep
Ethete	22-Apr	5-May	19-May	1-May	16-May	31-May	19-Oct	4-Oct	18-Sep	6-Oct	24-Sep	11-Sep
Evanston	4-May	22-May	8-Jun	21-May	5-Jun	20-Jun	11-Oct	26-Sep	10-Sep	3-Oct	18-Sep	3-Sep
Evansville	15-Apr	30-Apr	15-May	1-May	11-May	20-May	24-Oct	7-Oct	21-Sep	13-Oct	28-Sep	13-Sep
Farson	10-May	28-May	14-Jun	27-May	15-Jun	4-Jul	1-Oct	14-Sep	28-Aug	19-Sep	3-Sep	18-Aug
Fort Washakie	27-Apr	8-May	20-May	3-May	18-May	2-Jun	18-Oct	3-Oct	17-Sep	4-Oct	21-Sep	9-Sep
Ft. Laramie	19-Apr	3-May	16-May	1-May	16-May	31-May	18-Oct	3-Oct	19-Sep	5-Oct	23-Sep	10-Sep
Gillette	18-Apr	2-May	16-May	2-May	15-May	29-May	25-Oct	7-Oct	19-Sep	11-Oct	29-Sep	16-Sep
Glendo	20-Apr	3-May	15-May	1-May	14-May	27-May	20-Oct	4-Oct	17-Sep	6-Oct	24-Sep	12-Sep
Glenrock	20-Apr	3-May	15-May	2-May	11-May	21-May	23-Oct	6-Oct	19-Sep	8-Oct	26-Sep	13-Sep
Green River	27-Apr	11-May	24-May	7-May	24-May	10-Jun	19-Oct	4-Oct	18-Sep	8-Oct	22-Sep	7-Sep
Greybull	9-Apr	24-Apr	10-May	25-Apr	7-May	20-May	23-Oct	8-Oct	24-Sep	12-Oct	28-Sep	14-Sep
Guernsey	16-Apr	30-Apr	15-May	1-May	12-May	24-May	23-Oct	7-Oct	21-Sep	8-Oct	25-Sep	12-Sep
Hanna	29-Apr	9-May	18-May	10-May	26-May	11-Jun	17-Oct	2-Oct	16-Sep	30-Sep	18-Sep	6-Sep
Hoback Junction	5-May	23-May	10-Jun	28-May	15-Jun	3-Jul	15-Oct	27-Sep	10-Sep	29-Sep	15-Sep	2-Sep
Hulett	22-Apr	6-May	19-May	3-May	19-May	4-Jun	18-Oct	2-Oct	17-Sep	6-Oct	23-Sep	10-Sep

	Probability of Last Spring Temperature						Probability of First Fall Temperature					
	Spring: 28F			Spring: 32F			Fall: 28F			Fall: 32F		
	90%	50%	10%	90%	50%	10%	90%	50%	10%	90%	50%	10%
Jackson	7-May	23-May	7-Jun	29-May	17-Jun	6-Jul	2-Oct	18-Sep	4-Sep	18-Sep	4-Sep	20-Aug
Kaycee	17-Apr	1-May	14-May	30-Apr	11-May	23-May	22-Oct	8-Oct	24-Sep	10-Oct	27-Sep	13-Sep
Kemmerer	7-May	29-May	19-Jun	26-May	15-Jun	5-Jul	4-Oct	17-Sep	31-Aug	20-Sep	4-Sep	19-Aug
La Grange	21-Apr	3-May	15-May	2-May	15-May	28-May	22-Oct	7-Oct	22-Sep	8-Oct	24-Sep	11-Sep
Lander	22-Apr	5-May	18-May	1-May	15-May	29-May	21-Oct	6-Oct	21-Sep	9-Oct	26-Sep	14-Sep
Laramie	30-Apr	15-May	30-May	13-May	29-May	14-Jun	15-Oct	29-Sep	14-Sep	30-Sep	18-Sep	5-Sep
Leiter	17-Apr	1-May	15-May	30-Apr	12-May	25-May	23-Oct	6-Oct	19-Sep	8-Oct	25-Sep	13-Sep
Lovell	8-Apr	25-Apr	11-May	26-Apr	10-May	24-May	24-Oct	8-Oct	22-Sep	11-Oct	26-Sep	12-Sep
Lusk	28-Apr	9-May	20-May	4-May	19-May	3-Jun	19-Oct	3-Oct	17-Sep	4-Oct	22-Sep	9-Sep
Lyman	29-Apr	16-May	3-Jun	14-May	1-Jun	20-Jun	12-Oct	26-Sep	10-Sep	3-Oct	17-Sep	2-Sep
Medicine Bow	29-Apr	10-May	20-May	12-May	27-May	11-Jun	11-Oct	27-Sep	12-Sep	24-Sep	13-Sep	3-Sep
Meeteetse	27-Apr	10-May	23-May	11-May	25-May	7-Jun	18-Oct	2-Oct	16-Sep	2-Oct	20-Sep	7-Sep
Midwest	21-Apr	3-May	15-May	3-May	15-May	26-May	24-Oct	7-Oct	21-Sep	9-Oct	26-Sep	12-Sep
Moorcroft	21-Apr	5-May	19-May	6-May	18-May	29-May	18-Oct	3-Oct	19-Sep	8-Oct	25-Sep	13-Sep
Mountain View town	29-Apr	15-May	30-May	13-May	1-Jun	19-Jun	14-Oct	29-Sep	15-Sep	5-Oct	19-Sep	4-Sep
Newcastle	16-Apr	2-May	17-May	3-May	12-May	22-May	28-Oct	10-Oct	22-Sep	11-Oct	28-Sep	15-Sep
Pine Bluffs	18-Apr	2-May	16-May	2-May	14-May	26-May	24-Oct	9-Oct	24-Sep	10-Oct	27-Sep	14-Sep
Pinedale	22-May	9-Jun	28-Jun	9-Jun	27-Jun	15-Jul	19-Sep	3-Sep	18-Aug	12-Sep	25-Aug	7-Aug
Powell	17-Apr	29-Apr	12-May	28-Apr	10-May	21-May	22-Oct	5-Oct	18-Sep	8-Oct	25-Sep	12-Sep
Ranchester	18-Apr	3-May	17-May	4-May	15-May	26-May	19-Oct	4-Oct	20-Sep	4-Oct	20-Sep	6-Sep
Ranchettes	22-Apr	4-May	17-May	3-May	14-May	26-May	24-Oct	9-Oct	23-Sep	14-Oct	29-Sep	14-Sep
Rawlins	26-Apr	8-May	20-May	6-May	23-May	9-Jun	15-Oct	1-Oct	17-Sep	5-Oct	22-Sep	8-Sep
Riverton	18-Apr	2-May	15-May	28-Apr	16-May	3-Jun	19-Oct	4-Oct	18-Sep	7-Oct	23-Sep	8-Sep
Rock River	29-Apr	11-May	23-May	9-May	25-May	10-Jun	13-Oct	29-Sep	15-Sep	27-Sep	16-Sep	6-Sep
Rock Springs	25-Apr	8-May	21-May	6-May	23-May	10-Jun	20-Oct	3-Oct	17-Sep	10-Oct	24-Sep	9-Sep
Rolling Hills	22-Apr	4-May	16-May	3-May	14-May	25-May	22-Oct	5-Oct	18-Sep	7-Oct	25-Sep	13-Sep
Saratoga	28-Apr	8-May	18-May	8-May	25-May	12-Jun	13-Oct	30-Sep	17-Sep	4-Oct	19-Sep	4-Sep
Savery	25-Apr	6-May	17-May	6-May	25-May	13-Jun	18-Oct	3-Oct	18-Sep	7-Oct	23-Sep	10-Sep
Sheridan	21-Apr	4-May	18-May	5-May	17-May	29-May	19-Oct	3-Oct	18-Sep	6-Oct	22-Sep	9-Sep
Star Valley Ranch	26-Apr	16-May	6-Jun	25-May	15-Jun	5-Jul	7-Oct	20-Sep	4-Sep	19-Sep	7-Sep	26-Aug
Story	17-Apr	2-May	17-May	5-May	17-May	29-May	23-Oct	6-Oct	19-Sep	8-Oct	25-Sep	11-Sep
Sundance	26-Apr	10-May	24-May	8-May	21-May	3-Jun	20-Oct	3-Oct	16-Sep	8-Oct	22-Sep	6-Sep
Ten sleep	11-Apr	26-Apr	12-May	28-Apr	10-May	21-May	23-Oct	9-Oct	25-Sep	13-Oct	30-Sep	16-Sep
Thermopolis	11-Apr	25-Apr	10-May	27-Apr	9-May	21-May	23-Oct	8-Oct	24-Sep	14-Oct	30-Sep	15-Sep
Torrington	14-Apr	29-Apr	14-May	27-Apr	10-May	22-May	24-Oct	8-Oct	23-Sep	10-Oct	27-Sep	13-Sep
Upton	18-Apr	2-May	16-May	1-May	14-May	26-May	23-Oct	7-Oct	21-Sep	9-Oct	26-Sep	14-Sep
Wamsutter	1-May	15-May	30-May	15-May	2-Jun	21-Jun	12-Oct	27-Sep	12-Sep	1-Oct	18-Sep	4-Sep
Weston	18-Apr	2-May	16-May	1-May	13-May	25-May	20-Oct	5-Oct	20-Sep	8-Oct	25-Sep	13-Sep
Wheatland	16-Apr	29-Apr	13-May	1-May	13-May	26-May	25-Oct	10-Oct	24-Sep	11-Oct	28-Sep	14-Sep
Worland	3-Apr	20-Apr	6-May	22-Apr	6-May	19-May	26-Oct	11-Oct	26-Sep	17-Oct	2-Oct	17-Sep
Wright	22-Apr	5-May	17-May	5-May	18-May	31-May	23-Oct	6-Oct	19-Sep	9-Oct	25-Sep	10-Sep
Wyarno	21-Apr	5-May	18-May	4-May	18-May	31-May	17-Oct	1-Oct	15-Sep	3-Oct	21-Sep	8-Sep

SOME GREAT EDIBLE CROPS THAT ARE EASIER TO GROW AT HIGHER ELEVATIONS THAN SOME OTHERS IN WYOMING:

- Asparagus
- Green beans
- Beets
- Broccoli
- Brussels sprouts
- Cabbage
- Carrots
- Cauliflower
- Garlic
- Greens including arugula, pak choi, mustard greens such as mizuna, and Chinese cabbage
- Green onions (bunching onions)
- Herbs: dill, parsley, and many others
- Kale
- Kohlrabi
- Lettuce
- Leeks
- Onions (choose "long-day" varieties)
- Peas
- Potatoes
- Radishes
- Raspberries
- Rhubarb
- Spinach
- Strawberries
- Summer squash (zucchini, etc.)
- Swiss chard

THESE CROPS CAN BENEFIT FROM SOME FORM OF PROTECTION OR SEASON EXTENSION IN MANY HIGHER ELEVATION WYOMING LOCATIONS.

- Cucumbers
- Eggplants
- Muskmelons (cantaloupes)
- Peppers
- Sweet corn
- Tomatoes
- Watermelons
- Winter squash

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WILDLIFE

Wildlife can be a major challenge in some areas. Exclusion methods such as fencing will be the most reliable option for dealing with many different kinds of wildlife. They can't eat your produce if they can't reach it.

PESTS AND DISEASES

One advantage of having short seasons and tough winters is that our insect pest problems tend to be less numerous than in more gentle climates; however, issues do crop up. Correctly identifying the pest is the first step, whether an insect or a weed issue. Many beneficial insects and their young can look pretty alarming (look at a ladybug larvae to see what we mean) so you might assume they are pests. Accurate identification is critical to determine if you have a problem and what to do about it. Along with this publication and online resources, your local University of Wyoming Extension or weed and pest district offices can help identify potential pests and weeds. If there is an issue, the next step is to decide what, if anything, to do about it. For insects, determine if beneficial insects or diseases are already taking a toll on the pest; if so, waiting might be your best option. If not, then determine your strategy. You'll find many great publications on insect pests and their control in this guide and on the barnyardsandbackyards.com website under "Insects", including the publication "What's In Your Toolbox? Options For The Management Of Pests In Wyoming Gardens And Greenhouses", http://bit.ly/bug-toolbox, which gives more detail on control measures. Read the Weeds section, page 34, of this guide to learn about weed identification and control steps.

Plant diseases are less of a problem in Wyoming; however, they can still occur. One of the best defenses against many plant diseases is choosing vegetable and fruit varieties resistant to them. If shopping for vegetable seeds in a catalog or online, they'll list which diseases they are resistant to. Another good defense is making sure your crops

aren't stressed. Also, many soil issues can give plants symptoms that look like plant diseases. Remember correct management of any pest situation is proper identification.

WIND

Wind can be a major issue–whether in spring when it dries out the soil and carries dirt that can injure seedlings or in the winter when it can pick up and carry off your precious topsoil if not protected. Consider wind when you initially site your garden. Careful placement in a more sheltered area can prevent some difficulties. Windbreaks can also be constructed or planted. If are planning to build a windbreak fence of some sort, visit the barnyardsandbackyards.com website to see how windbreak fences function (such as how the ratio of open space to fencing material affects wind and snow deposition). Depending on your wildlife issues, sometimes a fence built to keep out wildlife (the larger herbivores) can also act as a windbreak, creating a cozy microclimate for your vegetables.

Growing fruits and vegetables in Wyoming can be extremely satisfying whether growing food just for family, or to share or sell. Each growing year is different–planning ahead and being prepared for some of the possible challenges will increase your chances for success.

Visit barnyardsandbackyards.com for a wealth of publications, videos, and links to great websites.

SELECTING A SITE TO RAISE PRODUCE AND LAYOUT OPTIONS

Growers must consider the plant's needs as well as their own (a convenient location) when selecting a site suitable for production. Consider these factors: USDA growth zone (for perennial crops), amount of sunlight received, soil type and quality, water availability and quality, prevailing wind direction, pressure from wildlife, day, and night temperatures, hail probability, flooding potential, insects, weeds, and diseases. Since we cannot control Mother Nature, choosing where to grow becomes one of the most important decisions a new grower will make, followed by deciding what needs to be done to improve the site conditions.

A site analysis, to determine the site's current condition, is a good first step when making these decisions. Map or draw the site to scale after taking measurements of the land, existing structures, and other features. Make sure to identify utilities, water sources, buildings, pathways, and other important features. Scale drawings will help you decide what and how much can realistically grow in the given space.

ASK YOURSELF THESE QUESTIONS WHEN DOING A SITE ANALYSIS

How much sun does the site receive?
The sun is a grower's most valuable resource. Most fruits and vegetables mentioned in this guide need full sun (at least 6 hours of direct sun each day). Try to find an area that receives full sun throughout the growing season. A space might have sun during the end of June but might become shaded during the end of the growing season in September as the sun's angle on the horizon changes. Also keep in mind some locations that receive full sun next to buildings might become too hot for some vegetable and fruit crops grown at lower elevation sites. Consider whether young trees nearby may grow and eventually shade the site.

What is my water situation?

Before investing in a new property, be sure that both water quantity and quality are adequate for your growing operation. Are you going to irrigate with municipal water, well water, or another source? Wyoming is inherently dry, and water can be a limiting factor when growing produce. Water can be expensive depending on the municipality and the size of your growing area. If planning to use well water, test the water before using it to irrigate.

What quantity of water is available?

Test your water source to determine the gallons per minute and water pressure (PSI) for your system. This determines how much area you can irrigate and the best irrigation method.

Is the water close to where you will be growing your crops?

Close access to water is important. Hauling or pumping from a long distance can become a challenge. Automatic timers and drip irrigation systems help manage water effectively and significantly reduce the labor involved in watering.

What is the water quality?

Growers using city water should not have many water-quality concerns with their irrigation system. The amount of chlorination and/or fluoridation a municipality uses will not compromise the health of garden plants. However, water with high levels of hardness could shorten the life expectancy of a drip irrigation system. Well water should be tested for all sorts of things: salinity, pH, hardness, and total dissolved solids, carbonate, bicarbonate, sulfate, nitrate, calcium, magnesium, sodium, potassium, chloride, and boron. Additional tests can be conducted for other elements including: phosphorous, aluminum, iron, manganese, copper, zinc, nickel, molybdenum, cadmium, chromium, barium, lead, arsenic, nitrogen, mercury, and selenium. High levels of salt and/or heavy metals can be detrimental to plant health and may not be economically feasible to correct. Depending on what type of irrigation you intend to use and the source of your water, you may need to use a filter to remove larger particles to keep systems from clogging.

What is the condition of the soil?

Wyoming is home to a broad range of soil types. Growers should have their soil tested to identify soil texture, pH level, organic matter content, salt content, and nutrient levels. This information assists growers in making informed decisions regarding watering and soil amendments. Understanding and improving soils will be covered in more detail in the Soils section. Here are a couple of common issues growers should look for in their soil test results.

Alkaline soils (pH 7.5 or higher) are common throughout Wyoming. As pH increases, certain nutrients become unavailable for plants to take up through their roots. Iron availability is perhaps the most common issue with high pH soils. Iron becomes less available as pH increases. Iron deficient plants exhibit yellow leaves and green leaf veins. They are less healthy and grow more slowly. Changing the soil's pH to correct these issues is extremely difficult. Plants with iron deficiency symptoms can be treated with iron chelate fertilizer when deficiencies show up.

Wyoming's soils are often low in organic matter. If a soils test indicates low organic matter, this situation can be improved by incorporating compost, peat moss or other organic matter into the soil or growing a cover-crop on the site prior to planting. It can benefit the site's production by improving the soil's water holding capacity, improving drainage, and improving the soil's tilth.

Soil tests may indicate a soil is sodic or saline if salt content is high. Flooding sodic and saline soils with water to leach out the salt is often the best remedy.

Where are the utilities (above and below ground)?

Avoid some expensive and potentially dangerous problems by looking up to avoid overhead obstacles such as power lines and by calling 811 to have the underground utilities marked on your property before you determine a growing area and start digging.

Are there micro or macro climates on the site?

Find microclimates on your site. What is the prevailing wind direction during the growing season? Do windbreaks exist or will they be installed? Natural or man-made windbreaks are great for preventing water loss and damage to plants. The wind can be harsh for both young and mature plants.

Try finding a south-facing space to receive the greatest amount of sunlight and heat during the growing season if living in higher elevation parts of the state. How will cold air flow across the property? Cold air tends to flow downhill and can pool at the bottom of slopes. Growing areas in these locations can experience later frosts in the spring and earlier ones in the fall than surrounding areas.

Other questions to ask

- What local wildlife inhabit the area and how will they be kept out of the crops?
- Are my plans compatible with the neighbors or neighborhood?
- And importantly overall, what needs to be done to improve site conditions? What do I have time to do? What will it cost?

LAYING OUT A GROWING SPACE

What crops can (or should) be grown at this site?

Growers must decide what to grow and how to grow it after choosing the site and improving general site conditions. There are many fruits and vegetables that look great in a seed catalog, grocery store, or farmers market but might not be well-suited for your growing environment. Your site analysis will have provided a better understanding of your site and help determine what crops you'll be able to grow.

Deciding what you want to grow will also influence the size of the growing area. There is a drastic difference in space needed if looking to only grow a few lettuce and spinach plants compared to a dozen squash plants. How many people am I trying to feed? Is it one person, one family, or are you planning on growing produce for sale? Do you plan to only consume the vegetables fresh, or will you also preserve the produce? What do you like to eat, or if selling, what is the demand for different types of produce? Growing plants not consumed can be a major waste of time, money, and resources.

Many cool season crops (lettuce, spinach, kale, peas, cabbage) and root crops (radish, carrot, potato) grow well outdoors throughout Wyoming. Successfully growing some warm season crops (tomato, pepper, corn, cucumber, squash, pumpkin, melon) may require a high tunnel, row covers, or other enclosed spaces to extend the growing season in parts of the state. Perennial crops such as strawberries, raspberries, asparagus, rhubarb, and fruit trees need to be sited well as they require year-round attention including winter watering, scouting for pests, and protecting plants from wildlife.

Growers need to carefully select fruit and vegetable varieties that will produce in the limited number of days we experience in a growing season.

Time to design

You can start to plan out how you'll fit your crops in the area where you plan to grow in after implementing improvements. Taking the time to design helps develop a space to efficiently provide enough vegetables and/or fruit for each growing season. There can be a lot of complexity to a design depending on what you plan to grow and what the physical space looks like, or it can be fairly simple. There are many options.

Drawing a simple map of your planned growing space is helpful. Along with a map of the general space and all relevant features, have a list of crops on hand and their spacing requirements as you draw. Keep a multi-year plan in mind—remember crops need to be rotated throughout the growing space over time. Rotating crops from different plant families in each physical space helps break disease cycles and help soil nutrient issues. Try to avoid planting crops from the same family in the same spot every year (a three-year rotation is often recommended). For areas with cold and short growing conditions, this can be a challenge since cool season crops often perform the best, and they tend to be from just a couple of plant families.

As you draw your plan, you may want to place taller crops on the north end of the growing area and shorter crops on the south end. This arrangement of plants allows for the greatest amount of sunlight to reach all the crops.

PLANTING STRATEGIES AND ARRANGEMENT

Direct seeding or transplants

Directly planting seeds or transplants is the oldest and perhaps most common method for growing crops. Direct planting seed into the ground allows plants to be seeded into rows, mounds, hills, or other

Garden using banded rows

WildAwake/iStock.com

patterns. The distance between rows, hills, and plants depends on the crop. Read the recommendations on seed packets for spacing and planting depth. Keep in mind some plants can be planted close together and in a multitude of ways to fit a space.

Traditional rows

Planting seeds in rows at certain increments is perhaps one of the oldest designs. Rows allow access between plants for weed management and walking, room for irrigation water to reach plants, and a certain distance between plants to avoid decreased yields from competition. Traditional rows generally consist of the same plant species in the row. The distance between rows depends on the crop.

Banded or wide rows

This method allows for more than a single row of crops. Wide or banded rows are similar to a single or traditional row, except multiple plants are planted next to each other. A banded row might have three or four plants growing next to each other without another row between the plants. Banded or wide rows work great for small or root crops. Banded rows can also be slightly raised in a hill design so the row is higher than the area left unplanted between the banded rows.

Companion planting

Many crops can complement each other above and below ground. Companion plants are great for increasing the production of crops in a smaller space and providing other benefits that might include reduced fertilizing, increased weed control, a vertical structure for other crops to use, increased crop production, reduced space needs, and multiple species for consumption. Companion planting can lead to some problems with crop rotation if the same crops are planted in the same location each year.

Intercropping

Multiple crops can be seeded or planted together in a multitude of ways. Using the companion planting idea, intercropping uses different species that work well together. Multiple crops can be planted in a variety of ways using the different planting strategies presented.

Broadcasting

Just like seeding a lawn, seeds can be broadcast in a growing area. This method works best for crops with smaller seeds. Thinning stands of crops that have been broadcast seeded is common. Multiple species can be planted together in a broadcast seeding method. Using seeds from multiple crops can help decrease the seeding rate for certain crops.

Succession planting

Crops with relatively short days to maturity can be seeded at different time intervals throughout the season. An initial planting can occur early in the season and can be planted again as the season progresses for a continuous crop throughout the entire growing season. For crops that enjoy cooler temperatures, one seeding can take place in the early spring and then a second in the mid- to late summer to achieve a summer and fall harvest. Succession planting can also involve more than one crop. A very fast maturing crop can be planted in an area at the very early portion of the growing season followed by another crop species that enjoys warmer temperatures after the first crop has been harvested.

Square foot gardening

Square foot gardening is exactly what the name suggests. Square foot gardening involves breaking the garden area into 1-foot by 1-foot square sections or larger squares if desired. Individual crops are planted in each section. Multiple or single plants are used in each section depending on their size. Companion planting is important in this system since plants are grown very close together. Square foot systems allow crops to be rotated more easily. Keep in mind that, although plants are easily rotated, the same family of plants might be closely rotated in the same bed or space.

Intensive planting

Very similar to square foot gardening, intensive planting involves planting crops as close together as

possible to avoid wasting space and at the same time making sure crop production is not diminished too greatly. Intensive planting is really a combination of many of the planting strategies already listed. This strategy involves fitting as many crops into one area as possible. Different crops might be planted in a variety of arrangements to achieve the greatest number of plants and production within an area.

Raised or framed beds

Raised beds help warm the soil earlier in the spring, provide a space for raising crops that has unsuitable native soils, and allow for greater intensity of management. Raised or frame type beds use material that makes a border for the growing space. The frame is raised above the soil. Raised beds contain the soil and allow space to walk between beds.

Liana Lofi Sa/shutterstock

Beds can be filled with native soils or an outside soil source. The beds should not be made with wood such as railroad ties or treated wood that contain harmful chemicals. Various types of metal, plastic, or natural wood can be used for the frame. The size of raised beds can vary. Make raised beds small enough the middle of the bed can be reached for planting, weeding and harvesting produce. Heights of 18–24 inches allow one to sit on the sides to work in the garden or to kneel outside the beds and reach into the middle to plant, weed and harvest.

SMALLER SCALE/SPACE CONSTRICTED GROWING

Container gardens

Containers can also be used for growing vegetables. Containers provide options when access to a garden space is not possible. A sunny area on a porch, driveway, or patio can be a great location. Container plants can also be moved to protected locations during cold or bad weather events. Container gardening has its own unique set of challenges. Containers need to be large enough for structural support to prevent larger plants from falling over, enough soil for proper plant growth and to maintain adequate soil moisture (smaller containers often dry out faster than larger ones). A wide assortment of containers can be used for gardening from recycled milk jugs to extremely fancy and expensive decorative pots. For more information on container gardening, visit http://bit.ly/uwyo_containergarden.

Go vertical

Luckily, there are many options that can be purchased or built for vertically growing vegetables. Grow walls or towers, fencing, used gutters, used support material made of wood, plastic, or metal, used pallets, and many other various options exist for building or purchasing vertical structures. Vertical gardening does not work for all vegetables but can be an excellent addition to many gardens. Look to add vertical garden to the space where it will not interfere with other plants by shading them.

Make sure that whatever design or material is used for vertical structures it is well-secured and placed so it can be easily accessed for maintenance and work. Heavier plants such as melons and squash plants can become quite heavy and will tip over structures that are not sturdy enough or well-secured. Remember, there are additional considerations for vertical gardening.

Certain structures such as grow towers or walls have specific water and nutrient requirements.

- Gutters or similar structures that need to be filled with soil will also need to be managed in a similar fashion to the regular garden or container with water holding limitations.
- Some structures might need to be watered more frequently than a traditional garden.
- Not all plants can be grown in vertical structures due to the limitation of space, soil, and available water. Look for plants with small root systems, relatively small aboveground biomass, or natural climbers.
- Also remember that other plants can be put to use as a structure. Think pole beans or peas climbing corn stalks as another option for vertical growing.
- Some plants will need secured with string, rope, or clips when grown vertically.

Hydroponics and **aquaponics** are other growing systems which are often conducted in enclosed spaces (high tunnels, etc.). We will not get into these specialized growing systems in this guide.

Other layout considerations

Season extension and cold frame products are important pieces for making the most of a Wyoming growing season. Consider any additional inputs or space requirements needed for your garden space if planning to incorporate some type of season extension. See the season extension section, page 30, in this guide for more information.

SOILS

Healthy soil is the very first, and perhaps most important, step to growing healthy food.

The soil in your garden or field is a living system of plants, insects, and microorganisms. These organisms live in an environment made of tiny pieces of ancient rocks that have weathered to become what we know as sand, silt, and clay.

Knowing what you have is the first step to becoming good soil managers. A shovel and computer are a couple of ways to figure this out.

The Natural Resources Conservation Service has mapped most of the soils in the country, and all this information is readily available on the University of California SoilWeb website: https://bit.ly/UC-soilweb. Use this website to look up how soils vary across the landscape and what challenges you might expect at your site. These maps provide general information for your location so you will need more precise information. Your soil can vary greatly across the planned growing area.

Getting your hands and shovel dirty is still the best way to learn about your soils. Is it heavy and sticky? Light and sandy? Does is smell earthy or metallic? Are there worms? How deep are the plant roots? What color is it?

Soil samples sent to a lab can provide you with even more information. More on this below.

TEXTURE

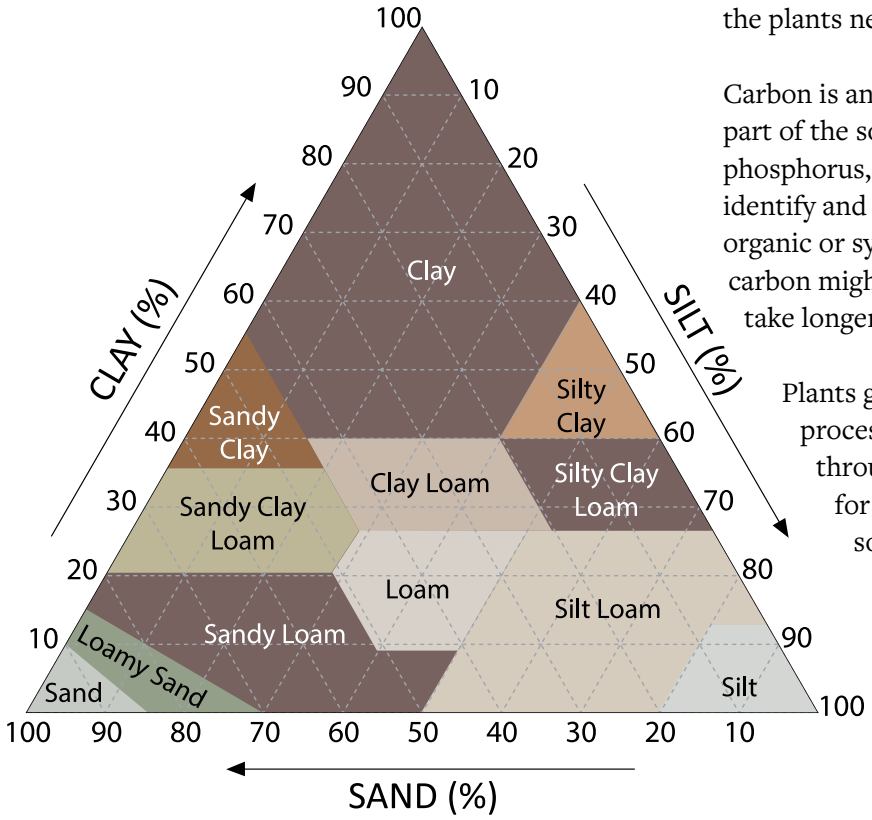
All soils are made up of some combination of all three particle sizes (sand, silt, and clay) and this dictates their texture. Knowing the texture of your soil will give clues about how to best manage it to grow healthy plants.

A soil dominated by clay is sticky and heavy when wet. When dry, the surface often cracks, or crusts.

It also holds tightly to water and plant nutrients, is easily compacted, and does not drain well. Compaction limits the amount of air in the soil and makes it harder for plants to grow and reach water and nutrients. These are often what we call "heavy soils." A spoonful of clay particles has the surface area equivalent to a football field.

A soil high in silt feels smooth and silky. It is not as sticky and heavy as clay and is very susceptible to wind and water erosion. It can be highly fertile and productive soil and is more resistant to compaction than a soil high in clay.

Sandy soils are very well drained and loose, lose nutrients easily, and dry quickly. They are not very easily compacted. These are what we often call "droughty soils."



Soil type based on percentage of clay, silt and sand.
Becris, shutterstock.com

When gardening in containers or raised beds, a mix of compost, peat moss, or coconut coir with sand is often used. Perlite or vermiculite can be added to aid with drainage and airflow. This not actually soil but a "soilless" growing medium.

SOIL ORGANIC MATTER AND CARBON

While it is helpful to understand and manage for the soil texture, the living component of the soil is most critical to success in growing vegetables and fruits. This living system is entirely driven by photosynthesis and organic matter in the soil. Adding diverse sources of organic matter and minimizing tillage as much as possible are the two most important things you can do for your soil.

Soil organic matter (SOM) is mostly carbon (about 45 percent), hydrogen, and oxygen, along with all the other 17 essential plant nutrients. The nutrients held in soil organic matter are released slowly over time as the plants need them.

Carbon is an often overlooked, but very important, part of the soil system. Deficiencies in nitrogen, phosphorus, potassium, or micronutrients are easy to identify and can be improved relatively rapidly with organic or synthetic fertilizers. Symptoms of low soil carbon might be harder to recognize, however, and take longer to remedy.

Plants get carbon from the air through the process of photosynthesis and put it into soil through their roots. This soil carbon is critical for soil microbial life, earthworms, good soil structure and porosity, preventing compaction and erosion, and increasing water holding capacity. It is what gives healthy soil a dark brown color and rich, earthy smell.

The *organic* soil carbon is of most interest (carbon that was once a part of a living organism) when considering soil health.

In contrast, soil *inorganic* carbon includes things like charcoal and calcium carbonate (agricultural lime).

Soil organic matter encompasses all organic components of the soil system. This includes living and dead plant and animal tissues as well as root excretions and soil microbes. SOM is typically a small percentage of the soil (less than 3 percent in most Wyoming soils) but has a very important role to play in soil health, disease suppression, drought resistance, water quality and quantity, and soil tilth.

Sources of soil organic matter include manures, compost, dead plants, and secretions from living plant roots. All of these sources contain different forms of carbon-rich materials, including lignin, cellulose, sugars, lipids, and humic acids.

Plants do not take up any significant amount of carbon from the soil, but organic matter is the food and energy source for soil bacteria, fungi, worms, and the rest of the soil food web. These soil microbes rely on organic matter as a food and energy source. They work hard to break down the complex carbon-based molecules in dead plants and manure like lignin, fat, and protein, into smaller components. As a result, nutrients are made available to plants. Many of the microbes involved in decomposition are aerobic, which means they use oxygen and create carbon dioxide as a byproduct (just like humans).

Tillage introduces a large amount of oxygen into the soil very quickly. This stimulates microbial activity, which leads to rapid organic matter metabolism (decomposition) in the soil. As a result, valuable soil carbon is lost as carbon dioxide. This is why tillage is a primary factor in loss of soil carbon and declining soil health worldwide. Not only is tillage a major contributor to soil carbon loss, but it can damage soil structure, lead to long-term subsoil compaction, increase the risk of erosion, and discourage earthworms and beneficial soil fungi.

SOME NOTES ON USING LIVESTOCK MANURE IN VEGETABLE PRODUCTION

Livestock manure is a good source of nutrients and organic matter for garden soils but must be managed with care. Manure from poultry and from cattle in feedlots is often high in salts. Soil and irrigation water in many areas of Wyoming are already high in salts, so the addition of more salts from manure can be problematic. More information on saline soils can be found in the Fall 2017 Barnyards & Backyards article "Saline soils present special problems", https://bit.ly/saline-soils-2017.

Fresh cattle or poultry manure can "burn" plants if applied at high rates during the growing season. The nitrate and ammonia salts damage plant tissues. If concerned about high salts in your soil or water, use manures lower in salts: horse, rabbit, goat or sheep on pasture, or alpaca.

Fresh manure may also contain pathogens like *salmonella* sp. and *E. coli*, and weed seeds. When using manure where vegetables will be grown, either fully compost it first or add in the fall after the growing season. For safety, the USDA National Organic Program (NOP) standards allow a 90-day period between manure application and incorporation, and harvest for crops that don't have direct contact potential with soil. Otherwise, they require application at least 120 days before harvesting a crop that has the potential for soil contact (leafy greens, root crops). Those who are more at risk for food-borne illness shouldn't eat uncooked vegetables from areas fertilized with manure. Waste from cats and dogs or swine can be a source of diseases and parasites and are not recommended as manure sources.

HOW TO BUILD HEALTHY SOIL

The simplest way to add carbon to your soil is with **mulch**, **compost**, and **manure**. These can be added on top of the soil or incorporated before planting. Leaves and grass clippings make good mulch and can also be composted with manure or food scraps. Alfalfa hay is excellent as a mulch or compost addition. Straw and wood chips can be used as mulch but are less useful in the compost pile. And don't forget your coffee grounds and vegetable scraps--these can be added to the compost pile or buried directly in the growing area.

Mulch is simply organic material placed on top of the soil and around plants to conserve water, protect the soil, reduce weed pressure, and provide food for the worms and soil microbes.

Compost is the result of billions of microbes breaking down raw organic materials into a stable and safe soil amendment high in humus and beneficial to plants. It can be incorporated into the soil or used as a topdressing around annual and perennial plants. Fall is the best time to incorporate compost into the soil.

Living plant roots are another source of soil carbon. Plants secrete polysaccharides (complex sugars) into the soil that feed the microbes. As perennial plants go through cycles of growth and dormancy, they shed dead roots and grow new ones. These dead roots become food for the soil microbes and are recycled, continually adding more carbon to the soil. This is why soil under pastures, lawns, or prairie grasses can be so productive when converted to a garden or farm. The grasses have been busy adding carbon to the soil (through photosynthesis) and losses due to tillage or erosion have been minimal. This process is also called "carbon sequestration"–taking the carbon out of the atmosphere (as carbon dioxide) and storing it as part of the soil organic matter. Cover crops can be a great way to capture even more carbon from the atmosphere and store in your soil.

Correcting soil carbon deficiency is done by increasing gains and decreasing losses. By reducing tillage, adding organic matter, and keeping living roots in the soil, we can keep more of the carbon in the soil where it is useful.

Changes in soil carbon can be measured in a lab or in a field. The simplest method only requires a shovel, while more advanced methods involve laboratory analysis. You can learn a lot about your soil carbon by digging a small hole and taking note of the color, smell, and structure of the soil. Soil with more carbon will typically be darker in color, have a stronger earthy smell (humus), and better tilth. You may also notice more earthworms and deeper roots. Compare soil from a cultivated field to soil from a pasture, fencerow, or lawn. Observing changes in three basic characteristics (color, smell, and structure) over time can tell a lot about the effects of your current management on soil health and carbon status.

Laboratory soil tests will typically include SOM (as a percent of soil by weight) along with N (nitrogen), P (phosphorus), K (potassium) and micronutrients. Watching how these numbers change over time can be very informative, especially if making any changes to your soil management systems.

As you manage soil N, P, and K for maximum crop production, consider ways to manage C (carbon), too. The long-term benefits will be well worth the time and effort.

USING SOIL TESTS TO MANAGE NUTRIENTS

Soil tests can provide detailed information about soil chemistry other methods do not.

There are many labs that test soil for gardeners and farmers. Contact your local UW Extension educator for help finding a lab and choosing an analysis package. Most routine soil tests include macronutrients, salts, pH, and organic matter. If requested, the lab will provide fertilizer

recommendations based on what you plan to grow.

Soil samples must be collected and handled correctly to get accurate results. Spring is the best time to test soil. Using a clean bucket and trowel, collect 8-12 small samples (subsamples) from around the growing area. Dig all soil subsamples to a depth of 6 inches and include all 6 inches in the subsample. Mix all the subsamples together to create a composite sample, remove plant debris and rocks, and lay it out on a paper towel to dry for a few days. After the composite sample has dried, submit a total of 2 cups of soil to your lab of choice for analysis.

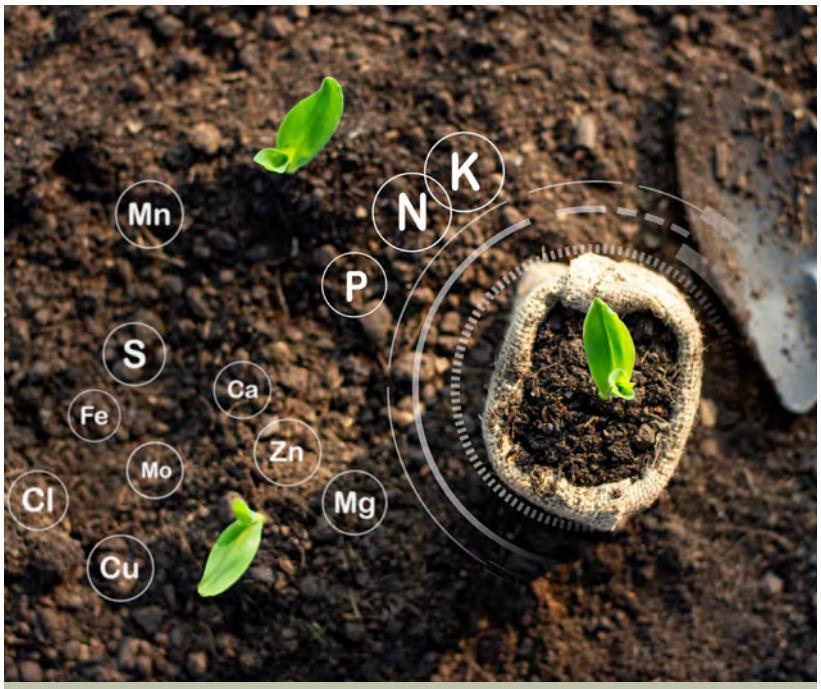
Labs that test soil will also test manure and compost for nutrients and salts.

The fertilizer recommendations given on the soil test report are only guidelines based on test results and information provided when the soil sample was submitted. There may be other adjustments that should be made based on factors beyond the control or knowledge of the laboratory that makes the recommendation.

Some of the items often included in soil tests

Electrolytic Conductivity (EC): This is a measure of soil salinity. Saline soils are common in arid and semiarid regions and may be corrected by improving soil drainage and leaching. The sensitivity of plants to salts varies with growth stage. Most plants are more sensitive to salts during germination and emergence than during vegetative growth.

In this context, salts are positive and negative ions that dissociate in water. For example: $MgSO_4$ (epsom salt), NaCl (table salt), $CaSO_4$ (gypsum), NH_4NO_3 and KNO_3 (fertilizers).



kram-9, shutterstock.com

CALCULATING YOUR FERTILIZER NEEDS

Soil testing results may suggest the application of fertilizer to address a deficiency. How do you determine how much fertilizer to apply?

Fertilizers are rated by percentage of available nutrients. Diammonium phosphate fertilizer with a grade of 18-46-0 contains 18 percent nitrogen (N), 46 percent phosphorus (P_2O_5), and 0 percent potassium (K_2O).

One 10-pound bag of 16-20-0-24S contains 16 percent (1.6 pounds) nitrogen, 20 percent (2 pounds) phosphorus (P_2O_5), no potassium, and 24 percent (2.4 pounds) sulfur. The rest is filler or companion ions.

To calculate the amount of fertilizer needed:

$$\frac{(\textit{Pounds nutrient needed}) \times 100}{\textit{\% nutrient in fertilizer}} = \textit{pounds of fertilizer needed}$$

For example, if the fertilizer grade is 34-0-0 (34% N, 0% P_2O_5, 0% K_2O), and you need 1 pound N per 1,000 sq ft, you would apply 2.94 pounds:

$$\frac{(\textit{1 pound N}) \times 100}{\textit{34\%}} = \textit{2.94 pounds fertilizer (34-0-0) per 1,000 sq ft}$$

Note that with the exception of sodium (Na), all salts are also essential plant nutrients. When salts accumulate in the soil, it is difficult for the plants to use the water, and excess salts often cause stunted growth, or makes the leaves look "burned" along the edges.

Sodium is a component of some salts and creates special problems in the soil. In addition to causing symptoms like high salt, sodium can cause a loss of soil structure, which can slow water infiltration and movement or even stop it. Under sodic (high sodium) conditions, the pH often increases to 8.5 or above, and the decay of organic material may be slowed.

Nitrogen (**N**) is the nutrient required in the greatest quantities by plants. It is part of chlorophyll molecule and necessary for amino acids and proteins.

Phosphorus (**P**) is essential for all plants and is often applied as fertilizer because much of the total P in the soil is in forms unavailable to plants. It is one of the major factors in photosynthesis, nutrient transport, and energy transfer. Manure and manure-based compost are good sources of plant available phosphorus.

Potassium (**K**) assists in photosynthesis, stronger stalks and stems, cold tolerance, and movement of water, nutrients, and carbohydrates in plants. Most Wyoming soils have large K reserves, and K fertilizer applications are usually not necessary; however, sandy soils sometimes show K deficiencies.

Iron and zinc: Iron (Fe) and zinc (Zn) are often abundant in Wyoming soils but are in forms unavailable to a plant. Deficiencies of these nutrients may be observed in susceptible plants growing in high-lime soils. Zinc may be applied to soil, but soil applications of Fe are often ineffective because the iron is rapidly transformed to an unavailable form. When Fe and/or Zn deficiencies are confirmed, foliar fertilizer treatments may be beneficial.

RAISED BEDS ARE USEFUL FOR OVERCOMING CHALLENGING SOIL CONDITIONS

If mainly producing crops for smaller scale consumption or sale, one very effective way of dealing with poor soil (especially soil with issues that are not easily fixed) is to use raised beds. These beds can be filled with topsoil and decomposed organic material such as compost and peat moss to create a great soil for growing vegetables. The soil mix also tends to warm up a bit earlier in the spring, and the vegetables are easier to tend as you don't have to lean down so far. When considering how wide to make the raised beds, consider how easy it will be for you to reach the middle of the bed to tend plants or harvest. Raised beds can be made from a variety of materials including lumber, composite materials, and even straw bales. Keep in mind that eventually all organic materials (wood, straw bales, etc.) will eventually decompose. Creating raised beds can be a bit more expensive to get started and new beds should be monitored for new weeds that may grow from any seeds brought in with any imported soil mixtures.

COVER CROPS TO MAINTAIN AND IMPROVE SOILS

A **cover crop** is a crop grown specifically to protect and improve the soil, compete with weeds, or interrupt pest and disease cycles. Unlike cash crops, cover crops are not harvested for market or consumption, although sometimes they are grazed by livestock.

Cover crops can provide many benefits to those growing vegetable crops. They can improve soil health, add nitrogen, attract pollinators and other beneficial insects, discourage weeds, and break disease cycles.

A rotation system is the simplest way to use cover crops when growing annual vegetables. Plant half or one-third of a growing area with cover crops in the spring and plant the rest of the area with annual

vegetables and flowers. This will give your soil a boost, and each year rotate the area that has been in cover crops back into vegetable crops. Designate a separate spot for perennial crops like herbs and strawberries and keep them out of the cover crop rotation.

Selecting cover crops

Cover crop species selection depends on your goals, location, the time of year of planting, and seed availability. **Legumes** (clovers, peas, vetch, beans) "fix" nitrogen from the atmosphere with the help of symbiotic bacteria living in their roots. This means they take nitrogen from the air (unavailable to plants) and put it into the soil (where it is available to plants). For this reason, most cover crop mixtures will include at least one legume.

Mustard and **buckwheat** attract pollinators and beneficial insects to their flowers.

Many grains and grasses tolerate cool, early spring temperatures, rapidly outcompete weeds, and provide structure for vining legumes. Grains like wheat, barley, and oats are often readily available and inexpensive. Millet is well-adapted to the warm summers (in some areas) and alkaline soils of Wyoming.

Radishes and **turnips** can help loosen soil and will continue to grow beyond the first light frost. The table, page 19, shows a few examples of cover crop mixes to help you get started.

Planning, planting cover crops

A cover crop may need to be watered at establishment and periodically during the summer, depending upon where you live. In areas that receive at least 14 inches of moisture per year, some cover crop species may not need watered at all (growth may be significantly less than when watered).

The goal when planting cover crops, is to quickly establish a thick, healthy, stand that can outcompete and smother weeds.

The timing and method of planting will depend on location, growing area, available tools, and goals. Cover crops can be planted in rows, broadcast, or drilled. Seeding depth and rate will depend on the species being planted. Larger seeds like peas can be planted up to 2 inches deep, while smaller seeds need to be closer to surface. Carefully follow instructions on the package, if included.

Here is a simple way to get started creating your first cover crop mix. Simply choose one species from each column and plant at the rates specified. Document your experience, take notes, and adjust the seeding rates for future plantings. Additional species like buckwheat or mustard can be added as you gain more experience with cover crops.

Grains — pick 1		Legumes — pick 1	
	Seeding rate per 100 sq ft		Seeding rate per 100 sq ft
Oats	¼ lb	Field peas	¼ lb
Wheat	¼ lb	Crimson clover	1/8 lb
Barley	¼ lb	Vetch	1/8 lb

Cover crop of peas and oats
Tomas Vynikal, shutterstock

If purchasing seed in bulk to make your own mix, ask the seed company for seeding rate and planting depth recommendations.

A perfect seed bed is not required, and seeding rates can be increased to accommodate rough ground; however, keep in mind smooth ground will make life easier if trying to get a mower through the cover crop later in the year.

Mow the cover crop a few times during the year to keep it from going to seed. This is very important. Cover crops in the wrong place are still weeds! **The goal is to prevent the cover crop from going to seed, while also getting the maximum soil benefit.** Mowing can be done with a lawnmower, weed eater, hand scythe, or even small livestock, like goats (remember the earlier considerations with manure). The residue left after mowing will protect the soil and discourage weeds.

Wyoming winters are cold enough to kill many common cover crops (such as oats); however, some vetches, clovers, and grains are hardy enough to survive winter in some parts of the state. Do your research to avoid any surprises if counting on winter to kill your cover crop. Crops that do not winter kill can be chemically terminated.

Getting ready for growing season

Some soil prep work will be required in early spring to get the area that was under a cover crop ready for this year's crops. When plants die, they become a valuable mulch that continues to protect the soil and discourage weeds until the next spring.

If transplanting, leave the cover crop mulch in place and simply clear a small area for each transplant. This mulch will continue to suppress weeds and conserve water throughout the summer.

The cover crop residue can be incorporated with a rototiller several weeks before planting if a smooth seedbed is needed. Tilling the soil will increase weed seed germination and remove your protective mulch.

Other methods grow benefits

There are other ways to benefit from cover crops that require more precise planting, termination dates, methods, and management. For example, planting a cover crop in the summer after early spring crops like lettuce have been harvested, but before fall crops like kale and spinach are planted, reduces weed pressure and adds nutrients.

Fall cover crops can be planted after summer harvest and allowed to grow until they are winter-killed (just don't let them go to seed!). Annual cover crops like wheat or barley between vegetable rows can reduce weeds and protect the soil. Regular mowing helps keep the growth short and thick.

Another method, called relay seeding or inter-cropping, establishes cover crops before vegetable crops are harvested. This requires a careful choice of species and timing of planting but gives the advantage of establishing a cover crop early enough in the fall to allow good growth before a killing frost. For example, a cover crop is planted in between rows of a well-established crop, and once the crop is harvested, the cover crop will continue to grow.

Cover crops can add nutrients and organic matter to soil, improve tilth and workability, suppress weeds, break disease cycles, and feed soil microbes. Start with a small section and try a few different seed mixes to find one that does well in your region. And remember, don't let them go to seed!

For more information

The following bulletins provide more information about using cover crops, including recommended seeding rates. For links to these bulletins and other resources:

- http://bit.ly/soilsandfertilization, Methods for Successful Cover Crop Management in Your Home Garden. Washington State University Extension. FS119E. February 2014.
- https://bit.ly/usu-cover-crops, Cover Crops for Utah Gardens. Utah State University Extension. June 2010.

IRRIGATION

Growing fruits and vegetables in Wyoming successfully will require irrigation. Most of our state is too arid to grow these crops well without supplemental water. Adequate irrigation is a key element in getting a great harvest. Hopefully, as was outlined earlier in this guide, you have located your growing area near a convenient water source, know the water quality is adequate for good plant growth, and know the texture of your soil (amounts of clay, silt, or sand). Your next consideration is what method to use to water the plants.

TYPES OF IRRIGATION

Hand watering

Hand watering is one method for watering fruits and vegetables, such as using a hose, often with a wand with a breaker on the end (device that "breaks" the water into droplets). One plus for hand watering is it is a method that many growers enjoy doing on a smaller scale. It also gives the grower time to closely observe their plants and monitor how they are doing. They can spot insect infestations, nutrient deficiencies, and disease issues while watering. The downsides are that it is time-consuming (especially when getting into larger production systems), can be hard to judge how much water you have applied, and some diseases can be spread by splashing droplets. Consider investing in some high-quality hoses to make the job easier if you decide to hand water your plants.

Sprinklers

Sprinklers can reduce some of the work required to water, especially when timers are used, but also have some of the disadvantages of hand watering. They also apply water where not needed, reducing irrigation efficiency, and promoting weed growth in unmulched areas. Water coming out of sprinklers can be reduced by evaporation and be blown off course by our Wyoming winds.

Furrow irrigation

Some growers use furrow irrigation to water vegetable and fruit crops. Furrow irrigation requires creation of good furrows, an adequate supply of

Watering green pepper plants with drip irrigation

Bidgeon ur Zoonar GmbH, shutterstock.com

water, and some experience in applying the right amount of water. As when growing large-scale row crops, applying a consistent amount of water at all points in the furrow can be difficult.

Soaker hoses

Soaker hoses are hoses made of porous material. The water weeps out of the material and onto the ground all along the length of the hose. The advantages are that the water gets applied more precisely than the previous methods, and a timer can be attached to the soaker hose so you can water when you are not there. The disadvantages are that the water gets applied to areas where no vegetables or fruit are growing (and will promote weed growth if not mulched), they can become clogged with minerals over time, and can be damaged by ultraviolet light (UV) and equipment.

Drip irrigation

Drip irrigation is used by many growers to water crops. Drip hose can be purchased that contains holes/emitters where the water drips out at a precise spacing (such as ½-inch drip tubing with inline pressure-compensating emitters spaced every 9 or 12 inches). Often these systems are used with a timer that takes a lot of the work out of watering. The advantages of these systems are that they place the water right where needed and not where unwanted. This increases irrigation efficiency and decreases the unintended growth of weeds. If your water supply and pressure is adequate, these systems can be used to water small areas or large growing areas, especially if broken into zones. The emitters used in these systems will be rated on how much water they emit, for example, ½ gallon per hour. So growers know exactly how much water they are applying. The disadvantages of these systems are that they take a little more time to set up, emitters can become clogged with minerals, UV will eventually break down the plastic, and lines can be chewed on by rodents or damaged by equipment. Depending on the water source, filtration may be required to reduce clogging of lines.

Drip irrigation is often used to establish fruit trees. Since trees are placed farther apart than vegetables, these systems often use impermeable stretches of hose between the plants so water is not lost to the ground between the trees. If using drip irrigation to water fruit trees, make sure to move the drip out as the root systems grow outward. Most tree roots that should be targeted for water applications grow at the drip line (outer edge of the tree canopy or beyond). Also make sure your system can supply enough water for trees as they age. Trees can consume large amounts of water, and systems that were adequate when plants were younger may not be adequate later and/or they should be run for longer periods of time.

There are many manufacturers and styles of drip lines. They can have single emitters that are placed along a hard polyline, or the emitters can be incorporated into the line by the manufacturer at 4, 6, 12, or 18-inch spacing. Drip lines can be as small as ¼-inch diameter or ½-inch or larger diameter flat tape. The flat tape type can be laid on top of the soil or buried (or pulled/plowed through) in the soil profile (known as subsurface drip). Subsurface drip is the most efficient method of watering in Wyoming, however, rodent damage can be an issue with subsurface drip since it requires digging up the tape for repair.

DRIP IRRIGATION RESOURCES

- You can find a short video on watering vegetables at https://bit.ly/water-veg-video
- If interested in more details on drip irrigation and irrigation scheduling, check out the irrigation section of the High Tunnel Handbook at https://bit.ly/1234-high-tunnels
- Links to both and much more can be found on the Barnyards & Backyards Gardening page at bit.ly/BBWYgardening

Combining methods
Oftentimes, growers use a combination of methods throughout the season. Those using soaker or drip hoses may need to hand water after crops are planted but before they germinate to keep the soil constantly damp so seeds will germinate and plants grow to the point where their roots will be able to access the water from the drip lines. This depends on the layout of the irrigation system, the planting pattern used, and the type of crop.

HOW MUCH WATER IS NEEDED?

How much you will need to water will change over the season. What is adequate in June will most likely not be in August. How do you tell if you are watering adequately? One way is to water and then dig a small hole 6 to 12 inches down and look to see how far down the water has saturated. Most vegetable and many fruit roots can be found in the first foot or so of soil when they are mature, so this is where the water should be. The texture of your soil will influence how you water. Clay soils tend to absorb water more slowly (and the water spreads more widely), so slow and steady deep watering will work for these soils. In sandy soils, the water will tend to go more straight down quickly. Sandy soil may need to be watered more frequently for less time than in clay or loamy soils.

You are not watering enough if your vegetable crops are wilted in the morning. Some vegetable crops such as squash have leaves that naturally get a little wilted on hot afternoons because their roots have difficulty extracting water from the soil fast enough to keep up with transpiration from the leaves; however, they should recover by the next morning. You should water more if they are not.

Soaker Hose

STARTING PLANTS FROM SEED INDOORS

Starting plants from seed indoors can help growers get a jump on the season. It also can give the grower a wider range of vegetable varieties from which to choose since some varieties may not be available as transplants. Some vegetables do quite well when started indoors while others (carrots) are generally not suited for transplanting and should be sown directly into the growing area rather than started indoors from seed.

HOW TO GET STARTED?

Seeds

Flipping through a seed catalog (or browsing an internet site) in January is a boost to the spirits during cabin fever season. As mentioned previously, as you shop for seed, note the numbers given for days to maturity for vegetable varieties and make sure they work with the number of frost-free days in your area. Sometimes, days to maturity is based on the seed germination date, sometimes on the transplant date. Make sure your calculations are accurate. Seed left from a previous year usually can be used but must be stored correctly in a cool, dry place.

A surprising number of plants can be started from seed using simple light setups in one's basement or a spare room.

Growing medium

Special soil-less mixes (made up of vermiculite, peat moss, perlite, etc.) are best for starting seed. One of the reasons is that these are usually fairly disease-free. This is important because seedling diseases such as "damping off" (discussed later) can quickly decimate a flat of young seedlings. Depending on the size of your operation, locally owned garden centers can be a good source for quality mixes.

Pots

Use containers with drainage holes to hold the mix and trays to put the containers in to catch the water that drains out the holes. You can purchase seed-starting flats, or you can recycle clean containers. Other pots used for home seed starting include peat pots, ones made from newspaper, milk cartons, and more. If reusing pots, clean them well with warm, soapy water and then reduce any pathogens by soaking them in a 10 percent bleach water solution (1 part bleach to 9 parts water) for 30 minutes, rinsing with water and thoroughly air drying.

A good location

A good source of light is important, especially for vegetables, which will become leggy (the stem area between leaves starts to elongate as the plant "reaches" to try to find better light) without it. These leggy plants are highly susceptible to stem injuries through wind action once they are transplanted outside. Shelves with fluorescent lights (such as shop lights) that can be lowered or raised are very good for starting seedlings; a south-facing window can do in a pinch, and greenhouses or hoop houses with adequate light can be used. Shelves for indoor

growing can easily be made, and fancy fluorescent bulbs aren't needed–use either two cool white bulbs or one cool white bulb and one warm (soft) white bulb to get a broader spectrum of light. Other types of lights (LEDs and more) are available as well. A timer is useful for turning the lights on and off.

Choose a spot with reasonable temperatures; sometimes, cooler temperatures will help keep young plants stocky, but seeds often like warmer soil for germination (especially crops that grow better in warm temperatures such as tomatoes, squash, and peppers). Ensure there is reasonable air circulation. Seedlings can, of course, also be started in a heated greenhouse or hoop house structure if temperatures and other environmental conditions are adequate.

Time to plant

Read all the seed packets and separate them into groups by the recommended weeks before the average last frost that they should be planted indoors (for example, one pile each for those needing eight-10 weeks, six weeks, four weeks, etc.). Now look on the calendar and mark when those average last frost dates are. For example, start seeds March 28 for an average last frost date of June 6 and seeds that need 10 weeks to grow before transplanting.

Materials should be gathered and the planting mix prepared once the planting date has arrived. If dry, pre-moistening the mix with warm water until it is damp but not soggy makes initial watering easier. Warm water tends to be absorbed more quickly in many soil-less mixes than cold water. Fill containers with mix to about ½–1 inch from the top edge, higher for smaller containers such as cells.

Tamp lightly to slightly compact the mix. Sprinkle the seeds on top of the mix. The number of seeds planted in each "cell" or container depends on how many plants are wanted. A few seeds may not germinate, but most should. Cover the seeds with soil-less mix. Seed packets will generally have guidelines for how deeply seed should be planted. A few plants like lettuce need some light to germinate, so cover those very thinly or simply sprinkle them on top of the soil and then gently tamp the surface again to make sure the seeds are in good contact with the soil surface.

Label containers with the name of the variety. Immediate labeling saves many headaches down the road.

Water the pots with a gentle surface spray (so as not to dislodge the seeds) or place the pots in a shallow container filled with water to bottom-water the plants (the water will soak up to the surface of the soil-less mix). Warm water can be used for the first watering.

Once the soil is moist, keep it moist until seeds germinate. You can use "greenhouse" tops (clear plastic tops) on the trays or slip the containers into a clear plastic bag (to let light in); just leave some room for air circulation. The goal is to have the soil stay moist but not soggy.

Place containers in a comfortably warm spot with some light, but not strong direct sunlight, which can "cook" the seeds or seedlings if covers are in place and it gets quite hot. If using sunlight such as in a greenhouse or hoop house, you may not want covers due to these issues but should be diligent in watering regularly to keep seed moist. Watch for signs of growth. If you've had difficulty germinating seed such as peppers a heat mat can help increase your chances of success. Electrical heat mats for germination can be purchased. Don't use a regular heating pad to germinate your seeds: they are not waterproof and can cause an electrical fire if used for this purpose. Containers/flats that have been planted are placed on top of these mats to increase the temperature and hasten germination.

When plants start to break the soil surface, remove any covers and move the containers to a place with good light. If growing plants under fluorescent lights, keep the plants just a couple of inches below the lights and keep the lights on for 12–16 hours a day. Raise the lights as the plants get taller.

Monitor the moisture of the soil as the plants grow. Aim for damp but not soggy soil; overly wet soil can lead to problems for seedlings. The most common of these is "damping off," which results in seedlings that collapse at the soil line and is caused by a variety of fungi. To reduce chances of damping off, use a soil-less mix, make sure containers are clean, and let the soil surface dry out slightly between watering (more information on seedling diseases follows).

If seedlings are growing too tall too quickly (often referred to as being floppy or "leggy"), the light source might not be strong enough or close enough to the plants, or the temperature might be too warm.

TRANSPLANTING SEEDLINGS

When to transplant seedlings into individual pots (or into the garden) varies with the species. The plants need at least two true leaves (not their first seed leaves) and shouldn't be overly crowded.

Carefully tip the pot of seedlings onto its side and ease out the entire soil mass being careful not to damage those fragile stems. Alternatively, you can pry out individual seedlings from a pot by levering them up gently with a pencil or similar implement.

Roots that are present throughout the soil or that have started circling in the container indicate you should have transplanted the seedlings earlier. Use those seed leaves (or a true leaf) to carefully lift the seedlings and lower them into individual (labeled!) pots (or into a planting hole in the garden). A plant with a damaged leaf is likely to survive, but one with a damaged stem will most likely die.

If transplanting into larger containers, use a variety of soil and soil-less mixes depending on the needs of your plants. A soil-less mix does not have a lot of nutrients. Consider watering seedlings periodically (before or after transplanting) as they grow with a weak fertilizer or as recommended on fertilizer containers.

HARDENING OFF

Hardening off gradually gets plants used to outdoor conditions (brighter light, cooler temps, wind, etc.). One way to harden off plants is to place pots of young plants in a sheltered, shaded area outside and then gradually move them into more exposed locations. Move them back inside (the house, garage, etc.) if frost or severe weather is possible. A second way is to transplant plants directly into the garden and then protect them from the elements with covers or wind shelters until they adjust to outside conditions.

Starting plants from seed is not difficult. It does, however, require a little planning and tending your plants once they have started to grow. The benefits of this process are many.

The difference between seed leaves (cotyledons) and true leaves can be seen on this growing plant sequence image. On the final plants the seed leaves are the round, fat pair of leaves lower on the stem. The true leaves are the ones at the top of the plant. These are the ones to count to determine if your seedling is ready to transplant.
Valentina Razumova, shutterstock.com

SEEDLING DAMPING-OFF DISEASES

Many vegetable and flower seedlings are susceptible to soil-borne fungal pathogens that can cause damping-off disease. Infected plants rarely survive to produce a vigorous plant, and disease can sometimes affect large areas of seedlings both in germination flats and in the soil when planted outdoors. Damping-off diseases are characterized by the following symptoms:

- Seedlings that fail to emerge from the soil.
- Cotyledons and seedling stems become water-soaked, soft and mushy, and may be discolored.
- Seedling stems can become almost thread-like.
- Young leaves wilt and turn grey-green to brown.
- Roots are decayed, stunted, or absent.
- Under high humidity, white cobweb-like growth of the fungus is evident on infected plant parts.

Damping-off disease may be confused with abiotic disorders like plant injury from excessive fertilizer/salts, drowning in wet soil, desiccation, excessive heat, cold, or chemical injury. These types of injury typically involve damage to above ground tissue before roots are affected as opposed to fungal damping-off.

The most common damping-off fungi include *Rhizoctonia* spp., *Botrytis* spp. and *Fusarium* spp. along with the water molds *Phythium* spp. and *Phytophthora* spp. Many of these pathogens can also cause root and crown rots in mature plants under certain environmental conditions. These pathogens are well suited to survive in the soil and plant debris. The pathogens can be introduced into a seedling tray by contaminated hands, hoses, pots, tools, windblown Fusarium spores, and infested soil and potting media. Once introduced to a tray, plant-to-plant infection can occur rapidly.

Seeds directly sown into the soil can also become infected since many of the pathogens are common soil inhabitants. Infection can be severe when planted into soil that is too cool for germination or when conditions turn cool and wet, slowing germination and emergence.

Conditions unfavorable to germination and growth generally favor damping-off disease organisms. These includes cool, wet conditions, low light, overwatering, and excess salts from over fertilization.

Prevention and management of damping off

For germination flats

- Use high-quality seed planted at the proper depth and density.
- Sterilize all germination trays and pots in a 10 percent bleach solution for 30 minutes.
- Use new potting mix, avoid compost and garden soil.
- Clean all tools used in seed starts. Keep hose heads off the ground.

Damping-off in a beet seedling
Mariusz Sobieski, Bugwood.org

- For indoor starts, use a heated germination pad under trays set at 70 to 75 F.
- Use potting mix with good drainage, avoid overwatering. Use pots or flats with drainage holes.
- Use warm water (68 to 77 F) to water seedlings.
- Avoid fertilizers until several true leaves have formed.
- Provide 12 to 16 hours of supplemental grow light to the seedlings.

For planting directly into soil

- Remove plant debris after the growing season prior to seeding the following year.
- Wait until soil has reached optimal temperature before planting. Optimal temperature varies for each plant species.
- Some commercial seed will be pretreated with fungicide to help combat these diseases.

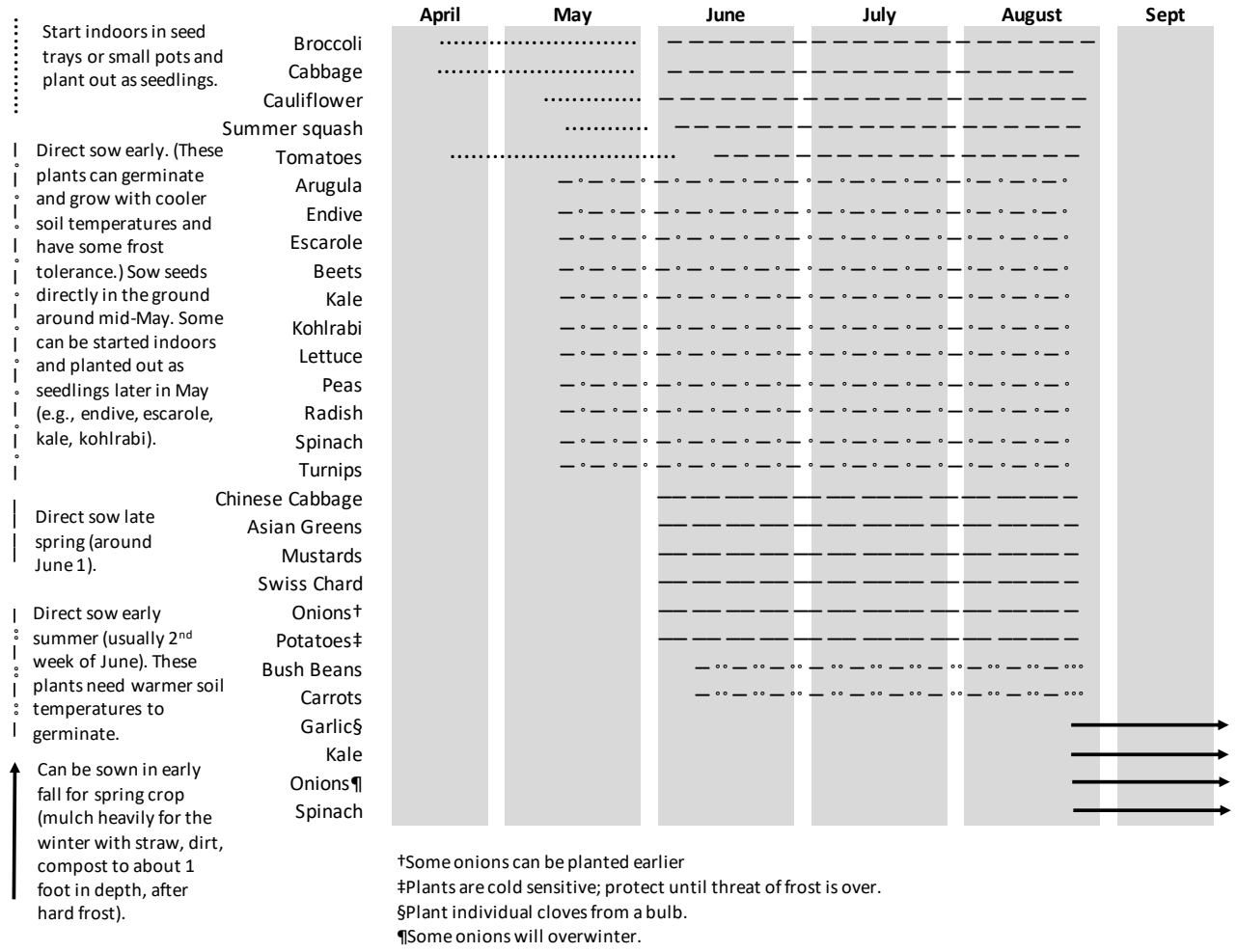
TIMING OF PLANTING

Creating a rough schedule of what you intend to plant when can help you stay on track when planting out your crops for the year, especially if you are very busy. It is very easy for time to slip by and not get your peas planted out before the weather turns too hot. So having a rough schedule of when you will plant each crop can be useful. This rough schedule can be one based on the calendar. An example of one such chart follows.

However, as was mentioned before, each year is different so more precise information on when to plant is provided under each crop in this guide. These sections often provide soil or air temperatures and other environmental guidelines that can help you determine when to plant.

Example planting chart - Recommended Crops and Their Planting Dates, Laramie, Wyoming

* Chart originally printed in the brochure "Vegetable Gardening for Beginning Gardeners of Laramie" by Laramie Garden Club and Laramie Local Foods members



†Some onions can be planted earlier
‡Plants are cold sensitive; protect until threat of frost is over.
§Plant individual cloves from a bulb.
¶Some onions will overwinter.

SEASON EXTENSION

Wyoming's climate is not always conducive for growing and producing certain vegetables or fruits. The early spring and late fall are often the most challenging. The use of season extension structures and strategies can sometimes mean the difference between harvesting a crop or not.

This gardener transplants her tomatoes outside and places wall-o-water structures around them. These structures have multiple, long plastic pockets that are attached to each other to form a large tube. Growers add water into these pockets, which then heats up in the sun and raises the temperature around the plants. The tops of these structures can be pushed together to create a cone around the plant when temperatures are coldest and then opened to form more of a tube when temperatures are warmer to allow excess heat to escape. This high elevation-grower leaves them on all growing season. They can be removed in warmer parts of the state once warm temperatures arrive.
Amy Fluet

The main purpose for season extension is to provide a system that allows plants to avoid periods of cold temperatures without overheating. Growing seasons can be extended by using many different types of plastic, glass, metal, or wood structures. Season extension might be as simple as adding a wall-of-water around a tomato plant or more complex such as constructing a large high tunnel. No matter the size or shape of the structure used for season extension, find the type of structure that will best suit the crop you are growing. Season extension structures are different from greenhouses in that season extension does not use supplemental heat outside of the sun, whereas greenhouses use supplemental heat (and/or cooling).

CHALLENGES

Structures can become too hot during late spring through early fall if they are not properly ventilated. Sunshine in Wyoming is intense, and a structure can quickly heat up to the point where plant growth is halted and plants are damaged on sunny days. Season extension structures provide a great environment for not only plants, but also potential problems such as diseases, problem insects, and small rodents. Careful monitoring and management are important to decrease the impact from these issues. With high intensity light at high elevations in Wyoming and reflective surfaces within structures, plant issues can arise with too much light. Plants can become light saturated and look as if they had been injured from herbicides and lose productivity. Shade cloth can be a useful tool to help cut down on heat and light sensitivity issues.

Wyoming's harsh climate can play havoc on the structures themselves. Hail, wet snowstorms, and strong winds can shorten the lifespan of many structures. The economics of installing season extension for the amount of extra produce gained is important to consider. For more information on season extension structure repair, designs, and management, please visit the season extension information on at the Barnyards and Backyards

website, www.barnyardsandbackyards.com, under the "Gardening" link.

STRUCTURE DESIGNS AND SIZE

High tunnels

High tunnels can be made of wood, plastic, and/or metal. Designs vary from a straight hoop design or one that resembles more of a gothic style. A hoop design generally involves the use of a material that can be shaped into a semi-circular design from materials such as PVC pipe or metal. A gothic design can be built out of wood or other materials not as easily bent. (The program in Wyoming that has helped teach Wyomingites how to build high tunnels for over a decade no longer recommends Gothic PVC designs as these designs seem more prone to collapse than some others due to heavy snow loads, etc.).

High tunnels are large structures that provide ample space for people to move and work around inside. Air circulation is important for high tunnels. Many structures use fans, doors, windows, or roll up sides to help release hot air from the structure. High tunnel structures provide enough space for larger crops and greater crop production compared to other smaller structures. They also provide enough space that a variety of crops can be planted. High tunnels can be useful for home or commercial fruit and vegetable production.

Crops can be planted directly into the ground or grown in raised beds. The larger size of high tunnels provide space for vertical gardening. Some agriculture producers build high tunnels on rollers that can be moved between various crops and plantings. Rollers allow for high tunnels to help certain crops to get a head start on the season in one area and then rolled to a new location to start a new set of crops better suited for later in the growing season.

High tunnel structures can be scaled up or down depending on the size of garden and the crops to be grown. Most high tunnels start around 10 to 12 feet wide and 16 to 20 feet long, and plans get larger from here. Smaller structures that resemble high tunnels can be attached to a raised bed or built with a separate frame to be moved on and off raised beds or the ground. These smaller structures, which are sometimes called low tunnels or frames, will not necessarily have doors for easy access like those of a larger high tunnel.

High and low tunnels can be covered with a wide variety of plastic coverings. These coverings vary drastically. Some plastics can be fairly inexpensive and purchased at local hardware stores; however, they may have a very short lifespan (such as a year or less) before they deteriorate due to sunlight, wind, and other factors. Other more expensive UV resistant plastics might last seven or eight years and can be made of woven material that doesn't tear as easily, or sturdy plastic materials. Polycarbonate sheeting can be used for gothic style high tunnels instead of plastic cover coverings.

High tunnel, Torrington, Wyoming

Geodesic domes

Geodesic domes are yet another type of season extension structure. As the name suggests, these types of structures are dome-shaped. The inputs and considerations regarding materials for constructing, cooling, and growing in a geodesic dome are very similar to that of high tunnels.

There are a wide variety of geodesic dome shapes, sizes, and plans available for construction. Geodesic domes may be purchased in kits or constructed from locally sourced materials. UW Extension, in partnership with the Wyoming Department of Agriculture, has built various geodesic domes around Wyoming that are being evaluated for use in our challenging conditions.

The taller sides of geodesic domes are a positive attribute for many growers who use them. The shape of geodesic domes has been a positive attribute for high snow load and wind prone areas. In some instances, geodesic domes may fit better into landscapes and backyards.

Building materials

The material used for both geodesic domes and high tunnels greatly influences the overall strength and lifespan of structures. The materials used to cover structures will dictate the amount of light that can reach plants, longevity in Wyoming's harsh and sunny climate, and overall strength for snow loads and wind-prone areas.

High tunnel designs from other parts of the U.S. (or kits) may not be able to handle the wind and snow loads found in many parts of the state. For example, additional anchoring (such as using batten straps) for wind-prone areas is important. These additional measures can increase your chances for success. Read Barnyards & Backyards magazine article "101 (almost) ways for a high tunnel to die" in the Fall 2014 issue for more tips. https://bit.ly/high-tunnels-2014.

Cold frames

Cold frames are another great option that can be made from a variety of materials. Many cold frames are made from old windows or pieces of polycarbonate materials. Cold frames tend to heat up very quickly. There is generally not as much air space with a cold frame compared to that of a high tunnel, so it is important to open the cold frame before plants become overheated. Greenhouse vent openers (there are non-electronic ones that open when the temperature increases) can assist those who are not around to open the cold frame; however, they will add to the cost of the cold frame and can be limited in how far they open (distance) or how much weight they can handle. Cold frames are great because they can be made from recycled materials and are of simple design. They are smaller in size and fit easily in many backyard gardens. The downside to cold

Building a geodesic dome, Sundance, Wyoming

Backyard cold frame

frames is they are not as well suited for larger crops or large quantities of crops. Safety is also a concern while working near cold frames made of glass since they can be quite dangerous if the glass is broken.

Multiple strategies

Remember, one form of season extension does not need to be the only strategy for extending the growing season. Walls of water, sailor caps, hot caps, row covers, low tunnels, or cold frames are few examples of secondary methods that can be used inside larger structures such as high tunnels. There is generally ample light for plants to continue to grow once the use of multiple structures is implemented. These added methods can help during critical times when temperatures dip and then removed during warmer temperature periods. Jugs or containers of water are also often used in smaller structures to help heat retention.

Other benefits of season extension structures

Mitigating cold temperatures is an obvious reason for implementing season extension structures; however, there are other benefits to season extension such as decreased damage to plants from wind, providing a more humid environment for decreased water loss from plant leaves, and in some cases preventing insects or small and large animals from eating plants. Keep in mind a more humid and protected environment can create a more hospitable home for insects and diseases.

Consider nighttime temperatures as well

Unfortunately, many warm season crops (tomatoes, peppers) can struggle in some locations in Wyoming (they grow better in the lower elevations and basins of the state). Season extension can help growers successfully produce these types of warm season crops. Remember, just because a high tunnel or other season extension structure is installed does not guarantee the success of growing these types of crops in challenging areas. Season extension uses energy from the sun. Once the sun sets, the main source of heat is no longer available to keep plants warm. Even though a structure may reach well over 100 degrees during the day, it is very difficult for warm season plants to function properly when nighttime temperatures fall into the 40s. Peppers, for example, need temperatures to remain above 60 F for proper fruit set.

Consider where your garden or farm is located and the environment of your growing area when selecting a season extension structure and crops to be grown inside the structure. Although season extension might allow for some warm season crops to be grown in cold regions of Wyoming, selecting various types of cool season plants grown with protection might

White row cover material is placed over hoops to create this low tunnel.
Sever180, shutterstock.com

One of the other benefits of many season extension structures is they protect produce from small hail.
Aleksandr Ozerov, shutterstock.com

provide better success and greater production. Season extension can potentially allow for a cool-season crop to be harvested at two separate times (spring and fall).

As stated earlier, season extension structures can be made from a multitude of materials with endless design options. Season extension might not be the best or most suitable option for every garden or farm, but can be an added value for many. Matching crops, the growing environment, and season extension structure will provide the greatest potential success for season extension on your farm or garden.

ADDITIONAL RESOURCES

- Season extension information and articles. www.uwyo.edu/barnbackyard/resources/gardening.html
- Gardening: extending the vegetable growing season. https://bit.ly/1148-extend-season
- Hot Beds and Cold frames. https://bit.ly/1151-hot-beds
- Hard-sided high tunnel construction. https://bit.ly/1240-high-tunnels
- Insect control. https://bit.ly/insect-control-2013
- Microclimates. https://bit.ly/microclimates-2007

WEED MANAGEMENT

Weed control is important in most vegetable and fruit growing efforts. Competition from weeds can seriously impact yields or serve as a source of various diseases or insect pests. Weed management can be easy or extremely difficult depending on the size of the area, the species of weeds, and the management options available for control.

Think about what you are trying to accomplish when considering weed management. First, prioritize what weeds and what populations you want to control. Then ask yourself some questions such as: Do I want to eliminate every weed in the area? Are there certain weeds I will tolerate, but others I want completely removed? Is it possible to eliminate weeds with the resources I have at hand for control?

Deciding what you want as an end result is important. This decision will help prioritize steps needed for control. It should be noted there is no "silver bullet" for weed control.

WHAT MAKES A WEED?

If we think about what makes a plant "weedy," we can start to understand how to reduce or eliminate their competitiveness. Weeds are unwanted plants that interfere with what we are trying to accomplish. They are hard to get rid of and rarely have redeeming attributes. By most definitions, weeds can be native to North America or introduced from another continent. Regardless of origin, these plants generally have at least one highly competitive trait and often more than one. These competitive traits often include the ability to outcompete other plants for available resources (nutrients, water). Whatever the competitive advantage, weeds can reduce crop production, create aesthetic eyesores, and make physical work within a garden difficult.

WEED MANAGEMENT

Now that you have determined what you'd like to accomplish, it is time to make sure the weeds in the garden are properly identified. Improper identification can lead to decreased efficacy in control and lots of frustration. If unsure of identification, you can take a plant sample to your local University of Wyoming Extension office (https://www.uwyo.edu/uwe/county/), Weed and Pest District Office (https://wyoweed.org/), or use resources located on the Barnyards and Backyards (www.barnyardsandbackyards.com) website. A plan of action can be made once a plant has been properly identified. There are three general management strategies to go about managing weeds. These strategies are chemical, cultural and mechanical, and biological control.

CHEMICAL

Chemical control generally refers to the use of pesticides to control weedy plants. Pesticides that control plants are known as herbicides. Chemicals can be purchased at local home and garden stores, nurseries, or weed and pest districts. Organic or synthetic herbicides can provide long- or short-term control for many weeds. Before applying any herbicide, read the label to understand the potential harms to you, desired plants you are growing, the environment, and any other animals, plants, insects, or humans that might come into contact with the area sprayed. The label will also list the types of areas where it can be used.

There are home remedy herbicides you can mix yourself for weed control. While most of these remedies may be perfectly fine to use (or not), it should be understood these make-it-yourself herbicides have not been approved by the EPA. The acute toxicity to humans, animals, plants, and insects has not been scientifically tested, and they most often have not been tested scientifically for their effectiveness. Home remedy herbicides are "mix and use at your own risk."

Herbicides can be applied during the spring, summer, or fall. Herbicides might be selective or non-selective. Non-selective herbicides will harm any plant they come into contact with, while selective herbicides only affect certain types of plants (either grasses or broadleaved). For example, an herbicide effective at controlling broadleaf weeds (non-grasses) will not only kill the broadleaf weeds, but also harm or kill any broadleaf vegetables (tomatoes, beans, peas) that it contacts. This same type of herbicide will not kill weedy species of grass or a crop such as corn, which is a grass. There are also grass selective herbicides available that only control grasses.

Herbicides can also be categorized as foliar active or soil active herbicides. Foliar active herbicides will only be active and absorbed by plants when the herbicides comes into contact with a plant leaf. Soil active herbicides remain active in the soil after they have been applied. Soil active herbicides become a challenge to manage if they have been applied at a higher rate than recommended or applied by accident. This is an issue because there is not an easy way to remove these types of herbicides from the soil. A multitude of factors influence how fast pesticides break down in the environment. An accidental or over application of the wrong type of herbicide in the wrong location may preclude vegetable crops from being grown in a soil that has been treated for several years.

If you still have questions after reading the label of a herbicide, contact your local University of Wyoming Extension Office or Weed and Pest District. These groups can help answer questions such as which herbicides control what plants, what is the best timing for use, potential long- and short-term effects, and what safety measures should be taken. Always calibrate your application equipment if you choose to apply herbicides so the correct amount will be applied.

CULTURAL AND MECHANICAL

Cultural and mechanical weed management involves the types of activities used in and around the growing area. Methods vary depending on the size of the space and weed species.

Mechanical weed management can be used to physically harm plants. Plants can be physically removed (hand pulling, etc.), or certain plant parts can be harmed such as mowing off flower heads. The timing of mechanical treatment can change based on the specific species of weed you are trying to control. Mechanical treatments such as tilling also have the potential of spreading weeds. Chopping up the rhizomes of Canada thistle for example during tilling can spread new plants to different areas of the garden. New Canada thistle plants can start from pieces of chopped up rhizomes less than an inch long.

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Cultural practices such as cleaning equipment, not bringing in contaminated soil or compost, and buying seed completely devoid of weed seeds are effective for preventing new weed populations from starting in the garden. This can sometimes be a challenge depending on the size of the growing area and who is allowed to use the space. For example, community type gardens can be hard to regulate.

Mulching is another effective method for controlling weeds used by many growers. A variety of products can be used as mulch such as plastic, newspaper and straw, natural wood material, or grass clippings. Wind is often a consideration in our state when selecting mulch types. Mulch can be effective at suffocating weeds and not allowing new weeds to pop up. Mulch also helps conserve water, helps add organic matter (natural mulches), and add heat to the soil for some plants (black plastic mulch). If using natural products, make sure they are free from herbicides. Grass clippings that have been sprayed with herbicides for weed control and then moved to the garden may still harbor chemicals that will impact garden crops. Mulch works well for all of the same reasons listed above for fruit trees and shrubs. It also helps cut down on impacts from weed eaters used in lawn care around trees.

Hand pulling weeds is one of the oldest and most common cultural weed management methods; however, it can require a lot of labor in larger areas. Hand pulling is great because it physically removes the plant from the area. Properly disposing of weeds is important. Weeds that have matured to produce seed can be composted only if the compost gets hot enough to properly kill weed seeds; however, hand pulling can stimulate some weeds with large rhizomatous root systems to produce more plants (Canada thistle). Unfortunately, hand pulling needs done throughout the growing season for effective control.

Various types of hoes can speed up the weeding process in larger areas when the weeds are not too large. Along with the traditional "draw" hoe, there are others that may be easier to use and cause less soil disturbance (which may bring more weed seed to the surface). Some different kinds of hoes are the stirrup hoe, scuffle hoe, collinear hoe, wire hoes, etc. Some research will help find the best tool for your purpose. As with other tools, maintenance is beneficial– periodically sharpening hoes (if their design benefits from this) will decrease the labor needed to control weeds.

CROP ROTATION AND FERTILIZER

Can you reduce or eliminate fertilizers in a garden? Excess nutrients in the soil can sometimes encourage the competitiveness of certain weeds such as Canada thistle. Crop rotation that includes a legume for adding nitrogen, for example, can help keep the nitrogen within the garden system and potentially decrease excess nitrogen that moves to the garden edges where weeds are often prevalent. Do not use fertilizer products that contain fertilizer and weed control chemicals. The herbicides within these products can negatively impact vegetable crops.

Crop rotation is an easy cultural practice that helps break up weed and disease cycles. Switching up what vegetables that are in each bed, field section, or other specific location will impact each weed differently. Some vegetables such as squash will help shade out certain types of weeds, while other types of vegetables will compete with the roots of weeds. Planting crops dense enough to not impact production but cut down on the number of weeds that are able to establish is an important strategy.

Cover crops grown in vegetable gardens are a great weed control option. Annual crops such as grains or legumes can be planted to decrease the prevalence of weeds from increased competition, provide stability to soils during the winter, can be cut and left as a mulch on top of the soils surface, and increase soil organic matter. Finding enough growing season for both a cover crop and vegetable production might be a challenge in some areas.

BIOLOGICAL CONTROLS

Biological control (such as releasing insects to control weeds) might be the least effective control method. Due to the actual physical space, it is more effective to hand pull the weeds of concern or use another cultural or chemical control option. Biological control methods most often only keep a weed population in check and prevent spread. It will not usually eliminate a population since the biological control needs a host to feed on and support the next generation.

IPM

Integrated Pest Management (IPM) is a strategy that implements a combination of chemical, cultural, mechanical, and biological control methods to have the greatest effect on control and benefits for the environment and human health. Using multiple strategies can help provide the greatest control for weeds. Monitoring success is an important part of IPM. Understanding what methods are the most effective for control can help save time and money for future efforts when controlling weeds.

FINAL THOUGHTS

Early response to weed issues is critical no matter what you decide as a method for weed control. Controlling a small population of weeds is much easier than trying to control a large population. Early control also helps decrease the risk of weeds going to seed, establishing large root systems, and having a negative impact on vegetable crop production. Weed seed can not only produce many more weeds in the short term, some weed seed (such as bindweed) can survive for many years in the soil. One season of neglect will lead to years of weed problems. For more questions related to weed control, visit your local University of Wyoming Extension or Weed & Pest District Office.

DIAGNOSING PLANT PROBLEMS

HERE'S HOW TO DETERMINE WHAT'S AILING THEM.

Your tomatoes have developed strange-looking yellow spots on their leaves.

And the apples have odd-looking patches on the fruit.

Where do you start to determine the causes of these ailments?

Trying to diagnose plant problems without training can be tricky, but, if you follow some general guidelines, it's not impossible. Keep in mind the probability of diagnosing a problem based on only one or two symptoms is often low. Totally different factors can cause similar symptoms on the same plant. Looking at the plant alone usually does not tell the full story.

IS THERE *REALLY* A PROBLEM?

Determine if there truly is a problem. Identify the plant and learn its characteristics and normal growth patterns. Compare the damaged plant with a healthy one of the same species (plantfacts.osu.edu is a good online plant photograph source) and variety. Some plants are naturally variegated or have different pigmentation during various parts of their life cycles. Differences in color may not necessarily indicate a problem.

SIGNS VERSUS SYMPTOMS

Next, distinguish between signs and symptoms. A sign is the presence of the actual insect, mite, bacterial slime, or fungus. An example would be seeing a pear slug munching on the leaves of your favorite sand cherry in the back yard. Another example would be seeing the white, powdery mycelium characteristic of powdery mildew.

A symptom is the plant's reactions to a pest or pathogen. Concentric rings of dead tissue will form on impatiens leaves in response to the presence of the impatiens necrotic spot virus. Tips of apple or pear tree branches will blacken and curl in response to bacteria-caused fireblight. Keep in mind many factors produce similar symptoms, so, relying on symptoms alone often does not produce a definite diagnosis.

Now step back and look at the whole plant. Oftentimes, the plant part showing symptoms is not the plant part that has been damaged. For example, damage to root systems of trees frequently results in foliar symptoms such as wilting or premature leaf drop. In this case, the primary problem is with the roots and not the leaves.

LIVING VERSUS NON-LIVING CAUSES

The next step is to look for patterns in the damage to the plant. This is where biotic and abiotic causes come into play. What's the difference? Simply put, biotic problems are caused by living organisms such as insects, mites, nematodes, fungi, or bacteria. Abiotic problems are far more prevalent in our Wyoming climate and have non-living causes such as improper temperatures or irrigation, nutrient deficiencies, and mechanical damage.

Note that biotic problems are more random and less organized than abiotic problems. There is usually no uniform pattern. For example, if scattered damage in the plant canopy is seen, it's possible there is a foliar or aerial problem and not involving roots; however, if scattered branches gradually decline and eventually die, there is a strong possibility a canker pathogen, shoot blight, or borers may be causing the problem. Living organisms will usually damage foliage or needles in random ways and not in patterns.

Problems caused by cultural or environmental (abiotic) issues tend to affect all plants in the same area pretty much the same way. For example, damage from a chemical may appear on all leaves of the same age. Or all the foliage on one side of a plant may be

affected, as happens with sunscald on the southwest side of trees. Also, damage will generally appear on more than one type or plant species.

THE TIME FRAME

Another factor in the diagnostic process is whether the damage occurred suddenly or gradually. Sudden declines in plant health are typically caused by nonliving factors such as frost or chemical drift. Plants that show gradual declines have generally been attacked by a living factor. Wilt diseases and damage from root weevils are examples.

GETTING CLOSER TO A DIAGNOSIS–BIOTIC CAUSE

So, you think you've narrowed the problem down to a biotic factor caused by some six- or eight-legged creature or evil fungus. How do you know which?

Problems caused by pathogens can be fairly distinctive. Fungal diseases often show signs of thread-like mycelium and fruiting bodies. You may need a hand lens or microscope to see these. Bacterial diseases may have characteristic water-soaked lesions associated with them. Viral diseases often cause foliar distortion, stunting, or leaf yellowing.

Problems caused by insects or mites will also show typical damage depending on the culprit and their feeding habits. Chewing insects such as caterpillars or leaf beetles can consume parts of or entire leaves. Sucking insects like aphids and whiteflies leave behind a stippled or mottled appearance on the foliage. Heavy infestations of spider mites will be evident from webbing, and slugs can skeletonize leaves and leave behind slimy trails wherever they go.

GETTING CLOSER TO A DIAGNOSIS–ABIOTIC CAUSE

What if you think it's an abiotic problem? How do you determine the cause? These can be put into three general categories: mechanical, environmental, or cultural.

With mechanical damage, there may have been recent construction, excavation, or paving activities close by.

THE DIAGNOSTIC PROCESS

- Is it really a problem?
  - Find out what a normal plant of this type looks like.
  - Check the whole plant and its surroundings.
- Look for patterns. Is it one plant? More than one species?
  - Non-uniform or irregular damage is usually caused by a living or biotic factor.
  - Uniform damage patterns indicate nonliving or abiotic issues.
- How long did it take for the damage to show up?
  - If progressive, it's probably an insect or disease.
  - If it hasn't spread or occurred suddenly, it was probably environmental or cultural.
- Identify the possible cause.
  - Possible living factors
    - Signs and symptoms of disease-causing pathogens
    - Signs and symptoms of insects, mites, or other animals
  - Possible non-living factors
    - Mechanical
      - Construction
      - Excavation
    - Environmental or physical
      - Temperature extremes
      - Moisture extremes
      - Improper light for the plant
    - Cultural or chemical factors
      - Nutritional disorders
      - Pollutant or pesticide phytotoxicities
  - Use references or labs to help determine the exact cause of the problem.
- Put all this information together to determine probable causes.

Resources available to help diagnose plant problems

- University of Wyoming Extension. www.uwyo.edu/uwe/county/
- Barnyards & Backyards: Rural Living in Wyoming. www.uwyo.edu/barnbackyard/ (Plant Disease, Insects and other useful sections)
- University of Wyoming Extension Plant Disease Diagnostic Clinic. wyoextension.org/plantclinic/
- David Leatherman and Whitney Cranshaw. 2004. *Insects and Diseases of Woody Plants of the Central Rockies*, Colorado State University.
- PlantFacts Web site: plantfacts.osu.edu
- 2012. *The New Sunset Western Garden Book: The Ultimate Gardening Guide*. TI Inc. Books.
- Cranshaw, Whitney. 2017. *Garden Insects of North America*. Princeton University Press, Princeton, NJ.

Kwangmoozaa, shutterstock.com

Diseased tomato plant

Suspect mechanical damage if there are broken stems, branches, and torn leaves.

Environmental or physical factors include temperature extremes, flooding, high wind, and high or low light levels. High temperatures often cause wilting while exposure to overnight frost can cause blackening of foliage tips. High winds can dry plants out very quickly. Exposure to high light levels can cause wilting and burning of the foliage with brown tips showing up on the leaves.

Cultural or chemical factors include improper irrigation or pesticide application, exposure to air pollutants, and nutritional disorders. Erratic or insufficient irrigation is quite common leading to death of upper plant parts or even the whole plant. Spray drift from herbicide applications is, unfortunately, very common. Every herbicide has its distinctive mode of action with accompanying symptoms. Air pollutants in urban areas often cause injury to some types of plants, and nutritional problems often arise in our poor Wyoming soils because of high pH, poor soil quality, and poor irrigation water quality. Every nutrient essential for plant growth and development has its own specific deficiency (and toxicity) symptoms–some of which mimic pathogens.

STILL NOT SURE?

Consider this: in Wyoming's climate, the vast majority of times the problem will be cultural or environmental and not caused by an insect or disease. Avoid the temptation to blame a plant's poor health on a critter of some sort. Also, avoid the temptation to look up the possibilities in one-book-fits-all-locations references. Plants, insects, mites, and disease-causing pathogens have very individual geographic distributions and environmental requirements. The pest you find in that problem-solver might not even be found in Wyoming.

THERE IS HELP!

Contact a local office of University of Wyoming Extension if help with the diagnostic process is needed. Contact information is at https://www.uwyo.edu/uwe/county/. Extension educators and Master Gardeners can help sort through issues to determine a probable cause as well as offer remedies. There are also numerous specialists on the UW campus in Laramie to help with more specific issues.

And remember, the culprit just might be you.

INTEGRATED PEST MANAGEMENT (IPM) FOR INSECT PESTS

When you find insects and mites on your crop, the first thing you will need to do is identify them. Identification is very important–it can tell you whether the creature is a pest or not, help you learn its lifecycle and if needed, help you determine what management tools are available.

Once you know what the arthropod is, determine if it is a beneficial creature or a pest. If it is a pest, what are appropriate management steps you can take? It is important to try to implement more than one management method to suppress pests, especially if they are an issue every year. This is what is meant by the phrase Integrated Pest Management (IPM). Pests can become resistant to just about any single control method applied over and over again with the exception of hand picking. Types of IPM practices include biological control (using natural enemies), cultural control (such as changing irrigation practices), mechanical or physical controls (such as row cover to exclude insects), and chemical control (using the most selective pesticide possible, whether they are conventional or organic). Care should be taken in choice and application of pesticides so you do not unintentionally impact insect pollinators or other beneficial insects. Pollinators are often critical to getting good yields of fruits and some vegetables.

The economics of pest control becomes an important consideration when growing fruits and vegetables for sale. The cost of management cannot exceed the value of the crop yield protected and still make economic sense. Physical and cultural pest management methods are often some of the

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Aphids

lowest cost pest management measures. They are often implemented ahead of or at the start of the growing season to reduce pest populations. They can also be used to provide economical protection from perennial problems, such as using row covers to help exclude common pests like flea beetles or grasshoppers from crops.

If using this publication to help you transition from producing a small amount of fruits and vegetables to larger scale production you are likely already familiar with common pests for most crops. However, the management practices that worked well for a home garden may not be as effective on a larger scale (while allowing you to make a profit). For example, hand picking Colorado potato beetle larvae off pepper plants in a 25-foot garden row is doable but isn't feasible on a one-acre field if you factor in cost of labor. The tolerance for pest damage in a commercial operation may be lower as well. When you find a corn earworm under the husk of your sweet corn picked from your own garden most people trim the damage off and eat the ear anyway. Unfortunately, a customer who finds a corn earworm in the sweet corn they purchased might never buy from you again at a farmers market.

Determining the economic and action thresholds for the various pest populations on your crops is a very important consideration for IPM. How many pests present or how much crop damage should trigger control measures? Knowing this will allow you to take the appropriate measures quickly enough to be effective.

Important factors to consider when setting these thresholds are the potential crop price and yields per acre. You need to estimate potential loss in yield and/or value of the crop versus the cost of management for example, a pesticide and the cost to apply it. The cost of the control measure has to make economic sense in order to have a profitable business.

You should be able grow healthy vigorous plants by following the plant health guidance information provided for each crop in this publication. Healthy plants are able to tolerate light pest pressure and, in some instances, even mount a strong defense against insect feeding. Frequent and thorough inspection of your plants for potential pests is a critical step to protect and prevent damage to your crop. Special attention should be given to the pests that may damage the saleable part of your crop. For example, aphids feeding on tomato plant foliage may slightly reduce yield or product size, but tomato fruit worms can make your product worthless at the market.

Scouting for insect pests by regularly examining plants for pests and damage and other problems is an important part of IPM. The earlier you catch an issue, the better prepared you will be to address it. A pest calendar can be useful tool to remind you what pests you need to be alert for as the growing season progresses. Using monitoring tools such as sticky cards and pheromone traps can help reduce the time required to monitor your crops.

In this guide we have listed many common and some uncommon pests for a wide variety of crops. Budget and page limits constrain the number of and the depth with which we can detail the pests of each crop. Pesticide recommendations are only provided in generalities as changes in product names, labeling and registrations could make specific recommendations obsolete the day after publication.

For more information on pest control options, see University of Wyoming Extension publication "What's in your toolbox?" at http://bit.ly/bug-toolbox.

For more information on aphid and variety of insects check out "Insects" page on barnyardsandbackyards.com and the following books: *Pests of the West* by Whitney Cranshaw and *Garden Insects of North America* by Whitney Cranshaw.

COMMON CROP PESTS

Aphids

Green peach aphid colony on underside of pepper leaf.
Whitney Cranshaw, Colorado State University, Bugwood.org

With over 1,500 species of aphids present in North America you will probably have to manage some of them to protect your crops. For some aphid species, on certain crops, no management is required as light feeding damage can be tolerated by healthy, vigorous plants. If you are trying to use or encourage biological control of aphids in your crops you cannot have a zero-tolerance policy toward aphids and still have self-sustaining populations of their predators and parasitoids. Aphid species attacking the saleable portion of your crop, vectoring a plant disease, or overwhelming the ability of natural controls with a population explosion will require implementation of management tactics compatible with your crop.

Identifying a pest species as precisely as possible will help you determine its life cycle. Life cycle information allows identification of possible strategies to attack vulnerabilities. This is especially true with aphids as different species often have complex annual life cycles that involve different plant hosts and even different plant parts. A classic example of two host aphid life cycle is the **sugarbeet root aphid** (*Pemphigus populivenae*). This aphid species initially starts its annual life cycle as eggs that spend the winter on the bark of poplar trees. The eggs hatch in the spring as the tree's leaves develop. The aphids feed on the new leaves and inject chemicals as they feed that form protective hollow galls for them to inhabit on the leaves' surface. In late June, the leaf galls dry and split open to release the now winged aphid females. The new sugarbeet aphids fly away to find plants in the beet plant family. Their offspring are "wooly" wingless females that feed on the roots of beets and reproduce. At the end of summer, a generation of winged male and female aphids fly back to poplar trees to mate and then deposit the overwintering stage eggs on the bark.

Sugarbeet root aphid (*Pemphigus populivenae*) in the wooly form feeding on the roots of a plant.
Whitney Cranshaw, Colorado State University, Bugwood.org

A leaf gall formed by sugarbeet root aphid on its poplar tree winter host.
Petr Kapitola, Central Institute for Supervising and Testing in Agriculture, Bugwood.org

With the example of the sugarbeet root aphid, it would be impossible and impractical to treat all the poplar trees in a river valley for these pests to prevent them from moving into beet fields. However, a root

vegetable production area that is isolated with a just a few infested poplar trees nearby might be worth implementing control treatments on. Other common pest aphid species can sometimes be suppressed outside of crop fields with mowing, tillage, and herbicides to eliminate "green bridge" host plants that sustain their populations until your crop plants become available in the spring. Pest management practices that prevent a pest from getting into your crop often have a better cost-to-benefit ratio than treating them once they get in the crop.

Cutworms

Army cutworm larva.
Whitney Cranshaw, Colorado State University, Bugwood.org

Cutworm is a generic name applied to some of the larvae of the over 400 species of moths from the family Noctuidae. Multiple cutworm pest species are widespread in Wyoming and can rapidly damage many different crops. The worst damage tends to occur in the spring. The army, pale western, dingy, and variegated cutworms are the most common crop pest species in Wyoming. These cutworm species vary somewhat in their coloration and exact timing of life cycle events. One thing they all have in common is the larvae are primarily nocturnal feeders. When scouting for these pests during the day growers should look closely for their diagnostic feeding damage and search the upper soil and crop residue for hiding cutworms.

The population density at which pest cutworms should be treated varies with the crop and the cost of the treatment available. The crop may be able to outgrow cutworm pests if the feeding damage is just a light defoliation. However, if the cutworms are killing seedlings, weakening plant main stems, or feeding on the saleable part of the crop, then management is advisable to keep the damage below the economic injury threshold.

Scouting the edges of fields which are adjacent to the grassy and weedy habitats cutworms favor can reveal the larvae moving from those areas into the crop. Treatment of the source habitat and field edges may be required to protect the crop when it is most vulnerable to damage.

Cultural control options

Weed and crop residue management with tillage or herbicides in the late summer, fall, and in the early spring before planting, can eliminate the habitat the adult female cutworm moths select to deposit their eggs in. In the spring, removal of green weedy plants can starve these pests. It disrupts the "green bridge" the cutworm larvae survive on until the crop plants start growing. You can also plant seeds at a higher rate to compensate for seedlings lost to these pests but the cutworms may not "thin" the crop evenly for you. In a small garden, putting protective collars, as a physical barrier to cutworms, around seedlings may be useful but in a large field they are not very practical if labor costs are considered.

Conventional control options

Cutworms attacking and killing seedlings will need a fast-acting insecticide to end the damage. If the plants are small, most of an insecticide spray application will land on the soil. A "stomach" type insecticide, that must be consumed to kill the insect, isn't a good choice if most of it ends up on the soil around the plant. A contact active insecticide applied to the soil is generally more effective as cutworms crawl through it. The cutworms will encounter a lethal dose of insecticide as they move to feed on the plant. This information from the "*Southeastern U.S. 2020 Vegetable Crop Handbook*" provides useful topical insecticide application tips to increase cutworm control:

"If cutworms are actively cutting plants, a post-planting contact treatment may be necessary. The following procedures may help improve control when a contact insecticide treatment is used:

- *Direct sprays at the base of the plants where cutworms are actively feeding.*
- *Increase the amount of water used to at least 30 gallons per acre, especially in dry weather.*
- *Spray between midnight and 5, when cutworms are most active.*
- *Cultivate after insecticide application to improve contact with cutworms, especially in dry weather. In all cases, consult the label for application details."*

Insecticidal treated baits are available for cutworms that are applied to the soil surface in the field. When the cutworms move to the soil surface to feed on the plants in the evening, they encounter the bait and, ideally, eat it before they get to the plants. Baits can do a better job of targeting just the pest and are usually less damaging to non-target species than broad spectrum insecticide sprays. There are also systemic insecticides that can be applied to the soil furrow when planting or as a seed treatment that can be used against cutworms. However, the particular vegetable crop you are protecting has to have a product labeled for that use. The cutworms will still inflict some damage to a treated plant before succumbing to the insecticide as they must eat some of the plant to get a dose of insecticide.

Organically acceptable biological control

Organic Materials Review Institute (OMRI) certified bait formulated with active ingredients such as spinosad or *Bacillus thuringiensis* var. *kurstaki* can be used to combat cutworms. Applications of liquid solutions carrying insect attacking nematodes to moist soil around seedlings can also kill cutworm larvae. Commercial parasitic nematodes are shipped with very specific information regarding application and the environmental parameters necessary for their success. The nematodes are a living organism and require storage and application in hospitable conditions, such as moist soils above 50 F, if they are going to be successful. Climbing cutworms can be controlled with pyrethrum based foliar treatments to quickly control the pests before they cause extensive damage to the saleable portion of a crop. In addition to mechanical cultivation, fire can be used to control weeds where conditions are suitable and if it can be done safely and in compliance with local ordinances.

Flea beetles

Adult palestriped flea beetle
Frank Peairs, Colorado State University, Bugwood.org

Potato flea beetle damage
Whitney Cranshaw, Colorado State University, Bugwood.org

A grower first seeing a flea beetle may not realize these insects are actually true beetles. Unlike many other beetles, flea beetle species are very small (flea sized) and can jump long distances. They can rapidly move away from growers inspecting plants due to their jumping and flying ability. This can leave the grower wondering what insect is creating the distinctive pitting and shot style holes on the leaves of many of their plants.

Just about every garden vegetable has a species of flea beetle that likes to feed on it. Some flea beetles

species are serious agricultural pests, either through direct feeding damage on vulnerable seedlings or by transmitting plant diseases as they feed. The individual species of flea beetles that plague the many crops covered in this guide are specified in each crop section.

All the flea beetle species share some common life cycle steps and behavioral traits, so some management steps are universal for them. Flea beetles generally originate from outside crop fields in the spring. A great first management step is weed control around and in growing areas, especially the control of the early season mustard family plants, which are a favorite late-winter and early-spring food for overwintering adult flea beetles.

Monitoring seedling crops with yellow sticky cards and frequent visual inspection will help discover and then treat infestations early. Flea beetles are very mobile and can fly in and infest an area in a day. Another method of dealing with flea beetles is to plant crops when conditions will allow rapid, vigorous growth so the plants will be able to "outgrow" the flea beetle damage. Trap crop planting can be used to intercept flea beetles moving into fields. Radish is an example of an easily germinated species that can be used as a trap crop for many of the flea beetle species. The trap crop can then be treated to kill the beetles. Row covers can be used to protect plants from flea beetle depredations. The recommended mesh hole size is .35 mm^2 or smaller to exclude the beetle.

Insect predators can kill flea beetles if they can catch them; however, early in the season generalist insect predators, such as lacewing larvae, are too small to be effective. The insect fungal pathogen *Beauveria bassiana* can be applied to infect and kill flea beetles. The products containing the spores of the pathogen are labeled for a wide variety of crops. The spores of the disease are rapidly deactivated by the ultraviolet radiation in sunlight so applications made in the evening will help increase the percentage of flea beetles infected by the pathogen.

A wide variety of insecticides can be used against flea beetles. You must make certain the crop and the pest is on the product's label. A general guideline for an action threshold before treatment can be 10 to 30 percent defoliation. Of course, that varies by crop and growth stage. Organic insecticides that use pyrethrin or spinosad as active ingredients can be used against flea beetles. In addition, many synthetic insecticides are available with labeling suitable for use on a wide variety of crops. Keep in mind field sanitation and weed control at the end of the growing season can help reduce flea beetle problems the next spring.

Grasshoppers

Two-striped grasshopper
Whitney Cranshaw, Colorado State University, Bugwood.org

Over 120 different grasshopper species are found in Wyoming. Four species (twostriped, redlegged, migratory, and differential) in the genus *Melanoplus* cause the vast majority of damage to crops. Understanding their shared life histories and behaviors will help growers effectively manage them. Their lifecycle begins during summer when female *Melanoplus* grasshoppers deposit their eggs, which are enclosed in pods, into the top 2 inches of soil amid plant cover. These types of plant cover can often be found around crop fields and farmsteads. Over 100 eggs per square foot can be deposited in good habitat. The egg pods can't survive mechanical tillage and don't survive well in areas submerged in water for multiple days at a time. The pest grasshopper's eggs hatch in the spring over an extended period. The emerging grasshopper nymphs are a miniature, wingless version of the adults and

are less than 3/8 inch long. These small nymphs are very vulnerable to many causes of mortality. If the young grasshoppers have adequate amounts of food plants around where they hatch, they will stay there eating and growing rapidly. Eventually the developing grasshoppers will have eaten all the leaves off favored food plants in the area, such as yellow sweet clover, and move on. As large nymphs or young adults, they move considerable distances into crops and start to damage them.

When and where to scout for pest grasshoppers

The four major pest species in Wyoming will start hatching as early as mid-May and continue all the way until July. This means just one insecticide treatment, with a short residual, applied in the area they hatch from usually won't be sufficient to reduce the population to sub-economic levels. The grasshoppers are initially very small and can be easily overlooked. Note that a few non-economically important species spend the winter as nymphs and become adults very early in the spring. Grasshoppers tend to deposit their eggs on the warm, south facing slopes of borrow ditches and weedy areas around the south sides of outbuildings. The grasshopper embryonic development within the egg is dependent on warm soil temperatures. Prolonged wet weather after the eggs hatch can sometimes kill the tiny nymphs but unhatched eggs will be unaffected by bad weather. If you don't find them hatching by the first week of June, you still need to scout for them until early July. Very high numbers of eggs may be found in the ground in the year after a grasshopper outbreak. The following year, even with high natural mortality in the spring, enough may survive to cause economic damage later in the summer.

What control options are available?

Grasshoppers are more susceptible to insecticides when they are young and small. You can use lower rates of less toxic pesticides and still get control of them at this stage. As of this date there are over 527 pesticide products labeled for grasshopper in all possible situations. The most effective tactic is to kill the grasshoppers before they grow big enough to migrate out of their hatching area and into crops. The best grasshopper management programs are the ones conducted outside of the crop fields and in the habitat where the pest grasshopper eggs hatch. The insecticide products labeled for use on crop plants in fields are often more expensive than those labeled for grasshoppers in non-crop areas such as fencerows.

The *Melanoplus* pest grasshopper species will eat insecticidal baits that are designed for them. Baits are a control option that is very pest specific and less hazardous to non-target insects than broad spectrum sprays. The most common insecticide applied to grasshopper bait is carbaryl, as of this date, and the bait is usually wheat bran or apple pumice formed into pellets, depending on the source. Bran baits that use a pathogen (*Nosema locustae*) that is specific to grasshoppers and other members of the insect order Orthoptera is also an option that is even less hazardous to non-target animals. The slow acting infection the pathogen causes affects the youngest grasshoppers the most, and several weekly applications will be required to ensure all the grasshoppers are exposed to the pathogen. In 2019, no supplies of the pathogen bait were produced in the U.S.A. Hopefully, that doesn't happen again.

Depending on the pesticide product chosen they will need to be re-applied as frequently as the label allows for as long as grasshopper nymphs keep hatching in large numbers. Currently, there are five conventional insecticide types of active ingredients that are effective, widely available, and economic to use on non-crop grasshopper hatching areas. They are insecticides with the following active ingredients: diflubenzuron, carbaryl, chlorantraniliprole, many pyrethroids and malathion. Currently, for organic production, only the insect pathogen treated bait and OMRI listed pyrethrin based insecticide products are options.

The most important things to remember for effective grasshopper management are:

- Start scouting for the pests early in the spring,

- Repeat treatments if warranted, due to continued hatching, and
- Work to gain neighborhood cooperation on control if needed. Neighborhood cooperation may give you a better opportunity to effectively and economically manage young grasshoppers on habitat that is within easy migration distance from crop fields.

Spider mites

Two-spotted spider mite
Frank Peairs, Colorado State University, Bugwood.org

The **two-spotted spider mite** (TSM) is probably the most common pest mite to attack vegetable crops in Wyoming; however, confirm the identification of any suspected pest as other species such as the Banks grass mite, cyclamen mite, and russet mite species can also be found in the state. The plant feeding mites are distant relatives of insects and spiders and share some physiological traits. This can work either for or against us when managing them. Mites can be resistant to insecticide applications that will kill their insect predators. Pest mite populations can boom following insecticide treatments. Conversely, there are some mite-specific pesticide products available that target physiological processes unique to the plant feeding pest species. This can allow for mite population control and still leave beneficial insects such as lady beetles and lacewings unharmed.

Cultural control options

TSM populations are favored by hot, dry, and dusty conditions—conditions that can occur during much of the growing season in Wyoming. One reason heat and water stress can favor spider mites is that it reduces the water contents of plant cells. Spider mites feed on the liquids in the plant cells, and reducing the percentage of water in the plant makes the food more nutrient dense. Higher temperatures and low humidity also speeds up mite feeding by helping evaporate the excess water produced by this process. This efficient feeding allows the mites to consume more nutrients from the plant and then allocate more resources to reproduction. TSM can develop from egg to adult in as little as five days, and each female can potentially produce hundreds of offspring. If your crop is under irrigation, an important way to reduce spider mite population outbreaks is to make sure the crop has enough water to avoid drought stress.

Why dust on leaves increases spider mites is not known. TSM mainly utilize the underside of leaves, which get less dust accumulation. Perhaps dust on the top of leaves negatively impacts the predatory mite species and other insects that attack them, or it worsens the plant's water stress. Minimizing dust thrown up from dirt trails around a growing area is advisable. It is also good crop management as the dust, by its presence alone, can harm the plant and contaminate the crop if being grown for sale.

Conventional control options

Pesticides for mite control need applied in a way to get the active ingredient to the undersides of leaves. Some pesticides have translaminar activity that get the active ingredient into the plant systemically so spider mites pick up a lethal dose as they feed. Horticultural soaps and oils need applied in a way to directly contact the spider mites and have no residual activity; however, they can burn the foliage of sensitive plants, especially if already water-stressed by high temperatures. As with all pesticides, following product label guidelines for recommended droplet size, total volume of spray solution per acre, and appropriate environmental conditions for application, is very important to ensure pest mites are effectively managed. Consider a tank mix with a compatible miticide if you are a larger producer and need to

control a pest insect on a spider mite damage-prone crop in hot and dry climatic conditions. An effective tank mix of compatible pesticides may prevent pest mite outbreaks that often follow the unavoidable and unintended suppression of the predator arthropod populations from insecticide treatments. Mite growth inhibitors (Insecticide Resistance Acxion Committee mode of action 10 pesticides) are lethal to the TSM and their unhatched eggs and if labeled for the pest and crop are good products to consider.

Organically acceptable spider mite control options

Petroleum-based and plant-based horticultural oils solutions can be used if properly labeled for organic operations. Sulfur and potash soap combinations can also be used against spider mites instead of sulfur dust alone to reduce drifting when applying it dry. A warning about the use of the oil, soap, and sulfur products is that these products can damage sensitive plants, especially when applied in the hot, dry, and dusty conditions that favor spider mites. Testing these contact solutions on a few plants to make sure the "cure isn't worse than the pest" is advisable.

Biological control

Many predatory arthropods help suppress spider mite populations. If you had to treat for a pest that ended up decreasing your beneficial mite predator populations, you may consider augmentation or reintroduction of commercially available predatory mites and insect species. However, don't expect successful suppression of spider mites if their populations are already high in climatic conditions that favor them. The beneficial predators won't be able to keep up with the spider mite's rapid reproduction rate to suppress them back to non-economically damaging levels.

Thrips

Western flower thrips
Frank Peairs, Colorado State University, Bugwood.org

Western flower thrips damage on bean
Whitney Cranshaw, Colorado State University, Bugwood.org

Thrips is the common name for an Order of insects, the Thysanoptera, commonly not noticed due to their small size. For example, the western flower thrips and onion thrips (both plant pest species) are at most 2 mm long as adults (~2/25ths of an inch). If it were not for these types of widespread pest species, many people would never realize thrips exist on their plants and can be quite abundant in nature. Pest thrips, although they are small and only have tiny feathery wings as adults, can ride winds to disperse long distances.

Thrips that are pest species (some thrips species are predators of spider mites) can attack the foliage of plants with their liquid feeding mouthparts. They can also attack reproductive structures in flowers and interfere with seed set, and/or transmit plant

pathogens as they feed. The pest thrips have a life cycle that include the egg stage, which is inserted inside plant tissue, and have two non-feeding stages that relocate off the host plant to the soil. This means one insecticide application cannot successfully manage thrips, as a large portion of the population will not be exposed to common topical treatments.

Thrips have high reproduction rates through parthenogenesis (asexual reproduction) and short generation times. Even systemic-type insecticides that infuse the treated plant's tissues with the toxin are not that effective because many pest thrips' populations have rapidly developed resistance to the modes of action of those products.

Monitoring fields is the first step to manage pest thrips. Yellow sticky traps work well for monitoring many thrips species. You can also scout the crop by gently shaking flowers or foliage onto a white tray or sheet of paperboard. Remember, thrips are tiny, so a magnifier will be useful to examine results. Some beneficial predatory thrips species exist. Beneficial thrips adult coloration is often black with white bars, and the immature stages are red-orange. The foliage and flowers of your crop can also be scouted for discoloration. Plant-feeding thrips produce small black dots of tarry excrement on the plants that can indicate their presence even if they fly off the plant when disturbed. The first two stages in thrips development are active feeders and are tiny but cannot fly off the plant. Try to combine as many management strategies as possible to suppress thrips populations early in the season to prevent population explosions in the middle of the growing season.

For thrips, cultural control tactics include nitrogen management (high nitrogen spikes in plants after fertilization can cause thrips to thrive); use of mulches; trap crop and intercropping (for example, carrots planted to protect onions); overhead irrigation; and planting varieties with some resistance to thrips, if available.

The treatment threshold density of pest thrips varies with the crop value and the cost of treatment you want apply. You should rotate the mode of action of the products labeled for the crop you are trying to protect when insecticides are needed to save a crop. Rotation of insecticide modes of action can reduce the occurrence of resistance in pest populations. Because the predators that attack thrips reproduce more slowly than the pests, insecticide use often sets their populations back severely and sometimes cause flares in other plant pests, such as spider mites. Choosing and applying insecticides that will have the lowest impact on beneficial insects and are the most specific to the thrips damaging your crop is a wise thing to do.

NEWER INVASIVE PESTS IN WYOMING

Spotted wing drosophila adult male with spots on wings.
Hannah Burrack, North Carolina State University, Bugwood.org

Spotted wing drosophila (*Drosophila suzukii*)
Spotted wing drosophila (SWD) has rapidly spread across the U.S. since it was first detected in 2008. It is similar in appearance to many native small fruit or vinegar fly species. The female SWD differ from our native vinegar fly species in having an ovipositor, which is saw-toothed. Female SWD are able to pierce the skin of many varieties of non-ripe fruits and insert their eggs. The resulting larvae rapidly turn the fruit to mush, and the entry wounds allow for development of mold and bacterial rot. Caneberries, strawberries, and cherry species are among the many kinds of fruits used by SWD. They have even successfully reproduced in apples, grapes, and tomatoes. In one instance, SWD, was introduced to a Wyoming garden from infested peaches purchased in Illinois that were thought to be "overripe." The squishy peaches were improperly disposed of and introduced SWD to fruit being grown on the property. SWD has the ability to rapidly reproduce and has already impacted the profitability of fruit production in Wyoming. Initially it was thought SWD wouldn't be able to tolerate northern climes. That thought was wrong as SWD has even become endemic in many counties in North Dakota.

Quarantining fruit from outside sources before being brought to your place may help prevent its introduction if you don't already have SWD at your Wyoming fruit production area. In Wyoming, production areas isolated by miles of prairie or wheat fields may provide a barrier to the unaided spread of SWD. However, do not be surprised if SWD is already in your area. In wetter climates, roadside wild berry bushes provide a natural corridor for the spread of SWD.

If you already have SWD on your property IPM plans have been developed based on what we currently know about the pest. Using traps each growing season, monitor for the start of SWD adult activity around your vulnerable crops. Scouting for SWD is critical. Spray vulnerable crops when SWD populations are present and as fruits start to ripen as one part of an IPM strategy. Spraying insecticides for SWD may impact beneficial insects. Always follow the insecticide product label's re-entry and pre-harvest intervals. Aggressive harvest of fruit and proper disposal of SWD infested fruits are also important for reducing their populations. SWD's ability to produce multiple generations in a single season makes it very important to start your management program early and not let their population explode and infest your fruit before you can harvest it.

For more information on SWD IPM for certified organic producers and conventional growers, go to https://eorganic.org/node/23509.

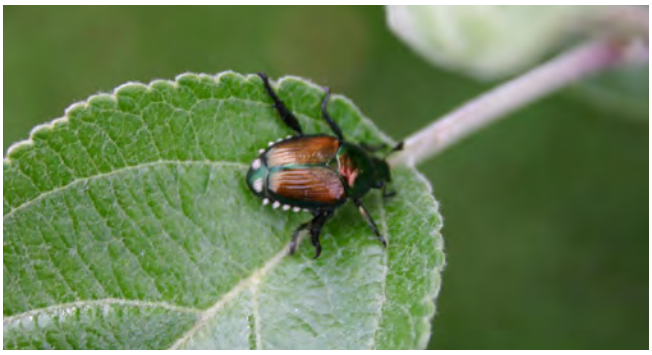
European paper wasp (*Polistes dominula*)

This image shows the beneficial aspect of European paper wasp feeding on imported cabbage worm larvae. The image also shows the distinctive gold antennae our native paper wasps do not have.
Whitney Cranshaw, Colorado State University, Bugwood.org

The European paper wasp (EPW) made its presence known in Wyoming in 2015. We are fortunate it took so long to arrive, as this insect started causing problems in Colorado and Utah in the early 2000s. Adult EPW feed on ripening fruit such as raspberries and cherries. EPW frequently nest in close proximity to human habitations. EPW behaviors give it a competitive advantage over the less pestiferous native paper wasp species. Learning how to manage EPW to minimize damage on vulnerable soft fruits is the best defense. Utah State University Extension has advocated management techniques that help reduce the populations of EPW to levels that reduce their impact on crops. Entomology Professor Diane Alston found homemade traps, or factory-made traps, baited with fermenting fruit juice lure EPW to their death quite well. Start trapping for EPW early in the spring to eliminate emerging overwintering queens. Each queen captured in the spring will reduce the population of EPW that would have attacked crops in the summer.

POTENTIAL AND PROBABLE WYOMING PESTS

Japanese beetle (*Popillia japonica*)



Japanese beetles are now potentially establishing in Wyoming.
William Fountain, University of Kentucky, Bugwood.org

This illustration shows the Japanese beetle life cycle through the calendar year.
Joel Floyd, APHIS

The Japanese beetle has been a pest in the northeastern United States for over 100 years. Recently, populations of this pest have become permanent residents of Billings, Montana, the Front Range of Colorado, and western Nebraska. In the summer of 2020, a population of this pest was found in Sheridan, Wyoming. This may mean Japanese beetles are adapting to our region's dry and cold mid-continent climate. The Japanese beetle is a pest of numerous important agricultural and ornamental plants. The larvae develop on the roots of turf grasses so any irrigated sod can be used by the Japanese beetle as larval habitat.

Adult Japanese beetles are very mobile and will readily feed on a diverse assortment of crop plants such as grapes, green beans, sweet corn, and raspberries. Extreme care should be taken not to accidentally import Japanese beetle adults or sod that may contain their larvae into other locations in Wyoming. If you find Japanese beetle on your plants, notify the Cooperative Agriculture Pest Survey program coordinator, http://www.uwyo.edu/capsweb, caps@uwyo.edu or (307)766-5278 or your local extension educator. This may enable you to get help to eradicate the pest before it can establish and become a perennial problem for you and your neighbors.

Brown marmorated stink bug (*Halyomorpha halys*)

Steven Valley, Oregon Department of Agriculture, Bugwood.org

Brown marmorated stink bug (*Halyomorpha halys*) image (top) shows the distinctive light-colored bands on the antennae that distinguish it from the similar looking native rough stink bug (*Bochymena quadripusulata*) (bottom). These insects are called "stink bugs" as they have scent glands in their thorax that when crushed release an offensive odor.

Steven Valley, Oregon Department of Agriculture, Bugwood.org

The brown marmorated stink bug (BMSB) is an invasive pest that has had a major impact on a wide variety of crops from New York to Tennessee since its accidental introduction in the 1990s in the mid-Atlantic states. However, it wasn't until the 2010 growing season that BMSB caused extensive crop losses in sweet corn, peppers, tomatoes, and fruit tree crops in the mid-Atlantic region.

Our neighbor state, Utah, first documented BMSB's presence in 2013. However, it wasn't until 2017 the first serious crop damage from it was documented. This should serve as a warning to Wyoming vegetable and fruit growers that BMSB is a potential threat to their specialty crops. Apples, green beans, grape, tomato, and the various pepper crops are all very vulnerable to BMSB damage. It would be easier to list the crops not damaged by BMSB than the ones vulnerable to this generalist pest.

The current goal for Wyoming produce growers is to monitor for and be able to recognize BMSB when it finally arrives in their area. Several native rough stink bug (Brochymena genus) species can be found in Wyoming and can be confused with BMSB because of their physical resemblance. However, BMSB have light colored bands on the joints of their antennae. Rough stink bugs have small spines on the leading edge of their thorax. You may need to view them under magnification to see these diagnostic characters. Alternatively, take a specimen to your local extension office for identification. IPM strategies for BMSB are available, and new control tactics are under development.

There are many invasive crop pests, which as of this date have not yet become established in Wyoming. If you find an insect, mite, or disease symptom in your crops you can't identify, please contact your local University of Wyoming Extension office for help. We are fortunate Wyoming is frequently the last place in the country new invasive pests show up. However, it is not impossible for a new pest to show up here first.

KEEPING CRITTERS OUT

Vegetables and fruit are a very nutritious and tasty part of the human diet. It is not surprising they also seem to attract the interest of wildlife. Vibrant fruits and vegetables are even more attractive to many animals when other vegetation is brown and dried out. This means one of the biggest challenges to growing vegetables and fruits in Wyoming can be keeping the wildlife from eating your crops before you have a chance to harvest them. Deer, rabbits, raccoons, skunks, gophers, birds ... the list is lengthy; however, while there are different parameters with each species of wildlife, when it comes to edible crops, exclusion and sanitation are the general approaches for many wildlife species.

Exclusion involves techniques that keep critters from being able to get to your crops–often fencing of various types. Sanitation is the practice of keeping areas around your property clean so they don't attract wildlife. Trapping can be used with some species of wildlife. Consult your local Wyoming Game and Fish Department personnel or Weed and Pest Control District (for some smaller species) to see if trapping a wildlife species is legal before you proceed. Many of our wildlife are considered game species, and their taking is governed by law. There are also repellents that can be used to deter wildlife; however, many of these products should not be applied to edible plants that have parts that will be eaten by humans. Also, repellents are variable in their effectiveness, must be reapplied periodically, and may only work where wildlife populations are low.

Exclusion usually involves the investment of time and money, but often yields the greatest benefits as long as the fences or other structures are maintained. Think about fencing the plants you value most when it comes to making the most of your investment of money and time.

When considering fencing, migratory and other movement patterns of wildlife should also be taken into consideration. Fencing your whole property with critter proof fencing may create barriers to the movement of wildlife across the landscape, so consider just fencing critical areas such as vegetable plots.

Selecting methods for keeping wildlife from eating your vegetables or fruit crops is dependent on the proper identification of the animals that inhabit your area and/or are eating your crops. Visit our "Wildlife" web page at barnyardsandbackyards.com for links to information that will help determine which animals are eating your crops or visit your local University of Wyoming Extension or Weed and Pest Control District office for assistance.

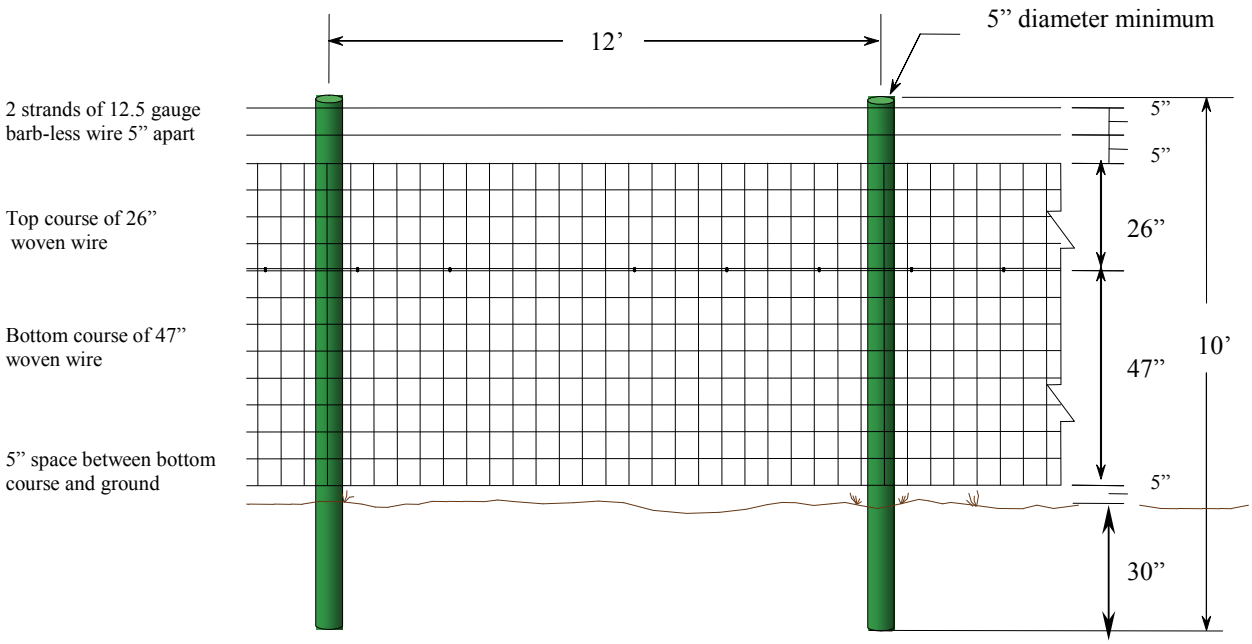
The effectiveness of exclusion methods depends on the capabilities of the animals involved and how motivated (by hunger, being chased, or other factors) they are to get through or around barriers. Exclusion methods tend to be most effective if they are implemented before wildlife start eating your crops (before they have learned that your garden is better than their normal fare). For animals such as deer, fences are also more effective if your vegetable plots aren't in the vicinity of existing routes of travel (deer paths). These animals will thoroughly investigate and test any new structures that appear in their usual areas of use.

Exclusion methods can be temporary–hardware cloth wire structures over newly planted seed to keep squirrels and birds from eating the seed before it sprouts, temporary electric fencing, netting of fruit bushes or trees to keep birds out until fruit is harvested, etc. — or more permanent — such as fencing or walls.

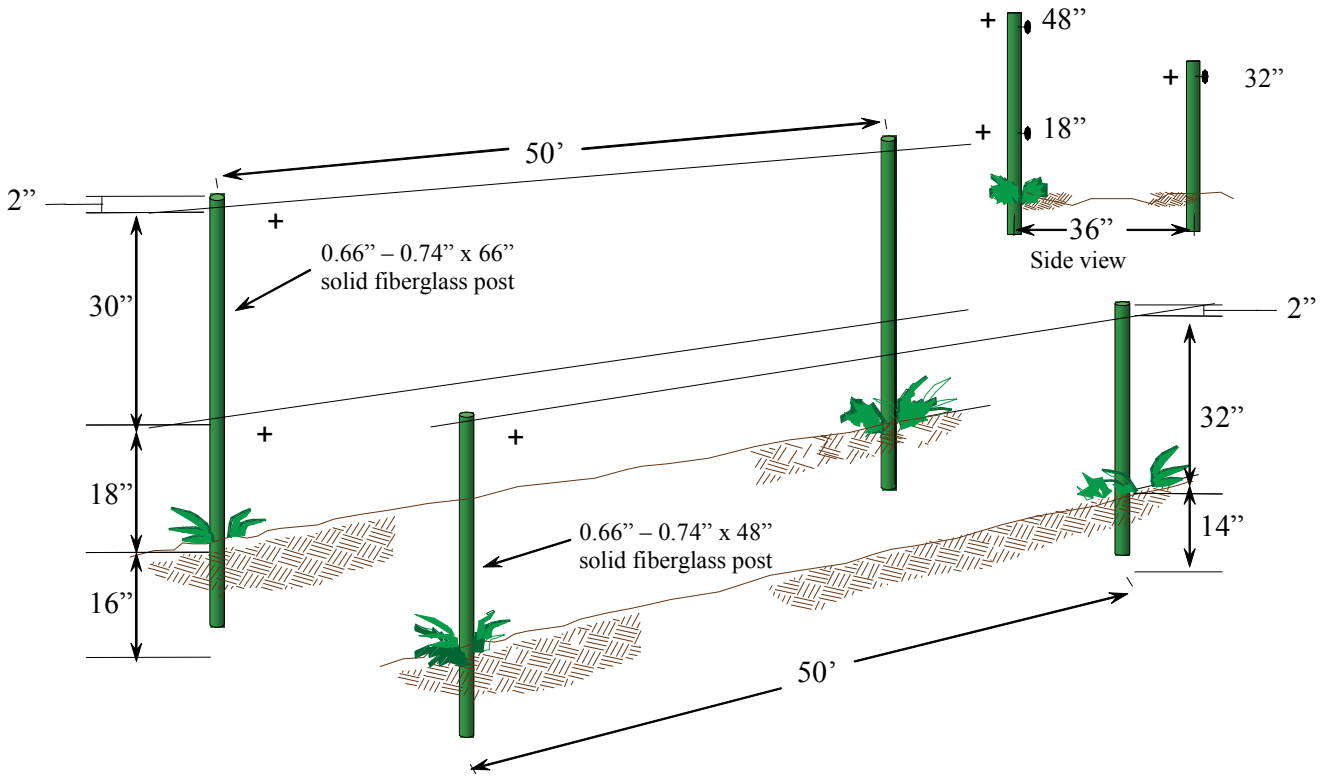
BRIEF TIPS ON WILDLIFE EXCLUSION

Deer

Deer are one of the more common raiders of gardens in Wyoming. Since deer are excellent jumpers, expect to build a fence that is at least 7 feet tall. Some feel that an electric fence is more effective, but keep in mind placement of the live, or hot, wire is critical



8-foot woven wire fence (above) and 3-D electric fence (below).



Illustrations: Wyoming Game & Fish Department publication “Fencing Guidelines for Wildlife” (Habitat Extension Bulletin No. 53) A link to this document can be found on our “Wildlife” web page at barnyardsandbackyards.com:

as well as the number of live wires. It is usually recommended that the placement of the live wire is 36 to 46 inches off the ground. Also remember wildlife can stretch their necks through a fence to get a few nibbles in, so keeping the fence a few feet away from consumables is a good idea.

Eight-Foot Woven Wire

Deer, elk and moose damage can be prevented with an 8-foot woven and smooth wire fence. This fence should be constructed with a bottom course of 47-inch woven wire, a top course of 26-inch woven wire, and two strands of smooth wire above the woven wire, see illustration previous page.

3-D fence

This fence design has been very successful at excluding white-tailed deer from orchards, tree farms, and vegetable gardens in many places throughout the United States, see illustration previous page It has not been tested thoroughly in Wyoming against mule deer; however, it has been tried in the Big Horn Basin around vegetable gardens and has worked very well. It is unknown whether or not this fence will effectively exclude other species. The basic principle is that deer are not comfortable jumping a fence that has both height and depth. Depending on your goals, this fence can be constructed with high-tensile wire (permanent fence) or with poly-rope or tape (temporary).

Electric fence

Electric fence can be useful for keeping out larger animals such as mule and whitetail but can be also used to deter smaller animals such as raccoons or rabbits. Many electric fence systems can be purchased at local home and garden stores or ordered over the internet. An electric fence system can be a useful tactic depending on the size of the area and the types of animals you are looking to keep out. Electric fence systems can be taken down each fall when crops have been harvested. Please keep in mind electric fence can be a bit traumatizing for pets and humans that are surprised by touching the fence without prior knowledge. Finally, grounding electric fence to ensure proper operation is an important issue in dry soil areas (wire return systems generally work better than earth return systems), so do your homework before you build electric fencing, and get a tester to check if it is working properly.

Antelope/pronghorn

Unlike deer that jump, antelope generally go under fences. If pronghorn are your issue, you can usually get away with a shorter fence. A 4- foot tall woven wire, with a couple of extra strands placed above it, is usually sufficient) but you must ensure the bottom strand of the woven wire fence is in contact with the soil surface.

Moose and elk

While moose and elk are less likely to be a problem in your garden, they can still be attracted to whatever fantastic fare you are growing. You can follow the same recommendations for deer to keep them away. Just remember, when a moose or elk decides to go through a fence, they usually do, so the sturdier you can build it, the better.

Other four-legged creatures

Having issues with the smaller four-legged critters like skunks, raccoons, and rabbits? There are a few things to consider. Are they diggers? If so, it is best to bury mesh fencing that has quarter inch in size or smaller squares at least one foot deep. And remember they are good diggers, so you have to be, too. Make sure to make a 90-degree angle at the base of the fence and tack the fence down before you bury it to make sure they don't just dig it up or dig under it.

On the other hand, some small mammals are also good climbers. Some recommend placing a 3-to 4-foot fence with a 1-foot top that is unattached at the top of the fence so it will fall back on the animals as it climbs.

Rabbits

Rabbits are one of the most common raiders of gardens! Generally, a 2-foot high fence will keep out cottontails and a 3-foot high fence will exclude jackrabbits; however, include an additional portion of

fence so it can be buried to keep them from digging into your vegetable plot.

Rabbits can also be an issue during the winter when we least expect it. If you grow fruit shrubs or trees and are considering fencing, you need to make sure to build your fence a foot higher than the deepest snow so they can't easily get over the fence when the snow is on the ground. Be sure fencing used to exclude rabbits doesn't have holes that rabbits can squeeze through–if using wire fencing, holes should be less than 1-inch wide or tall.

Raccoons

Raccoons are also common raiders of vegetable crops. Raccoons are nocturnal and usually travel in family groups or three or more. Due to their strength, digging and climbing abilities, electric fencing is usually the best deterrent to keep raccoons out of gardens. This can be done by building an electric fence or by using electric fencing components to add an extra layer of protection to existing fences.

Raccoons will sometimes force their way through an electric fence. If the fence is not built early, they will still get into the garden. They particularly prefer sweet corn. If protecting sweet corn, the fence must be built before the corn tassels. Strands must be 4 inches off the ground and 4 inches apart and at least 3 strands high.

Pocket gophers

Pocket gophers can be an issue in Wyoming. If you are growing in a smaller area, consider creating raised beds that have a layer of galvanized welded wire mesh (hardware cloth ¼- to 1/2-inch mesh) attached to the bottom. Raised beds should be tall enough (18-inch+) to deter pocket gophers from crawling up onto them. Gophers eat the roots of all plants, particularly trees and fruit trees. It is extremely hard to exclude gophers from eating the roots of trees, and eliminating the gophers is generally more practical; however, this can be challenging as well. Wire should never be placed around the roots of trees to prevent damage as the wire prevents proper root growth. Trapping gophers is likely the only way to eliminate them from your landscape and often requires a lot of persistence by the trapper.

Voles

Voles are small mammals that are very active during the winter. These pesky critters are known for eating the soft bark of young fruit trees during the winter under the cover of snow. If left unchecked, voles will eat all of the bark around the base of the tree and girdle the tree, cutting off the transport of water and nutrients in the trunk, leading to eventual death. To avoid damage from voles, ¼-inch wire mesh fence should be place around the base of the tree during fall, winter, and spring to protect young fruit trees. The mesh should be at least 12 inches tall. It should be placed so the bottom is slightly below the soil or mulch around the base of the tree to prevent voles from crawling underneath the fence and then secured in place so it does not rub against the bark of the trees when the wind blows, etc.

Birds

Birds can be attracted to seed or fruit crops. Bird netting or row cover can be used to exclude them from crops. Netting should be placed over a supporting structure so birds can't peck through the netting and reach the crop. Netting should be securely attached to the ground so birds don't go underneath it and get entrapped.

AVOID ATTRACTING WILDLIFE

Sanitation is an important part of not attracting wildlife to your place. Make sure garbage, active compost piles, pet food, and water sources are located where wildlife can't access them.

If you don't want smaller creatures to take up residence in your home or outbuildings, make sure that any entry routes into these structures are blocked off.

There are also gardeners who swear by methods such as motion detection lights, motion activated

sprinklers, or even inflatable objects that act like a surprising scarecrow. While these methods can work wonders, fences may be the best long-term defense. There are many commercial options available if you are interested in doing research on these tactics.

As you can tell, there are many ways to protect your delicious fare from animals you may not want to share with. One of the most important things you can do is identify the wildlife that is enjoying your garden. That will determine the best exclusion method for you!

For more information on methods to protect your produce, visit barnyardsandbackyards.com and click on "Gardening" or "Wildlife".

Bird netting has been draped around this 'Bali' cherry tree and secured at the bottom so birds cannot crawl under. Row cover and clips can also be used for this purpose on smaller trees or bushes for a shorter time period (as not as much sunlight will get through to the leaves). No fruit would be left for the grower if protection was not used.

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CHAPTER 2: VEGETABLES

INTRODUCTORY NOTES

Days to maturity

The days to maturity are approximate guidelines. Varieties will mature faster or slower depending on environmental conditions and other factors. Days to maturity can refer to days after planting the seed or days after transplanting a seedling, depending on the crop. They will be listed as numbers in paratheses after variety names, eg. (58).

Plant spacing

The plant spacings provided are general–different arrangements of plants may change the spacing required and growing for different purposes will change the spacing. For example, leaf lettuce grown for harvest as baby lettuce is often planted much closer together than lettuce grown for harvest at full size.

Seedlings

When discussing growing seedlings, “indoors” refers to growing seedlings in a greenhouse, hoop house or inside a house or other building with sufficient light (artificial or natural).

Integrated pest management

More information on management of several common pests of vegetables (cutworms, flea beetles, thrips, aphids, grasshoppers and spider mites) can be found under the Integrated Pest Management (IPM) section which is located earlier in this guide, page 42.

ASPARAGUS

Asparagus officinalis

A perennial vegetable, an asparagus plant can live up to 25 years. The plant is native to coastal areas of Europe, North Africa, and Asia. It will take a plant two to three years after planting to become fully mature and productive. Asparagus plants are either female or male. Most varieties grown today are male, producing no female flowers, fruits, or seeds. These varieties yield more spears than those with both female and male plants.

GROWING CONDITIONS

Asparagus plants grow best in full sun and with regular irrigation. They are very cold hardy, but make sure to water them even in winter, especially for the first few years. Soil should be loose and well-drained, since asparagus roots can extend 10 feet. Production is best when soil pH is between 6.0 and 7.5.

PLANTING

Asparagus should be planted in an area where it will not be disturbed. Start from 1- or 2-year-old crowns planted in April or May. Dig a trench 6 inches wide and 6 to 8 inches deep. Before planting, fertilize with 20 pounds of phosphorus per acre banded in the trenches. Set the crowns 15 to 18 inches apart in rows 48 inches apart. Place the crown in the bottom of the trench, spreading the roots out. Keep the crown higher than the roots. Cover the roots and crown with 2 inches of soil and gently firm it around the plants. As the plants grow during the first growing season, add more soil to the trenches until the soil in the trench is even with the surrounding soil, making sure not to cover the shoot tips.

MAINTAINING PLANTS

The plants are generating new root mass during the first season, so do not harvest but let the tops grow so they can generate energy to feed root growth. In fall after the stems have turned brown, they may be cut back to the ground. Better yet, wait until spring to cut spent stems. This will allow the old stems to act as snow collectors, helping to keep the soil moist around the plants. The second growing season is when harvest can begin. After the first year, nitrogen at 150 pounds per acre and potassium at 250 pounds per acre rates are recommended.

HARVESTING

Cut for four to six weeks during the second growing season. When spears start to be very thin, stop harvest to allow the tops to grow so the plants can regenerate for the third growing season. During the third growing season, harvest for eight to 10 weeks when spears are 5 to 8 inches long. Cut the stems at ground level at an angle. It is important to allow the ferns to grow after harvest is done. This top

Africa Studio, shutterstock.com

growth generates food from the sun to allow the plant to enter winter in good condition and support a bountiful crop the next year.

SOME COMMON VARIETIES

- Jersey King
- Jersey Knight
- Mary Washington
- Purple Passion
- Viking
- Jersey Supreme

INSECT PESTS

Unlike many vegetable crops, rotation is not a viable control option for insect pests, as asparagus is a perennial crop that is grown in the same location for many years in row. Specialist pest insects like the **common asparagus beetle** (*Crioceris asparagi*) and the **spotted asparagus beetle** (*Crioceris duodecimpunctata*) or **European asparagus aphid** (*Brachycorynella asparagi*) may require yearly management once they find your asparagus field. Not being able to use crop rotation as a pest control technique also means that crop sanitation tasks are even more important than in many annual crops (tasks such as removing and destroying dead foliage and other debris where pests can overwinter).

PESTS OFTEN AFFECTING ASPARAGUS SPROUTS (THE SALEABLE PRODUCT OF THIS CROP)

Beetles

A common asparagus beetle (*Crioceris asparagi*) shown with four green eggs above her on the asparagus spear. The adults are colorful but their exact pattern of markings is variable. The *Crioceris duodecimpunctata* species is similar in size to the common asparagus beetle but is orange with twelve black spots.
Ward Upham, Kansas State University, Bugwood.org

The larvae of both species of *Crioceris* beetles have shiny black heads but the spotted species larvae is orange not gray like this common asparagus beetle.
Clemson University - USDA Cooperative Extension Slide Series , Bugwood.org

Asparagus beetles overwinter as adults in and around asparagus fields under plant debris and will start to feed on the new asparagus spears in the spring. The female beetles eventually deposit eggs on the sprouts that will hatch and feed on the developing ferns. They can complete at least two generations per growing season in Wyoming. Severe summertime foliage feeding on the asparagus can also negatively impact the crop production the next year.

Aphids

The change in the asparagus plant's fern growth on the left was caused by the feeding of the asparagus aphid (*Brachycorynella asparagi*) as compared to the normal fern growth on the right.
Whitney Cranshaw, Colorado State University, Bugwood.org

European asparagus aphid can rapidly reach very high populations and overwhelm their predators in the field. The plant's reaction to the toxins injected as the aphids feed is to form "bonsai growth," which the aphids use as shelter from predators. This foliar damage can impact the asparagus bed's production the next year. The aphids also produce copious quantities of honeydew, which attracts ants that then defend them from predators (the ants "tend" the aphids so they can eat their honeydew). This aphid species overwinters in the egg stage on the old asparagus ferns, so residue management in the field can help reduce their population the next spring.

Cutworms

The **variegated** (***Peridroma saucia***) and **dark sided** (***Euxoa messoria***) **cutworms** are early-season pests of asparagus and are both found in Wyoming. The larvae are nocturnal and are both considered "climbing cutworms." This means they crawl up onto the plant at night to feed and damage the new asparagus spears and then return to the ground to hide during the day. Good weed control and crop residue management can reduce the attractiveness of asparagus fields to the adult female cutworm moths when they are depositing eggs starting in the midsummer. Having no green weeds to feed on will reduce both the egg population and the survival of the early instar cutworm larvae that hatch from them. See cutworm management under the Integrated Pest Management section for additional information, page 45.

Grasshoppers

Grasshoppers can consume asparagus ferns (green top growth) which can impact the following year's spear production. See grasshopper management under the Integrated Pest Management section for more information, page 47.

Thrips

Onion and **bean thrips**, despite their common names, will also feed on asparagus. The damage from the thrips rasping and sucking feeding on the plant increase the susceptibility of the plants to fusarium wilt. These thrips can complete development from egg to adult in 12 days. This fast development can result in a rapid buildup of thrips populations. Thrips feeding can damage all stages of asparagus and reduce production the next season. See thrips management in the Integrated Pest Management section for additional information, page 50.

DISEASES

Physiological disorders (abiotic disorders)

Hollow stem and loose heads

These problems tend to be more prevalent during periods of wet, warm weather resulting in rapid spear and head growth.

Hooking

Bent spears, resulting from either cold injury or physical injury (above or belowground).

Infectious diseases

Seedling diseases

Asparagus is susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

Foliar and whole plant diseases

Fusarium crown and **root rot** is a common soil-borne fungal disease that affects asparagus. Symptoms include stunted, yellowing ferns, reddish-brown vascular discoloration in the crowns and discolored or rotted roots. Infection can occur any time, but plants are more susceptible to infection during stressful growing conditions and root damage. The disease is spread by soil movement, infected seed, and infected crowns. To manage, use disease-free seed in non-infested soil to produce disease-free seedlings and transplants. Minimize plant stress and avoid extended harvest periods. Hybrids are available that have some disease tolerance.

Asparagus rust is caused by a fungus spread by wind-blown spores, typically later in the season. The fungus attacks spears, stems, and ferns resulting in dark to brown-red pustules on the affected tissue. Rust develops rapidly under warm, dry days and cool nights with dew. To avoid or reduce disease, plant resistant varieties, destroy wild asparagus growing nearby, remove infested crop residue, and spray with sulfur dust or other fungicides recommended for use in Wyoming. Remove overwintering sites by cutting down the aboveground parts in fall and disposing by burial or removal completely from garden area.

BEANS

Phaseolus vulgaris

Beans are an extremely diverse crop with origins in South and Central America. A hardy crop, beans are well-adapted to Wyoming's short growing seasons and soils, making them an easy addition to almost any growing space.

There are two main categories of beans—fresh beans (also called green beans, string beans, or snap beans) and dry beans. The seed pods and seeds can be consumed without cooking for fresh beans (though they are often cooked) whereas dry beans seed are allowed to harden in the pods before harvesting, and the seeds are almost always cooked before consuming. Green, wax, snap, string, and lima are all types of fresh beans. Pintos and black beans are types of dry beans.

teatian, shutterstock.com

An important food source for many people around the world, beans have a long history and widespread distribution. Many different types of beans in a wide variety of colors, textures, and shapes have been developed over the centuries. An example of this diversity can be found in bean pod color—purple, green, yellow, and red are a few common colors. Bean seeds, once dry, can be white, black, red to yellow, or brown, and some are speckled with multiple colors.

One can begin to feel overwhelmed with so many types of beans to choose from; however, you can narrow the possibilities by considering what you want to use the beans for and which varieties will match your growing environment.

Bean plants have two main growth patterns—bush and pole. Bush style beans rarely grow above 2 to 3 feet high, whereas certain pole bean varieties will reach heights of 10 to 15 feet. Some varieties of fresh beans are available in both a bush or pole form (such as the variety 'Blue Lake'). Bush beans can provide more concentrated harvests (more beans ready at one time) that are handy for those looking to preserve beans through canning or freezing. Pole beans tend to mature over a longer period, making them useful for those needing smaller amounts of beans spread out over the growing season.

GROWING CONDITIONS

Beans grow best when temperatures are between 70 and 80 F. Bean flowers can fall off (abort) when plants are stressed by hot temperatures (over 95 F) or conditions that are too dry. This can reduce yield and varies by variety. Consistent irrigation during flowering and pod growth is important. Irrigation methods that reduce the amount of water that gets on their leaves can help avoid foliar diseases.

Beans grow best in soils high in nutrients and with a pH between 6 and 7. Adding organic matter and

compost each year to low organic native soils can help improve production. Avoid heavy, poorly draining clay soils.

PLANTING

Transplanting beans as seedlings can be difficult. Directly seeding beans into the ground generally works best. Beans germinate best when soil temperatures are 68 to 80 F. Poor seed germination can occur when the soil temperatures are below 60 degrees. Bush beans can be planted in rows that are 18 to 24 inches apart. Seeds should be placed 2 to 4 inches apart in the row to avoid overcrowding. Pole beans can be planted with a trellis or similar structure to allow plants to climb. Polebean seeds should be spaced 6 to 9 inches apart in rows 36 to 48 inches apart. Beans are planted about an inch deep.

DAYS TO MATURITY

Growers at high elevations are advised to select a variety with a low number of days to maturity. Lower elevations of Wyoming can support a wider selection of bean varieties. Most beans mature in 50 to 80 days.

HARVESTING

Look to harvest fresh beans before the seeds have fully matured, before the pods bulge much from developing seeds. The pod should be firm, not tough, and the desired length for eating. Once the seeds have started to mature, the pods will become more fibrous and often less tender than younger pods. Beans should be harvested often to keep the plants at full production. The plants will quit producing new beans if beans are not harvested regularly. Older or drought stressed plants can produce beans that are more fibrous with less flavor. Once harvested, green beans are perishable, so they should be used quickly.

Dry beans should be harvested when the pods have fully matured. The seeds will be full-sized, hard, and the pods and plants will begin to lose their original color and dry out.

OTHER BENEFITS OF BEANS

Consuming beans is not only beneficial to your health, but growing them is also beneficial to the health of your soil. Beans are legumes. Legumes are great at taking nitrogen out of the atmosphere and putting it back into soil. The nitrogen fixed into the soil provides a rich nutrient source for other plants. Beans can be used in crop rotation or grown in conjunction with other crops as a companion. Planting climbing/pole beans with corn is a common example of companion planting. The corn receives much needed nitrogen from the beans, and the climbing beans use the cornstalks for structural support.

SOME COMMON VARIETIES

Fresh beans

Bush

- Early Contender (48)
- Topcrop (48)
- Provider (50)
- Purple Queen (52)
- Jade (53)
- Blue Lake (55)
- Golden Wax (58)
- Roma II (59)

Pole

- Kentucky Blue (58)
- Blue Lake (63)
- Kentucky Wonder (65)
- Kentucky Wonder Wax (68)
- Rattlesnake (70)

Lima

- Baby Thorogreen (67, bush)
- Fordhook 242 (75, bush)
- Henderson (65, pole)
- King of the Garden (88, pole)

Dry Beans

- Dwarf Horticulture (60)
- Pinto (80)

- Kidney (90)
- Great Northern (90)
- Anasazi (90)
- Garbanzo/chickpea (100)
- Black (100)

INSECT PESTS

Over 70 different pest insects can damage bean crops but luckily in Wyoming only a small percentage are likely to cause significant damage to bean plants.

Along with damaging plants directly, some insects can transmit harmful viruses between plants. Common bean mosaic virus disease transmission is the most difficult to prevent as it can occur rapidly from low populations of winged aphid foundresses arriving in a field. Other major pests of bean crops feed on the foliage or on the developing seeds and pods. The root feeding species are the most difficult types of pests to scout for. Roots should be examined on plants that are declining but have no apparent aboveground cause. Scouting crop fields to catch pest problems early is always recommended.

Pests often affecting seedlings

All of the life stages and the plant damage that seedcorn maggots (***Delia platura***) can inflict are illustrated in this painting.
Art Cushman, USDA Systematics Entomology Laboratory, Bugwood.org

Seedcorn maggot (*Delia platura*) and the similar but less common **bean seed maggot** (*D. florigela*) can attack bean seeds that have delayed growth due to cold soil temperatures. Plant bean seeds when root zone soil temperatures are above 60 F and preferably above 75 F to ensure rapid germination and growth to "outgrow" the maggots.

Garden slugs and multiple **cutworm species** can seriously damage bean seedlings. A recommended IPM practice is making sure the habitat in the bean field is not favorable to slugs and cutworms. These practices include good weed control and removal of debris cover where these pests can hide during the

day. If the bean crop is irrigated, allowing the field surface to dry down completely between applications or applying water in the early morning can reduce garden slug populations as they prefer damp soil to travel on at night.

Western spotted cucumber beetle (*Diabrotica undecimpunctata*)
Johnny N. Dell, Bugwood.org

Western spotted cucumber beetles will feed on the bean seedlings and can use bean plant roots for their larval habitat. Other very mobile leaf feeding beetle species such as **western striped cucumber beetles** and multiple **flea beetle** species can rapidly invade a bean field. Regular scouting for these pests and reacting quickly with properly labeled insecticides can help minimize their damage.

Pests that chew leaves or pierce and suck plant juices affecting vegetative growth

The bean root aphid (*Smynthurodes betae*) has been submitted for identification in Wyoming from a garden in Campbell County. The plants were exhibiting decline, and initially a plant pathogen was suspected.
Brendan Wray, AphID, USDA APHIS PPQ, Bugwood.org

Aphid populations can rapidly build in a field due to their rapid reproduction potential once winged foundress aphids arrive in a field after departing their winter host plants. The **cowpea** and **green peach aphid** are the two most common species in Wyoming bean fields. Determining the exact species in your field is important so overwintering habitat of the aphids can be reduced. Aphids take bean plant nutrients, damage leaves, vector plant diseases, and create conditions favorable for mildew on leaves with their excrement (honeydew). Weekly scouting to determine aphid population trends and the extent of the activity of their predators and parasites provides information to help guide their management.

Palestripped flea beetle can be present in crop fields throughout the growing season, but they cause the most damage when the bean plants are in the seedling stage. This species is difficult to control with a single insecticide application due to their staggered development and emergence from the protection of the soil. The mobility of adult palestripped flea beetles also enable them to rapidly reinvade treated fields from weedy fencerow and roadside ditch habitats. Increasing seeding rates to compensate for anticipated bean plant losses due to flea beetle damage is a common cultural management practice. (See flea beetle management in the Integrated Pest Management section for additional information, page 46.)

Crop eating **grasshopper** species are usually a late season pest of bean crops, moving into fields after they eat the vegetation around the crop borders. Highly mobile and voracious feeders, they can destroy a crop rapidly. Preventative treatments in the spring, outside of the crop fields in the habitat that grasshopper's hatch from, can prevent problems later in the summer in fields. (See grasshopper management in the Integrated Pest Management section for additional information, page 47.)

A dry bean leaf infested with larvae of the Mexican bean beetle.
Howard F. Schwartz, Colorado State University, Bugwood.org

Adult Mexican bean beetle
Whitney Cranshaw, Colorado State University, Bugwood.org

Mexican bean beetle larva will feed on the underside of bean leaves so plants have to be examined closely to find the larvae when they are very small. The adult beetles are very similar in size, shape, and even color of some beneficial lady beetle species.

High populations of Mexican bean beetle can cause significant foliage damage and reduce yields.

Twospotted spider mites can become a problem on bean crops in hot, dry, and dusty field conditions. Twospotted spider mite populations can also flare after certain insecticides are used to control insect pests. The common insecticide classes of carbamates, organophosphates, and some pyrethroids can kill spider mite predators and "release" the spider mites from natural population suppression. (See spider mite management in the Integrated Pest Management section for additional information, page 49.)

Onion thrips and **western flower thrips** will feed on bean and pea crops. Onion thrips are less damaging as they will feed on the leaves. Western flower thrips, true to their common name, will feed in the flowers, which can damage the development of the seeds or cause the flower to fail to form a pod. As few as five western flower thrips per blossom examined can reduce the total number of pods a bean plant will produce. Both species of thrips can also transmit tobacco streak virus to beans plants. The point at which it becomes economically viable to treat thrips infestations varies with the value of the crop and the cost of the selected treatment. See thrips management in the Integrated Pest Management section for additional information, page 50.

Insect pests affecting the saleable parts (pods) directly

Plant feeding true bugs such as multiple species of **stink bugs** and **lygus bugs** will feed on developing bean pods with their piercing-sucking type mouthparts. There are some species of stink bugs that are beneficial predators, so you want to distinguish between these species and the pest species. Virginia Tech published a great booklet to help with identification titled "Field Guide to Stink Bugs of Agricultural Importance in the United States," https://bit.ly/VI-stink-bugs.

DISEASES

Physiological disorders (abiotic disorders)

Bald head

Common in occurrence, seedlings affected by this disorder are malformed and stunted. There will be little growth above the cotyledons as the growing point is dead and the plant will die after several weeks. Bald head is caused by external or internal injury to the seed during harvest and processing.

Nutrient deficiency

Symptoms vary significantly depending upon the bean cultivar, the nutrient involved, and environmental conditions. In general, nutrient disorders are characterized by the foliage on the entire plant showing yellow, to tan, to bronze discoloration, beginning at the leaf edges with the veins remaining green. Typical soils in Wyoming have a high pH, which can lead to deficiencies in boron,

iron, manganese, and zinc. To manage, adjust soil pH and add the appropriate deficient nutrients.

Wind injury

High wind (this is Wyoming) can cause plant parts to rub, and leaves can experience tearing. Injured leaves have increased susceptibility to foliar pathogens, and roots can experience damage from plant swaying. Injured pods can have unsightly raised lesions. To reduce effects, plant in protected area; grow compact cultivars, and arrange rows in the direction of prevailing wind.

Sunscald

Symptoms first appear as small water-soaked spots on affected plant parts. These spots turn reddish-brown and coalesce to form large discolored areas. It is especially troublesome on the bean pods. Intense sunlight is the main cause, but high temperatures can also play a role. The disorder is most severe following periods of high humidity and overcast skies. There are no management measures.

Infectious diseases

Seedling diseases

Beans are susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

Foliar and whole plant diseases

Anthracnose is a fungal disease that attacks all aboveground parts of the plant, especially during cool, rainy weather. Symptoms include dark brown, sunken lesions on pods and elongate, angular spots on lower leaf veins. Affected seeds become discolored. To manage, start with anthracnose-free seed. Remove infected crop debris or incorporate well into the soil. Use a two-year rotation. Resistant varieties are available, but the anthracnose fungus has multiple races, and resistant cultivars are resistant only to one of these potential anthracnose races.

There are three distinct bacterial blight diseases found on snap and green beans: **bacterial brown spot**, **common bacterial blight**, and **halo blight**. Infection from these bacteria initially are characterized by small water-soaked spots on leaves. Spots become necrotic and, depending on the specific bacterium, spots remain small or coalesce into large necrotic lesions that may or may not have a yellow border. Symptoms on pods also start as water-soaked spots later turning to sometimes sunken, reddish-brown necrotic spots or streaks. Bacterial ooze can be observed on pods during periods of high humidity. Since these diseases can be seedborne, start with disease-free seed. Remove infected plant debris or fully incorporate in the soil as they can be significant sources of inoculum. Resistant cultivars are available.

Powdery mildew is a fungal disease common in Wyoming but usually does not cause major production problems. Symptoms are characterized by white powdery spots that can enlarge to cover the entire leaf surface. It can infect pods as well. Disease is favored by high humidity, but not free water (water droplets sitting on leaves, etc.), and cool temperatures. Spores are easily spread by wind and rain, and the fungus can be seedborne. To control, use disease-free seed, resistant cultivars, or sulfur sprays or dusts or other chemicals early in the season before pods become infected.

Curly top is a disease caused by the beet curly top virus and transmitted by the beet leafhopper insect. This disease can be particularly bothersome when beans are grown near sugar beet production areas of the state. Infected plant leaves pucker, curl, yellow, and die. Plants and pods can be severely stunted and overall growth of plant appearing bunched. Virus can survive on infected weeds such as mustards and Russian thistle. Dry conditions during the winter and spring favor the survival of the beet leafhopper. Use virus-free seed and curly top resistant varieties.

Root diseases

Fusarium root rot is caused by a soil-borne fungus and is found wherever beans are grown. First symptoms are small, elongate, tan-red lesions in

the lower hypocotyl and upper taproot. The lesions increase in number and size, often coalescing until the entire root system and lower hypocotyl show reddish-brown necrosis. Diseased plants are stunted in relation to the severity of root rot. Severely diseased plants may die, or adventitious roots may form that help to keep the plant alive. The disease is favored by warm soil temperatures, high soil moisture, and compacted soils and is spread by infested soil and bean tissue. To manage, practice crop rotation, avoid excessive irrigation, and deep, compacted soils. Use resistant cultivars if available.

Rhizoctonia root rot is also a common soil-borne fungal pathogen. The disease causes reddish-brown, sunken, elongate, cankerous lesions on the root and lower hypocotyl. Can infect both seedlings and more mature plants. Lesions that girdle stems can result in plant death. Warm and moist soils are optimal for infection. The pathogen moves through infested soil on equipment. Manage with crop rotations and fungicide treated seed (for seedling disease). Use resistant cultivars if available.

BEETS

Beta vulgaris

Wyoming's climate and soils are well-suited for beets. Sugarbeets, for example, are a major agricultural crop in our state. Both the leaves and roots of table beets are edible, making them a valuable crop for vegetable growers. Beets come in many different shapes, sizes, and colors. Red, pink, white, yellow, and orange are some of the more common colors. Some are even striped. Depending on the variety, beets might be round, cylindrical, or oblong in shape with varying sizes.

GROWING CONDITIONS

Beets are a cool-season plant that can withstand cooler temperatures. They grow best in temperatures 60 to 65 F. If beets bigger than a pencil in diameter grow in very cool conditions (under 50 F) for 21 days or more, the plants can bolt (produce flower shoots).

Denis Pogostin, shutterstock.com

They won't form edible roots at this point and should be pulled and replanted. Plants can handle full to partial sun. Weed management is important when growing beets. Beets do well following legumes such as peas and beans. Like most vegetable crops, beets should be used in a crop rotation system to avoid nutrient and potential disease and pest issues. Avoid heavy clay soils or soils that are not well drained.

PLANTING

Beets are a quick crop. They have short days to maturity and so can be planted in succession. Seeds can be sown at one or two week intervals to provide continuous crops of beets throughout the growing season.

Beets can be transplanted or directly seeded into the ground. Direct seeding is often the easiest for establishment. Seeds can be planted in the early spring before the last frost is expected. Do not plant seeds more than half an inch deep. Seeds are normally sown 2 to 4 inches apart in rows 12 to 30 inches apart. Beets should be not planted too close together or too deep in the soil to avoid poor production. Plants often need to be thinned to the best spacing for plant growth.

DAYS TO MATURITY

45–65 days.

HARVESTING

Most table beets are harvested when they are 2 to 3 inches in diameter and still tender. Many fresh beets sold in farmers markets or other venues are sold with their leaves intact; however, they store better if the greens are cut off, leaving 1 inch attached to the root to avoid bleeding. Store at temperatures down to 32 F.

SOME COMMON VARIETIES

- Harrier Hybrid (50)
- Early Wonder (50)
- Red Ace (52)
- Golden (55)
- Cylindra (55)
- Detroit Dark Red (58)
- Ruby Queen (58)
- Chioggia (60)

INSECT PESTS

Table beets and Swiss chard varieties share common pests with spinach (*Spinacia oleracea*), page 158.

Pests often affecting seedlings

Beet seedlings are not often attacked by pests; however, **spinach flea beetle** (*Disonycha xanthomeles*) will feed on spinach, Swiss chard, and beet seedlings. The flea beetle damage is problematic on leafy green crops as the pits they chew make the leaves unmarketable. (See flea beetle management in the Integrated Pest Management section for additional information, page 46.)

Insect pests affecting the saleable parts directly (leaves and/or roots depending on crop)

Leafminer damage
Whitney Cranshaw, Colorado State University, Bugwood.org

Spinach leafminers (*Pegomia hyoscyami*) are a bigger problem for the leafy green *Beta* species than the root crop species. At low population levels, leafminer feeding does little apparent damage to plant health but can make their leafy greens unsalable. Row covers, if practical, can exclude the adult female flies before they have a chance to deposit eggs on the leaves and help reduce damage. Weeds in the goosefoot family are alternate host plants for leafminers. Eliminating these plants from near crop fields can reduce the population of this pest. Applying contact insecticide to the leaves as frequently as the product label allows can also help prevent successful ovipostion and entry of the larvae into the leaf.

Beet webworm moth
Anton Starikov, shutterstock.com

Beet webworm (*Loxostege sticticalis*) is a summer pest of the foliage of many common weeds and, unfortunately, all the common beet family plants. The caterpillar of this small moth (3/4-inch maximum size) is the plant damaging stage. The caterpillars chew on the leaves and also put silk on the leaves, which reduces their market value.

Green peach aphid and **lettuce aphid** are the two most common aphids that will feed on these *Beta* species crops. Although aphid excrement (honeydew) and molted exoskeletons can be washed off of leafy greens, they can reduce attractiveness to the consumer.

Sugarbeet leafhopper
A.C. Magyarosy, Bugwood.org

The **sugarbeet leafhopper** (*Circulifer tenellus* now *Neoaliturus tenellus*) is a small insect with a piercing, sucking beak that feeds on plant sap. It doesn't cause much physical harm to the plant itself, but the insect is a vector of beet curly top virus. Despite the common name of both the virus and the only insect that spreads it by feeding, the virus can also infect spinach, chard, tomatoes, peppers, and many other plants. Sugarbeet leafhoppers overwinter in weeds outside of crop fields. Managing both the weeds and the insect vector in these areas reduces the risk of disease transmission to the crop from this pest. Current insecticides have not proven very effective in preventing this leafhopper pest from infecting plants with the virus once they enter a field.

Sugarbeet root maggot flies
Whitney Cranshaw, Colorado State University, Bugwood.org

Sugarbeet root maggot (*Tetanops myopaeformis*) is the larvae of a small fly that loosely resembles a house fly. The adult flies emerge from the soil in the spring where they have spent the winter in their pupal state. The adults mate and the females deposits eggs near the tops of suitable host plants. The maggots then hatch and feed on the surface of developing beet roots. This damage opens up the plant's root to decay and allows in other pathogens. Monitoring for the adult flies early in the spring can be done with fluorescent orange-colored sticky card traps. Cultural control methods are the only pest control methods available for sugarbeet root maggot management as no synthetic insecticides are currently labeled for this pest in table beet, spinach, and Swiss chard.

DISEASES

Physiological disorders (abiotic disorders)

Zoning

Zoning is a condition where there are alternating red and pale bands in a cross section of the root. Contributing factors are high temperatures and variety. This doesn't affect taste of the beet, and some susceptible garden varieties are marketed as novelty items.

Infectious diseases

Seedling diseases

Table beets are susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, on page 27.

Foliar and whole plant diseases

Cercospora leaf spot is a common foliar disease of beets caused by the fungus *Cercospora beticola*. It can also infect Swiss chard and spinach. Damage can range from a few necrotic spots to total leaf loss. Symptoms are tan-colored small spots on the leaf usually surrounded by a red to purple margin. Another common fungal foliar disease that can be confused with Cercospora leaf spot is **Phoma leaf spot** caused by *Phoma betae*. Phoma leaf spot causes similar but larger, darker-brown lesions that contain concentric rings (target-like). High humidity and warm temperatures favor the growth of these fungal organisms. Of the two, Cercospora can be the most severe and can be managed with preventative fungicides when symptoms first appear. Remove or bury infected residue and manage weeds in the

same plant family as beets (amaranth family) such as lambsquarters and pigweed as they can serve as alternate hosts.

Curly top is a disease caused by the beet curly top virus and transmitted by the beet leafhopper insect. Infected plant leaves pucker, curl, yellow, and die. The virus can survive on infected weeds such as mustards and Russian thistle. Dry weather conditions during the winter and spring favor the survival of the beet leafhopper. Use virus-free seed and curly top resistant varieties to avoid this disease.

Root diseases

Several genera of soil-borne fungi can cause a **beet root rot**, these include *Rhizoctoia solani*, *Fusarium* spp and *Phythium* spp. To manage these diseases, rotate garden space, remove infected residue, improve soil drainage, avoid water-logged soils, and use resistant cultivars if available.

BROCCOLI

Brassica oleracea var. *italica*

Broccoli is a popular vegetable grown throughout much of Wyoming because it produces well in cool seasons, as do other plants in the cabbage (*Brassica*) family. (Crops in this family of plants are also referred to as cole crops or crucifers.) In most of the country, broccoli is grown for spring and fall harvests, but in much of Wyoming, we may only be able to plant in the spring and harvest in summer and fall during our short growing seasons. Heat-tolerant varieties may produce better in warmer parts of the state. When choosing varieties, note that some varieties produce larger central heads with smaller side shoots. Others produce smaller central heads with larger side shoots.

GROWING CONDITIONS

Broccoli is a reliable cool-season vegetable that can be planted when soil temperatures reach 40 F. Broccoli grows best in temperatures between 60 and 68 F.

brackish_nz, shutterstock.com

Temperatures above 80 F tend to cause poor growth and quality. Broccoli is often transplanted into the field from seedlings started inside, but because it is cold tolerant, it can be planted from seed fairly early in the season. Broccoli prefers fertile soils and the growth and development of broccoli can be improved by growing in soils amended with compost. Fertilize transplants with a starter fertilizer and apply nitrogen fertilizer several weeks after planting. Broccoli prefers a soil with a pH of 6.0 to 7.0. Water regularly throughout the growing season, especially as heads are developing.

PLANTING

Broccoli plants can grow to 2 feet wide. Plant seeds or set transplants 12 to 24 inches apart in the rows (depending on variety) with 18 to 36 inches between rows. Yields will be reduced if broccoli plants are too close together.

Transplanting broccoli into a field rather than planting seeds is generally recommended in Wyoming. Broccoli can be grown successfully from direct sown seed, but transplants will produce earlier and extend the harvest periods. Start plants from seeds four to six weeks before transplanting outside. Broccoli can be transplanted when soil temperatures reach 40 F (two to three weeks before the average last frost). Older transplants will perform poorly if temperatures are too cool after being moved outdoors. Some varieties of broccoli are planted in the cool of spring and harvested in summer. Some heat-tolerant varieties can be sown in summer for late season harvests. Heat-tolerant varieties are better suited for lower elevation areas of Wyoming where summer temperatures in the 90s F are common.

DAYS TO MATURITY

Standard broccoli may produce one or two crops per year. The first harvest may be 50–80 days after planting. Days to maturity depends on the variety, so consider the growing season in your area and choose varieties that will mature within that time frame.

HARVESTING

The center broccoli flower (head) is harvested when heads are large, tight, and still green (before yellow flowers develop). Growers should watch broccoli development to give the head time to grow and develop as large as is possible, but waiting too long (the green buds will begin to show yellow from the flowers) to harvest will result in loose heads, flower bloom, and bitter flavors. Many mature broccoli varieties develop central heads 4 to 6 inches in diameter. Other varieties produce multiple, smaller heads with tender shoots.

Use a knife to remove the flower head and 3 to 4 inches of stem. After harvest of the center flower head, the side shoots will generally develop into smaller heads (2-inch or so wide) for further harvest.

Broccoli stores best at temperatures close to 32 F with high humidity. Under these conditions it may last 7 to 12 days. It should not be stored around fruits or other vegetables that produce ethylene or it will start to yellow.

SOME COMMON VARIETIES

Standard broccoli

Produces one central head, followed by lateral heads along stem.

- Packman (good side shoot development after harvest of main head)(50)
- Green Goliath (55)
- Green Magic (57)
- Gypsy (60)
- Arcadia (cold tolerant) (63)
- Premium Crop (65)
- Diplomat (bred for northern gardens) (68)
- Marathon (68)
- Sun King (heat tolerant) (71)
- Waltham 29 (74)
- Romanesco (interesting, spiral head) (75+)
- Royal Tenderette (mini-florets on delicate stems)

Mini broccoli

Produces multiple, smaller heads with tender shoots.

- Rich (27)
- Atlantis (33)
- Broccoli Raab (Rapini) (42)

INSECT PESTS

Cole crop varieties are all derived from a single plant species, *Brassica oleraceae*. The various cole crops can have very different plant forms. There are the "aboveground" cole crops such as Brussels sprouts, cabbage, cauliflower, collards, kale, kohlrabi, and broccoli. There are also "root cole crops" such as turnip, radish, and rutabaga. Because these crops are so closely related they all tend to suffer attack from the same species of pests; however, the threat a pest species is to profitable production varies by crop. For example, low levels of thrips damage on the foliage of a root cole crop isn't a major issue as compared to that same leaf damage on a cabbage head.

In Wyoming, the most commonly reported pests of cole crops, are: the **imported cabbageworm** (*Pieris rapae*), which is the larvae of the cabbage white butterfly; **two flea beetle** species that inflict foliage damage early in the growing season; and **aphids** later in the growing season. There are many other pest insects that can cause economic damage to cole crops that should also be scouted. Scouting for pests will need to start when the crops are planted or, in some crops, transplanted, and continued until harvest. Insects that physically damage the edible parts of plants can rapidly ruin the value of cole crops.

As a part of IPM, pesticides, either synthetic or organic, are an important tool for a grower. This is especially true as a rescue treatment when a crop is rapidly invaded by a flying pest or when a cultural or physical control method completely fails. To use pesticides on crops meant for direct

human consumption will require a grower to seek out the most up-to-date pesticide label information possible. This is not always easy to accomplish due to constant industry and regulatory changes. For more information on pesticides, see University of Wyoming Extension publication "What's in your toolbox?" at http://bit.ly/bug-toolbox.

Pest control considerations for those growing for the market

To grow undamaged produce without applying any pesticides at all will require cultural, mechanical, and physical control methods along with management practices compatible to biological control agents. For produce that will be consumed directly and in the case of cole crops, often raw, there is little tolerance by consumers of even cosmetic damage on the product. The goal of IPM is to raise your crop profitably and sustainably. Adopting all IPM suitable practices that can prevent or limit pest outbreaks in your field may be paramount to profitability if you are growing cole crops for sale.

COMMON COLE CROP PESTS

Early-season pests often affecting seedlings and transplants

Cutworms

Cutworms, the caterpillars of several species of "miller" moths, and flea beetles are the primary early-season pests of cole crops trying to get established. Effective fall and early season weed control around the production area can reduce the overwintering populations of these pests. Plastic or cardboard collars can be installed around transplants to protect them from cutworms. See cutworm management under the Integrated Pest Management section for additional information, page 45.

Army cutworm larvae
Frank Peairs, Colorado State University, Bugwood.org

The **army cutworm** (*Euxoa auxiliaris*) is the most common species in our region. The army cutworm cuts plants off at ground level and has one generation per year that causes damage in the early to mid-spring.

Variegated cutworm larvae
James Kalisch, University of Nebraska, Bugwood.org

The **variegated cutworm** (*Peridroma saucia*) looks similar to the army cutworm, but its behavior is different in that it climbs up on the plants to feed and has up to three generations per year so its damage can extend into the summertime.

Flea beetles

Protective collars for seedling plants don't work for the agile flea beetles. Using transplants versus direct seeding crops can help as the larger plants have more leaf area to compensate for flea beetle damage.

Having vigorously growing plants that can tolerate the early leaf damage from flea beetles is important. They are primarily an early-season pest as the adult beetles spend the winter in weedy areas adjacent to fields and will move in to feed on new transplants or seedlings. Cultural practices to eliminate overwintering habitat and row covers over seedlings can keep the beetle defoliation below critical levels. "Trap crops" of radishes planted at the edges of fields can be used to attract the flea beetles off of the more valuable cole crops.

If using seeds to establish your cole crops you will want to plant in excess of ideal plant numbers to ensure there is sufficient plant survival after pest losses in the field. Row covers can be very effective for excluding a variety of pests such as flea beetles and the adult stage of leaf feeding caterpillars later in the season. Row covers come with additional cost and labor to install; however, they become more economically feasible if you can protect the cole crop from multiple pest species by using row covers. See flea beetle management under the Integrated Pest Management section for additional information, page 46.

Adult crucifer flea beetles and cabbage damage
Whitney Cranshaw, Colorado State University, Bugwood.org

Western black and **crucifer flea beetles** (*Phyllotreta* spp.)The adults of these small, shiny beetles are very mobile, and their characteristic pitting and "shot hole" feeding on plant leaves is easier to see than the insects themselves.

Root feeding by cabbage maggot (*Delia radicum*) has stunted the plant on the left. The larvae of this true fly (Order Diptera) feeds on the roots of cole crops early in the season. The infested plants become chlorotic and fail to thrive. Planting or transplanting into soil warm enough for rapid plant growth to "outgrow the pest damage" is the primary cultural method used to fight this pest.

Clemson University - USDA Cooperative Extension Slide Series, Bugwood.org

Cabbage maggot

The **cabbage maggot fly** is an early-season pest of the roots of cole crops. The cabbage maggot larvae can feed on roots even when the soil is too cold for cole crops to actively grow. If the soil stays too cool for root growth for too long, the plants can't recover from the root damage. The cultural practices of planting in soil warm enough for vigorous plant growth, crop rotation, and destruction of crop residues after harvest can usually reduce damage from cabbage maggot to non-economic levels.

Pests that attack the saleable produce—chew or pierce leaves and suck plant juices later in the season

Caterpillars

The imported cabbageworm, and less frequent pests in Wyoming the cabbage looper, zebra caterpillar, and the larvae of diamondback moth, all attack cole crops. These insects are all members of the insect order Lepidoptera. This makes them susceptible to the *Bacillus thuringiensis* subspecies *kurstaki* (Btk) and *Bacillus thuringiensis* subspecies *aizawai* (Bta) biopesticides. The active ingredients in these products are insecticidal proteins derived from the

bacteria so, in the appropriate formulations, they are acceptable for organic crop production; however, either the subspecies Btk or Bta has to be used to be effective against Lepidoptera. Products for mosquito larvae containing Bt subspecies *israelensis* (Bti) would be both off label and also ineffective against caterpillars. Btk and Bta are very specific pesticides and will not directly impact beneficial insects. Many other conventional and a few organic insecticides are available for the control of these leaf feeding insects. You must follow the label restrictions on any pesticide you chose regarding rates, field re-entry, and pre-harvest intervals. And you must use the label required Personal Protective Equipment (PPE) during pesticide applications.

Imported cabbageworm larvae
Phil Sloderbeck, Kansas State University, Bugwood.org

Imported cabbageworm adult butterfly
Robert J. Bauernfeind, Kansas State University, Bugwood.org

The **imported cabbageworm** (*Pieris rapae*) has small green larvae that can be hard to spot. The ragged holes the caterpillars chew into leaves and the resulting excrement are sometimes noticed first. This species can overwinter in northern climates as pupae and the adult butterflies appear early in the spring.

The adults of the imported cabbageworm are small day flying white butterflies whose common name is cabbage white. They are very mobile and deposit small white elliptical shaped eggs on the cole crop and related weed species leaves.

Adult diamondback moth
Alton N. Sparks, Jr., University of Georgia, Bugwood.org

The **diamondback moth** (*Plutella xylostella*) is a small, slender insect that cannot overwinter in cold climates. It travels north on warm south winds to arrive in fields in the spring and summer. The first stage larva are tiny and feed as a "leaf miners" initially. Older stages of the larvae emerge from the leaf, and the damage the caterpillars inflict on leaves is similar to the imported cabbageworm. The difference is that the ragged holes in the leaves are on average smaller in diameter.

A close up view of a cabbage looper (*Trichoplusia ni*) caterpillar.

Alton N. Sparks, Jr., University of Georgia, Bugwood.orgThe **cabbage looper** caterpillar moves in the distinctive "looper" or "inchworm" manner. The damage it inflicts on

the crop consists of ragged feeding holes in the leaves, larvae (alive and dead), and excrement contamination. This pest cannot overwinter in northern states, but the adults travel on south winds and spread onto susceptible crops in the spring and summer.

Zebra caterpillar
Whitney Cranshaw, Colorado State University, Bugwood.org

The **zebra caterpillar** is a widespread insect. This very colorful caterpillar will feed on both cole crops and various beet crop tops.

Aphids

Cabbage aphid with aphid "mummies" and lady beetle eggs.
Whitney Cranshaw, Colorado State University, Bugwood.org

The aphids species that attack cole crops are the **cabbage** (*Brevicoryne brassicae*), **turnip** (*Lipaphis pseudobrassicae*), and **green peach** (*Myzus persicae*) species. Aphid infestations on the leaves of root cole crops are not as serious as when they are found on the leaves of kale or cabbage. The use of broad spectrum insecticides to treat other pests can negatively impact the predators of the aphids. This will sometime result in an aphid population boom that needs treatment. Pest scouting should always continue after pesticide applications, following the R.E.I. (restricted-entry interval), to both determine the efficacy of the treatment and to watch for population booms of other pests.

The dense population of aphids on this cabbage leaf show some "mummy aphids" with expanded tan colored bodies. This indicates the successful attack of the aphids by parasitoid wasps (as do the exit holes, where the emerging wasps chewed their way out of the mummies). There are also the clusters of yellow eggs of lady beetle predators present amongst the aphids; however, the density of aphids seen in this picture shows the predator insects couldn't keep up with the pest. This level of aphid infestation would cause stunted growth and present contamination problems during harvest of the crop. (See aphid management under the Integrated Pest Management section for additional information, page 44.)

Thrips

Cabbage damaged by thrips
Gerald Holmes, Strawberry Center, Cal Poly San Luis Obispo, Bugwood.org

Two species of thrips (*Thrips tabaci* and *Frankliniella occidentalis*) will attack cole crops.

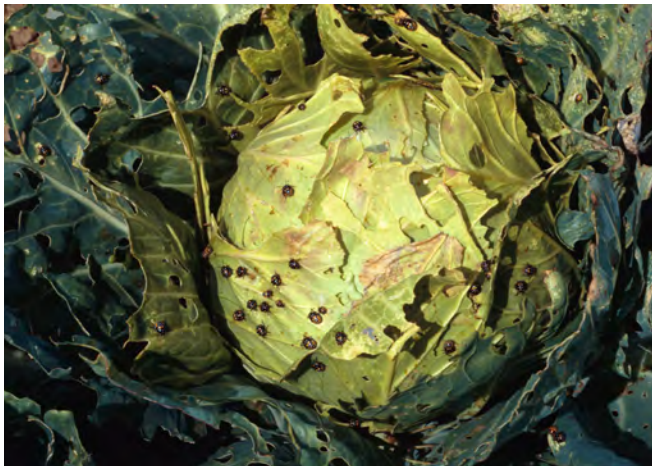
The feeding damage of these tiny insects causes both loss of photosynthetic function and cosmetic damage to the leaf surface of the plants. The cosmetic damage alone can significantly reduce the sale value of a crop. See thrips management in the Integrated Pest Management section for additional information, page 50.

Grasshoppers

See grasshopper management under the Integrated Pest Management section for more information, page 47.

Less common cole crop pests

Harlequin bug



Harlequin bug damage
Whitney Cranshaw, Colorado State University, Bugwood.org

Adult harlequin bug
Lisa Ames, University of Georgia, Bugwood.org

Harlequin bugs (*Murgantia histrionica*) have a piercing sucking mouth and feed on plant cell contents. In arid climates, the injured leaf material can dry and flake away to resemble the ragged holes caused by typical caterpillar feeding.

Adult two-spotted stink bug, a beneficial predator
Kevin D. Arvin, Bugwood.org

The harlequin bug adults, pictured, and nymphs are colorful insects; however, don't mistake the red color morph of the beneficial predator two-spotted stink bug (*Perillus bioculatus*), for the pest species.

Leafminer

Leafminer damage
David Riley, University of Georgia, Bugwood.org

The larvae of vegetable **leafminer** (*Liromyza sativae*) makes a serpentine-shaped leaf mine typical of larvae of pest flies from the Agromyzidae family. This can be mistaken for the damage made by the first stage caterpillar of the diamondback moth. The vegetable leafminer will attack all cole crops but is not a common pest in cool climates.

Lygus

Adult lygus
Frank Peairs, Colorado State University, Bugwood.org

The most common plant bugs (Family Miridae) pests of cole crops are usually the two species of lygus (*Lygus lineolaris* and *Lygus hesperus*) common in Wyoming. They feed on plants with their piercing sucking mouth parts to remove the cell contents. These plant bugs feed on many types of crop plants besides cole crops. Lygus bugs can be quite abundant in areas where alfalfa is grown, as it is one of their preferred plant hosts.

The adults of the two species of lygus can vary in color from brown to green but both have a pale colored "V" on the scutellum in the middle of their back. As adults, their body length averages around 3/8 of an inch (9.5 mm).

Garden symphylan

Garden symphylan
Whitney Cranshaw, Colorado State University, Bugwood.org

Garden symphylan (*Scutigerella immaculata*) is not an insect but is a species of centipede that feeds on the roots of many plant species, including cole crops. As with many other root-feeding pests, the damage they cause can be hard to diagnose without digging up the affected plants. Unfortunately, there is no rescue treatment for infested plants. Sampling the soil to determine the density of symphylans before planting can identify field areas likely to suffer damage. Conventional tillage can then be used to reduce garden symphylan populations; however, conventional tillage may not be compatible with your soil management. There are pesticides labeled for garden symphylans when applied as broadcast or banded applications, but the product labels need to have cole crops specifically on them. Crop rotation between potato and more vulnerable cole crops, has shown to reduce garden symphylan damage in subsequent years.

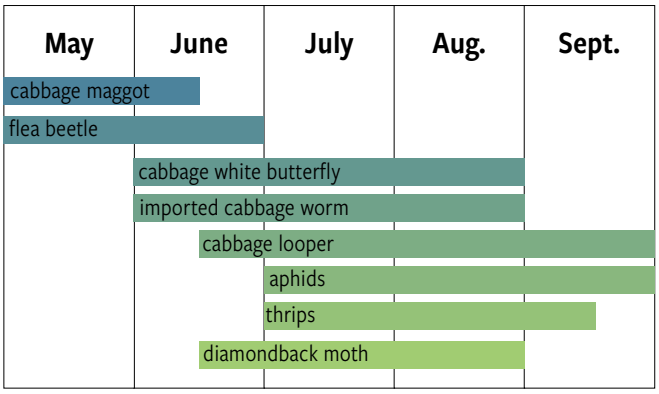
The pale colored-garden symphylan adults are only approximately ¼-inch long (6.3mm) and have 12 pairs of legs. The nymphs will have from 6 to 11 pairs of legs, depending on age.

Often the root damage is only in part of a field where soil conditions are most suited to this pest's requirements.

Rodents

Rodents can damage cole crops in Wyoming. They have been known to feed on the heads of developing crops, particularly broccoli.

Scouting calendar for common pests of cole crops grown outside.



Pest scouting calendar adapted from https://bit.ly/scouting-veg-pests

DISEASES

Physiological disorders (abiotic disorders)

Yellow or brown heads

These conditions are a result of an issue affecting the florets. Yellowing of florets can be an indication of over maturity, high temperatures in storage, or exposure to ethylene (plant ripening hormone given off by some fruits and vegetables such as apples). Brown heads are an indication that florets have improperly developed and died and are starting to senesce. This could be due to insect feeding or nutrient imbalances. Brown heads can also be due to problems with calcium uptake (due to rapid growth conditions or irregular irrigation).

Premature head development (buttoning) and lack of heads

Too early of head development can be caused by planting transplants that are too old or stress factors such as low soil nitrogen and/or moisture, disease, and micronutrient deficiencies. Some varieties are more susceptible than others, early varieties especially so.

Lack of head development can occur during periods of warm weather, which cause plants to remain in a vegetative state (head formation requires a period of cool temperatures).

Leaves (bracts) in heads

High temperatures and low moisture can result in the formation of small leaves or bracts, between segments in the head.

Hollow stem

Environmental conditions promoting rapid growth such as high nitrogen or moisture can lead to a cavity within the stem as it grows. This cavity can provide access to secondary disease organisms causing stems to rot.

Infectious diseases of broccoli, cauliflower, cabbage, Brussels sprouts, and kohlrabi

Seedling diseases

Plants are susceptible to seedling diseases (**damping off**) under the right conditions. See section on seedling damping-off diseases in the Starting Plants from Seed section for more specifics, page 27.

Foliar and whole plant diseases

Leaf spots. Most of the Brassica crops are susceptible to leaf spot diseases, a common one caused by fungal *Alternaria* spp. pathogens. This disease is characterized by small brown-black circular spots that can enlarge over time with concentric rings (like a target). Prevention is the best measure, use certified seed and disease free transplants. The fungus prefers wet and warm conditions, so it's typically a disease of later in the season. Remove weeds in the mustard family from the area as they can harbor the disease. The leaves or whole plant should be removed and disposed of in severe infections. Fungicides can be effective during early stages of the disease.

Powdery mildew is caused by the fungus *Erysiphe polygoni* that produces a white powdery growth on the leaf surface. It is favored by cool and humid conditions. Unlike many fungal pathogens, it does not like free water droplets on plant surfaces. In Wyoming, we typically see this disease on leafy vegetables and other garden hosts later in the season, as canopies become dense with shadier conditions that create favorable conditions for disease development. Remove and destroy diseased tissue at the end of season. It can be managed in some crops with fungicides if applied at first appearance of disease.

Black leg is caused by the fungal organism *Phoma lingam* and affects the stems and leaves of brassica vegetables. The lesions are light brown with a purplish outline and often contain pinhead-sized black dots. These lesions can grow to girdle the base of the pant. The pathogen overwinters in infected plant residue and can be carried on seed. Wet and windy conditions favor spread of disease. Manage by

planting disease-free seed, crop rotations, sanitation, and removing brassica weeds (alternate hosts).

Black rot is caused by the bacteria *Xanthomonas campestris* pv. *campestris*. The disease is favored by rainy conditions, and symptoms include yellow to brown patches on leaf margins. Eventually, patches become necrotic and form a v-shaped lesion. For management, plant disease-free seed, use sanitation practices (removing diseased crop residue,) and avoid sprinkler irrigation.

Root diseases

Club root is a root disease caused by the pathogen *Plasmodiophora brassicae*, an organism similar to slime molds. Wilting of plants during the day is usually the first symptom. As the disease progresses, leaves will yellow, die, and plants will be noticeably stunted compared to healthy plants. Belowground, roots will start out by having small, swollen growth characteristics and then will eventually have large club-like masses. Early infected plants will die, and ones that survive will not produce a marketable product. The club root pathogen can survive in soils for up to 10 years and can spread by infected transplants and water and soil movement. It can be managed by maintaining a soil pH of 7.3 and higher.

BRUSSELS SPROUTS

Brassica oleracea var. *gemmifera*

Brussels sprouts is also a cole crop (member of the cabbage family) and grown for its "sprouts," which appear as miniature heads produced in the leaf axils along the stem of the plant. Although a cool-season crop and able to withstand (and grow well with) light frosts, Brussels sprouts can be slow growing and usually require a long growing season of at least 80 days. Varieties requiring over 100 days to harvest are not well-suited for many parts of Wyoming unless grown in a high tunnel. Several newer varieties are available that can work in all but the shortest growing seasons in Wyoming.

olenaa, shutterstock.com

GROWING CONDITIONS

Although the leafy portions of the plant grow reasonably well in warmer temperatures, the best sprout development occurs when temperatures are below 75 F. Brussels sprouts can tolerate cold temperatures for short periods of time. Brussels sprouts grow best in fertile soils, and soils amended with good quality organic matter will improve production. Fertilize transplants with a starter fertilizer and apply nitrogen fertilizer several weeks after planting. Water regularly throughout the growing season. Drought-stressed plants will not produce well.

PLANTING

Plants are usually grown as transplants in Wyoming due to our shorter seasons. Start Brussels sprouts indoors four to six weeks before transplanting outside. Transplant when soil temperatures are at least 40 F. Set transplants 18 to 24 inches apart in the rows with 24 to 40 inches between rows.

DAYS TO MATURITY

Brussels sprouts time to harvest ranges from 80–110 days.

HARVESTING

Buds, or sprouts, will form small heads 1 to 2 inches in diameter at the base of each leaf along the stem. Buds at the base of the stem will mature first. Cut or pick when the sprouts are at least 1 inch in diameter. The leaves near the sprout can be removed to make harvesting easier. If interested in having all the sprouts mature around the same time, rather than sequentially, the top growing point can be cut/pinched out when bottom sprouts are about ½-inch in diameter. This can be done at least seven weeks before a hard freeze to get the sprouts to the point they can be harvested all at once.

Brussels sprouts can be stored for four weeks or more at temperatures close to 32 F and high humidity. Brussels sprouts should be stored away from fruits and other vegetables that may produce ethylene gas. Ethylene contributes to early ripening, and the brussels sprouts may start to yellow.

SOME COMMON VARIETIES

- Octia (78)
- Green Gems (85)
- Long Island Improved (90)
- Hestia (93)
- Diablo (110)

INSECTS PESTS

See the insect pests listed under cole crops in the Broccoli section, page 78.

DISEASES

Physiological disorders (abiotic disorders)

Bolting

Under extended conditions of low temperatures (less than 50 F) plants will be stimulated to flower and produce seed rather than the edible sprouts.

Tip burn and hollow stem

Refer to Broccoli section, page 84.

CABBAGE

Brassica oleracea var. *capitate*

Cabbage is grown for its large heads of compact leaves that are used in salads, slaws, soups, and sauerkraut. Green, red, and purple cabbages are commonly grown. Most varieties have smooth leaves, but the savoy varieties have a textured leaf. Some varieties keep their quality longer than others when not harvested promptly. Choose these varieties if an extended harvest is desired. Producers in most areas of Wyoming should be able to grow cabbage successfully.

GROWING CONDITIONS

A cool-season cole crop, like broccoli and Brussels sprouts, cabbage prefers rich, fertile soils, consistent water, and full sun. Cabbage does not grow well in temperatures over 75 F. Cabbage is particularly susceptible to drought stress during the time period starting when the leaves begin to cup through to when heads are mature.

Garsya, shutterstock.com

PLANTING

Cabbage is very cold tolerant and can be among the first plants in the garden in spring. Cabbage can be seeded or transplanted out when soil temperatures are above 40 F. Start seeds indoors four to six weeks before transplanting into a field. If expecting an extended period of cool weather (month or more), plant out small seedlings as larger ones may get vernalized and then they will bolt and form flowers rather than the desired heads. Space plants 12 to 24 inches apart in rows 24 to 36 inches apart. Closer spacing will produce smaller heads. Depending on the variety and planting date, heads will develop during cooling temperatures in fall.

DAYS TO MATURITY

Varieties that perform best in Wyoming will require 65–85 days to mature.

HARVESTING

Depending on the variety, cabbage heads can range from 2 to 8 pounds. Larger heads are often grown by those who plan to process the cabbage into slaw or store the heads longer. Heads can be harvested at any time after they form. For highest yields, cut the heads when they are firm to the touch. Heavy rain or too much irrigation can cause a mature head to split. Cabbage stores best at temperatures close to 32 F with high humidity. Under these conditions, many varieties will last a month or two, those bred for storage can last up to five months or so. Cabbage should not be stored around fruits or other vegetables that produce ethylene or the outside layer of leaves will start to yellow.

SOME COMMON VARIETIES

Red/purple varieties

- Red Express (63)
- Candy Red (78)
- Ruby Perfection (85)

Green varieties

- Golden Cross (40)
- Tiara (63)
- Farao (65)
- Stonehead (65)
- Emerald Cross (67)
- Tendersweet (71)
- Omero (73)
- Primo Vantage (73)
- Early Flat Dutch (80)
- Late Flat Dutch (105) (storage type)

Savoy varieties

- Alcosa (72)
- Famosa (75)

INSECTS PESTS

See the insect pests listed under cole crops in the Broccoli section, page 78.

DISEASES

Physiological disorders (abiotic disorders)

Oedema or Edema

Spots are visible on the upper side of the leaves and small "blisters" can be seen on the underside. Conditions of high soil moisture associated with sudden low temperatures create a situation in the plant of excess water causing epidermal cells to swell and burst. Impact on the plant is minimal and mostly cosmetic.

Tip burn

Edges of inside leaves of the head are brown and become increasing necrotic with age and are thought to be caused by periods of rapid growth when the plant cannot take up enough calcium. Avoid excess nitrogen, and some resistant varieties are available.

CARROTS

Daucus carota subsp. *sativus*

This iconic orange vegetable is well-suited for Wyoming. Carrots are relatively easy to grow once germinated, resist periods of light frost and have low fertilizer requirements compared to other vegetables.

Carrots are biennial plants, meaning they complete their life cycle in two years. They produce leaves and roots the first year. At this point they are usually harvested. If the plants are left in the ground and survive until their second year, they will send up a flower stalk, which looks much like the wild Queen Anne's lace, and produce seed. Carrots come in more colors than orange. Heirloom and other varieties are available in red, white, yellow, purple, as well as orange color variations. The shape of carrots varies from long and slender to short and stubby. Taste can also vary widely.

Max_555, shutterstock.com

GROWING CONDITIONS

Planting carrots in areas that receive full sun and have soil with adequate moisture and nutrients will produce high yields. Carrots also need adequate room between plants to yield well. Carrots grow best at temperatures between 60 and 70 F. Hot (over 86 F) and dry conditions can cause carrot roots to develop strong/bitter flavors. Carrots planted into heavy clay soils are often less productive. Carrots may become twisted, forked, or otherwise misshapen due to rocks, stones, or nematodes in the soils.

PLANTING

Direct seeding is the most common practice, but avoid planting the seeds too densely or thin out after germination. Carrots can be planted when soil temperatures are over 45 F. Seeds should be sown 1 to 3 inches apart and not too deeply in the soil. A general rule of thumb is to not plant seeds any deeper in the soil than one and half times the length of the seed. Carrot seeds take two to three weeks to germinate. Soil should be kept evenly moist during germination and early growing stages to avoid poor carrot stands. Carrots can be planted in succession (three weeks apart) for multiple harvests.

Carrots can be thinned once seeds have germinated. If carrots are planted too close together and not thinned, expect to get a lot of carrots, but they will be small, spindly, and not saleable. You can also expect individual carrots to "twist" or several different carrots to grow together and form what appear to be odd mutations when they are grown at too high densities.

As with other vegetable crops, rotation through your growing area is important to avoid disease and nutrition issues.

DAYS TO MATURITY

55–90 days to maturity. Shorter days to maturity varieties are ideal for many of Wyoming's short growing seasons.

HARVESTING

Carrots can be harvested at different sizes depending on market demand or your individual consumption preferences. Carrot roots become woody if left growing too long. The tops of carrot roots can turn green and develop an off taste when exposed to the sun. Cover them up with soil a couple of weeks before harvest to avoid this greening effect. Carrots sold or eaten quickly can have the leaves still attached but store best with the leaves removed (or at least substantially trimmed to reduce water loss). After leaf removal, store them in a cool (down to 32 F) area with high humidity. They can be stored for a couple of months or more in these conditions.

SOME COMMON VARIETIES

Orange

- Mokum (56)
- Little Finger (65)
- Nantes varieties (70)
- Danvers varieties (70)
- Chantenary Red Core (75)
- Oxheart (80–90)

Purple

- Purple haze (70)
- Cosmic Purple (70)
- Dragon (75)

White

- Lunar White (75)

Yellow

- Yellowstone (70)
- Amarillo (75)

Red

- Atomic Red (75)
- Red Samurai (75)

INSECT PESTS

Carrot (*Daucus carota*), cilantro (*Coriandrum sativum*) and parsley (*Petroselinum crispum*) share common pests.

Pests often affecting seedlings

Slugs can feed on the foliage and the tops of the roots. Leaf feeding is less of a cause of concern than the damage to the roots. Decay organisms and other plant pests can enter the root through this type of feeding damage.

Affecting vegetative growth (Pests that chew leaves or pierce and suck plant juices)

Multiple **climbing cutworm** species, **alfalfa webworm**, and **parsley worm** feed on foliage with their chewing mouth parts. On cilantro and parsley, crops which are in the carrot plant family as well, this is especially damaging as that is the saleable part of the plant. **Carrot aphid** feeds on phloem and can wilt plants under water stress and contaminate the leaves with honeydew.

Insect pests affecting the saleable parts directly

This carrot root has surface damage caused by the feeding of the small white maggots of the carrot rust fly (*Psila rosae*). This damage allows decay organisms to enter and further damage the root.
Whitney Cranshaw, Colorado State University, Bugwood.org

Carrot rust fly (*Psila rosae*) is a damaging pest of carrots and parsnips. This pest produces multiple generations per season in warmer areas, with the third generation often causing severe crop damage. The short length of Wyoming growing seasons may prevent this third generation from being produced; however, because of the damage this pest can do to the marketable portion of the crop, a variety of control methods may be necessary to protect your crop. Crop rotation, mixed planting with companion crops, and row covers are some of the methods that can help manage this pest. At this time, this pest is not widespread in the Mountain West. Wyoming doesn't have a lot of root vegetable production currently, so maintaining strict quarantine on your place to prevent the local introduction of the carrot rust fly is recommended.

Other pests of carrot roots are **millipedes**, **slugs**, and the **lessor bulb fly**. The millepedes and lessor bulb fly need the root to have suffered some physical damage and decay to soften the root tissue before they can start to feed.

DISEASES OF CARROTS AND PARSNIPS

Physiological disorders (abiotic disorders)

Splits and cracks

The splitting and cracking of roots occurs after a time of little irrigation and then a sudden onslaught of moisture, such as a downpour after a period of drought (or with quite erratic irrigation). To avoid, grow these crops in well-drained soil and maintain consistent watering.

Deformed and misshaped roots

Deformed roots are caused by a number of environmental factors and some diseases but mostly due to poor soil conditions. Compacted soils should be loosened and amended with compost. Avoid overcrowding of plants.

Root cavity spot

Cavities occur under the epidermis, which over time ruptures resulting in a sunken cavity on the surface of the root. Cause is not entirely known. Some varieties seem to be more susceptible, and it seems to occur more often in cool, wet conditions with low levels of nutrients in the soil. Manage with proper plant nutrition and irrigation practices.

Infectious diseases

Seedling diseases

Carrot and parsnip are susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

Foliar and whole plant diseases

Carrot: Common foliar diseases are **Cercospora leaf spot** caused by the fungus *Cercospora carotae* and **Alternaria leaf blight** caused by *Alternaria dauci*. Both fungi are seed-borne, survive in crop residue, and in or on weed hosts. These diseases are favored by periods of prolonged wet weather. Symptoms of Cercospora are small circular to elongate lesions on leaves, petioles, or stems with a chlorotic border. Spots can coalesce into larger affected areas and cause leaf collapse. Alternaria lesions are more irregular in shape and have darker brown-black necrotic areas. Manage these diseases with use of disease-free seed and removing or incorporating infested crop tissue. They can also be managed with protective fungicide sprays at first sign of disease.

Parsnip: The fungal disease **Itersonilia canker** and **leafspot** can cause a canker disease in roots as well as a leafspot blight on foliage. This disease is favored by wet soils and wet conditions and typically occurs late in the season. Planting on raised beds in well-drained soil, crop rotation, and controlling wild *Apiaceae* weed hosts (such as Queen Anne's Lace) will help control this disease.

Affecting both carrot and parsnip, **powdery mildew** is caused by the fungus *Erysiphe heraclei* and *E. umbelliferarum* (respectively). Powdery white fungal growth initially appears on the oldest leaves but then spreads to cover all leaf surfaces. Plants are not killed but yields are reduced. Favored by high humidity and moderate temperatures, spores are easily spread by wind. Infection typically occurs late in the season, so fungicide control is generally not needed. Remove infested plant material or incorporate it well into the soil.

Root diseases

Scab is caused by soil bacteria *Streptomyces* spp, and affected carrot and parsnip roots will have a corky, scab-like lesions. More common in alkaline soils and high organic matter soils, these bacteria will also infect potatoes. Once established in soil, it is persistent and difficult to manage. Avoid rotating carrots with potatoes, and lower soil pH if above 7.

Both carrot and parsnip are susceptible to **bacterial soft rots** caused by several common soil bacteria. Bacterial soft rot appears as a soft, watery, and slimy decay of the taproot. The decay rapidly consumes the core of the carrot, often leaving the epidermis intact. A foul odor may be associated with soft rot. Aboveground symptoms include a general yellowing, wilting, and collapse of the foliage. Disease is favored by warm temperatures, standing water, and physical injury to roots and crowns. To reduce incidence, avoid over-saturating the soil, especially when temperatures are warm, and take care to avoid plant injury.

Several genera of soil-borne fungi can cause a **root crown rot** on carrot and parsnip, these include *Rhizoctonia solani*, *Fusarium* spp, *Phoma* spp. and *Phythium* spp. To manage, rotate crops, remove infected residue, improve soil drainage, avoid waterlogged-logged soils, and use resistant cultivars, if available.

CAULIFLOWER

Brassica oleracea var. *botrytis*

As a member of the Brassicaceae, cauliflower is a great fit for many growers in Wyoming. Like other vegetables in the cabbage family, cauliflower enjoys cooler temperatures and grows best during the spring and fall when temperatures are between 50 to 70 F. Immature flowers that grow on a stalk are the edible portion of the plant and are collectively known as the "curd." Cauliflower is often considered to be one of the more challenging crops to cultivate.

Curds can be grown in a wide variety of colors with white or blanched being the most common. In order to obtain a white-colored curd on many varieties, the inner leaves of the plant must be wrapped around the curd to prevent different colors from developing due to sunlight. Leaves can be wrapped and tied around the curd using rubber bands or string. There are varieties that do not need to be wrapped to obtain a white color known as self-blanching varieties. White is the most common color, but cauliflower can also be grown with curds that are purple, green, yellow, or orange in color.

veres szilard, shutterstock.com

GROWING CONDITIONS

Cauliflower grows best in high-quality, well-drained soils. It has a shallow root system, which means adequate and consistent soil moisture is important for proper plant growth and curd flavor. Cauliflower grows best in full sun; however, shade cloth can be used to decrease the temperature for plants. Curds should be harvested before high temperatures arrive and flowers begin to open. Consistent temperatures are important for cauliflower growth and proper curd formation. High temperatures or fluctuating temperatures can lead to heads becoming loose or the stalk or flowers opening prematurely before the curd has reached adequate size. Remember to avoid planting cauliflower in the same area where other mustard family vegetables have previously been growing (cabbage, broccoli, brussels sprouts, etc.). Crop rotation is important for disease management.

PLANTING

Cauliflower can be planted as a spring or fall crop. Seeds can be directly planted into the garden or started indoors prior to the last freeze. Planting in the spring should occur after the threat of the last frost has passed, prior to temperatures becoming too hot. Fall plantings should occur sometime in the middle of July to provide enough time for plants to grow and produce adequate-size curds before the threat of fall frosts. Consider heat-tolerant varieties for spring planting and cold-tolerant varieties for fall plantings. Heat-tolerant plants will handle the hot temperatures during the last part of the growing season better and cold-tolerant varieties will be better suited for the colder temperatures that arrive in early fall.

Most varieties should be planted with a spacing of 18 inches between plants. Standard rows for cauliflower are 2 to 3 feet apart. Seeds planted outside should be covered with ¼ to ½ inch of soil. It is better to plant seeds close together and then thin the seedlings once plants begin to establish. Plants started indoors should be moved outside when four to five true leaves have developed.

DAYS TO MATURITY

45–85 days.

HARVESTING

The size of mature curds varies and depends on the growing environment plants are exposed to. Expect curds to weigh between 1 to 3 pounds when mature. Cauliflower can be stored for around one week after harvest. Prior planning is important with cauliflower since the large yields generally mature around the same time and must be eaten relatively quickly if not preserved.

SOME COMMON VARIETIES

- Snow Crown (55)
- Bishop (65)
- Cheddar (68)
- Snowball (70)
- Veronica (78)
- Skywalker (80)
- Viletta Italia (85)

INSECT PESTS AND DISEASES

See the insect pests and diseases listed under cole crops in the Broccoli section, starting on page 78.

CUCUMBERS

Cucumis sativus

Cucumber, pumpkins, summer/winter squash, watermelons, and melons are in the Cucurbitaceae plant family. They are often referred to as "curcurbits." The growing conditions needed by cucurbits tend to be pretty similar.

Cucumbers are fast-growing plants that need warm temperatures, consistent irrigation, and space to grow. There are many varieties of cucumbers, including those specifically bred for slicing and those used for pickling. Pickling cucumbers are short and blocky in shape. They mature and become seedy at a smaller size than slicing cucumbers. Slicing cucumber types include those with thinner and thicker skins. Thinner skin varieties can be consumed without peeling but are more prone to lose water after harvest and may suffer more damage from insects or environmental conditions. Thicker skinned varieties stay crisp longer since the skin helps them retain more moisture after harvest but are generally peeled before consuming. We will concentrate on thick-skinned varieties.

Lipatova Maryna, shutterstock.com

There are different plant growth types as well. Bush cucumber types maintain a more compact plant and are useful in areas where there is less space; however, vining types can be trellised to take advantage of vertical space.

GROWING CONDITIONS

Cucumbers prefer fertile, well-drained soils and regular irrigation. Cucumber fruits may become bitter if plants are grown under severe stress caused by lack of water, low fertility, disease, or unusually hot weather.

Cucumbers are very sensitive to cold and grow best when air temperatures are between 65 to 85 F. Temperatures above and below these temperatures will impact growth and below 50 F are likely to damage the plants.

Pollination by bees must take place for the flower to develop into a fruit. Bees carry pollen from male flowers to female flowers. Female flowers look like they have a tiny "pickle" at their base. Male and female flowers may be on the same or different plants. Most cucumber flowers are only open for one day, so poor cucumber set (or misshapen fruit) is common during rainy or cool weather when bees are inactive. Cucumber plants often produce male flowers earlier than female flowers—and in much greater numbers. Newer hybrids are often gynoecious and will produce only female flowers. As a result, they have a high yield potential if plants with male flowers are near. Make sure to plant a "pollinizer" variety along with gynoecious varieties. Seeds of these pollinizer plants are usually provided in the packets along with the seeds of the gynoecious variety.

Cucumbers need consistent irrigation since the fruits are 95 percent water. Irrigation amounts of 1 to 2 inches per week are often recommended, but required amounts will be dependent on temperature,

soil type, and plant growth stage. Irrigation methods (such as soaker hoses, drip irrigation) that reduce the amount of water that gets on cucumber leaves can help reduce the likelihood of vines developing powdery mildew. Overhead watering should be done early in the day to allow leaves to dry. If you see bees are active you should adjust watering times to cooler parts of the day if possible, as overhead watering can temporarily inhibit bee activity. It is normal for cucumber vines to look a little wilted during the hottest part of hot days, but if they look wilted in the morning, they are not receiving enough water. Lack of water can cause vines to yield less and cause small fruit with shriveled ends.

PLANTING

Direct seeded cucumbers should be planted after all chance of frost is past and soil temperatures at 2 inches deep are above 60 F. Cucumbers can be planted in hills, groups of two to three seeds planted together, in areas 1-foot apart in rows 3 to 6 feet apart. Seeds should be planted ½ to 1 inch deep.

Starting plants indoors and then transplanting them outside can reduce the time to first harvest by up to two weeks; however, it should be done very carefully. Transplants should have two to four true leaves (not seed leaves) when they are transplanted. This will be roughly three to four weeks after seed sowing. Care should be taken not to disturb the roots when transplanting. Damaged roots slow growth considerably and plants may never fully recover.

Depending on the plant growth type, cucumbers can be trained on a trellis to save space and keep the fruit off the ground.

DAYS TO MATURITY

48–78 days. Generally, pickling cucumbers take fewer days than slicing.

HARVESTING

Cucumbers may be harvested and used from the time they are 1¼ inches long until before they begin to turn yellow. Harvest cucumbers regularly to keep them producing longer. A mature fruit left on the vine will inhibit further flower formation.

To maintain fruit quality if storing, cucumbers can be plunged into cool water to decrease their temperature. Cucumbers can then be stored in a cool area with temperatures above 55 F. If they are held at lower temperatures, they will be susceptible to color changes and pitting of the skin, which will encourage rot. They should be stored away from fruits and other vegetables that produce large amounts of ethylene (melons, tomatoes, apples, etc.).

SOME COMMON VARIETIES

Pickling types

- Bush Pickle (45)
- County Fair (50)
- Lucky Strike (52)
- National Pickling (53)
- Pickalot (54)
- Homemade Pickles (55)
- Boston Pickling (55)

Slicing types

- Early Spring Burpless (52)
- Sweet Success (54)
- Bush Crop (55)
- Salad Bush (57)
- Fanfare (57)
- Marketmore 76 (63)
- Straight Eight (65)
- Lemon (65)

INSECT PESTS

Pests often affecting seedlings

Seedcorn maggot
Helene Doughty, Virginia Polytechnic Institute and State University, Bugwood.org

Seedcorn maggot (see page 67) can attack the seeds that experience delayed growth due to cold soil temperatures. Only plant cucumbers when soil temperatures are above 59 F (preferably closer to 77 F) to ensure rapid germination and growth.

Striped cucumber beetle feeding injury on cucumber fruit.
Gerald Holmes, Strawberry Center, Cal Poly San Luis Obispo, Bugwood.org

Adult western spotted cucumber beetle.
Clemson University - USDA Cooperative Extension Slide Series , Bugwood.org

The **western striped cucumber beetle** (*Acalymma trivittatum* also known as the Western corn rootworm) and the **western spotted cucumber beetle** (*Diabrotica undecimpunctata* also known as the Southern corn rootworm) are serious pests of cucurbits. The adults of the striped species that have overwintered will damage seedling's foliage and will lay eggs in the soil. Their larvae will then feed on the roots of a variety of young plants, which can stunt plant growth. The spotted species adults will feed on seedling leaves but uses the roots of other crops and grasses (i.e., corn) as hosts for its larvae.

Pale striped flea beetle
Frank Peairs, Colorado State University, Bugwood.org

Pale striped flea beetles are ubiquitous early-season pests of many vegetable crops including the cucurbits. Good conditions for rapid plant growth can help crop plants cope with the leaf damage inflicted by flea beetles. See flea beetle management under the Integrated Pest Management section for additional information, page 46.

Affecting vegetative growth (pests that chew leaves or pierce and suck plant juices)

Both cucumber beetle species (mentioned above) will continue to feed on the cucurbit foliage as plants mature. These beetles are known vectors of bacterial wilt and multiple species of mosaic virus. Nothing can be done to save a plant once infected by the wilt-causing bacterium. The plant should be removed from the garden and destroyed. The cucumber beetles are attracted to infected plants, and the disease spreads when they move on and feed on healthy plants.

Onion thrips feed on cucurbit leaves. Young leaves often curl in response to this type of damage. See thrips management in the Integrated Pest Management section for additional information, page 50.

Cucurbits grown in dry, dusty conditions are susceptible to infestation by **spider mites**. (See spider mite management under the Integrated Pest Management section for additional information.)

Insect pests affecting the consumable/saleable parts directly

The cucumber beetles are by far the worst arthropod pest of these crops in Wyoming. The adult beetles of both species will feed on all aboveground parts of cucurbit plants. Among other impacts, their feeding damage can scar the outside of the fruits reducing their value or even making them unmarketable. Summer generations of western striped cucumber beetle's larvae will also tunnel into developing fruits.

Monitoring with yellow sticky cards for these two beetles needs to start early and continue throughout the growing season. The western striped beetle can fly/be carried long distances in high altitude winds. As a result, a clean field has the potential to become infested overnight. The Michigan State University extension bulletin on the cucumber beetle recommends treatment be considered at "one adult cucumber beetle per plant for cucurbit seedlings and five adults per plant for mature plants."

DISEASES AND DISORDERS OF CUCURBITS (SQUASHES, MELONS, CUCUMBER, GOURDS, PUMPKINS)

Physiological disorders (abiotic disorders)

Blossom-end rot

The blossom end of cucurbit fruit develops a dark leathery appearance. Symptoms may progress until the entire end of the fruit turns black and rots. Associated with insufficient calcium uptake and alternating periods of wet and dry soil. Damage to the root system may also account for decreased calcium uptake. Maintain constant soil moisture through irrigation, avoid damaging plant roots, and avoid excessive nitrogen levels in the soil.

Hollow heart

Hollow heart affects all cucurbits but is especially a problem in watermelon. Cracks and gaps in the internal flesh of the fruit form during periods of rapid growth. Thought to be the result of environmental conditions resulting in poor pollination (such as cold or rainy weather) followed by conditions favoring

rapid growth. This disorder can be managed by avoiding varieties that are prone to hollow heart and maintaining consistent growth conditions.

Light belly color

Light belly color is a cosmetic condition in which the underside of the cucumber is light in color rather than dark green. It is commonly found on fruit lying on cool, moist soil. Avoid excessive vine growth that creates a lot of soil shading. Vertical trellising will also eliminate this condition.

Measles

Symptoms are most evident on smooth-skinned melons and cucumbers. Small brown spots are scattered over the surface of the fruit. The spots are superficial and do not penetrate beyond the outer epidermal layers of the fruit. These spots also may occur on leaves and stems. Associated with environmental conditions favoring guttation (water droplets are exuded out of specialized plant pores). The guttation droplets develop high concentrations of salts, which burn the epidermis and creates measles spot. Control measles by reducing irrigation frequency and duration as the fruit approaches maturity in fall-harvested crops (it appears to happen most when soil is warm and air is cool). Reducing irrigation at the later stages of fruit development has not shown any adverse effects on fruit size and soluble solid content (sugars and other compounds).

Sunscald

Sunscald is characterized by papery white areas that develop on the fruit. Sunscald develops during hot summer weather when fruit are suddenly exposed to direct sunlight. It can be prevented by maintaining adequate vine growth to cover fruit.

Infectious diseases of cucurbits

Seedling diseases

Plants are susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

Foliar and whole plant diseases

Powdery mildew is caused by the fungi *Erysiphe cichoracearum* or *Spaerotheca fuliginea* which produce a white powdery growth on the leaf surface. This disease is common and occurs in squashes, melons, gourds, cucumbers, and pumpkins. It can cause foliage loss under high disease pressure and is favored by cool and humid conditions. Unlike many fungal pathogens, it does not like free water on plant surfaces. In Wyoming, we typically see this disease on curcurbits and other garden hosts later in the season as canopies become dense with shadier conditions that create favorable conditions for disease development. To remedy, creating conditions that increase air flow and removing and destroying diseased tissues at end of season can help control this disease. It can also be managed with fungicides if applied at first appearance of disease.

Alternaria leaf spot is a foliar disease caused by the fungus *Alternaria cucumerina*. Lesions tend to appear first on the older leaves as small circular spots. The spots are light brown with a light center and form concentric dark rings as they enlarge, thus the alternate name of target spot. Fruit infections begin as sunken brown spots and may later develop a dark powdery appearance as the fungus produces spores. Remove or incorporate crop residue at end of season. Crop rotation (keeping cucurbits out of the area for two years) is helpful.

Anthracnose, caused by the fungus *Colletotrichum lagenarium*, is a common pathogen of cucurbits during warm and moist seasons. Significant damage can occur to cucumber, muskmelon, and watermelon unless resistant varieties are grown. Squash and pumpkins are rarely, if ever, infected by the pathogen. All aboveground parts can be infected and have different symptoms depending on the cucurbit. Leaf lesions begin as water-soaked areas that then become yellowish circular spots. The spots on watermelon foliage are irregular and turn dark brown or black. On cucumber and muskmelon, spots turn brown and can become quite large. Stem lesions on muskmelon can girdle the stem and cause vines to wilt. Stem

cankers are less obviously prevalent on cucumbers. On fruit, circular, black, sunken cankers appear. For management, use disease-free seed to avoid introducing the disease, rotate out of cucurbit crops for three years when possible, remove infected plant material or incorporate into the soil if the disease appears, and use anthracnose-resistant varieties if available.

Several Fusarium species can cause various fungal diseases in cucurbits. **Fusarium wilt** of melon is caused by *Fusarium oxysporum* f.sp. *melonis*. This disease is soil-borne or seedborne and specific to melon. Typically, symptoms are expressed after fruit set and consist of yellowing of a runner on one side of the plant followed rapidly by wilting of the infected runner. Runner lesions develop externally and extend from the crown to the yellowed tips. Other runners collapse in a similar manner—whole plant collapse occurs rapidly. External lesions may develop on melon roots accompanied by red gumming (vascular tissue breaks down creating a colored gum formation) at or just below the soil surface. Dark, red-brown vascular discoloration occurs inside the melon roots. Manage this disease with resistant cultivars, sanitation, and reducing disease inoculum by rotating out of melons for five years.

Fruit rots caused by various *Fusarium* spp. are some of the most common pre- and postharvest diseases of cucurbit fruits. Fusarium rots have been reported on cucumber, melon, honeydew, watermelon, squash, and pumpkin. Infection typically starts at the stem end or where fruit rests on the soil. Cull out affected fruits to reduce spread of the Fusarium pathogen. Rotate out of cucurbits for up to three years.

Verticillium wilt is a soil-borne fungal disease (*Verticillium dahlia*) that can affect all cucurbits. The first symptoms are wilting and yellowing of crown leaves, which eventually dry up. Wilting gradually progresses out toward the runner tips; in severe cases, the plant dies over several weeks. A light-brown vascular discoloration in roots and stems is sometimes seen in cross section. Use tolerant or resistant varieties to manage this disease. Once in the soil, the fungus can survive for a number of years.

EGGPLANT

Solanum melongena

Eggplant is a member of the nightshade family (Solanaceae) and is related to other common vegetables such as tomatoes, peppers, tomatillos, and potatoes. The fruit of eggplants can be shaped like an egg, round, oblong or cylindrical. Traditionally, fruits are black or purple in color, but they also come in the colors of green, white, yellow, or pink. Fruits might be a solid color or a combination of the various colors.

GROWING CONDITIONS

This crop needs warm temperatures. Plants do not consistently produce fruit when nighttime temperatures are below 50 F. Temperatures should not fall below 60 F at night, and daytime temperatures should be kept below 95 F. This might be a challenge for many areas of Wyoming. Season extension strategies can be helpful for low temperatures, and shade cloth and/or adequate ventilation can be important for warmer areas of the state.

Denis Pogostin, shutterstock.com

PLANTING

Due to these temperature issues, eggplants should start as seedlings indoors and then moved outside when temperatures are appropriate. Eggplants should be started about six to eight weeks before they moved outside. Nighttime temperatures should be consistent and well above 50 F before transplanting outdoors.

Keep in mind plants placed outside too early might not produce fruit properly since proper fruit pollination and growth does not take place with low temperatures. Plants might also show other physical issues from low temperatures. Hardening off plants before planting them in the field is a good idea. Please see the section related to starting plants indoors for more information on this process.

Eggplants grow best in fertile, well-drained soils that have a pH between 5.5 and 7. Since they grow a deep tap root, consistent deep watering is important for maintaining plant health and consistent fruit quality and production. Keep in mind eggplants are in the nightshade family, and diseases can be transferred easily between members. Potatoes, peppers, tomatillos, and tomatoes should not be planted following eggplants, and decaying plant material should be removed from areas where these crops might be planted.

Once transplants are moved to the field, they can be placed in rows 24 to 48 inches apart and 18 to 30 inches between plants. Plants should be staked similarly to tomatoes if needed and kept upright to keep the fruits from contacting the soil surface. Plants are self-pollinating yet can benefit with the addition of pollinating insects.

DAYS TO MATURITY

Eggplants can take between 50–80 days to reach maturity after transplanting outdoors. Choose short days to maturity varieties for high elevation and short growing season locations, and look for cooler climate performance information.

HARVESTING

Consistent fruit production can be maintained by prompt harvest of the fruit. Eggplants do not store well, so plan to sell or consume the fruits soon after harvest. They can be stored in a refrigerator at high humidity for several days.

SOME COMMON VARIETIES

Black

- Ichiban Imp (54)
- Midnight Queen (55)
- Satin Beauty (65)
- Black Beauty (70)
- Diamond (70)
- Shikou hybrid (80)

White

- Japanese White Egg (65)
- Casper (75)

Pink/purple

- Rosa Bianca (80)
- Rosita (80)
- Listada de Gandia (90)

Green and orange

- Turkish Orange (80)
- Thai Long Green (85)

INSECT PESTS

As a member of the nightshade family, Eggplant can share common pests with potato and tomato.

Pests often affecting seedlings

Because eggplants are usually started indoors in Wyoming and then transplanted outdoors, seedlings should be protected from most early spring pests. However, indoor pests such as green peach aphid and twospotted spider mites can get started on the plants inside and be transplanted with the crop.

After transplanting the crop to the field, scout for mobile early-season pests such as the several black or metallic brown **flea beetles species** in the genus *Epitrix* that prefer plants from the nightshade family, such as eggplant. See flea beetle management under the Integrated Pest Management section for additional information, page 46.

Affecting vegetative growth (pests that chew leaves or pierce and suck plant juices)

See the Integrated Pest Management section for additional information (including control tactics) on most of the pests below, page 42.

SNeG17, shutterstock.com

Multiple **cutworm species** can attack the new transplants and established plants. Cultural methods to reduce cutworm populations through weed and crop residue management in fields is recommended.

This eggplant flea beetle (*Epitrix fuscula*) is representative of the many small leaf feeding "flea" beetles that can jump and fly to rapidly invade a crop field.
Natasha Wright, Braman Termite & Pest Elimination, Bugwood.org

Both the western striped cumber beetle and western spotted cucumber beetle adults will chew on the surface eggplant fruits, causing losses.
Whitney Cranshaw, Colorado State University, Bugwood.org

Multiple **flea beetle species** will feed on eggplant leaves. The **Colorado potato beetle** adults and larvae will also feed heavily on the leaves.

Crop pest **grasshoppers** from the genus *Melanoplus* will feed on eggplant. This usually occurs late in the summer as the plants around field edges are defoliated and the grasshoppers invade fields looking for food.

In hot, dry conditions or when an insecticide treatment reduces their predator's populations, **twospotted spider mites** can rapidly increase and damage eggplant.

The **green peach aphid** and the **potato aphid** are two of the common species of aphids that will feed on eggplant. Any honeydew from these pests (or whiteflies) on the fruits can make them unmarketable unless they are cleaned, which raises labor costs.

Insect pests affecting the saleable parts directly

Western flower thrips can attack the eggplant flowers, and this can result in "blossom drop" and/or deformed or scarred fruits. The corn earworm (aka tomato fruitworm) adults will put eggs on eggplants when corn, their preferred host plant, isn't available. The resulting caterpillars chew their way into the fruits, quickly ruining them.

DISEASES

See the Pepper section for a discussion of diseases which affect eggplant, page 136.

GARLIC

Allium sativum

Garlic has been around for millennia, and it's still going strong. This relative of onions and chives is a good choice to plant in the fall in our region. There are a couple of different types of garlic that are often grown–softneck and hardnecked garlic are the most common. Hardneck types don't braid well and have a shorter storage life than softneck types, but have a milder flavor and are slightly more winter hardy.

GROWING CONDITIONS

Garlic grows best in cool weather and in fertile, well-drained soils. Planting garlic in the fall allows it to overwinter and take advantage of cooler weather in spring for growth. Garlic planted in the spring in our region tends to result in smaller bulbs.

Consistent irrigation during the growing season is needed to produce the largest bulbs. Mulch can be used to maintain soil moisture and suppress weeds.

Hardneck garlic—as the garlic grows the next year they will produce flower stalks (scapes). Removal of these will increase bulb size.

PLANTING

Garlic is not planted from seed, instead, garlic cloves are planted. Fall sown garlic can be planted from around mid-September to mid-October. To get the best growth, take garlic bulbs that have been stored before planting between 40 and 50 F and remove the largest, outside cloves. Plant these in the soil (root side down and pointy side up) about 2 inches deep and 4 to 6 inches apart in rows 12 inches apart. Larger cloves will yield larger bulbs the next year. Small cloves can be eaten or planted for garlic greens. Roots will form on the cloves in the fall months. If you receive little snow in your area, mulch the planting with 3 to 5 inches of straw or other organic material.

DAYS TO MATURITY

Usually harvested in mid- to late-summer.

HARVESTING

Harvest when lower leaves are turning yellow and the bottom couple are brown, or the tops fall over (before plants are totally dry). Dig the bulbs out carefully with a digging fork to avoid bruising the bulbs, brush off some of the soil and set in a shady warm spot with some air flow. (Placing them on wire mesh to cure is common.) Let cure for 2 to 3 weeks. After curing remove tops from the garlic plants, leaving 1 inch or so above the bulb. They can now be stored in a well-aerated sack. The tops of softneck varieties can be left on and braided if desired. Bulbs can be stored in dry conditions between 40 to 55 F.

alicja neumiler, shutterstock.com

SOME COMMON VARIETIES

Hardneck

- German Extra-Hardy
- Chesnok Red
- Spanish Roja
- Music

Softneck

- Inchelium Red
- New York White

INSECT PESTS

See Leek section for insect pests of garlic, page 114.

DISEASES

See Onion section for diseases of garlic, page 126.

HORSERADISH

Armoracia rusticana

Horseradish is a perennial plant from the Brassicaceae family grown for its strong flavored, fleshy tap root. This plant's roots are peeled, grated, and mixed with vinegar or cream to make a tangy condiment. It is a perennial, with the Latin name of *Armoracia rusticana*, originally from southeastern Europe. It is easy to grow and well adapted to many areas of Wyoming.

GROWING CONDITIONS

Horseradish plants prefer full sun, moist soils, and cool temperatures. Production systems can be either annual where new roots are planted each spring, or perennial where plants can be productive for up to 20 years. The perennial system is preferred for areas with a short growing season, such as found in most of Wyoming. Soils should be well-drained and loose, with an optimal pH range of 5.5 to 7. Horseradish plants require regular irrigation.

PLANTING

Horseradish is generally propagated as sets cut from another plant's root. Root sections (sets) are planted in late winter or early spring. Plants can be fairly large at maturity, up to about 3 feet tall and wide. Root sections from the previous year's growth are planted horizontally in a 3- to 4-inch deep trench with sets about 3 feet apart, in rows at least 3 feet apart. Horseradish can also be increased by dividing the crowns for small plantings—dig up a plant and split it into sections, each with roots and foliage. Replant pieces at a 45-degree angle in the soil, with the crown a couple inches below the soil surface.

MAINTAINING PLANTS

Fertilize each acre with about 150 pounds nitrogen and between 50 and 250 pounds phosphorus and potassium, depending on soil test results. Consistent irrigation in late summer and fall is important since this is when most root growth develops.

HARVESTING

In the recommended perennial system, thickened underground shoots coming from the mother root are harvested every other year. The original mother plant is left to regenerate for future harvests. In the annual system, harvest occurs after frost in the fall. Foliage can be mowed down a few days before harvest. Potato harvesters work well for digging horseradish, although they should be set to dig down to about 2 feet.

SOME COMMON VARIETIES

- Common
- Bohemian
- Big Top Western

Kuttelvaserova Stuchelova, shutterstock.com

INSECT PESTS

Pests often affecting seedlings

Horseradish flea beetle (*Phyllotreta armoraciae*) adults and the characteristic pitting and holes on a horseradish leaf.
Whitney Cranshaw, Colorado State University, Bugwood.org

Flea beetles from the genus *Phyllotreta* can damage the new growth from the root set. The horseradish flea beetle (*P. armoraciae*) is one insect species that specializes on horseradish and other plants in this plant family. See flea beetle under the Integrated Pest Management section for additional information, page 46.

Affecting vegetative growth (Pests that chew leaves or pierce and suck plant juices)

The many aphid species that feed on other brassica species plants can live on horseradish leaves but rarely cause issues for plants that have sufficient water.

A cabbage looper (*Trichoplusia ni*) "inching" along the edge of a leaf exhibit the loop form its body takes as it travels.
David Cappaert, Bugwood.org

Cabbage looper (*Trichoplusia ni*) caterpillars can occasionally migrate into Wyoming from our southern-most states, where it can successfully overwinter. The defoliation by the caterpillars occurring late in the growing season is infrequent and rarely serious enough to warrant treatment; however, if the defoliation is severe, many pesticides labeled for the crop can provide rapid control of this pest.

Insect pests affecting the saleable parts directly

No common pests of the root occur on horseradish roots in North America. The plant is not native to the continent so any root feeding specialist insect species were not imported with it. North American root feeding generalist insects probably are not able to withstand the protective phytochemicals concentrated in the roots.

DISEASES

Physiological disorders (abiotic disorders)

Splits and cracks

The splitting and cracking of roots occurs after a lack of irrigation and then a sudden onslaught of moisture, such as a downpour after a period of drought. Maintain consistent watering and have a well-drained soil.

Deformed and misshaped roots

Caused by a number of environmental factors and some diseases, but mostly due to poor soil conditions. Compacted soils should be loosened and amended with compost. Avoid overcrowding plants.

Root issues in horseradish

Excess nitrogen can lead to large top growth (lots of leaves) and small roots. Too much or too little water over the season can lead to reduced flavor.

Infectious diseases

Seedling diseases

Brassica root crops are susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

Whole plant and root diseases

Leaf spot fungi are caused by *Alternaria* and *Cercospora* spp. These pathogens do not infect the root, but infection can reduce yield, and blighted foliage can reduce the value of fresh-packed plants. To help reduce leaf spot, buy hot-water treated seed and reduce weeds, and plow under crop debris in the fall. (See the Broccoli section for more information on the fungal and bacterial diseases.)

Some other diseases which can affect horseradish include:

- **Brittle root disease**—carried by beet leafhoppers
- **Xanthomonas**—a bacterial disease causing leaf spotting, wilting, and eventual plant death
- **White rust**—a fungal disease causing pustules on most upper parts of the plant spread by wind, rain, and insects resulting in decline in growth and production
- **Turnip mosaic virus** (TuMV)—a virus causing black spots, ring spots, and mottling resulting in declines in growth and production.

KALE

Brassica oleracea var. *sabellica*

Kale is a cool-season crop in the Brassicaceae family of plants with varieties available in many sizes, shapes, and colors. Kale is tolerant of cold weather and considered a nutritionally valuable crop (it can provide adult daily requirements for vitamins A and C and a fair amount of calcium).

GROWING CONDITIONS

Kale grows best in cooler temperatures below 75 F. Quality decreases in temperatures over 85 F. Kale is often sown for a spring or fall crop.

Kale requires consistent and fairly high fertility levels and grows best in soils with plenty of organic matter. It also grows best with consistent moisture. 1 to 2 inches of irrigation water per week is often suggested, but actual irrigation requirements vary by temperature, soil type, and plant growth stage.

Ga_Na, shutterstock.com

Organic mulches can be used to suppress weed growth, keep the soil cool, and maintain soil moisture levels.

PLANTING

Kale is quite hardy when young and can be planted in the spring as early as the soil can be prepared. Seeds are planted ¼- to ½-inch deep. Plants should be spaced 18 to 24 inches apart in rows 24 to 36 inches apart. Young kale can be harvested as greens for salad mixes, etc. Kale can be seeded more densely if this is the intended use. The plants may also be grown indoors and transplanted to a field after about three weeks. Being cold hardy, plants can be transplanted outside three to four weeks or so before the frost free date. Seedlings can be covered with fabric covers to protect them from insect pests.

When timing fall harvests, early maturing kale should be planted so it reaches harvestable size two to three weeks after the first fall frost. Kale can tolerate temperatures as low as 16 F, and quality is improved by a few light frosts. Kale can be harvested into the winter in warmer areas of the state or with protection. If kale overwinters (survives until spring), then a quick, small crop can be harvested before the plants bolt (produce flowers) and leaf quality declines.

DAYS TO MATURITY

50–70 days (harvestable greens take about 30 days).

HARVESTING

Kale leaves can be harvested when they are smaller or after they have reached full size by stripping the older leaves off the outside of the plants and allowing the younger inner leaves to keep growing, or the whole plant can be cut. Kale can be stored for around two weeks at 32 F and high relative humidity.

SOME COMMON VARIETIES

- Vates Blue Curled (56)
- Dwarf Siberian (58)
- Red Russian Heirloom (60)
- Lacinato (62)
- Winterbor (65)

INSECTS

See the insect pests listed under cole crops in the Broccoli section, page 78.

DISEASES AND DISORDERS OF LEAFY KALE VEGETABLES (COLLARDS AND KALE)

Physiological disorders (abiotic disorders)

Lower leaf yellowing (chlorosis) and leaf loss may be attributed to two cultural conditions: water stress and excessive or deficient fertility.

Infectious diseases of leafy kale vegetables (collards and kale)

Seedling diseases

Plants are susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

Foliar and whole plant diseases

Alternaria leaf spot—see broccoli section, page 76.

Frogeye leaf spot is caused by the fungus *Cercospora brassicicola*. Frogeye leaf spot causes pale green, gray, or white spots on the leaves. The spots are bordered by a brown ring and can take any shape. You can prevent this disease by planting disease-free seed or transplants. Good soil drainage and avoiding excess moisture in the growing area, along with crop rotation and removal of crop residue, will help prevent development of this disease.

Powdery mildew—see Broccoli section, page 76.

Root disease

Root rot or bottom rot is caused by the soil-borne fungus *Rhizoctonia solani*. Bottom rot initially infects the lower leaves that touch the soil causing brownish red lesions on petioles and midribs. Eventually, the infected vegetables turn black and wilt. The pathogen can also move to the roots, causing a root rot. The rot is dark brown, sunken, and spongy, and the affected tissue separates easily from the advancing edge of the rot. This fungus can persist indefinitely in the soil but will be more problematic with soils with recently infected plant debris. Prolonged moist soil will also favor disease development. Use proper crop rotation to non-crucifer crops and properly dispose of infected plants. Replace the soil with uninfested soil in severe cases where the growing area is small.

KOHLRABI

Brassica oleracea var. *gongylodes*

Kohlrabi is a biennial member of the cabbage family that produces an edible, enlarged stem. If not harvested the first year, the plant will produce flowers the next year, and the stem quality will be poor. Kohlrabi plants grow quickly and can be harvested within about 60 days. This vegetable can be peeled, sliced, and served raw. Slices or chunks can be steamed or sautéed, and young leaves can be steamed.

GROWING CONDITIONS

The quality of kohlrabi is best when growth is rapid. Soil high in organic matter along with consistent irrigation help promote this type of growth. Organic mulch can be used to conserve irrigation water and reduce weeding.

Digihelion, shutterstock.com

Kohlrabi grows best in cool spring and fall weather or in locations where the summer climate is cool. Temperatures between 61 and 70 F are optimal for growing kohlrabi. Temperatures below 45 F can cause mature kohlrabi plants to bolt, or develop a flowering stalk, which greatly decreases kohlrabi quality. High temperatures can cause reduced growth and cause stems to become tough.

PLANTING

Seeds are most often planted directly in the field ¼- to ¾-inch deep. The crop is cold-resistant and can be planted as early as cabbage. Make several plantings two to three weeks apart to have a continuous supply of tender kohlrabi. For earlier yields, 4-week-old transplants can be planted outdoors a couple of weeks before the last frost date. The plants should be spaced 3 to 6 inches apart in rows 12 to 36 inches apart.

DAYS TO MATURITY

40–60 days.

HARVESTING

Stems should be harvested when they are about 2- to 3-inches in diameter (larger in some newer varieties) and still tender. They become woody and fibrous when they get too large. After cutting off the root and removing the top foliage, stems can be stored for up to four weeks at 32 F and high relative humidity. Storage life is greatly shortened by water loss if foliage is not removed.

SOME COMMON VARIETIES

- Eder (38)
- Rapid (45)
- Sweet Vienna (45)
- Grand Duke (48)
- Early White Vienna (55)
- Purple Vienna (60)

INSECTS

See the insect pests listed under cole crops in the Broccoli section, page 78.

DISEASES

Physiological disorders (**abiotic disorders**)
Kohlrabi not harvested early enough can be tough and stringy; harvest when 1½- to 3-inches in diameter.

Infectious diseases of broccoli, cauliflower, cabbage, Brussels sprouts, and kohlrabi
Seedling diseases
Plants are susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

See the Broccoli section, page 76, for information on all of those listed below:

Foliar and whole plant diseases
- Leaf spots
- Powdery mildew
- Black leg
- Black rot

Root diseases
- Club root

LEEKS

Allium porrum

Leeks are a less commonly grown crop in the U.S. that is a close relative of garlic and onions. Leeks have a mild taste and unlike garlic and onions, are grown for their edible stalk. Leek stalks look similar to long, chubby green onions. Unlike onions or garlic, they do not form bulbs or cloves.

GROWING CONDITIONS

Leeks are a cool-season, hardy crop and grow well in many soils with adequate fertility and consistent moisture. Leeks have shallow roots so they show the effects of inadequate water very quickly. Moisture stress or weed competition will reduce yields. Any cultivation should be done shallowly to avoid injuring the leeks' roots. Mulching is a good way to reduce weed competition and reduce water loss from the soil.

Al.geba, shutterstock.com

PLANTING

Leeks can be directly seeded or transplanted into the field. If starting plants from seeds indoors, allow ample time for seedlings to grow (14 to 16 weeks) before transferring them outdoors. If planting seeds directly in the field, consider adding season extension methods to get an early start. Plants require 75 to 120 days after transplanting for maturity, so plan well in advance if incorporating leeks into your growing season.

Seeds should not be planted more than ¼-inch deep. If direct seeded, plants should be 2 to 6 inches between plants in rows 12 to 36 inches apart. It is important to hill soil around leeks started from seed. Soil should be gradually pulled up around the base of the plant when leeks are around the diameter of a pencil. This practice creates the desired stem for leeks (a long length of tender white stem). Transplanted leeks can be managed in the same fashion or planted in a trench 6 to 8 inches deep or dibbled into holes. As the plants grow, soil can slowly be added to the trench to achieve the desired white stem. This process for transplants and directly seeded plants should be performed over several weeks. The plants might rot or die if the trenching process occurs too quickly. Once leeks have been hilled, they should be cared for in a similar fashion to onions.

DAYS TO MATURITY

75–120 days from the time they are transplanted, 100–150 days from seeding.

HARVESTING

Plants are ready for harvest when they are 1 to 2 inches in diameter. Generally, the roots are cut off and all but an inch or two of the green top when harvested. Harvested plants can be stored in a cool

and dark location that has high humidity conditions. Keep in mind leeks are biennials. Plants left in the field will often continue to grow a second year, but, unfortunately, they produce flowers (bolt) and the taste deteriorates.

SOME COMMON VARIETIES

- Large American Flag
- King Richard
- Lancelot
- Blue Solaise

INSECT PESTS

Insect pests can be the same for all *Allium* species including garlic, leeks, onions, chives, and shallots.

The plants in the genus *Allium* are grown for the flavor they add to many foods. The phytochemicals that give them their characteristic aromatic odor and flavor also deter some plant eating insects; however, alliums can be attacked by both specialist and generalist insect species. An example of generalist pests are the several species of grasshoppers in the genus *Melanoplus* that will eat the green tops. Specialist onion maggots (*Delia antiqua*) attack *Allium* species bulbs. With the valuable bulbs growing underground, they are more difficult to monitor for pest damage than the tops.

Pests often affecting seedlings

If you grow *Allium* species from seeds, **cutworms** can quickly kill the delicate seedlings . Plants grown from sets can also be severely damaged. Good weed control in the field throughout the year should be used to discourage cutworm moths from depositing eggs. Many insecticides are labeled for cutworms but, for most of them to work, the plant has to be at least partially eaten by the pests (so that the insecticide will be ingested by the cutworms). Reducing the population of the cutworms before planting with cultural management methods is a better control strategy. See cutworm management under the Integrated Pest Management section for additional information, page 45.

Onion maggot (*Delia antiqua*) adults are flighty, small gray flies that are hard to spot in an allium crop field.
Pest and Diseases Image Library , Bugwood.org

First generation **onion maggots** and **seedcorn maggots** (*Delia platura*) can damage allium seedlings. The subsequent second and third generation of these pests can feed on and damage the expanding bulbs.

Affecting vegetative growth (pests that chew leaves or pierce and suck plant juices)

Onion thrips (*Thrips tabaci*) are tiny insects that start their infestation in the folds of and spaces between the new growth of allium plants.
Whitney Cranshaw, Colorado State University, Bugwood.org

Onion thrips (*Thrips tabaci*) can migrate into allium fields when nearby alfalfa hay fields are cut, as alfalfa is also a host for thrips. If the crop is grown for bulbs,

a light infestations of onion thrips can be tolerated, but heavy infestation can reduce plant vigor and bulb size. Thrips feeding damage results in leaf scarring, reducing the value of green onions. Severe feeding also increases the occurrence of foliar diseases and reduces the effective leaf area to support vigorous growth. See thrips management in the Integrated Pest Management section for additional information, page 50.

The best management strategy for allium eating **grasshoppers** involves controlling them outside of your crops before they get big and mobile enough to invade your field and cause damage. See grasshopper management under the Integrated Pest Management section for more information, page 47.

Insect pests affecting the saleable parts directly

Both the allium's bulbous roots and/or the green tops can be harvested for food, depending on the crop. The most economically damaging pests of the alliums are the onion maggot and, occasionally, the seedcorn maggot. Onions are more susceptible to their damage than garlic, chives, and shallots, but those crops can still be harmed. If the bulbs are already being attacked by maggots, it is too late for control to be profitable, so prevention is critical. Decreasing pest pressure, such as using cultural practices to reduce maggot population, helps. An example of a cultural control would be destroying allium crop residue completely to deny insect pests overwintering habitat. Crop field rotation also helps because adult onion maggot flies are not strong fliers, and not able to emerge from old fields and then fly very far to infest new crops. Even with these cultural control methods implemented, in-furrow treatments with systemic insecticides to provide protection for onions may still be necessary for conventionally grown crops. Foliar treatments of contact insecticides to try and kill the adult onion maggot flies are not successful enough to be recommended.

DISEASES

See the section on diseases under Onions, page 126.

LETTUCE

Lactuca sativa

Lettuce, an annual cool-season crop, is very versatile. Tolerance to cold temperatures, short days to maturity, and the ability to grow in a wide range of physical spaces and soil conditions and consumer demand makes lettuce a great crop for growers of all interests. Growers may be surprised to learn lettuce is in the Asteraceae family. Close relatives include sunflowers, chrysanthemums, yarrow, and tarragon.

There are five main groups of lettuce: loose leaf, crisphead, butterhead, romaine (Cos), and Stem (Celtuce). Crisphead is the head lettuce you often see in the grocery store with its leaves tightly packed together in a ball. Butterhead lettuce also holds its leaves in a head shape; however, the heads are much looser than crisphead types. Its outer leaves are generally smoother than the inner leaves, and inner leaves are often yellow. Crisphead and romaine (Cos) lettuce tend to store longer than more fragile types of lettuce. Loose leaf lettuce tends to produce tender leaves that are held on the stem in a more open shape. Some varieties of leaf loose lettuce can be harvested earlier than head lettuce and will tolerate cut-and-come-again harvesting (leaves are cut off leaving 1 inch of stem, leaves will grow back for multiple harvests). Romaine (Cos) lettuce generally has upright, more rigid leaves that grow closer together than leaf lettuce. Stem lettuce (Celtuce) is a bit unusual and less well known than other types of lettuce. It grows upright with leaves on a long stalk–both the leaves and the stalk are eaten.

David A Litman, shutterstock.com

There are many lettuce varieties available for planting. When narrowing down what lettuce variety to plant, consider the type of lettuce (head or leaf), days-to-maturity, flavor, color, and texture. Red, yellow, and green are the most common colors.

GROWING CONDITIONS

Many parts of Wyoming are well-suited for growing lettuce (cool weather and limited number of growing days). Laramie was one of the larger producers of the crop in the nation during the early 20th century. The cool climate helped to keep the lettuce plants from bolting. The river's winter ice was cut and stored for use in shipping the crop out fresh via the railroad during the harvest season. The potential to grow productive lettuce still exists in Wyoming. Pest management for lettuce can be difficult because consumers have exhibited little tolerance for cosmetic damage on the leaves of a plant that is eaten raw.

Plants do not tolerate hot temperatures, so it is best to grow lettuce when the weather will be cool. Leaves may become bitter or tough when temperatures are over 85 F. These temperatures can also make plants "bolt," or begin to flower, which causes quality to decline. Romaine and leaf lettuces are considered a little more tolerant to higher temperatures. Reading variety descriptions to find ones that are more heat

tolerant and bolting resistant can help growers select varieties suited to their conditions.

Lettuce has a very shallow root system, so consistent watering during the growing season is very important. Drought stress can cause bitterness to develop. Lettuce seedlings do not compete well with weeds, so weeding is also important.

PLANTING

Lettuce can be planted in the spring and fall. It can be direct seeded or started indoors and transplanted. Due to the hardiness of lettuce, transplants can be planted outside earlier in the spring than many other crops. As a cool-season plant, lettuce can withstand periods of frost. Younger plants can tolerate temperatures as low as 25 F, older plants are more sensitive to frost.

Seeds can be planted outdoors after soil temperatures reach 40 F. Plants grow best when daytime temperatures are 60 to 70 F and nights are cooler. Seeds are quite small and can easily be planted too deeply. Plants seeds ¼ to ½-inch deep. Broadcasting or rows can be used for planting. Leaf type lettuce is most often broadcast into a growing area, whereas head types are commonly planted in rows. Plan on 8 to 15 inches between plants (variety dependent) and 12 to 24 inches between rows depending on type. Seed for baby lettuce production is usually planted closer together. Keep in mind lettuce should be rotated throughout the growing area like other vegetables.

DAYS TO MATURITY

35–80 days. Consider short days to maturity varieties for planting as a spring and fall crop.

HARVESTING

Plan to harvest lettuce early in the day before the plants become heat stressed. Wash leaves or heads with cold water after harvesting to help preserve crispness and taste. Store at 34 to 36 F. Leaf type lettuce can be harvested several times, whereas head type lettuce will only be harvested once. Crisphead can be cut when the heads are firm. Cos and butterhead varieties should be harvested when heads are starting to mature. Waiting too long can cause off flavors with these varieties. Heads and stalk types can be cut with a serrated knife or large scissors. Leaf lettuce can be harvested by using scissors or tearing leaves by hand.

SOME COMMON VARIETIES

Crisphead

- Iceberg (65)
- Great Lakes (75)
- Ice Queen (80)

Cos (Romaine)

- Cimmeron (65)
- Crisp Mint (65)
- Paris Island (70)

Leaf

- Red Sails (40)
- Salad Bowl (45)
- Royal Oak (50)
- Merlot (55)
- Black Seeded Simpson (55)

Butterhead

- Buttercrunch (65)
- Butter King (65)
- Dynamite (75)

Stem

- Celtuce (80)

INSECT PESTS

Lettuce varieties vary greatly in form but share the same pests. More information on **aphids** and **flea beetles** can be found under the Integrated Pest Management section, page 42

Pests affecting seedlings

Lettuce root aphid (*Pemphigus bursarius*) can arrive from their winter host, Lombardy poplar trees, to infest the roots. They are generally not a significant pest when this tree species is not in the vicinity of lettuce fields.

The **palestripped flea beetle** (*Systena blanda*) can be an early season pest of lettuce. The feeding damage creates pits and eventually holes in the young lettuce leaves.

Affecting vegetative growth (Pests that chew leaves or pierce and suck plant juices)

Multiple species of **slugs**, (which are not insects but gastropods) can damage leaves and leave behind slime trails on lettuce that make the produce unsaleable. Irrigation management should be used to keep the field surface habitat too dry for this moisture-loving creature. Also, steps should be taken to remove or incorporate any large organic debris such as corn husks or big clumps of compost in the lettuce fields. These nocturnal feeders use such debris as shelter from the sun during the day.

Adult cabbage looper
Joseph Berger, Bugwood.org

The adult **cabbage looper** (*Trichpluisia ni*) is a small moth that has both camouflage coloration and projections that unfold at rest. These projections change the shape of its outline, which helps it hide from its predators during the day. This insect can occasionally migrate into Wyoming from the U.S.'s southern-most states, where they can successfully overwinter. The defoliation by their caterpillars occurs late in the growing season. If the defoliation is discovered, there are many pesticides labeled for the crop that would provide rapid control of this pest.

Potato aphid — winged (alate) form
Joseph Berger, Bugwood.org

The **potato aphid** (*Macrosiphum euphorbiae*), and **green peach aphid** (*Myzus periscae*) will all feed on lettuce leaves along with many other plant species. The aphid honeydew and other debris left on the lettuce leaf surfaces as they feed are not good for sales. The green peach aphid can also vector multiple virus diseases that harm lettuce. Because the winged form of these aphid species can rapidly invade a field, regular scouting for these pests is recommended. If discovered early, control measures can keep the damage below the economic injury threshold.

Winged (alate) generations of the potato aphid (*Macrosiphum euphorbiae*) move from winter hosts, such as roses, where they survived as eggs, to a wide variety of crop plants such as lettuce, potato, and tomato. Crowded conditions on summer host plants can also result in a winged generation being produced to disperse within a field. The wingless generation will often be green in color.

DISEASES

Physiological disorders (abiotic disorders)

Lower leaf yellowing (***chlorosis***) ***and leaf loss*** may be attributed to water stress and excessive or deficient fertility.

Tip burn is the most common and easily recognized physiological disorder of lettuce. Tip burn is a calcium deficiency in the tissue that causes the edges of young and maturing leaves to turn brown or have a speckled appearance. The disorder can be controlled by planting resistant varieties, avoiding cultural practices such as over-fertilizing that promote rapid and excessive growth, and maintaining the soil moisture at uniform levels.

Russet spotting is very common in head lettuce and is characterized by small brown to tan lesions that can occur anywhere on the plant but mostly on the midrib. Russet spot is caused by ethylene production and can occur in mature to over-mature lettuce, especially following anaerobic conditions (water soaked soils) in the field. Avoid storing lettuce with ethylene producing fruits like melons, strawberries, apples, and pears.

Infectious diseases of Lettuce

Seedling diseases

Plants are susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

Foliar and whole plant diseases

Bottom rot is caused by the soil-borne fungus *Rhizoctonia solani*. Symptoms include small red to brown spots on lower leaves, usually on the underside of the midrib, which may expand rapidly causing the leaves to rot; amber-colored liquid may ooze from leaf lesions; as stems rot, the heads of head lettuce varieties becomes slimy and brown and collapse; a tan or brown mycelial growth may be visible in infected tissue. Fungus survives on crop debris and in soil. Disease development is favored by warm, wet weather. To manage this disease, practice crop sanitation, crop rotation, avoid irrigation close to harvest, and use upright varieties to reduce leaf-to-soil contact.

Anthracnose or shot-hole is caused by the fungus *Microdochium panattonianum*, which survives in crop debris and the soil. Symptoms are small water-soaked tan spots on the outer leaves that may expand and turn straw-colored; centers fall out of mature lesions giving plants a shot-hole appearance. To manage, rotate crops, incorporate crop residue, and avoid overhead irrigation.

Leaf drop, caused by the soil-borne fungus *Sclerotinia minor* and *S. sclerotiorum*, is first characterized by outermost leaves wilting and dropping to the soil surface. As the disease progresses, leaves are killed in succession until it reaches the heart of the lettuce plant. Under moist conditions, white mycelium is evident, and fungus forms numerous black sclerotia (nondescript hard fungal structures from quite small up to the size of a bean seed) on the affected tissue. These are the long-term survival structures of the fungus. Use long-term rotations of up to three years away from lettuce, beans, celery, or carrots. Well-drained soil or raised beds can help reduce disease severity.

Fusarium wilt, caused by the soil-borne fungus *Fusarium oxysporum* f.sp. *lactucae*, can cause a seedling blight or attack more mature plants. This disease is especially a problem on iceberg and romaine lettuces. On older plants, the main disease symptoms before collapse can include yellowing (chlorosis) of one or more leaves, and a reddish-brown discoloration in the cortex of the crown and upper root. An effective control measure is to avoid planting head lettuce in infested fields for at least several years. Use resistant varieties if available and crop sanitation.

MUSKMELONS (CANTALOUPES)

Cucumis melo

Muskmelons are a warm-season crop. Many varieties require a long growing season from seed to produce mature fruit, plus a considerable amount of space. Choosing short-season, disease-resistant varieties can increase the odds of success.

Muskmelon is classified as *Cucumis melo* and is in the Cucurbitaceae family. Its cousins include cucumbers, watermelon, and gourds. Muskmelon is thought to have its origins in Africa. Muskmelon fruit have characteristic deep, lobed veins, whereas cantaloupe fruit do not. Descriptions often include details on "netting" or the roughness of the melon skin.

Pollination is important to successful fruit set. Male and female muskmelon flowers (which stay open for about a day) occur as separate flowers on the same plant, so allowing bees to visit the flowers is important. If you use row covers or other enclosed spaces to deter pests or to create a warmer growing environment, the covers should be opened part of the time during flowering to allow bees to enter. If pesticide use is needed during this time, it should be applied very carefully–read and follow label instructions to protect the bees.

Arina P Habich, shutterstock.com

GROWING CONDITIONS

Muskmelons need warm temperatures and well-drained soils to grow well. The use of black plastic mulch can help increase soil temperature early in the season, maintain soil moisture and reduce weed numbers. Muskmelon seeds can be planted or plants can be transplanted into holes cut in the mulch.

Consistent soil moisture through deep but infrequent irrigation is needed for best growth. Use soaker or drip hoses to irrigate to reduce incidence of leaf mildews. If overhead irrigation is used, irrigate early in the day to allow leaves to dry quickly. Muskmelon plants under stress (such as lack of water) will have a reduced number of flowers and fruit. Too much irrigation near harvest can cause melons to crack.

PLANTING

Muskmelons can be produced from transplants or can be sown directly. Transplanting will gain a few days to a couple weeks of growing time; however, great care should be taken to be gentle with their roots when transplanting. Start transplants about three weeks before planting them outdoors so they can reach the two to three true leaf stage by transplanting time. To minimize root disturbance, they can be started in peat pots so the entire pot can be planted. Be sure to cover up all of the pot with soil, otherwise the pot material will wick moisture, dry out, and the roots won't be able to grow outside the pot to enter the surrounding soil.

When sowing directly, all danger of frost should be past, and soil temperatures should be a minimum of

60 F, with the optimum being 90 F or more. Rows can be spaced 5 to 7 feet apart with hills spaced 2 to 3 feet apart within the row. Seeds should be sown ½- to ¾-inch deep with two or three plants per hill.

Vines can consume a lot of space. In areas with limited space, vines can be trained up a fence or trellis, and slings or mesh bags can be used to support the weight of the fruit while it grows.

DAYS TO MATURITY

65–100 days.

HARVESTING

If melons are to be sold or eaten right away, they can be harvested when the fruit pulls away (full slip) from the vine attachment easily and smoothly. If they will be stored, they can be harvested at half slip (half of the stem separates easily from the fruit); however, they may not be as sweet as full slip harvested melons. This ripeness characteristic varies a bit by cultivar.

Muskmelons can be stored at 50 to 55 F. They should be washed or otherwise treated before cutting and consumption to reduce the chance of consuming harmful human pathogens.

SOME COMMON VARIETIES

- Alaska (65)
- Minnesota Midget (65)
- Sweet 'n Early (66)
- Alvaro (65)
- Sweet Granite (70)
- Athena (75)
- Rocky Ford (84)
- Hales Best (85)
- Ambrosia (86)

INSECT AND DISEASE PROBLEMS

See Cucumber section for information on insect pests and diseases of melons, page 96.

Rodents, particularly voles, can become a problem and will attack melons–they have the ability to burrow inside and completely remove the flesh leaving the hollowed-out rind.

OKRA

Abelmoschus esculentus

Originating from tropical Asia, okra is in the Malvaceae family and related to hibiscus and mallows. Okra can grow well in some warmer parts of the state. Some cooler areas can produce okra when season extension techniques are employed. Varieties of okra vary in their days to maturity. Height varies, too, as some grow up to 6 feet tall, while others are shorter. Color is another variable with both green and red varieties available.

GROWING CONDITIONS

For most Wyoming growers, some extra thought and planning should be invested in growing okra. When selecting varieties, look for those with fewer days to maturity and the ability to tolerate lower temperatures. If okra is grown in areas that have short growing seasons and low temperatures, season extension techniques should be considered.

Benchaporn Maiwat, shutterstock.com

Okra plants grow best with hot temperatures, fertile soil, and adequate water. A soil test prior to planting is a good idea to understand current nutrient levels. Okra produces a lot of foliage and might require additional nitrogen or other fertilizer during the growing season.

PLANTING

Okra can be planted from transplants or seeded directly in the ground. Seeds or transplants should be planted in the field well past the last anticipated frost. Okra seeds will germinate faster if they are soaked in warm (not hot) water overnight, before planting.

Plants should be spaced with a minimum of 12 to 24 inches between plants and at least 36 inches between rows. This distance should be adjusted to meet specific varieties' needs. Seeds should be planted ¼- to ½-inch deep. Seeds germinate best when soil temperatures are between 70 to 85 F. Care should be taken not to damage the roots of okra when transplanting.

DAYS TO MATURITY

Transplants 40–70 days, direct seeded 80–90 days.

HARVESTING

Harvest pods frequently once plants have established. Pods should be harvested when they are 2 to 3 inches long, but actual harvest length may vary between specific varieties. If pods are left and become over-mature, they will become too woody and hard for consumption. Pods form in leaf joints and should be harvested using gloves to avoid hairs on the plant that can irritate skin. Pruning shears work well for cutting pods off the plants. Pods that are past maturity should be removed to allow better

production of new pods. Harvesting should occur three to four times per week.

Okra pods can be stored a in a cool, dry location for about a week. With a fairly constant crop, be prepared for preserving or cooking the pods as they are picked. Some growers in warmer locations will prune taller okra varieties to around 3 to 4 feet tall to help promote branching and make the harvesting of pods easier.

SOME COMMON VARIETIES

Green

- Clemson Spineless (56)
- Emerald Green Velvet (60)
- Emerald (60)
- Go Big (65)

Red

- Burgundy (55)
- Red Velvet (60)

INSECT PESTS

Okra is a heat-loving plant that needs ambient temperature to be above 70 F for best growth. It is always important to have environmental conditions for a crop to be as optimal as possible to give plants the best chance to naturally suppress or outgrow pests.

Pests affecting vegetative growth (pests that chew leaves or pierce and suck plant juices)
Two of the most common species of aphids that will feed on okra are the **green peach aphid** and the **potato aphid**.

The egg masses of armyworms are covered with white "hairs" by the female as illustrated by this mass deposited by a beet armyworm (*Spodoptera exigua*).
Alton N. Sparks, Jr., University of Georgia, Bugwood.org

Armyworm species from the genus *Spodoptera,* will feed on okra, and they usually appear and cause damage after the moths arrive in Wyoming from the south in mid-to-late summer.

Striped and spotted cucumber beetles
Whitney Cranshaw, Colorado State University, Bugwood.org

Both the **western striped cumber beetle** and **western spotted cucumber beetle** will feed on okra. These beetle species can vector the plant pathogen that causes bacterial wilt.

The **cabbage looper** will feed on okra and chew holes in the leaves. **Two-spotted spider mite** populations can increase rapidly on okra in hot, dusty conditions or after insecticide treatments that impact their predators. Heavy feeding by mites can cause leaves to turn yellow and fall off the plant. Okra can also be attacked by **European corn borer** with the caterpillars living up to their common name and boring into the plant's stalk. Once inside the plant, the caterpillars are safe to feed, which weakens the stems and reduces seed pod yield.

Insect pests affecting the saleable parts directly

Corn earworm will damage the leaves initially, but worse damage is caused when they feed on the buds, flowers, and the pods of the okra, which all reduce crop yield.

Stink bug is the common name given to members of the family Pentatomidae, like these brown stink bug nymphs (*Euschistus servus*). Many stink bug species are plant feeders with a piercing beak they use to penetrate plant tissue and suck out the cell contents.
Herb Pilcher, USDA Agricultural Research Service, Bugwood.org

An adult, green color morph Say stink bug (*Chlorochroa sayi*) is typically about the diameter of a dime and has fully functional flight wings tucked away, giving it the superficial appearance of a beetle. They cause their worst damage by feeding on the developing seed pods.
William M. Ciesla, Forest Health Management International, Bugwood.org

Multiple species of **stink bugs**, (Family Pentatomidae) will feed on many different crops but are most damaging when they feed on the pods of the crop. Virginia Tech published a great booklet to help with identification titled "Field Guide to Stink Bugs of Agricultural Importance in the United States," https://bit.ly/VI-stink-bugs.

ONIONS

Allium cepa

There are some species of onions (alliums) native to Wyoming; however, the onions grown in the garden are much larger and not found in the wild. Our vegetable onions originated from Europe and are far more productive than the native species. Bulb onions are in the Amaryllidaceae family, which also includes daffodils, jonquils, amaryllis, and spider lilies. One may find references to previous families in which Allium had been placed: Liliaceae and Alliaceae. Leeks and garlic are both alliums as well.

Bulb onions can be a valuable addition for a grower. They consume a relatively small amount of space and can be stored for many months after harvest. Yellow, white, and red are the three common colors. Onions can be mild, sweet, or hot in flavor. Onions can also be harvested before they bulb and sold or used as green onions. Growers can plant these onions closer together and then harvest every other one for green onions if desired.

Grigoriy Pil, shutterstock.com

Onions are a cool-season, biennial plant. A bulb is developed during the first year of growth. The bulb supplies the plant with nutrients for growing flowers and seeds during the second year. The creation of a bulb on an onion is controlled by day length, so short-day and long-day varieties have been developed for different areas of the U.S. The 35th parallel is the dividing line for use of short-day and long-day varieties. Growers north of the 35th parallel should grow long-day and those south of the line should grow short-day varieties. Wyoming is well north of the 35th parallel (Oklahoma City and Albuquerque are on the 35th parallel).

GROWING CONDITIONS

Onions prefer cool temperatures while growing and then warmer temperatures while their bulbs are developing. They will tolerate light frosts but not prolonged freezing below 20 F. Onions grow best in full sun, so try so avoid shaded areas. Soils high in organic matter, nutrients, and have good drainage are important for onion production. Mulching between rows of onions can help reduce weeds and increase productivity. Onions are shallow-rooted, so consistent water throughout the growing season is important.

PLANTING

Onions from seeds

Onions can be started from seeds and transplanted. Onion seeds need plenty of time to get established if started indoors. They are often started 8 to 12 weeks before transplanting. Transplants can be planted one to two weeks before the last anticipated light frost.

Seeds can also be directly planted into the ground. Seeds can be planted early in the spring and then

thinned once seedlings begin to establish. Depending on your growing site, this might not provide enough time for the onions to establish and develop properly. Top growth ends and onions begin to bulb once their daylength requirements have been met—even if they are very small at that point. Seeds should be planted ¼-inch deep.

Onions from sets and transplants

Onion sets and purchased transplants can also be directly planted into the ground. Onion sets are immature plants that allow you to get a head start on the growing season. Smaller sets should be used for bulb-type onions, while larger sets are best used for green onions. Planting sets larger than a quarter in diameter will tend to produce plants that only send up a seed stalk and not develop a bulb. Most sets should be the size of a dime in diameter. Sets should be firm and dormant.

Transplants can be purchased online, via mail order, local nurseries, and often from local grocery stores. Purchased transplants are live plants planted directly into the ground. Transplants are generally sold in large quantities.

No matter how onions are started, individual plants should be 2 to 4 inches apart in rows 24 to 36 inches apart. Plants growing too close together can be harvested as green onions.

DAYS TO MATURITY

100–120 days (bulb onions), bunching onions/scallions usually mature more quickly (50 days or so).

HARVESTING

Onions should be allowed to grow until the tops fall over naturally. Most onions mature in 100 to 120 days. Do not "top" onions (knock the tops over) as this reduces yield. Onions that quickly mature and start to flower should be pulled. Onions can be pulled and dried for storage once their tops have fallen over. Onion should be allowed to develop a firm skin by placing them in a dry shady area for a couple of weeks (until tops are all dried up). Once dried, many onions will keep for two to four months in a cool, dry location. Remove the tops of the plant except for 3 to 4 inches. Any onions that show signs of rotting in storage should be removed and not allowed to touch healthy onions.

SOME COMMON VARIETIES

- Candy (85)
- Red Zeppelin (90)
- Columbia (95)
- Patterson Hybrid (104)
- Copra (110)
- Yellow and White Sweet Spanish (115)
- Walla Walla (115)
- Redwing (118)

INSECT PESTS

See the section on Leeks for common insect pests of onions, page 114.

DISEASES OF ONION, LEEK, AND GARLIC

Physiological disorders (abiotic disorders)

Seedling disorders

Seedlings can be affected by a number of common disorders including tip dieback, stunting, poor growth, uneven emergence, and physical injury. The most common causes include adverse soil conditions (too hot, too dry, too wet); unfavorable pH levels; unfavorable salt concentrations; nutrient imbalances; injury from pesticides; wind, rain, or hail injury. With the exception of weather factors, most of these conditions can be monitored and managed to reduce adverse effects.

Bulb splitting

The first symptom observed is the splitting of the basal plate (the bottom of the onion where the roots emerge). One to several small bulbs often develop from the split basal plate. Caused by uneven irrigation

(overly wet and very dry cycles), especially in areas of uneven stands. To manage, maintain uniform stands and consistent watering practices.

Greening

Exposure of sunlight on outer scales can cause greening of the outer scales (chlorophyll production). Conditions of excessive nitrogen late in the season can delay maturity and enhance greening of bulbs. Greening can also occur when bulbs are exposed to sunlight during the growing season or when curing. Avoiding excessive and late season nitrogen application and reducing the time bulbs are exposed to sunlight when curing can help avoid greening.

Sunscald

Sunscald is primarily a problem on young seedlings and mature bulbs. High soil temperatures damage seedling tissue at the soil line, resulting in shriveling and collapse of plants. On onion bulbs, affected tissue collapses and becomes bleached, soft, and slippery. Affected areas dry and shrivel rapidly, and scales eventually become brown and necrotic. Harvesting and curing onions in direct sunlight can result in sunscald. Plant onion seeds/transplants early enough to avoid high soil temperatures. Reduce sun exposure of harvested onion bulbs.

Wind, hail, and pelting rain injury

Can cause serious injury to all stages of growth. Pelting rain drops can cause whitish spots along one side of the leaves. This injury can make them more susceptible to foliar diseases.

Infectious diseases

Seedling diseases

Onion, leek, and garlic are susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

Foliar and whole plant diseases

The **Botrytis** fungal group (*Botrytis* spp.) attacks onion, leek, and garlic leaves following periods of warm, wet weather causing necrotic spots. Another species of Botrytis can infect the neck and bulbs in storage. Symptoms include water-soaked stems, which is why the disease is often called "neckrot." In severe infections, the bulbs may rot. In mild infections, the disease may not be noticed during the season but may attack the bulb during storage. Control this disease by watering earlier in the day and promoting air movement through the growing area so foliage does not remain wet long. Rapid drying during harvest, followed by good aeration during storage, will also minimize the problem. Use planting stock free of the disease.

Black mold (*Aspergillus niger*) occurs on onions and garlic. The fungus is first evident at the top or sides of the bulb where disease or injury has caused an opening in the skin. The fungus develops between dry, dead outer scales and the first inner fleshy scales of the bulb. Invaded scales initially become water-soaked. Under dry conditions, diseased scales dry and shrivel, and black masses of spores are visible between outer scales. Diseased scales may also be invaded by soft rot bacteria, causing the whole bulb to deteriorate into a watery soft rot. This disease is most common when onion and garlic are grown under warm, dry conditions. Avoid damaging bulbs to limit infection. Remove diseased plant material from the growing area at end of the season.

Onion smut is caused by the soil-borne fungus *Urocystis cepulae* and infects the flag leaf (cotyledon) as it grows through the soil. Onions and leeks are susceptible; garlic only moderately so. Often, the seedling survives this initial infection, and the characteristic black streaks and blisters appear in the leaves and small bulbs later in the growing season. Seedlings can be killed by the disease in most years. A cool, wet spring increases incidence of smut infection because the onion seedlings grow slowly and the flag leaf is in the soil for a longer period. Planting onion seeds too deeply will also make them more likely to be infected. Smut spores survive in the soil for many years, and even long crop rotations may not reduce disease incidence. Seed treatments can reduce losses

to the disease, and growing onions from transplants avoids the disease. The disease is spread when contaminated soil or onion sets are transferred to smut-free areas.

Fusarium (**basal or bottom rot**), a common soil-borne fungus (*Fusarium oxysporum* f.sp. *cepae*), affects onion, leek, and garlic but is mostly a problem in onion. The disease is most prevalent when soil temperatures are very warm. The early symptoms in the field are yellowing of leaves and tip dieback. As the disease progresses, the whole plant may collapse and, if the plant is pulled, often comes out without any roots attached since they have decayed. The basal plate of the onion becomes pinkish-brown, and secondary bacterial rots may develop in the affected area. Symptoms may not show up until the onions are in storage if infection occurs late in the season. This disease is controlled by proper crop rotation with non-hosts for four years, removal of infected plants, and planting disease free seed or sets.

PARSNIPS

Pastinaca sativa

Parsnips are related to carrots and grown for their creamy-white to yellowish roots. The plant family they are in, Apiaceae, also includes celery, coriander, and fennel. They are a cool-season vegetable, which require a long growing time, at least 100 days. They take some effort to get the seed germinated and growing. Originally from Siberia and Europe, they are relatively hardy. Some people are sensitive to parsnip leaves and can develop a skin rash after contact, especially on hot, sunny days. Wearing long sleeve shirts, pants, and gloves can reduce exposure to irritants.

BMJ, shutterstock.com

GROWING CONDITIONS

Parsnips grow best in fertile, deep, loose soils with adequate moisture and temperatures under 75 F. Heavier soils can be dug deeply and amended with compost to lighten them, making them more suitable for parsnip growth. Lack of watering can result in tough, bitter, misshapen roots. Organic mulches can help reduce water evaporation from soil.

PLANTING

Parsnip seeds lose their viability quickly, usually within one year, so be sure to use fresh seeds. Seeds should be planted ½-inch or less deep about two weeks before the average last frost date in rows 18 to 36 inches apart with plants 2 to 4 inches apart. The seed is slow to germinate (up to three weeks or more), and a good stand may be difficult to produce in heavy soils and with low moisture. Care should be taken to keep the sown area consistently moist to assist germination.

DAYS TO MATURITY

100–130 days.

HARVESTING

Dig parsnips with a spading fork in late fall or leave them in the ground throughout the winter. They will tolerate alternate freezing and thawing but will be damaged if frozen after harvest. Some of the starch in their roots converts to sugar if the plants undergo some frosts. If left over winter, they should be harvested in the spring before top growth starts for tender, sweet roots. Do not try to save and store parsnip seeds as they have a very short life span.

SOME COMMON VARIETIES

- All-American (105)
- Hollow Crown (105)
- Javelin (110)
- Harris Model (120)
- Andover (120)

INSECT PESTS

Parsnip is grown mainly for its carrot-like tap root. Some of the same pests that attack carrots will feed on parsnips.

Pests often affecting seedlings

The seemingly ever-present and destructive larvae of multiple cutworm moth species are the most serious pest of parsnip seedlings. Parsnips are hardy plants adapted to growing in cool weather, so they are often planted early in the spring. This can make them vulnerable to attack by overwintering cutworm larvae. See cutworm management under the Integrated Pest Management section for additional information, page 45.

Affecting vegetative growth (pests that chew leaves or pierce and suck plant juices)

Willow-carrot aphid (*Cavariella aegopodii*) will feed on parsnip foliage and a heavy infestation can yellow and distort leaves and reduce root growth. This aphid species can vector many plant viruses including "parsnip yellow fleck," the most damaging pathogen for this crop.

Beet armyworm (*Spodoptera exigua*) will feed on parsnip tops but, at this time, is rarely a pest in Wyoming because it can't overwinter in the state.

Insect pests affecting the saleable parts directly

Carrot rust fly (*Psila rosae*) is a damaging pest of carrots and parsnips. Presently it is not widespread in the Mountain West. Keeping it from being introduced to your place is presently the best control tactic in Wyoming. See the Carrot section for more information on this pest, page 90.

DISEASES

See section on carrots for diseases that affect parsnip, page 90.

PEAS

Pisum sativum

Peas are native to southern Europe and are often known as the plant used by Gregor Mendel in his studies of genetics. They are in the Fabaceae family along with beans and alfalfa. Tolerant of cooler temperatures and quick growing, peas are a good early crop for many parts of Wyoming.

Peas are vining legumes that come in several growth types. Dwarf or bush peas, determinate types, are often grown and tend to be fairly self-supporting. They can grow 2 to 4 feet high. They can be planted in succession (plant new rows of peas every one to two weeks) to extend the harvest if your area has enough time for them to mature before the heat of summer. You can also extend the harvest period by planting different varieties with different days to maturity at the same time. Climbing types, called indeterminate, grow significantly taller than bush peas. Providing some kind of support makes harvesting easier since the pea pods won't be on the ground. The plants produce tendrils, which coil around supports such as fencing or wooden poles, allowing them to grow their vines up to 6 feet high.

Peas can also be broken into types where the pod is not eaten, shelling peas, and types where the pod is eaten, snap peas, and snow peas. In general, snap peas are harvested when the pods are plump and succulent and the peas inside the pods are starting to grow. Snow peas are usually harvested when the pods are almost completely flat but succulent. Shelling peas are harvested when the peas inside the pods are large enough for eating but before they start to fully mature and most of the sugar gets converted to starch.

GROWING CONDITIONS

Peas are light-frost hardy when young and should be planted in early spring. They will not yield well if they mature during hot weather. In some areas, they can be planted from July 1–15 for fall harvests. Organic mulches can help soils cool, retain soil moisture, and control weeds for peas sown for fall harvest. Peas will produce during the summer in high altitude areas where the summer climate is cool.

Peas will grow in many soil types as long as they are well drained. They grow well in soils with sufficient organic matter and fertility. Over-fertilization may cause vines to channel growth into leaf growth at the expense of flowering and pod set. Peas require consistent water to thrive; watering is most critical during flowering and pod set. Peas should be irrigated so the soil is moist but shouldn't be overwatered. Overwatering will promote root rots and decrease growth.

PLANTING

You can plant garden peas as soon as the soil can be worked. They germinate in a wide variety of soil temperatures (40 to 80 F) but germinate and grow best around 55 to 65 F. They germinate and grow poorly when soil or air temperatures get in the 80s. Young plants are more tolerant to cold temperatures than older plants. Also, blossoms and pods are more sensitive to cold temperatures than leaves, in general. Peas can be pre-sprouted before planting if desired. Place pea seeds between two sets of damp paper towels. Keep damp until the roots start to come out of the pea seeds, then plant. This can give you more consistent stands of pea vines if growing conditions are favorable.

Seeds can be planted 1-inch deep, 1 to 3 inches apart in rows 24 to 48 inches apart. As mentioned previously, pea varieties vary in height from 18 inches to 6 feet. The taller varieties should be grown on a trellis for easier picking and fewer disease problems. The trellis can be made of wire fencing, wood, or even string.

DAYS TO MATURITY

50–70 days.

HARVESTING

Timely harvest is important with peas. If peas are left too long on the vine, the quality of the peas will decrease, and the vine will stop producing new pea pods. Picking every other day is common. Cooling the pods as soon as picked is important to quality. The longer the pods stay at room temperature, the more the sugar content in peas will convert to starch. Significant loss can occur in as little as three hours.

SOME COMMON VARIETIES

Edible-pod

- Snowbird (58)
- Little Sweetie (60)
- Dwarf Gray Sugar (66)
- Oregon Sugar Pod II (68)

Snap types

- Sugar Ann (56)
- Sugar Sprint (62)
- Super Snappy (65)
- Sugar Snap (70)
- Sugar Daddy (72)

Garden types

- Early Alaska (52)
- Spring (57)
- Early Frosty (60)
- Maestro (61)
- Little Marvel (62)
- Lincoln (67)
- Green Arrow (70)

INSECT PESTS

Pea plants have many fewer pests than their bean relatives. Some of the most common pests on peas in Wyoming are insects that also feed on alfalfa, a widely grown forage crop. Unfortunately, the adults of these shared pests, such as the pea aphid, are quite mobile and can migrate into pea crops from distant alfalfa fields.

Pests often affecting seedlings

Seedcorn maggot can attack pea seeds but unlike many other crops, pea seeds are vulnerable when soil temperature are *warmer* than optimum and germination and growth is slowed. Soil temperatures need to be a minimum of 40 F for germination. Once started, peas grow best in the cooler conditions of spring or as a late summer/early fall second crop.

Slugs and various **cutworms** can also damage seedlings. See cutworm management under the Integrated Pest Management section for additional information, page 45.

Ewa-Saks, shutterstock

Affecting vegetative growth (pests that chew leaves or pierce and suck plant juices)

Pea aphid
Whitney Cranshaw, Colorado State University, Bugwood.org

Pea aphid (*Acyrthosiphon pisum*) is common in alfalfa and overwinters there so that fields in the area can be a source of infestation for pea crops. Their feeding activity can wilt the pea plants, and they can be vectors of plant viral diseases.

Climbing cutworms and **grasshoppers** will also damage pea plant leaves (See the Cutworm, page 45, and Grasshopper, page 47, management sections under Integrated Pest Management for additional information).

The **cabbage looper** (*Trichoplusia ni*) can show up later in the summer on pea crops, but it doesn't overwinter in Wyoming well and needs to migrate back to southern regions. The **alfalfa looper**, (*Autographica califomica*) is a native insect of the western U.S. and will feed on many crops beside alfalfa, including peas.

Insect pests affecting the saleable parts directly

Western flower thrips and **onion thrips** feeding can cause surface damage on pea pods, reducing their salability. Western flower thrips damage in pea flowers and on buds can cause them to abort or reduce the number of peas that form in the pod. See thrips management in the Integrated Pest Management section for additional information, page 50.

DISEASES

Physiological disorders (abiotic disorders)

Freezing injury

Frost can kill the growing point on young pea plants or injure young developing leaves. Crop development will be delayed when this happens, as axillary buds develop to continue plant growth. Freezing injury is more common in low-lying areas of a field/garden or where air movement is restricted. This is because colder air tends to travel downhill and pool in such areas.

Nutrient deficiency

Symptoms vary significantly depending upon pea cultivar, nutrient involved, and environmental conditions. In general, nutrient disorders are characterized by the foliage on the entire plant showing yellow to tan to bronze discoloration, beginning at the leaf edges with the veins remaining green. Typical soils in Wyoming have a high pH, which can lead to deficiencies in boron, iron, manganese, and zinc.

Hail injury

Hail injury can severely reduce yield and quality. Injury is characterized by crushed stems and whitish bruised areas. If pods are present, they will exhibit white bruises that will eventually turn dark brown. Peas may stop developing due to this damage.

Infectious diseases

Seedling diseases

Peas are susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

Foliar and whole plant diseases

Ascochyta blight is an important fungal disease of peas and is caused by up to four separate fungal organisms that cause the same disease symptoms.

The pathogens infect all aboveground parts of pea plants as well as the crown below ground level. Symptoms consist of purplish-black necrotic spots that coalesce into large lesions on stems, leaves, and pods, and root rot may occur in severe cases. Spots on the pods may coalesce to form large, sunken, purplish-blackish areas. Development of this disease is favored by high moisture conditions. To reduce the chance of disease development, use disease-free seed, three to four year rotations, and incorporate infested pea residue into the soil.

Anthracnose is a fungal disease (*Collectotrichum pisi*) that attacks all aboveground parts of the plant, especially during warm, rainy weather. Symptoms include brown, sunken lesions on pods and elongate, oval spots with tan centers and brown margins. Affected seeds become discolored. To manage, start with anthracnose-free seed. Remove infected crop debris or incorporate well into the soil. Use a two-year rotation. Resistant varieties are available, but the anthracnose fungus has multiple races, and resistant cultivars are resistant only to one of the potential anthracnose races.

Bacterial blight disease, caused by the bacterium *Pseudomonas syringae* pv. *pisi*, is typically introduced with infected seed or because peas were grown near common bean that had bacterial brown spot. Infection from this bacterium initially is characterized by small water-soaked spots on leaves and stems. Spots become brown, shiny, and translucent and can enlarge into angular lesions. Pod infections also start out as water-soaked spots, which later expand along the pod suture into large necrotic lesions with purplish-brown margins. Since these diseases can be seedborne, start with disease-free seed. Remove infected plant debris or fully incorporate it in the soil as they can be significant sources of inoculum.

Powdery mildew is a fungal disease common in Wyoming and sometimes can cause major production problems. Symptoms are characterized by white powdery spots that can enlarge to cover the entire leaf surface. The fungus can infect pods as well. Tissue beneath affected areas can turn purplish then brown. Disease development is favored by high humidity, but not free water (water in liquid form), and cool temperatures. Spores are easily spread by wind and rain, and the fungus can be seedborne. To control, use disease-free seed and resistant cultivars. Sulfur sprays or dusts or other chemicals, if available, can be used early in the season before the pods become infected.

Root diseases

Fusarium root rot is caused by a soil-borne fungus (*Fusarium solani* f.sp. *pisi*) and is found wherever peas and other legumes are grown. First symptoms are small, elongate, tan-red lesions in the lower hypocotyl and upper taproot. The lesions increase in number and size, often coalescing until the entire root system and lower hypocotyl show reddish-brown necrosis. Diseased plants are stunted and unthrifty in relation to the severity of root rot. The disease is favored by warm soil temperatures and sufficient soil moisture for plant growth. It is spread by infested soil and pea tissue. To manage, practice crop rotation and use resistant cultivars if available.

Aphanomyces root-rot (fungus – *Aphanomyces euteiches*): Early infection often causes complete crop loss due to seedling death. Late infection results in poor plant growth and reduced seed formation. The cause of the problem (roots rotting) may be hard to see at first as tissue decay does not develop above the soil line unless the weather is extremely wet. Infection occurs in both wet and dry soils but is most destructive in wet soils. Optimum temperatures for infection are between 65 to 75 F. The use of high levels of fertilizer will encourage continued root development as nitrogen acts as a suppressant to fungal growth; however, the effects of such fertilizer on other plants and nutrient runoff should be considered. Growing peas in well-drained soil, the use of three-year rotation, and the liberal use of fertilizer should the disease develop will help reduce losses.

PEPPERS

Capsicum annuum

Originally from Central America, peppers are available in a wide variety of shapes, sizes, and colors. They are closely related to tomatoes, petunias, and potatoes, which are all in the Solanaceae family. Peppers can be grown for fresh eating, cooking, or dried as a spice. All pepper fruit start out green. As they ripen they can stay green or change to red, orange, yellow, or other colors. Varieties are split into sweet or hot categories. Bell peppers fall in the sweet category. Hot peppers can vary drastically in heat. The degree of "hotness" of hot peppers is reported in Scoville Heat Units. For example, jalapenos can be in the 1,000 to 10,000 SHU range, while habaneros can reach 350,000 SHU. There are hundreds of varieties from which to choose. Select varieties according to the use of the pepper, how long your growing season is, your growing conditions, the level of heat you want, and the resources available for keeping plants healthy.

Denis Pogostin, shutterstock.com

GROWING CONDITIONS

Peppers can be a challenge to grow in cooler parts of Wyoming; night temperatures are a major issue. Pepper plants are less productive once night temperatures are below 55 F and will slowly start to die once temperatures are below 40 F. Pollen production is affected, and pepper blossoms will often fall off once night temperatures are below 60 F. Ideal temperatures are between 70 and 90 F during the day and 60 to 70 F at night. Temperatures above 90 F during the day can also cause blossoms to drop. Hot peppers like temperatures even warmer than sweet peppers and will set fruit at temperatures over 90 F. With a narrow range of ideal temperatures, the addition of warming or cooling methods is important for pepper production.

Black plastic mulch, natural material mulch, row covers, season extension structures, moving plants indoors at night, walls of water, and other additional heating methods can be used for keeping pepper plants warm during cooler temperatures. If peppers are grown indoors, then mechanical agitation (gentle shaking, a gentle fan) of blossoms may be needed to ensure adequate pollination and fruit set. Shade cloth or other cooling methods should be used when temperatures become too warm for proper flower function. Wind can damage plants (they are brittle and break easily), so look for ways to help keep plants protected in the windy portions of Wyoming.

Peppers grow best in nutrient-rich, well-drained soils with adequate moisture throughout the growing season. Too much irrigation will cause the flowers to abort, too little, or erratic, irrigation can cause blossom-end rot.

PLANTING

Peppers can be seeded directly into the ground or transplanted with immature plants. Due to environmental constraints, transplants started from seed indoors or purchased are generally the best options in Wyoming. When purchasing plants, make

sure to look for plants with hardy stems, free of disease and pests, and do not have flowers since the existing flowers will generally fall off once planted. Transplants should have five to six leaves. Plants should be planted outside when all chance of frost has ended. They should be placed 12 to 24 inches apart depending on the variety. Peppers can be planted in rows 18 to 36 inches apart. Seeds should not be planted more than ½-inch deep if directly seeded.

HARVESTING

When peppers are harvested depends on their use. Sweet peppers can be harvested once 3 to 4 inches long. Use scissors, pruning shears, or a knife to cut them from the stem. They will also snap off the stem when ripe. Some types of sweet peppers are harvested before maturity to maintain a desired color or shape. Fruit should be firm, smooth, and full. Use rubber gloves to protect your skin when picking or harvesting hot peppers. Washing your hands after handling hot peppers is also important to avoid contact of irritating pepper chemicals with eyes and sensitive skin. If drying and grinding hot peppers, be sure to take adequate precautions to protect yourself from the pepper dust created during the grinding process. Fresh peppers do not have a long storage life (one to two weeks).

SOME COMMON VARIETIES

Sweet

- Crispy Bell (65)
- King of the North (65)
- Sweet Banana (68)
- Purple Bell (70)
- Bell Boy (70)
- Lady Bell (72)
- California Wonder (75)
- Lipstick (75)

Hot

- Anaheim 118 Hybrid (65)
- Early Jalapeno (66)
- Big Chili (68)
- Masivo Hybrid (70)
- Garden Salsa Hybrid (73)
- Cayenne (73)
- Red Chili (84)

INSECT PESTS

There are many different cultivars of *Capsicum annum* plants. Short growing seasons and cool night temperatures are the biggest challenges growing many of these cultivars in Wyoming. Growers should be aware of some insect pests as they overcome the challenges. **Corn earworms** and **European corn borers** are the most damaging insect pests of peppers in Wyoming as they attack the developing fruits.

Adult corn earworm moth
Steve L. Brown, University of Georgia, Bugwood.org

The adults of the corn earworm (*Helicoverpa zea*) are very variable and look similar to many other species of moths. The use of traps baited with pheromones attractive to just the moths in the genus *Helicopverpa* help simplify monitoring for the pest. In Wyoming, the harmless false corn earworm (*Helicoverpa phloxiphaga*) can end up in monitoring traps.

Pests often affecting seedlings

With Wyoming's short growing season, peppers will likely be started from transplants initially grown in protected conditions (greenhouse, high tunnel, or in other indoor locations). This gets the plants past the vulnerable stage as seedlings.

Affecting vegetative growth (pests that chew leaves or pierce and suck plant juices)

Western flower and **onion thrips** will feed on peppers. If the thrips feed on a plant with tomato spotted wilt virus, they will become a vector and spread the disease to any subsequent susceptible plant they feed on. Western flower and onion thrips are common plant pests in the row crop growing regions of Wyoming. Fields will need to be constantly monitored for thrips due to the mobility of the flying adults, which can lead to rapid infestation of a crop. Alfalfa, alliums, and dry bean crops can be a source of thrips. See thrips management in the Integrated Pest Management section for additional information, page 50.

The **green peach aphid** will feed on peppers. They are a common species of aphid frequently found in greenhouses and high tunnels, so new transplants to the field can arrive with a population of this pest already present (See the Aphid management section under Integrated Pest Management for additional information, page 44).

Colorado potato beetle
Whitney Cranshaw, Colorado State University, Bugwood.org

Colorado potato beetles are native to Wyoming, and their larvae can rapidly defoliate a pepper plant. Many populations have become resistant to many common insecticides. The adult beetles are mobile and can move into a field and quickly deposit a lot of eggs on suitable host plants.

Tomato hornworm
Whitney Cranshaw, Colorado State University, Bugwood.org

Tomato hornworms can also defoliate peppers. Infestation of peppers by tomato hornworms is usually light, and the caterpillars can be easily removed by hand and destroyed.

Insect pests affecting the saleable parts directly

Both the corn earworm and the European corn borer larvae can target developing peppers. Nothing can be done to save a fruit once the larvae chew their way into a pepper. Commercial pheromone traps for both species can be used to monitor for the arrival of the adult moth from southern regions. When adult moths are detected, preventative treatment with insecticide should be done to kill the pest's larvae before they can enter the developing fruit. The number of treatments needed will depend on the insecticide selected and the duration developing pepper fruits are present in the field until harvest.

DISEASES AND DISORDERS

Physiological disorders (abiotic disorders)

Blossom-end rot

A water-soaked area near the blossom scar of the fruit is the first visible symptom of blossom-end rot. This area later develops into a tan to brown, leathery lesion. Saprophytic fungi often colonize these lesions, which gives them a gray to black, velvety appearance. This disorder is associated with insufficient calcium uptake and alternating periods of wet and dry soil. Damage to the root system may also account for decreased calcium uptake. Avoid blossom-end rot by maintaining constant soil moisture, adding calcium

fertilizer if necessary, and avoiding excessive nitrogen levels.

Cracking

Superficial cracks are characteristic of jalapeño peppers but are considered problematic in other pepper fruit types. Splitting of the epidermis occurs in fruit under stress, near maturity. Fine, superficial cracks on the fruit's surface give a rough texture to the fruit, and deeper cracks can be colonized by secondary pathogens, which can cause the fruit to rot after harvest. The severity of fruit cracking is related to stress sustained by fruit during stages of rapid growth. In the field, wide differences in day and night temperatures or heavy rain or water availability promote cracking. Proper irrigation and nutrition management can help reduce cracking. In greenhouse operations, avoid high relative humidity and temperature fluctuations at night to reduce plant stress. Some cultivars are less susceptible to fruit cracking than others.

Sunscald

Sunscald occurs on the side of fruit exposed to direct sunlight. It first appears as a wrinkled area that can be soft and lighter in color than surrounding tissue. In peppers, this area later collapses and turns white and paper-like. The affected area often turns black due to colonization by saprophytic fungi. Sunscald primarily affects fruit, but leaves and stems also can be injured. Fruit near maturity are more sensitive to sunscald injury than immature fruit. Fruit suddenly exposed to direct sunlight due to defoliation from disease, pruning, or stem breakage are susceptible to sunscald. Maintain adequate plant growth to cover fruit or deploy some sort of shade cloth.

Infectious diseases of peppers and eggplant

Seedling diseases

Plants are susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

Foliar and whole plant diseases

There are a number of fungal *Collettrichum* species that infect peppers and eggplant, causing the disease **anthracnose**. Anthracnose affects all aboveground parts of peppers and eggplants during any stage of growth. Seedling infection may be confined to the cotyledons and not spread. Necrotic gray to brown spots may develop on leaves and stems, but fruit lesions are the most economically important aspect of this disease. Fruit symptoms begin as small, circular water-soaked areas that turn to tan or brown lesions. Lesions can coalesce to cover large areas of the fruit. Under moist conditions, pink, salmon, or orange masses of spores are formed, usually in concentric rings. Warm, wet weather favors infection and disease development. This disease can be managed by sowing good quality seed, rotating out of Solanaceous crops for two to three years, removing weeds and infected debris, and choosing fields that drain well. Minimize fruit wounds by controlling insects. Copper fungicides are available but have limited economical value for controlling this disease.

Leaf spot diseases are caused by a number of fungal pathogens including *Alternaria* spp., *Septoria melongenae*, and *Cercospora* spp. First visible symptoms of foliar infection are expanding necrotic spots with yellow to dark-brown margins. Infection usually starts on lower leaves and moves up the plant as the disease progresses. Leaf spots caused by *Septoria melongenae* later break apart, giving the appearance of "shot holes." Leaf spots caused by *Alternaria* spp. are irregular in shape with concentric rings that enlarge and can cover the leaf blade. *Cercospora* spp. can also cause small, irregular leaf spots that later are covered with gray sporulation. Fruit lesions start as necrotic spots and develop into sunken, scab-like lesions that extend into the flesh of the fruit, turning it hard and brown. Disease development for these leaf spots is generally dependent on high humidity. Fungi survive in infested debris or on alternate weedy hosts. Splashing irrigation water facilitates the spread of these fungi. To manage, practice good sanitation of previous year's crop, weed control, and crop rotation.

Use mulching and watering techniques to reduce splashing and excess leaf wetness.

Powdery mildew on pepper and eggplant is caused by the fungi *Levenilla taurica* that produces a white powdery growth on the leaf surface. This disease can cause foliage loss under high disease pressure. Disease progresses from older to younger leaves and is favored by cool and humid conditions. Unlike many fungal pathogens, it does not like free liquid water on plant surfaces. In Wyoming, we typically see this disease on leafy vegetables and other garden hosts later in the season as canopies become dense with shadier conditions that create favorable conditions for disease development. Remove diseased plants from the growing area at the end of season. Powdery mildew can be managed with fungicides when applied at first appearance of disease.

Fusarium and **verticillium wilt**, both soil-borne fungal pathogens, affect both peppers and eggplants causing a wilt. Fusarium wilts are caused by several variants of *Fusarium oxysporum*. They are characterized by initial yellowing of foliage and wilting, then to more death of leaves and more pronounced wilt. Reddish brown streaks are visible in the vascular tissue when stems are cut diagonally. Verticillium wilt of pepper and eggplant are caused by several *Verticillium* spp. This disease also results in a general wilt, but a characteristic symptom of infection is a v-shaped lesion that develops on older leaf tips that later expands to cover the leaf. Wilting can also be asymmetric, with sections of the plant being wilted whereas other parts remaining unwilted. Fusarium and verticillium can survive in the soil for years and infection is favored by root injury. Crop rotation can help as well as soil fumigation in larger growing areas. Fusarium resistant varieties are available in peppers, but selection can be tricky as resistance is usually for only one of the three races (genetically distinct individuals within the same species) of Fusarium. Resistant pepper or eggplant cultivars are not available for Verticilium. Maintain well-drained soil and avoid root injury.

POTATOES

Solanum tuberosum

Potatoes are an ancient crop, native to the Andes region of South America. They are closely related to tomatoes, peppers, eggplants, and petunias, all in the Solanaceae family. Today's varieties come in a range of sizes and colors (from deep purple skins and flesh to red, brown, and yellow). They can be grown as a crop for use from early summer (harvested as "baby" or "new" potatoes) and as a late harvested crop that can be stored and used in winter. Harvests can also be extended in some parts of Wyoming by choosing both an early variety and a medium-to-late maturing variety. Make sure to select certified seed pieces or disease-resistant varieties when selecting potatoes to grow. Potatoes are prone to a number of insect and disease problems.

Uroš Medved, shutterstock.com

GROWING CONDITIONS

Potatoes grow in a variety of soils, but they do not grow in compacted soils or ones that aren't well drained. They prefer loose soils and are heavy feeders so are best grown in soils with adequate fertility.

Potatoes grow best in cooler temperatures below 75 F with uniform moisture throughout the growing season. Black plastic mulch can be used to speed harvest in very cool areas, and organic mulch can be used to cool the soil in warmer areas.

PLANTING

Along with ranges of maturity (early, mid, late), differing skin and flesh colors, potato varieties have varying degrees of plant disease resistance and other characteristics that make some better for baking, boiling, frying, etc. Spending time researching desirable variety characteristics will be beneficial.

Purchase high-quality certified seed potatoes. These have been inspected for diseases you don't want introduced into your field. They can be purchased as larger potatoes that are then cut into chunks for planting or as small individual potatoes that don't require cutting. Seed potatoes should be firm with no sprouts. Wilted potatoes or potatoes that have sprouted too far usually have lost vigor from being too warm in storage.

Larger seed potatoes should be cut into pieces that weigh around 2 ounces (about 1¼ inch wide) and have one to three good buds or "eyes." (https://bit.ly/unl-cutting-tubers) A 6-ounce potato can yield three to four seed pieces. You can plant the seed pieces right away or let them "cure" by sitting them in a cool area (60 F) for about a week. If cutting larger amounts of seed potatoes, sanitary measures should be taken with knives and cutting surfaces to reduce possible disease transfer.

Potatoes can be planted when the danger of hard frost is past and soil temperatures have reached

50 F (faster shoot emergence will take place when soil temperatures are above 59 F). Seed pieces can be planted in furrows 3 to 4 inches deep, 6 to 12 inches apart, in rows about 30 to 42 inches apart. Surrounding soil can be pulled into a pile around the base of the plant as it grows (hilling) to make sure that developing tubers are covered and do not turn green. A green color on the tuber indicates the toxic compound solanine is accumulating in the skin. Hilling can be done about four weeks after planting (when plants have emerged and are about 6 inches tall) to mid-season.

Another method of growing potatoes involves planting them more shallowly (1 to 2 inches) and then covering them with organic matter (straw, dried grass clippings). More organic matter is added as the season progresses. This allows potatoes to be harvested more easily.

Potatoes are sensitive to water stress due to their shallow root system. They require good soil moisture throughout the growing season. Over or underwatering can result in potato tubers with abnormal growth. Make sure to be careful during cultivation to avoid damaging developing potatoes.

DAYS TO MATURITY

90–120 days.

HARVESTING

An early crop of potatoes can be dug or harvested by hand before the skins are set; however, yield will be greater if the crop is harvested after the vines have died back or been killed by frost and dead for about two weeks. At this point, the skins of the potatoes will have toughened, and they will be easier to harvest without damaging the tubers and store better.

Store in a cool (50 to 55 F), humid (95 percent relative humidity) and dark area (light can cause greening and development of solanine). Potatoes store even better at lower temperatures (above freezing) but when held at these temperatures, the starch in potatoes can start converting to sugar. The sugar will caramelize and cause burned areas if the potatoes are fried. Increasing the temperature to around 66 F for several days allows the sugar to convert back to starch before cooking.

SOME COMMON VARIETIES

- All Blue (blue tuber)
- Early Ohio (white skin)
- French Fingerling (red skin, yellow flesh with dapples of red)
- Kennebec (brown skin)
- Magic Molly (purple skin and flesh)
- Red Norland (red skin)
- Red Pontiac (red skin)
- Yukon Gold (yellow tuber)

INSECT PESTS

Pests often affecting seedlings

Although potatoes are generally started from pieces of tubers rather than seed, the young plants can still be easily killed by **cutworms**. Multiple **flea beetle** species are common early spring pests that can harm young plants with their pitting and "shot hole" type leaf damage (See the Cutworm and Flea beetle management sections under Integrated Pest Management, page 42, for additional information on both of these pests.). **Wireworms** can be an issue for seed potatoes (see following section, page 143).

Affecting vegetative growth (pests that chew leaves or pierce and suck plant juices)

See the Integrated Pest Management section, page 42, for additional information on several of the insects listed below.

Green peach aphid and **potato aphid** feed on potato, and their excrement (honeydew) can result in sooty mold on the leaves. The mold and feeding damage can reduce potato yields. **Beet leafhopper** (*Neoaliturus tennelus*) is present in the state and can vector curly top virus to potatoes. Their feeding activity can also

physically damage leaves. Conventional control methods for aphids and flea beetles in the field also work on leafhoppers.

Colorado potato beetles (*Leptinotarsa decemlineata*), adults and larvae can rapidly defoliate plants with their chewing mouth parts.

Grasshoppers are usually a late summer problem and generally move into fields from the fence rows and borrow ditch habitats where they hatch.

Blister beetles, **cabbage looper**, and **climbing cutworm** species can also defoliate potatoes. The most critical time to prevent defoliation is just before and during "tuber bulking," which starts soon after potato flowering.

Insect pests affecting the saleable parts directly

Shallow tubers can be damaged by various cutworm species, field mice, and slugs. Proper hilling of the plants should prevent damage from these pests and tuber greening.

Several species of click beetles whose soil-dwelling larvae are called wireworms will feed on the tubers. This illustration shows all of the life stages and the typical damage the larvae can inflict on potatoes, roots, and bulbs.
Art Cushman, USDA Systematics Entomology Laboratory, Bugwood.org

Wireworms, the larvae of multiple species of click beetle, and the larvae of the tuber flea beetle can damage the marketable portion of a crop. The damage happens out of sight in the soil, so it can be hard to detect and impossible to cure.

Wireworms are ubiquitous insects on farmland, and populations of their larvae can become high in the soil following certain crops such as corn and small grains. If potato crops follow those crops favored by wireworms or are planted in pastures being converted to production, the damaging, multi-year-old larvae

can feed on seed pieces, seedlings, and eventually tubers. A potato grower should determine before they plant if they have crop damaging densities of some of the over 30 species of wireworms known to attack the crop. Detecting them early will give growers more options to control the pest or allow them to choose not to plant potatoes in an infested field. Determining the population density of wireworms requires either sifting soil samples to reveal the presence of the larvae or the use of bait stations. University studies have shown wireworm baiting is a superior, less labor-intensive method of checking fields than the soil sifting method. A complete and detailed bulletin on wireworm sampling titled "*Wireworm Biology and Nonchemical Management in Potatoes in the Pacific Northwest*" bulletin PNW 607 is available online at: https://bit.ly/SARE-wireworm.

There are multiple nonchemical methods of control detailed in the bulletin. These can be integrated with some chemical control options detailed in a 2020 bulletin ENT-216-20 title "*Wireworms*" from Utah State University, https://bit.ly/usu-wireworm.

A potato grower has to keep in mind all the options for wireworm management are preventative and not curative. They must determine if their fields are infested and decide what control options they can take to prevent crop damage before planting the potatoes.

Unlike wireworms, species of **flea beetle** show up first as adults feeding on the foliage of potato plants. There are many species of flea beetles that will feed on potato plant leaves, but only one has larvae that will feed on the developing tubers. The descriptively named **tuber flea beetle** (*Epitrix tuberis*) is dull black, barely 2mm long as an adult, and has yellowish-brown legs. This combination of characteristics help distinguish them from other flea beetle species found feeding on potato leaves.

The pitting and shot holes the adult beetle's feeding damage inflicts on the leaves of a vigorously growing plant is minor. The damage to the tuber surface by the larvae feeding is severe in that it can make an otherwise fine spud unmarketable. Foliar treatment with a wide array of insecticide products labeled for both garden and agricultural use against the adult tuber flea beetle is advisable when the pests are detected on your potatoes. For those growing larger crops of potatoes, pest population thresholds have been developed using the number of adult tuber flea beetles caught with a standard 15-inch diameter, sail-cloth insect net. As few as four beetles per 50 net sweeps through potato plants can be the action threshold for treatment. Early detection and action is needed in the growing season as the tuber flea beetle can produce three generations per year. If the overwintering tuber flea beetle population can be suppressed, damage to tubers appearing later in the growing season can be reduced. The economic threshold varies with the pest's population, cost of treatment, and value of the potato crop.

Adult potato/tomato psyllid
Whitney Cranshaw, Colorado State University, Bugwood.org

Potato psyllid (*Bactericerca cockerelli*) insects feed with piercing, sucking beaks on the leaves of the plant. While feeding, they can transmit zebra chip virus, which both reduces yield and destroys the commercial value of the tubers. The infected potatoes are still edible but will exhibit brown strips when they are cooked. Monitor your fields weekly with yellow sticky cards or a sweep net so you will detect the arrival of the psyllids. If psyllids arrive infected with the bacterium that causes zebra chip, they can rapidly transmit it to the potato plants with just one feeding. At this time, the University of Idaho Extension recommends in-furrow treatment of potato sets with a systemic insecticide from the 4A mode of action group for commercial growers. Then follow up with

foliar treatments using insecticides with modes of actions (such as group 3A,5,6, 9B or 23 insecticides) different from the systemic product after its residual activity dissipates, to protect conventionally grown potatoes from disease transmission by the psyllids.

The adult potato/tomato psyllid (*Bactericera cockerelli*) migrates into northern states on winds from the south. They resemble miniature cicadas in form and feed on plant sap. Their saliva alone is enough to damage the plant and cause premature sprouting of tubers while in storage after harvest. The pests also have the ability to vector plant pathogens such as the one that causes zebra chip disease. More detailed information on the management of this damaging pest of potatoes can be found at: https://bit.ly/UID-psyllid.

DISEASES AND DISORDERS

Physiological disorders affecting potato plants (abiotic disorders)

Physiological leaf roll

Leaf roll is associated with hot dry weather, rapid growth, and certain varieties. It can be confused with virus symptoms or psyllid infestations that can cause similar leaf rolling symptoms. Typically, starting with the lower leaves, leaf margins roll inward in an almost tube-like fashion. The affected leaves will be firm and leathery to the touch. Once rolled, the leaves typically do not unroll, but this condition does not seem to affect yield.

Tip burn

Margins turn yellow, then brown at the end of the leaf. Tip burn can be caused by excess moisture loss from leaves during hot weather followed by cooler conditions. The effect is mostly cosmetic and does not harm the potato.

Herbicide injury

Potatoes are very sensitive to many of the broadleaf herbicides commonly used by homeowners that include the auxin-type herbicides like 2, 4-D. Injury, in the form of leaf and stem distortions, can occur from direct contact from foliar spray and indirectly from herbicide-treated grass clippings, or grass-clipping compost applied around potatoes.

Physiological disorders affecting potato tubers (abiotic disorders)

Enlarged lenticels

Lenticels are the small and usually inconspicuous pores present on the tuber surface used for gas exchange. Under conditions of excessive soil moisture, or very dry compacted soil, tissue beneath these lenticels can swell and then burst resulting in tissue damage. This damaged tissue eventually is replaced by raised corky tissue (like a scab). Mostly a cosmetic issue, but enlarged lenticels can predispose the tuber to decay-causing organisms. Avoid overwatering especially toward the end of the growing season to manage this disorder.

Sunscald and tuber greening

Both disorders are associated with exposing developing tubers to excessive sunshine. Sunscald tubers can develop under frequent or prolonged exposure to intense sunlight and temperatures. These tubers have a blistered and metallic appearance. In contrast, even low light exposure on tubers can stimulate chlorophyll production causing a condition called tuber greening. The alkaloid compounds produced with greening can be mildly toxic to humans. To manage these disorders, maintain soil coverage over developing tubers and avoid long-term exposure of tubers to light at harvest and storage.

Hollow heart

Hollow heart can occur when growing conditions fluctuate rapidly during tuber development. This disorder is not apparent until the potato is cut open, revealing a crater in the middle or stem-end center of the potato. Brown discoloration may or may not be present. Environmental conditions such as inconsistent watering, large fertilizer applications, or highly variable soil temperatures increase the likelihood hollow heart will develop. Hollow heart can be difficult to prevent, but consistent watering and fertility can reduce occurrences.

Infectious diseases of potato

Seed tuber diseases

Seed tubers are susceptible to fungal and bacterial diseases that can affect their ability to produce a viable plant. Purchase high-quality certified seed potatoes. Select seed tubers that are free of surface defects and have firm (not spongy or rotted) tuber flesh.

Whole plant and root diseases

Early blight disease symptoms are brown to black spots on the leaf, which sometimes resemble targets. Disease symptoms usually show themselves later in the season on older leaves. Lesions will appear on newer leaves if the disease worsens. Significant disease can cause tuber yield reductions. Good control measures include removing fallen, diseased leaves, avoiding wetting leaves during watering, no dense plantings, and not planting potatoes in the same space next year (rotation). Using protective fungicides at the first sign of disease can be effective in reducing severity.

Fusarium and **verticillium** are soil-borne fungal pathogens that attack the plant's vascular system (which carries water and minerals up from roots to leaves). Symptoms include lower leaves yellowing then dropping, with overall plant wilting, leading eventually to an early plant death. A cut stem is a handy diagnostic test. Disease is present if there is a dark discoloration of the vascular system instead of a nice, healthy, green color. Once these fungi enter the vascular system, there is little that can be done for the plant; the best defense is prevention. Remove affected dead tissue on plants and avoid planting back to potatoes in that space for at least three years.

Rhizoctonia stem canker is caused by the soil-borne fungal pathogen *Rhizoctonia solani*. Symptoms can be found on all underground parts of the potato during the growing season. Most prominent are reddish brown to black lesions on sprouts, stolons, and roots. Lesions are often sunken and can enlarge to girdle the affected plant part. This disease can be seed-borne (see black scurf tuber disease) or present in plant debris and soil. Plant disease-free seed tubers to avoid it. Planting too early in cool, wet soils can increase disease severity. Crop rotation may have limited impact unless it's out of potatoes for more than two years.

Viral diseases

Several viruses can infect potato in Wyoming including, but not limited to, **curly top virus, tomato mosaic virus,** and **leaf roll virus.** Symptoms of virus infections include leaf mosaic (alternating areas of light- or dark-green or yellow), yellowing, necrosis, malformation (leaf rolling, puckering and twisting), leaves and stems becoming stiff, and stunting. All of these viruses are spread by insects like leafhoppers and aphids and can survive in the absence of potatoes on many common weeds and some agronomic and horticultural crops (like tomatoes). Growing resistant varieties is the most effective management strategy. Read variety descriptions to determine which viral resistance each variety has. Little can be done once a plant is infected. Remove the plant to keep these viruses from spreading farther via insects.

Tuber diseases

Common scab is caused by a soil-borne bacterium and can be problematic in Wyoming's high pH soils. Symptoms are characterized by brown tuber skin lesions at harvest that are roughened, raised or sunken, usually 5 to 10 millimeters in diameter but can coalesce to cover large areas of the tuber. Yields and taste are not affected but tuber quality, and hence marketability, and storability are negatively impacted. Once established in the soil, this disease can be difficult to manage. Some potato varieties are less susceptible to common scab, but none are immune. Avoid introducing this disease to your growing area by not planting scabby seed tubers. Disease incidence can be reduced by lowering soil pH to below 5 and/or maintaining high soil moisture for four to six weeks starting at tuber initiation. A three- to four-year rotation out of potato can reduce the amount of inoculum in the soil.

Also caused by *Rhizoctonia solani*, **black scurf** is characterized by little brown-black, hard masses evident on the tuber surface at the growing season's end. These fungal resting bodies (sclerotia) are superficial and don't wash off but don't damage the tuber, even in storage. To manage, start with disease-free seed tubers and avoid leaving the tubers in the ground for prolonged periods after skin-set (when skin of the potato does not tear easily when a sideways pressure is applied).

PUMPKINS AND WINTER SQUASH

Cucurbita maxima

Pumpkin is a very popular vegetable that finds its way to the doorsteps of many households each fall. These brightly colored orange globes are actually a type of winter squash. Winter squash, including pumpkins, have thick rinds. This is one characteristic that differentiates them from summer squash, which have very thin skin. Winter squash is in the Cucurbitaceae family along with summer squash, gourds, and many other crops.

When selecting varieties of pumpkins or other winter squash, consider matching the variety to your growing area. Look for a variety that has a short number of days to maturity if your area is at a high elevation or is prone to early frost. Some species of pumpkin have vines that can cover up to 500 square feet, or a 20-by 25-foot growing area and might not be well-suited for smaller spaces. Decorative and eating varieties of winter squash come in a wide range of colors and shapes besides orange and round. They can be solid or a mix of pink, green, brown, white, yellow, orange, or red in color with smooth or bumpy skin. Many decorative varieties with warts are sought after for their distinctive shape.

Judith Andrews, shutterstock.com

GROWING CONDITIONS

Winter squash are warm-season plants that enjoy full sun and hot growing conditions. Think about the number of growing days for your area and the available space when considering growing pumpkins or other winter squash. Pumpkins generally take around 100 days for maturity and require large amounts water and nutrients.

Weed control and water are important for good production. Weeds should be pulled to help manage competition with plants. Try to plant winter squash dense enough to shade out any weeds if planting large numbers of plants. Water should be available to plants at all times, especially during hot weather conditions when plant growth and production is high. Winter squash prefer soil that is well-drained and high in nutrients and organic matter. Compost can be incorporated before and after planting.

PLANTING

Winter squash can be planted in hills or rows when soil temperatures reach a minimum of 60 F, with 70 to 90 F being more optimal. Varieties have vining, semi-bush, or bush growth habits. For vining varieties, 3 to 8 feet should be left between hills and 6 to 8 feet between rows. Shorter distances can be used for semi bush (4 feet between hills, 8 feet between rows) and bush types plants (3 to 6 feet between hills, 4 to 6 feet between rows). Seeds can be planted in groups of four to five and then thinned to one to two seedlings per planting location once they are several inches tall. Seeds should be planted 1 inch

deep. Transplants can be used to get a jumpstart on the season; however, care should be taken to be gentle with their roots when transplanting.

Unfortunately, due to the size of pumpkin and other winter squash plants, season extension for maintaining plant health early or late in the growing season can be challenging. Floating row covers and other materials can be used to help protect plants from cold temperatures. Removing these materials during the day is important once flowers open so they can be properly pollinated by bees. Winter squash have male and female flowers. Female flowers look like they have a tiny squash at their bases; male flowers have skinny stems. Inadequate pollination is often the cause for poor fruit set or malformed fruit. The first flowers to appear on plants are generally male flowers that help attract pollinators to the plant, so don't worry if they don't start to develop fruit right away.

DAYS TO MATURITY

90–120 days.

HARVESTING

Winter squash should be harvested when fruits have developed a hard skin and turned color and before they are injured by hard frosts. Make sure to leave at least 2 inches of the stem attached to the squash/pumpkin to help preserve the fruit. Fruits can be stored for many months in a cool, dry, and dark location. Remember to rotate where you plant squash each year.

SOME COMMON VARIETIES OF PUMPKINS

Medium-sized eating and decorative

- Lumina (90)
- Rouge Vif D'Etampes (95)
- Silver Moon hybrid (95)
- Connecticut Field (100)
- Long Island Cheese (105)
- Boston Marrow (110)
- Howden's Field (110)
- Musquee De Provence (120)

Large decorative

- Atlantic Giant (110-125)
- Big Max (110)

Small eating

- Red Kuri (95)
- New England Sugar Pie (100)
- Boston Marrow (100)
- Naked Bear hybrid (105)
- Small Sugar (105)

Small to medium decorative

- Mini Harvest hybrid (95)
- Jack-Be-Little (100)
- Black Futsu (105)

SOME COMMON VARIETIES OF OTHER WINTER SQUASH

- Early Acorn (75)
- Table Queen (80)
- Red Kuri (92)
- Buttercup—including bush varieties (95)
- Connecticut Field pumpkin (100)
- Waltham Butternut (105)
- Spaghetti (100)
- Boston Marrow (105)
- Delicata varieties (105)
- Blue Hubbard (110)

INSECT PESTS

Look under the cucumber section for information on common insect pests of Winter squash, page 96.

DISEASES

Look under the cucumber section for information on common diseases of Winter squash, page 96.

RADISH

Raphanus sativus

Look no further than radishes when looking for a fast-growing, cool-season and easy-to-grow crop in Wyoming. Although they might be small in size, radishes pack big flavor in a small root. This root crop fits into many tight spaces, and it does not take a large crop to add a lot of flavor to a salad mix.

Radishes are in the Brassicaceae family along with turnips and broccoli. They probably originated in the Mediterranean region and have been cultivated since before Romans roamed that region.

Not all radishes are small, red, and round. Radishes can be found in colors of red, white, pink, purple, yellow, green, and black. Some varieties are also shaped long and slender like carrots or cylindrical like beets. Spiciness can range from mild to a strong, pungent flavor. Spiciness can be managed by not allowing radishes to overmature, selecting varieties that are milder, and not stressing plants.

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Growers have split this cool-season plant into salad/spring and storage/winter types. Salad type radishes are fast maturing and can be harvested in 28 to 35 days. Winter type radishes take more time and are ready for harvest at 60 to 75 days. Daikon's are a type of winter radish. Salad type radishes are relatively small. Most are harvested when they are the size of a ping-pong or golf ball. Winter varieties are usually planted later than spring radishes. The goal is to plant them for an end maturity date close to the first frost of the year. For some Wyoming communities, the 60 to 75 days to maturity is the same length of time for the entire growing season. Some winter varieties can average 15 pounds, while most are the size of spring radishes.

GROWING CONDITIONS

Radishes do well in soils that are well-drained and receive consistent moisture. Irregular watering or delayed harvesting can cause bitterness, hot taste, and cracking of roots. High temperatures will create pithy, hot, poor-quality roots.

PLANTING

Radishes should be planted by seeds. Seeds can be planted once soils reach 40 F. They can be broadcast or seeded in rows. Allow 8 to 18 inches between rows and ½ to 1 inch between plants. Seeds should be planted ½ inch deep. Light raking can be used to work radish seeds into the soil when broadcast seeding. Radishes can be mixed with other seeds such as carrots. Mixing can help create a decreased seeding rate for the carrots and to prevent overcrowding. The radishes will mature much more quickly than the carrots, so they do not interfere with carrot growth. Radishes grown too close together (or too late in

the spring) will not develop normally. Short-season varieties can be sown for a spring and a fall crop. Succession planting will provide an extended season of harvest.

DAYS TO MATURITY

28–75 days.

HARVESTING

The size at which to pick radishes depends on the variety. They are often harvested once they are 1 to 2 inches in diameter. If radishes are to be sold immediately, their tops can be left on, but for better storage, the tops should be removed and the root washed once picked. The roots without their tops can be stored in a cool, humid location for two to four weeks. Winter radishes can be stored longer.

SOME COMMON VARIETIES

Winter

- China Rose (52)
- Chinese White (60)
- Round Black Spanish (60–70)

Salad

- Saxa (18)
- Cherry Belle (21)
- French Breakfast (25)
- Champion (25)
- Early Scarlet Globe (25)
- German Giant (29)
- White Icicle (30)

INSECTS

See the insect pests listed under cole crops in the Broccoli section, page 78.

DISEASES AND DISORDERS OF BRASSICA ROOT CROPS (RUTABAGA, TURNIP, RADISH, AND HORSERADISH)

Physiological disorders (abiotic disorders)

Radish pithiness

Pores are formed in the root caused by excessive root growth, giving it a pithy texture. Tends to occur more in radishes that have been harvested too late. Avoid this disorder by harvesting promptly.

Splits and cracks

The splitting and cracking of roots occurs after a lack of irrigation and then a sudden onslaught of moisture, such as a downpour after a period of drought. Maintain consistent watering and have a well-drained soil.

Deformed and misshaped roots

Caused by a number of environmental factors and some diseases, but mostly due to poor soil conditions. Compacted soils should be loosened and amended with compost. Avoid overcrowding plants.

Infectious diseases

Seedling diseases

Brassica root crops are susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

Whole plant and root diseases

Leaf spot fungi are caused by *Alternaria* and *Cercospora* spp. These pathogens do not infect the root, but infection can reduce yield, and blighted foliage can reduce the value of fresh-packed plants. To help reduce leaf spot, buy hot-water treated seed, reduce weeds, and plow under crop debris in the fall.

Black leg or **Phoma leaf spot** is a fungal pathogen of rutabaga and turnip. From foliar lesions, the pathogen spreads into leaf veins to the petioles and eventually the main stem. On root crops, such as rutabaga and turnip, a dry rot of the bulb or hypocotyl

develops. The neck and shoulder areas have large, brown lesions, and an extensive dry rot develops deep into the fleshy tissue. Severely affected bulbs become shriveled and dry and are often invaded by secondary fungal and bacterial decay organisms. Start with certified disease-free seed or treat seed with hot water or fungicides. Rotate to non-susceptible crops. Completely cover with soil (turn under the soil) infected crop debris after harvest.

Diseases caused by *Rhizoctonia solani* include **wirestem** and **damping off** (seedlings), and **crater rot** (rutabaga, turnip, and radish). Rhizoctonia can be carried on the seeds of most brassica species and are a natural inhabitant of the soil where it can survive indefinitely. Start with certified, disease-free seed. Avoid soil previously used for brassica production. Practice good sanitation throughout crop cycle. Use treated seed for direct seeding into field. Practices that encourage rapid germination and establishment limit disease development. Avoid planting transplants too deeply. Rotate crops. Do not plant susceptible crucifers in fields with undecomposed crop residues. No highly resistant cultivars are available.

Fusarium Yellows, a fungal pathogen, is soil-borne and may also be seed-borne. Plant resistant varieties. Prevent the movement of infested soil to clean fields. Provide adequate fertility; potassium deficiency increases disease severity.

Root diseases

Club root is a root disease caused by the pathogen *Plasmodiophora brassicae*, an organism similar to slime molds. The first symptom usually seen is wilting of plants during the day. As the disease progresses, leaves will yellow, die, and plants will be noticeably stunted compared to healthy plants. Belowground, roots will start out by having small swollen growth characteristics and then will eventually have large club-like masses. Early infected plants will die, and ones that survive will not produce a marketable product. Can survive in soils for up to 10 years and can spread by infected transplants and water and soil movement. Can be managed by maintaining a soil pH of 7.3 and higher.

RHUBARB

Rheum rhabarbarum

Usually the earliest vegetable available in spring and showy enough to be an ornamental, rhubarb is a prized perennial vegetable. Rhubarb is a native of central Asia and is in the Polygonaceae, or buckwheat, family along with knotweeds and smartweeds. Rhubarb leafstalks are the plant parts used in sauces and pies. Types include red-stemmed and green-stemmed varieties. One very important point to remember about rhubarb is the leaves are toxic and should not be eaten.

GROWING CONDITIONS

Rhubarb prefers cool climates, grows well in Wyoming and best in well-drained soils with a pH between 5.5 and 7. Plants require regular irrigation.

PLANTING

Plant crowns about 3 to 6 inches deep, 2 to 3 feet apart, in rows 4 to 6 feet apart. For large plantings, fertilize each acre with 70 to 80 pounds of nitrogen, 70 to 80 pounds of phosphorus, and 140 to 160 pounds of potassium during the first growing season.

MAINTAINING PLANTS

From the second growing season on, fertilize each acre with 140 to 160 pounds of nitrogen, 70 to 80 pounds of phosphorus, and 140 to 160 pounds of potassium, depending on results of soil tests. Irrigate on a regular basis, including winter when there is no snow cover and the ground is not frozen.

HARVESTING

Rhubarb stalks should not be harvested until the third growing season after planting. At that point, stalks are pulled, not cut, for 4 to 5 weeks. Never over-harvest because the plants need stems and leaves to regenerate for the next growing season. When removing stalks, pull outward and to the side to remove the entire stalk. Cutting is not recommended because it leaves stubs behind on the plant, which usually rot and compromise the health of the plant.

SOME COMMON CULTIVARS

Red-stemmed varieties

- Cherry
- Canada Red
- Crimson Red
- Valentine

Green-stemmed varieties

- Riverside Giant

Pink-speckled types

- German Wine
- Strawberry
- Victoria

INSECT PESTS

Few pest insects feed on the fleshy stalks; however, **armyworms**, **cutworms**, and some **looper species** caterpillars eat the leaves. Implementing a good weed control program around the rhubarb patch will help reduce the number of egg-laying by female moths and survival of overwintering larvae. Another pest that can consume the leaves (which contain poisonous oxalic acid) are actually crustaceans and members of the family Armadillidiidae, with common names such as **rollie pollies**, **pill**, and **sow bugs**. Because

Steve Cymro, shutterstock.com

they are crustaceans, they are not capable of getting oxygen directly from air. They actually have gill-like structures on the underside of their abdomens that require very humid air to function. Modifications to dry out the habitat under rock, wood, and heavy mulch where these pests can shelter during the daylight hours can reduce the leaf feeding damage on rhubarb plants to a minor level.

Pests often affecting seedlings

Rhubarb is usually grown from pieces of root crowns. Like any new planting, the starts have limited resources to help them survive severe insect feeding damage; however, this type of damage is uncommon. Tarnished plant bugs will sometimes feed on the first leaves but will only be a problem on new plants. Pocket gophers are known to eat rhubarb roots.

Affecting vegetative growth (pests that chew leaves or pierce and suck plant juices)

The **black bean aphid** (*Aphis fabae*) and the **dock aphid** (*A. rumicis*) will feed on the underside of rhubarb leaves. The aphid feeding damage can curl the leaves, which reduces the leaf function and protects the aphids from predators, insecticide sprays, and inclement weather. The black bean aphid can also spread from rhubarb into other susceptible crops like beans and corn.

Garden slugs are another pest that can successfully feed on rhubarb leaves. They hide during the day so scouting at night or searching under adjacent mulch or leaf debris during the day may be necessary to locate them.

Insect pests affecting the saleable parts directly

Rhubarb curculio (*Lixus concavus*) can damage rhubarb stalks when they chew holes into them to deposit eggs. Despite the pest's common name, the insect's eggs cannot successfully complete their development in rhubarb plants but can on dock, sunflowers, and some thistles. Control of these alternative host plants, if possible, will eliminate the pest from your rhubarb patch.

DISEASES AND DISORDERS

Physiological disorders (abiotic disorders)

Edema

Edema appears on rhubarb as spots visible on the upper side of the leaves and small "blisters" that can be seen on the underside. Conditions of high soil moisture paired with sudden low temperatures create excess water in the plant. This causes epidermal cells to swell and burst. Edema is usually worse on older and lower leaves. Impact on the plant is minimal and mostly cosmetic in nature.

Tip burn

Leaf edges are brown and become increasingly necrotic with age. This is thought to occur during periods of rapid growth due to a plant not being able to take up enough calcium to support the new growth. Some varieties are resistant to tip burn. Avoid creating excess nitrogen levels in the soil.

Infectious diseases

Foliar diseases

Ascochyta leaf spot is a fungal disease characterized by leaf infections that first appear as small, green-yellow, irregular spots less than ½-inch in diameter on the upper leaf surface. The leaf develops a mosaic appearance as the lesions unite. Later, the spots develop white centers surrounded by reddish margins, bordered by a grey-green zone. In a few days, the infected spots turn brown, die, and fall out, producing a "shot-hole" appearance. Aschochyta does not cause stalk infections. Best management is to practice good sanitation by removing and disposing of infected plant tissue. Harvest infected leaves first as the stalks are still good to use. Dispose of the leaves to prevent disease spread.

Ramularia leaf spot is a fungal disease where foliar lesions first appears as small red dots that gradually enlarge to form circular lesions a ½ inch or more in diameter. Larger spots become white to tan with purplish halos. Stalk infections occur later, appearing as small spots that elongate as the stalk grows and can become sunken in appearance. A white fungus

develops in the centers of the spots on leaves and stalks, becoming brown as the tissue dies. The presence of stalk infection is a key symptom that differentiates Ramularia from Ascochyta infection.

Whole plant and root diseases

The fungal disease **anthracnose stalk rot** is favored by wet spring conditions or other environmental stresses. Initially, affected plants have wilted leaves and large water-soaked lesions on the stalks. The lesions increase in size and eventually turn black. The stalks may also look twisted and, eventually, the whole stalk may collapse. This disease overwinters in infected tissue, so practice good sanitation and promptly remove affected plant tissue.

There are several **root and crown rot diseases** from various fungi and bacteria that can affect rhubarb. Plants lack vigor, leaves may turn yellow to red before collapse. Crowns may exhibit a brown-black decay. Make sure to plant healthy root stock and plant in well-drained soil. Remove infected tissue completely from growing area.

RUTABAGA

Brassica napus

Rutabagas are thought to be a cross between a turnip and a cabbage. They are eaten far more in Europe than they are in the U.S. but deserve attention in the American diet as well. They are sweet and can handle cooler climates, making them ideal for Wyoming production. Botanically, they are in the Brassicaceae family along with broccoli and cauliflower.

Rutabagas are close relatives of turnips but have thickened yellow roots instead of the mostly white roots of turnips. They are best sown for fall harvest as they are a late-maturing crop whose flavor is often made sweeter by frosts.

GROWING CONDITIONS

Rutabagas grow well in loose, well-drained, fertile soils. Heavy soils should be dug to loosen the soil and amended with compost for best root growth. Rutabagas have a rather long growing season (90 days or so), but growth slows in hot weather; however, rutabagas are biennial plants, and temperatures below 50 F for extended periods can cause young plants to bolt (send up a flower stalk). This will produce poor-quality roots.

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Rutabagas grow best with consistent irrigation. Rutabaga flavor is milder if the soil is kept evenly moist during the growing season. Dryer soils tend to make flavors more pungent. Inconsistent irrigation can also produce woody, bitter roots. Organic mulches can be used to maintain soil moisture, reduce weed competition, and cool soils.

PLANTING

Selecting early maturing cultivars is useful when seeding this crop for fall harvest. Since rutabagas can tolerate frosts and the flavor improves with them, seeding dates can be scheduled using a maturity date about two to three weeks after the anticipated first fall frost.

Seeds should be planted ¼- to ½-inch deep. Plants should be about 5 to 8 inches apart in rows 18 to 36 inches apart.

DAYS TO MATURITY

90 to 100 days.

HARVESTING

Rutabagas are generally harvested after some fall frosts have occurred as cooler temperatures sweeten the roots. Generally the roots are 4 to 5 inches in diameter. Rutabagas can be stored for long periods at 32 to 35 F with a relative humidity of 90 to 95 percent. When raised for sale, the tops are trimmed off and their roots are often dipped in wax to prevent dehydration.

SOME COMMON VARIETIES

- American Purple Top (90)
- Laurentian (90)
- Joan (90)
- Helenor (90)

INSECT PESTS

See the insect pests listed under cole crops in the Broccoli section, page 78.

DISEASES AND DISORDERS

See the diseases and disorders listed under Radish, page 151.

SPINACH

Spinacia oleracea

Spinach is an annual vegetable with nutritious, dark-green leaves that mature quickly. Spinach is in the Amaranthaceae plant family (along with beet and swiss chard) and probably originated in western Asia but has been cultivated in Europe since the 1400s.

Spinach has a lot of attributes that make it a good crop for many parts of Wyoming. Spinach is a relatively short duration crop compared to other vegetables in part because the leaves are consumed so there is no need to wait for a root or fruit to develop for harvest. Spinach plants do not take up a lot of room, making it an easy addition to a growing space. Spinach does require cool temperatures for best growth and development. The plants will flower and go to seed quickly when days are long and temperatures increase in late summer.

Jiri Hera, shutterstock.com

GROWING CONDITIONS

Spinach grows best in cooler temperatures and can tolerate periods of frost. Optimum temperatures for growth are 59 to 68 F. Hot temperatures often cause spinach to bolt. Bolting occurs when cool-season annual plants such as lettuce or spinach begin to complete their life cycle by producing a flower head to develop seeds for the next generation of plants. Heat tends to promote this life cycle phase.

Spinach can be grown in a wide variety of well-drained soils. Consistent irrigation is important as drought stress will produce smaller, bitter leaves in spinach.

PLANTING

Spinach can be planted as soon as the soil can be worked in the spring. Most leaves are ready for harvest between 40 and 50 days. Successional seeding at two-week intervals can be completed to obtain a continuous crop during the early growing season. Seeds can also be planted during the latter part of summer to obtain a fall crop for harvest.

Seeds are best directly seeded into the ground but can be transplanted. Seeds can be planted in late fall (October–November) for an early spring crop. They will germinate once the soil begins to thaw in the spring (soil temperatures over 35 F). For spring planting, plant once the soil has started to thaw and two to three weeks before the last anticipated frost. Seeds planted in late summer for a fall crop should be chilled in the refrigerator for one to two weeks before planting. Season extension structures, greenhouses, and sunrooms can help keep spinach alive much longer into the fall or winter, and sometimes year-round.

Slow bolting types of spinach are best for spring and late fall plantings. Fast bolting or fast maturing

varieties work well for late summer plantings. Plant seeds ½-inch deep into high-quality soil. Maintain 2 to 6 inches between plants in rows 12 to 36 inches apart. Spinach being grown for baby spinach leaves can be planted closer (down to an inch apart or less).

Spinach is frost resistant and can be grown under protection for extended harvest periods into the winter and early spring harvest. For this, spinach should be planted early enough to be fully grown by the time winter arrives, as growth will come to a stop.

As with lettuce, spinach is shallow rooted. Consistent irrigation is important.

DAYS TO MATURITY

40–70 days.

HARVESTING

Soil on spinach and the associated cleaning can sometimes be an issue. Variety selection can reduce this issue. Savoy-type varieties have crinkled leaves that hold more soil than flat-leaved types and make it harder to clean off. Choosing varieties that have smoother leaves and are more upright in shape will help reduce soil collection.

Spinach can be grown as a cut-and-come-again crop. Baby spinach can be cut at 1 inch. It will grow back for successive harvests. For larger spinach, cut leaves just above the crown of the plant. After harvest, wash the leaves thoroughly, allow to dry, and store in a cold location at high humidity. Proper harvest and care is important for maintaining plants.

SOME COMMON VARIETIES

- Space (37)
- Indian Summer (39)
- Tyee (39)
- Avon (44)
- Noble Giant (45)
- Olympia (46)
- Teton (48)
- Bloomsdale Long Standing (50)

INSECT PESTS

See the Beet section for information on the insect pests of spinach, page 72.

DISEASES AND DISORDERS

Physiological disorders (abiotic disorders)

Edema

Edema appears on spinach as spots visible on the upper side of the leaves and small "blisters," which can be seen on the underside. High soil moisture paired with sudden low temperatures create excess water in a plant. This causes epidermal cells to swell and burst. Edema is usually worse on older and lower leaves. Impact on the plant is minimal and mostly cosmetic.

Tip burn

Leaf edges are brown and become increasingly necrotic with age. Thought to occur during periods of rapid growth due to the plant being unable to take up enough calcium to support new growth. Some varieties are resistant to tip burn. Avoid creating excess nitrogen levels in the soil.

Infectious diseases

Seedling diseases

Spinach is susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

Foliar diseases

Anthracnose is a fungus (*Colletotrichum spinaciae*) characterized by small, water-soaked spots on the leaves. Under favorable, very wet, conditions, the disease progresses and the spots enlarge, turn tan and coalesce. This can kill the entire leaf. Spores are spread by splashing water from rain or irrigation. The fungus can survive in crop residue. Avoid anthracnose occurrence and spread by using disease-free seed,

proper soil fertility, avoid wetting foliage if possible during irrigation, and disposing of infected crop debris.

Stemphylium leaf spot is caused by the fungus *Stemphylium botryosum* f.sp. *spinacia*. Initial symptoms of Stemphylium leaf spot on leaves are small (less than a quarter inch in diameter), circular to oval, gray-green leaf spots. These leaf spots enlarge and turn tan in color as the disease progresses. Older spots coalesce, dry up, and become papery in texture. Overall, symptoms resemble the tan, circular spots caused by pesticide or fertilizer damage. The fungus grows under a wide range of temperatures but prefers cool (65 to 74 F) and humid conditions. This pathogen is seed borne and can also survive in crop residue. To manage, treat suspect spinach seeds with hot water (104 to 122 F for 10 to 20 minutes) and incorporate crop residue after harvest.

Whole plant and root diseases

Fusarium wilt is a soil-borne fungal disease (*Fusarium oxysporum* f.sp. *spinaciae*) that can survive many years in the soil without a spinach crop. It can cause a seedling disease (see the seedling disease section, page 27) but also can cause a wilt with yellowing of lower leaves and premature death in older plants. Cross sections of roots and lower stems may exhibit darkening of the vascular tissue. Manage with crop rotation (up to six years), early planting of disease-free seed, and minimization of moisture stress. Fusarium wilt tends to occur more in acidic soils.

Verticillium wilt (*Verticillium dahlia*) is another soil-borne fungal disease of spinach. Like Fusarium, this fungus is long-lived in the soil and invades the plant's vascular system through the plant roots. Symptoms include lower leaf yellowing followed by interveinal chlorosis, stunting, and wilt. Disease tends to be more severe in high pH soils. Vascular discoloration is present but is light brown in color as opposed to the darker discoloration with Fusarium. Manage Verticillium wilt by using disease-free seed of resistant cultivars (if available), along with long crop rotations that avoid following potato crops.

SUMMER SQUASH

Cucurbita spp.

The squash plants we grow and eat today have an extensive history that can trace origins to South, Central, and North America. Squash are members of the *Cucurbita* genus, which includes other vegetables such as cucumbers. Three species, *Cucurbita pepo*, *Cucurbita moschata*, and, *Cucurbita maxima,* were domesticated in different regions of the Americas and provide us with most of the squash plants we use today. It is suggested many species were domesticated 7,000 to 9,000 years ago.

Selecting squash varieties for your farm or garden can be daunting. With such a long history of cultivation, trade, and importance as a food, there is a plethora of varieties to choose from. Squash varieties can be selected based on shape, color, plant growth pattern, taste, and days to maturity. Squash fruits might be smooth, have ridges, warts, or a combination of all three. Common fruit shapes are round, flat, scalloped, acorn, straightneck, crookneck, oblong, or a mix. With so many combinations of color and shape, squash can provide growers with something new and exciting each year.

inacio pires, shutterstock.com

Squash plants grow in a spreading vine pattern or in a bush growth pattern. Spreading vine types are great for fences or other vertical structures or can be grown directly on the ground as well. Those with a bush growth pattern (such as most summer squash) tend to grow more compactly. No matter the growth pattern, plan on squash using a lot of area for production compared to many other vegetable plants.

Since scientific names are not commonly used and there are so many varieties to keep track of, gardeners have placed these brightly colored vegetables in two categories to help with organization: summer and winter. Summer squash are harvested when the skin is still soft and fruits have not fully matured, whereas winter squash is harvested when the skin is hard and fruits have fully matured. Summer squash includes species such as zucchini, scallops, and crookneck squash. Winter squash includes pumpkins, gourds, butternut, spaghetti, and many other hard-skinned squashes. See Pumpkins and Winter Squash section for more information, page 148.

Summer squash can be a good fit for most Wyoming locations since they grow better in cooler weather than other vining crops such as melons. They also take less time than winter squash to be ready to be eaten.

GROWING CONDITIONS

Summer squash grow best in full sun and soils high in nutrients. Ample and consistent water is important for proper plant and fruit growth. Summer squash should be rotated to a different location each year to avoid disease issues.

Squash like warm growing conditions. You can increase warmth by using black plastic mulch to warm the soil, row covers, or other protective measures that will increase air temperatures. Remove covers before temperatures inside reach 90 F or when female flowers appear. Insect pollination is important for good fruit set on many squashes–poorly pollinated flowers will abort or fruit will be small or misshapen. If using row covers or growing squash inside hoop houses, you'll want to allow bees in for pollination. If you do not want to open these structures there are some parthenocarpic varieties available that will set fruit without pollination.

PLANTING

Squash can be directly seeded into the ground, usually around an inch deep after the danger of frost is over, unless frost protection measures will be used. A minimum soil temperature of 60 F is used for planting squash seed with temperatures between 70 and 95 F being more optimal. Plants can also be started inside and then transplanted outside to get a start on the growing season. If transplanting seeds, make sure baby plants have plenty of light so they do not become "leggy." Leggy plants get this name because of elongated stems formed when plants try to reach for adequate light. Leggy plants are often less structurally sound and can have issues once transplanted. Squash roots tend to be more sensitive to disturbance than many other vegetables, so use care when transplanting.

Planting in hills or on a level ground will work for growing squash. It is a good idea to plant several seeds in the same spot and then thin seedlings (you can pinch the unwanted ones off with your fingernails) to one or two plants. Hills should be spaced anywhere from 2 to 5 feet apart depending on the variety.

DAYS TO MATURITY

40–60 days.

HARVESTING

The flesh, seeds, and blossoms can be eaten on squash plants. Squash have male and female flowers on plants. If interested in eating or selling the flowers, you will want to harvest only the male flowers unless you are looking to reduce the production of the plant. Male flowers have a longer and thinner stem than that of the female flowers. Summer squash can be harvested shortly after flowering (for baby squash) or up to 8 inches long or so for zucchini, so the squash will be tender. If fruits are allowed to stay on the plant until they get too mature, the fruit will decrease in quality, and the plant will often stop producing new squash.

SOME COMMON VARIETIES

- Black Beauty and others (46)
- Cocozelle (50)
- Early Prolific Straightneck (50)
- Saffron (50)
- Sunburst Patty Pan and other green or white Scallop (50–60)
- Yellow Crookneck (Early Summer and others) (58)
- Cosmos (60)
- Lemon (60)

INSECT PESTS AND DISEASES

See the Cucumber section for information on insect pests and diseases of summer squash, page 98.

SWEET CORN

Zea mays var. *saccharata*

Corn, known as maize in many countries, is a staple of many diets and has been under cultivation for up to 10,000 years. It is a wind pollinated cereal crop in the grass (Poaceae) family along with cousins Kentucky bluegrass, wheat, rice, oats, barley, and bamboo. The species is native to Central America and Mexico.

There are dozens of different varieties of sweet corn, and they vary tremendously in their quality and time to maturity. Although days to maturity can help compare earliness between varieties, as a warm-season crop, weather is a big factor in how long it takes a variety to mature (the warmer it is the faster it will mature, below 100 F). There are different categories of sweet corn, based on their genetics. New types produce more sugar in the kernels and slow down the time it takes the sugar to convert to starch. Some categories are standard sugary (su)–aka traditional sweet corn, sugary enhanced (se), and super sweet (sh_2); however, breeders are developing new kinds fairly frequently so read variety descriptions closely. Some things to note when growing sweet corn, along with days to maturity, is that se and sh_2 types tend to germinate more poorly in cooler soils than traditional sweet corn (su types). Sweet corn can be hard to grow successfully in our higher elevation communities due to cool night temperatures not as conducive to sweet corn growth.

GROWING CONDITIONS

Sweet corn grows best with warm weather (70s and 80s F), fertile well-drained soils, and consistent irrigation. Irrigation is especially critical during tasseling, silk production, and ear formation. Tightly rolled leaves in the morning mean you are not irrigating enough, and the corn is under a lot of stress.

PLANTING

Plant sweet corn on the average date of the last killing frost. Sweet corn seed will not germinate in low soil temperatures. Untreated corn can be planted when soil temperatures reach 65 F but best germination occurs when they reach 70 to 85 F. You can sow sweet corn three to four weeks earlier if you plant it under clear plastic tunnels. Other types of row covers (such as floating row covers) can also increase growing temperatures.

Plants are usually started from direct sowing. They can be started from transplants (grown in peat pots so roots are not disturbed during transplanting) but this is more labor intensive. For a longer harvest period, plant early, mid-season, and late-maturing varieties at the same time. Or, make successive plantings of the same variety every week or two. Use only the earliest maturing varieties for July plantings or for cooler areas. Sweet corn varieties that mature in the fall will usually be the highest quality because of cool night temperatures.

Best pollination (and thus ear fill) occurs when sweet corn is planted in blocks (three or more rows) rather than in single long, skinny rows. Block configurations increase the likelihood of all the silks on corn ears receiving pollen (each silk creates one corn kernel). The source of the pollen affects what type of kernel is produced. If se or sh_2 types are pollinated by pollen from traditional sweet corn (or field corn), the ears produced will be more like traditional sweet corn

Naruden Boonareesirichai, shutterstock.com

(less sweet). So these varieties should be planted so they tassel (send up the male flower parts that produce pollen) at different times, or varieties of all the same type should be chosen, or they should be planted 300 to 700 feet away from each other.

For early-maturing varieties that produce small plants, plant seed 1 inch deep in rows 30 to 36 inches apart with plants 8 to 10 inches apart in the row. For medium to large plant sizes, use a 30- to 42-inch row spacing with plants 12 inches apart in the row. Crowding plants will cause ears to be smaller. Plant at least three or four rows of the same variety in a block for good pollination and full ears. Some early varieties may produce suckers from the base of the plant. There is no advantage in removing these.

DAYS TO MATURITY

60–95 days.

HARVESTING

Normally, sweet corn is ready for harvest about 20 days after the first silk appears on the ear. Sweet corn ears are mature when silks are drying and becoming brown but husks are still green. Kernels should be plump and when crushed the liquid that comes out should look milky. If the liquid is clear, then the corn is not ready. The sweet corn kernels will get starchy and less sweet if not harvested promptly.

Harvest sweet corn in the morning when cool and immediately put them in a cool location or the sugar in the kernels will start converting into starch. Sixty percent of the sugar may convert to starch within 24 hours at 86 F. Quality after storage depends in part on the category of the sweet corn planted but storing at 32 F will maintain kernel quality the longest.

SOME COMMON VARIETIES

- Quickie (64)
- Sugar Baby (65)
- Spring Treat (66)
- Early Sunglow (66)
- Northern Xtra-Sweet (67)
- Peaches and Cream (70)
- Sugar Buns (70)
- Xtra Tender 2171 (71)
- Earlivee (71)
- King Kool (72)
- Bodacious (75)
- Ambrosia (75)
- Honey & Pearl (76)

INSECT PESTS

Corn on the cob is popular with consumers, and short-season varieties are available that can produce crops in some growing areas in Wyoming. Field or dent corn is also grown in Wyoming's row crop regions, so many of the insect pests of that crop are present and will readily attack sweet corn.

PESTS OFTEN AFFECTING SEEDLINGS

Seedcorn maggot can attack seeds that have delayed growth due to cold soil temperatures. Only plant corn when subsurface soil temperatures are at least 50 F (ideally closer to 60 F or 70 F) and rising to ensure rapid germination and growth of your crop. Seeds pre-treated with pesticides or planting with furrow-applied insecticides can also be used on non-organic crops as added protection from pests and diseases.

Multiple **cutworm species**, the caterpillars of moths from the Noctuidae family, can quickly damage sweet corn seedlings by feeding at night or on heavily overcast days. The **army cutworm** (*Euxoa auxiliaris*) and the **darksided cutworm** (*Euxoa messoria*) are two of the most common springtime pests in Wyoming. Weed control the previous season in and around the edges of the field will help reduce their populations in the field the following growing season. See cutworm management under the Integrated Pest Management section for additional information, page 45.

Affecting vegetative growth (**pests that chew leaves or pierce and suck plant juices**)
Both the **Banks grass mite** and the **twospotted spider mite** will damage corn leaves. The foliar feeding damage of these mites can impact the vigor and the potential yield of sweet corn. Banks and twospotted spider mite populations can increase rapidly in hot and dry conditions, when corn plants are water stressed. Pesticide applications for other corn insect pests can sometimes cause a sharp increase in mites when the insect predators, such as minute pirate bugs, banded-winged thrips, and several species of ladybeetles, are more adversely affected by the insecticides than the mites. (See the spider mite section under Integrated Pest Management for additional information, page 49).

The heliothus trap used to monitor for the presence of adult moths such as corn earworm can also be used for European corn borer with the appropriate pheromone lure. In Wyoming, the "Iowa" or "E" strain lure should be used to attract European corn borer moths.
Whitney Cranshaw, Colorado State University, Bugwood.org

Adult males of the European corn borer, such as this one, will be captured in pheromone traps. Markings on these moths can vary.
Frank Peairs, Colorado State University, Bugwood.org

European corn borer (*Ostrinia nubilalis*) female moths will deposit eggs on plants, and the larva will chew their way in the stalk. Evidence of this appears as holes chewed into the leaves as they unfurl as the stalk grows. Scouting for this pest is used to discover egg masses of the borers early so treatment can be done before the insect chews into the corn stalk. They can't be controlled with typical insecticides after they've entered the stalk. The lifecycle of this pest is varied with some populations producing only one generation per year and other populations two. The common name is also confusing because, although

corn may be a favored host of the pest, it can also survive on hundreds of other plant species.

Northern, Western and Southern corn rootworm (*Diabrotica spp.*) larvae feed on the roots of corn, stunting growth and making the crop vulnerable to lodging in windstorms. Crop rotation is an important management strategy for the larvae of this pest. The larvae hatch in the soil in the spring, and they will die if they can't locate a suitable host plant root system.

Cornleaf aphid (*Rhopalosiphum maidis*) can be found on corn leaves but is only considered a serious pest when high populations infest corn tassels. The honeydew from high numbers of aphids feeding on tassels can interfere with the release of pollen.

Insect pests affecting the saleable parts directly

Corn earworm (*Helicoverpa zea*) larvae can vary in color from tan brown or green but can be identified by the dark stripes on the back and tiny spines originating from the dark spots on the body.
Todd Gilligan, LepIntercept, USDA APHIS PPQ, Bugwood.org

Corn earworm (*Helicoverpa zea*) is a destructive pest of many vegetables. Caterpillars enter the ear by following the silks. Their feeding damages the kernels and encourages other pests, such as sap beetles and earwigs, to infest the ear as the damaged kernels decay. The corn earworm cannot overwinter in Wyoming, so the adult moths arrive from the south in summer and start to deposit eggs in susceptible crops.

The adult **Northern, Western and Southern corn rootworm** (*Diabrotica spp.*) beetles can be a pest when they invade a corn field and perform "silk clipping" during pollination. Severe clipping can prevent the forming ear from having enough silk exposed during pollination. This results in missing kernels and poorly filled ears.

Western bean cutworm (*Loxagrotis albicosta*) larvae lack the prominent stripes down the length of the body the corn earworm larvae exhibits. The western bean cutworm also has three stripes on a dark brown background on the segment just behind the head.
Frank Peairs, Colorado State University, Bugwood.org

Western bean cutworm (*Loxagrotis albicosta*) overwinter in Wyoming fields as fully grown larvae, then pupate in the spring, and the resulting adult moths emerge in July to lay eggs on corn. Upon hatching, larvae will at first feed on tassels, foliage, and then get inside the forming ear.

DISEASES AND DISORDERS

Physiological disorders (abiotic disorders)

Lower leaf yellowing (***chlorosis***) ***and leaf loss*** may be attributed to two cultural conditions: water stress and excessive or deficient fertility, such as nitrogen deficiencies. Use sufficient watering and adequate fertility to avoid these problems.

Inward leaf rolling is an indication of moisture stress. Provide adequate water.

Leaf tip death and margin necrosis. These conditions may be attributed to potassium deficiency or high

levels of soil salt. Do a soil analysis prior to planting and apply fertilizers as needed.

Ear blanking or tip blanking (missing kernels) is a result of poor pollination due to weather conditions such as moisture and temperature extremes. Insect damage to silks can also interfere with pollination. Blank areas can occur anywhere on a cob. Tip blanks may be related to the cultivar being grown. Make sure plants have proper nutrition and water during pollination.

Over maturity

Kernels develop dimples or brown and soften. Taste is not sweet rather more starchy or even fermented. Caused by harvesting too late. Harvest should occur when kernels are in the milk stage (squeezed kernels release a milky liquid).

Poor emergence

Causes include poor seed quality (too old or stored improperly), seed planted too deeply, low soil temperature, soil crusting, and mice and insect predation. Plant newer, properly stored seed at a proper depth. Avoid planting too early in the season. Sweet corn seed germinates best when soil temperatures are between 55 to 85 F. On crust-prone soils, lightly wet the surface of the soil frequently after planting to help seedlings emerge.

Infectious diseases of sweet corn

Seedling diseases

Plants are susceptible to seedling diseases (**damping off**) under cool wet conditions. Use high-quality seed and plant when soil temperatures are at least 55 F. Plant on raised beds if the soil tends be heavy and wet in the spring. Most commercial sweet corn seed will come treated with a fungicide/insecticide that will deter most seedling issues.

Foliar and whole plant diseases

Common rust
Larry Osborne, Bugwood.org

Common rust is caused by the fungus *Puccinia sorghi*. Both sides of leaves may exhibit small oval, reddish, brown-colored pustules. Typically, rust is not a serious problem but can reduce yield. Moderate to cool temperatures and high humidity favors disease. Use resistant varieties if it is a common yearly problem. Foliar fungicide applications at disease onset can be effective.

Anthracnose leaf blight, a fungal disease, will cause variable-sized lesions (but most less than 1-inch long) with dark tan centers, brown borders, and yellowish to orange halos. Can develop at any growth stage during prolonged rainy weather. This disease is usually not an issue in Wyoming because of these environmental requirements. Manage with select hybrids, crop rotation, and destroying previous year's corn residue.

Northern corn leaf blight is caused by the fungus *Exserohilum turcicum*. Symptoms on leaves are long (up to 6 inches) cigar-shaped lesions, which start on lower leaves and progress upward on the plant. Lesions are initially silver-grey and water soaked. As lesions mature, they become tan and necrotic with darkened areas where the fungus is sporulating (producing spores). Development is favored by moderate temperatures between 65 to 77 F, high relative humidity, and heavy dew events. Manage by incorporating or removing infected plant material,

and growing resistant varieties. Foliar fungicide applications at disease onset can be effective.

Corn smut
Whitney Cranshaw, Colorado State University, Bugwood.org

Smut of sweet corn is caused by the fungus *Ustilago maydis*. Any part of the plant above the ground can be infected, although it is more common on the ears, tassels, and the nodes than on leaves. The boil-like growth is composed of a white, smooth covering, enclosing a great mass, sometimes 4 or 5 inches in diameter, of black, greasy, or powdery spores. After the spores mature, the covering becomes dry and brittle, breaks open, and permits the black powdery contents to fall out. Warm, dry conditions favor disease development. Removal of smut galls before spores are mature can help reduce disease in the future; however, since spores can travel great distances on the wind, effective control would require neighboring growers to also remove smut galls in a timely manner. Although this disease can be fairly common, it seldom causes serious issues. On a positive note, corn smut is considered a delicacy in Mexico (Cuitlacoche).

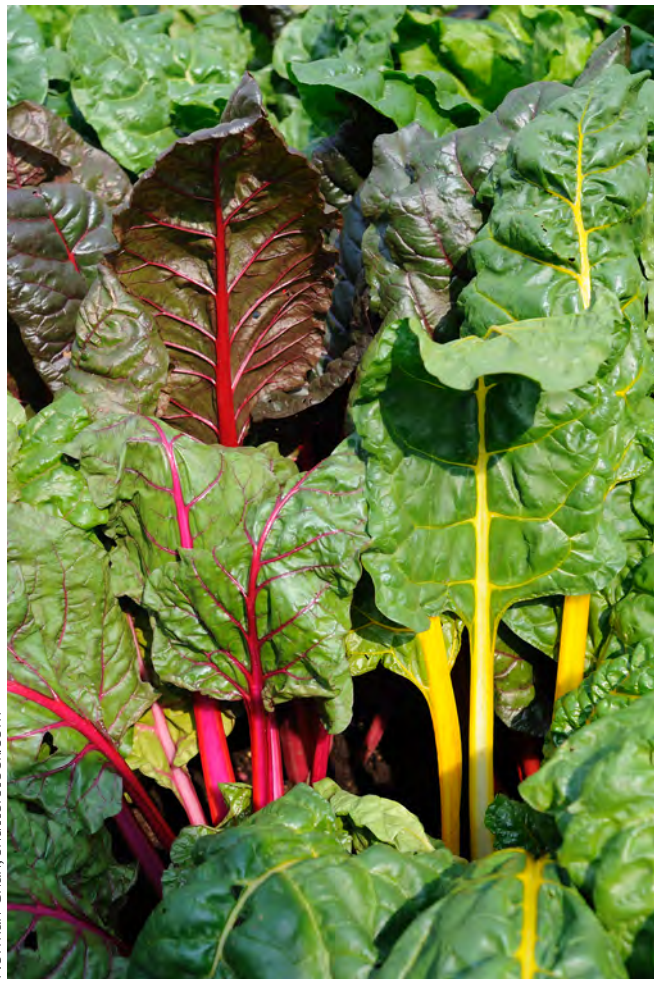
Several fungal diseases can cause **stalk rots**. These include the fungal species *Anthracnose*, *Diplodia* and *Fusarium*. Many stalk rots symptoms are very similar. Plant wilting is the first indication. Leaves may become discolored, turning grey or brown. Inside the stalk, decay causes discoloration on inner pith tissue, tissue that pulls away from the stalk rind resulting in a weakened hollow tube, which can lead to the corn falling over. Lower internodes turn from green to brown black. High soil temperatures favor stalk rots. Disease survives in infected tissue. To manage stalk rots, remove infected tissue at the end of the season and avoid growing corn in the same location year after year. Some hybrid varieties have resistance to these diseases (check each variety for resistance to each specific disease).

SWISS CHARD

Beta vulgaris var. *cicla*

Swiss chard is a cool-season plant that grows well in Wyoming. This plant looks similar to other leafy vegetables such as kale or spinach but is actually closely related to beets. While beet roots and leaves can both be consumed, swiss chard is grown for its leaves.

Swiss chard is thought to have originated in the Mediterranean area before being grown in England, the rest of Europe, and the Americas. The word "Swiss" was added to the name to distinguish it from French spinach. It is among the easiest of vegetables to grow and is a good substitute for spinach in many recipes.



Norman Chan, shutterstock.com

Plants can be found in a wide variety of colors, making them an attractive crop. The midrib, which is the center stem portion of the leaf, is the most colorful part of the plant. Plants can be found in red, purple, pink, yellow, and white colors. Seeds are often packaged as rainbow mixes for growers looking for a wide variety of colors.

GROWING CONDITIONS

Swiss chard grows best in well-drained soils high in nutrients. Consistent watering is important for growing Swiss chard to ensure good tasting leaves. Stressed or damaged plants can have a bitter taste.

Swiss chard can handle light to moderate frosts. Although Swiss chard is a biennial plant (forms leaves the first year, sends up a flower stalk the second year), some plants of certain varieties will on occasion bolt if exposed to repeated frost events. Bolting occurs when the flower stalk develops prematurely.

PLANTING

Early spring is an excellent time to plant Swiss chard. Plants can be directly seeded or transplanted. Plant seeds 1/4 to 1/2 inch deep if direct seeding (a couple weeks before the last average frost date). Seedlings started indoors can be transplanted when 2 to 3 inches tall. Plants should have 12 to 15 inches of space between plants and 24 to 36 inches between rows. Follow seed package instructions for specific varieties. Swiss chard can also be planted at different intervals to achieve a summer and a fall crop. The fall crop should be planted well in advance of the first frost (usually around 60 to 70 days before you'd like them to mature). Plan to rotate chard in a similar fashion to beets since they are closely related and have similar disease issues.

DAYS TO MATURITY

50–60 days (less if harvesting as "baby" swiss chard).

HARVESTING

For a progressive harvest, harvest leaves that are on the perimeter of the plant. New leaves will start from the center of the plant. Leaves do not store well, so plan to sell them quickly or use them within a couple of days.

SOME COMMON VARIETIES

Red

- Rhubarb
- Ruby Red
- Burgundy

White

- Large White Ribbed
- Lucullus
- Fordhook Giant

Mixed

- Rainbow
- Bright Lights

INSECT PESTS

See the Beet section for information on the insect pests of Swiss chard, page 72.

DISEASES

See the Beet section for information on the disease pests of Swiss chard, page 72.

TOMATOES

Solanum lycopersicum

Tomatoes are one of the most popular edible plants grown. Often considered a vegetable, tomatoes are technically fruit as they are produced from flowers and contain seeds. There are too many varieties to name, but personal and customer preference for size and flavor can help guide your choice of which to grow. Cherry tomatoes are often successfully grown in even the shorter Wyoming growing seasons, where varieties with medium to large fruit may not have enough time to ripen. Warm temperatures, especially warm nights, will increase the chance of success for Wyoming tomato growers.

Tomatoes are closely related to other Solanaceae family crops like potatoes, eggplants, and peppers, but tend to be easier to grow. Tomatoes are known in Latin as *Solanum lycopersicum*, *Lycopersicon esculentum*, or *Lycopersicon lycopersicum*. They are native to the Andes of South America and are technically perennial plants, although we grow them as annuals.

Valentin Valkov, shutterstock.com

GROWING CONDITIONS

Tomatoes should be planted where they will receive at least 6 to 8 hours of sunlight. Tomatoes thrive in warm temperatures and are sensitive to cold nights. Tomatoes grown in high tunnels will benefit from earlier planting dates, warmer temperatures, and protection from cold nights. Tomatoes grown outdoors may be covered to protect plants from light frost. Using wall-o-waters or other season extension methods can help tomatoes grow in cooler areas. Tomatoes planted near a south or west-facing slope will benefit from the sun's heat.

PLANTING

In Wyoming, tomato transplants should be planted outdoors well after the risk of frost has passed. Seeds may be started indoors 4 to 6 weeks prior to planting outdoors or transplants can be purchased from local garden centers. Plant tomato transplants deeper than you would normally plant other crops. Bury the stem up to the first set of leaves. Roots will develop along the stem, and this has been shown to increase yields.

DAYS TO MATURITY

Days to maturity depends on the variety, so consider the growing season in your area and choose varieties that will mature within that timeframe. In Wyoming, we often recommend varieties that ripen in 90 days or less.

DETERMINATE VS. INDETERMINATE TOMATOES

Determinate tomatoes, also called bush tomatoes, generally grow a more compact plant, usually 3 to 4 feet tall. Growth ceases when flower buds are formed at the tips of the vines. All of the flowers and fruit develop on the plant during a short period of time, and harvest usually lasts one to two weeks. Due to the smaller size of the plants, determinate tomatoes

often require limited trellising or staking and are good choices for containers, raised beds, and smaller spaces. Still, the weight of the tomatoes may pull the plant down, and staking may be needed to keep the tomatoes off of the ground. Determinate tomatoes do not require pruning.

Indeterminate tomatoes will continue to grow and produce flowers and tomatoes until the plants are killed by frost. Harvesting can last a long period of time throughout the growing season. Indeterminate tomatoes can grow fairly large plants, with 6 to 10 feet tall being common. Staking/caging/trellising is necessary, and there are various pruning techniques that can improve production.

Pruning indeterminate tomatoes

Left to grow unchecked, indeterminate tomatoes can put an excessive amount of energy into vegetative growth of stems and leaves and limit fruit production. Growers often prune the plants to two to four vines and remove all others. Choose the most vigorous vines and remove the runts. Pruning can open the plant up to better airflow and more sunlight, reduce disease problems, direct more of the plant's resources to fruit production, and increase yields.

HARVESTING

For best flavor, let the tomatoes ripen completely on the plant before harvesting. Size and color vary by variety. Fruit that has not completely ripened at the end of the growing season can be picked and may finish ripening indoors.

SOME COMMON VARIETIES

- 4th of July (50)
- Glacier (55)
- Early Girl (59)
- Oregon Spring (60)
- Sun Gold yellow cherry (65)
- Celebrity (70)
- Roma (70)
- Carbon (76)
- Black Krim (80)
- San Marzano (80)
- Cherokee Purple (80)

Tomatoes are susceptible to a number of pests and diseases. Choosing resistant varieties, crop rotation, consistent watering, and adequate fertility can reduce problems.

INSECT PESTS

Just like humans, there are pest insect species that just love tomatoes! Protecting your tomatoes requires regular inspection of the plants for pest insects or indication of their feeding damage. From a production standpoint, you have to keep in mind that pollination by insects, especially the "buzz" or sonication pollination by bumble bees, is important for good fruit set.

Here is a list of the common pests of tomatoes organized by plant growth stage and affected parts.

Pests often affecting seedlings

Whitefly

Whitefly adults
Whitney Cranshaw, Colorado State University, Bugwood.org

In greenhouses, high tunnels, and hoop houses, the greenhouse whitefly and the sweet potato whitefly can be severe pests on tomatoes. Most tomato seedlings are started in these controlled environments where they can become infested by

whiteflies. Close inspection of purchased seedling tomato plants for the presence of these pests is warranted. The sweet potato white fly is also a vector of a tomato disease that causes color mottling on the tomato fruits. For multiple control options, the basis of IPM, for whiteflies please see Insect and Mite Control Options in Wyoming Greenhouses https://bit.ly/insect-control-2013 .

Cutworms

Cutworm larva
W.M. Hantsbarger, Bugwood.org

Army cutworm is a frequent pest in field plantings once the seedling tomatoes are in the ground. The larvae of the most common miller moth species, army cutworms are nocturnal feeders and hide in the soil and under mulch during the day. Preventing weedy fields in the late summer and early fall reduces the attractiveness of the areas for the adult female moths that are depositing eggs that time of the year. This will reduce cutworm populations the following spring in the field. Physical barriers around the seedling transplants to prevent cutworm activity, although labor intensive, is a sure and long lasting way of protecting the seedling until they outgrow susceptibility to fatal attack from army cutworms. Cardboard or plastic collars, sized to make 4-to-5-inch tall rings 2 inches in diameter, can be pushed into ground 2 to 3 inches deep around each tomato set. Inserted this deep, the collars will stay put in the wind and last long enough to get the tomato seedlings through the cutworm danger period. The collars also protect the plants from abrasion in Wyoming's windy fields with sandy soil.

Affecting vegetative growth (**Pests that chew leaves or pierce and suck plant juices**)

Flea beetles

Potato flea beetle damage
Whitney Cranshaw, Colorado State University, Bugwood.org

Several species of small jumping beetles in the genus *Epitrix* will feed on tomato leaves. They create small pits that can increase the incidence of disease. Usually, vigorously growing plants can outgrow the damage. Row covers, as a physical barrier to the pests, can sometimes be used to protect plants.

Tomato hornworn larva
Whitney Cranshaw, Colorado State University, Bugwood.org

Tobacco and/or tomato hornworm larvae

Most of the time if you inspect plants you can catch hornworm infestations before they do irreversible harm. Hand picking the insects is a viable control method for these eventually very large-bodied pests. They are also vulnerable to most pesticides registered

for tomato plants. This includes the extremely pest specific pathogen *Bacillus thuringiensis* strain *kurstaki*. This strain of pathogen is specifically for use against leaf feeding caterpillars.

Multiple stages of the Colorado potato beetle
John C. French Sr., Retired, Universities:Auburn, GA, Clemson and U of MO, Bugwood.org

Colorado potato beetle adults and their larvae

Not as common as some of the other tomato pests, the Colorado potato beetle and its grubs eat the leaves of tomato and other plants in the plant family Solanaceae. Many Colorado potato beetle populations are very resistant to common pesticides; however, *Bacillus thuringiensis* strain *tenebrionus* formulated biopesticides are effective and very specific to the pest.

Aphids

Feed on plants with piercing, sucking mouthparts to extract water and nutrients from the plant. In the process they can transmit viruses. The **potato aphid** and the **melon aphid** are two common Wyoming pests. Reduction in tomato yield and quality can result from aphid infestations. The management of the species of aphids that will attack tomatoes is generalized and should include cultural practices such as avoiding excessive nitrogen fertilization, the management of aphid species alternate host plants, and "green bridges" that can allow aphids to persist from year to year in or near your fields. If insecticides are used, post treatment evaluation of efficacy should be conducted as some aphid populations have developed resistance to common insecticides. In greenhouses and high tunnels, natural enemies of aphids can be maintained at high levels to suppress populations. One way to support aphid predators is the use of "banker" plants, such as small grains, with aphid infestation of a species specific to grasses. The aphid population on the banker plants supports the aphid parasite/predator populations even when aphid populations are low or non-existent on the tomatoes.

Tomato psyllid frass.
Whitney Cranshaw, Colorado State University, Bugwood.org

Tomato psyllids

Are another pest of tomatoes that feed on plant juices with a piercing, sucking mouth parts. They cannot overwinter in Wyoming but return to the state on south winds during the growing season. The winged adults are small and mobile, able to both fly and jump. As you inspect the plants, you may see their white granular frass, often called to as "psyllid sugar." The nymphs are flattened and green and are easily overlooked as they feed on the underside of leaves. The use of yellow sticky cards to provide warning of adult psyllid arrival is an effective monitoring tool. As the psyliids feed, they inject a saliva that is toxic to the plants. This exhibits as "psyllid yellows" and can severely reduce yield and quality of the tomato crop.

Insect pests affecting the tomato fruits directly

Tobacco and **tomato hornworm** larvae will feed on the fruit as well as the leaves. They are usually first noticed as defoliators, but fruit damage is a more

serious issue. Pest scouting of field grown tomatoes on a frequent schedule to detect and manage the pest is crucial to protect the yield of saleable tomatoes.

The **tomato fruitworm** (AKA the corn earworm) cannot overwinter in Wyoming so it is a pest later in the growing season as the adult moths migrate north seeking suitable plants to deposit eggs on. Tomatoes grown in greenhouses and high tunnels are less likely to be infested than field grown crops. The adult moths start flying at dusk and put their eggs on tomato foliage. After hatching, the caterpillar eventually finds and usually eats its way into the fruit near where the stem connects to the fruit. To effectively manage this pest, the caterpillars need to be detected and killed before they enter the tomato fruits.

Tomato fruits can be discolored or otherwise damaged from **tomato psyllid** feeding. Psyllids need to be managed when they first attack the foliage to prevent subsequent fruit damage.

The **tomato russet mite** will feed on the foliage and the fruit. The fruit damage causes bronze discoloration and cracks in the fruit skin, making it unsaleable.

DISEASES AND DISORDERS

These consist of physiological disorders (due to poor environmental conditions) and infectious diseases (caused by viruses, fungi, bacteria, and nematodes).

Physiological disorders (abiotic disorders)

Physiological leaf roll

Leaf roll
Don Ferrin, Louisiana State University Agricultural Center, Bugwood.org

Leaf roll is associated with hot, dry weather, too much sunlight, rapid growth, certain varieties, and pruning. This disorder is commonly mistaken for herbicide damage. It is often a problem in tomatoes grown in the field but even more likely when grown in hoop houses. Typically, starting with the lower leaves, leaf margins roll inward in an almost tube-like fashion. The affected leaves will be firm and leathery to the touch. Once rolled, the leaves do not unroll, even if conditions improve, but this condition does not seem to affect yield. Providing shade will reduce this disorder.

Blossom end rot
Brenda Kennedy, University of Kentucky, Bugwood.org

Blossom end rot

Caused by a calcium deficiency, developing fruit have a tan to black flat spot at the blossom end of the fruit. Calcium is typically available in the soil, but the plant has trouble up taking the calcium if other salts are present or there is inconsistent watering. Maintaining uniform soil moisture, applying fertilizer per soil test recommendations, and avoiding root injury can minimize blossom end rot.

Growth cracks or fruit cracks

As the name implies, the developing fruit develops unsightly cracks near the stem end or encircling the fruit. These cracks are the result of rapid growth brought on by uneven watering or periods of high temperature. Cracks can invite secondary infection from fungi and bacteria, causing rot. Maintaining even soil moisture can help reduce fruit cracking.

Herbicide injury

Tomatoes are very sensitive to many of the broadleaf herbicides commonly used by homeowners that include the auxin-type herbicides like 2, 4-D. Exposure can be from direct contact from foliar spray and indirectly from herbicide-treated grass clippings, or grass clipping compost applied around tomatoes. Injury includes twisting of stems with curling and cupping of leaves.

Infectious diseases

Tomatoes are susceptible to several fungal, bacterial, viral, and nematode pathogens that would take an entire book to adequately cover. The following are some of the more prevalent diseases a Wyoming gardener could face.

Seedling diseases

Plants are susceptible to seedling diseases (**damping off**) under the right conditions. See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

Whole plant and root diseases

Early blight (foliar fungal pathogen) disease symptoms are brown to black lesions, which sometimes resemble target-like spots on the leaf. Disease usually starts later in the season on older leaves and will also attack potatoes. If the disease worsens, lesions will appear on newer leaves and even on the developing fruit. Good control measures include removing fallen diseased leaves, avoiding wetting leaves during watering, avoiding dense plantings, and not planting tomatoes in the same space next year (rotation).

Wilts and root rot pathogens

Fusarium and **Verticillium** are soil-borne fungal pathogens that attack the plant's vascular system (which carries water and minerals up from roots to leaves). Symptoms include lower leaves yellowing then dropping, with overall plant wilting, leading eventually to plant death. A handy diagnostic test is inspecting a cut stem. Disease is present if instead of a nice, healthy, green color, there is a dark discoloration of the vascular system. Once these fungi enter the vascular system, there is little that can be done for the plant; the best defense is prevention. When selecting plants, most tomato seed or transplants will be labeled with a code indicating which diseases it is resistant to. For example, a code like "VFA" would mean the plant is resistant to Verticillium (V), Fusarium (F) and early blight (A). If plants become diseased, remove affected plants and avoid planting back to tomatoes in that space for at least three years.

Viral diseases

Curly top virus
Whitney Cranshaw, Colorado State University, Bugwood.org

Several viruses can infect tomatoes in Wyoming including, but not limited to, **curly top virus**, **tomato mosaic virus**, and **spotted wilt virus**. Symptoms of virus infections include leaf mosaic (alternating areas of light- or dark-green or yellow areas), yellowing, necrosis, malformation (leaf rolling, puckering and twisting), leaves and stems become stiff, and stunting. All of these viruses are spread by insects like leafhoppers and aphids. The viruses can survive in the absence of tomato on many common weeds and some agronomic and horticultural crops. Choosing varieties with viral resistance is the most effective management strategy. Little can be done once a plant is infected, so it is best to remove the plant to stop further spread by the insect vectors.

WATERMELONS

Citrullus lanatus

Watermelons have been cultivated for upwards of 5,000 years with seeds having been found in many Egyptian tombs, including King Tut's. The fruit's popularity moved it from northern Africa to Mediterranean countries, and eventually across the Atlantic. The plant has been bred for sweetness over millennia, along with red flesh. As it turns out, the gene for the fruit's red color is linked to the gene for sweetness. So with increasing sweetness, watermelons have taken on more red color.

Watermelons are warm-season plants and require warm soil and air to thrive. Related to muskmelons and honeydew, they require a long growing season, hot days, and plenty of water. Because of their large vines, watermelons require a considerable amount of growing space (except for some bush types). The fruits come in a large range of sizes from 2 to 200 pounds. However, the "ice box" types with their smaller fruit are usually a better choice for many Wyoming growers due to their shorter days to maturity. Larger, fruited watermelon vines usually only bear a couple of fruit per vine, so they don't produce a lot of fruit per square foot of space.

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Watermelon varieties come in a range of colors of fruit flesh including red, pink, orange, and yellow. Most watermelons produce fruits with black seeds. Seedless watermelons can be grown but they tend to be harder to grow than seeded watermelons. They have weaker seedlings that need extra care, longer growing seasons, consistently warm temperatures, and a pollinizer plant. A pollinizer plant is a different variety grown solely to provide pollen for flowers of the variety wanted. The pollinizer variety's seeds are generally provided along with the seeds of the seedless watermelon variety. These plants will likely also produce melons on their vines that will have seeds in them. Some research and careful reading of the descriptions in seed catalogs can help growers be successful.

GROWING CONDITIONS

Watermelons prefer rich, well-drained soils and warm temperatures. Plastic mulches and covered tunnels can be used to help increase the temperatures and to protect them from wind. Clear plastic can be used to warm soil early in the season, and watermelons can be seeded or transplanted into black plastic mulch, which will also suppress weeds and retain soil moisture. Tunnels can be used over the plants. Those covered with clear plastic or fabric row cover material can keep temperatures elevated. These tunnels should be opened or removed when temperatures inside hit 90 F; otherwise, you can accidentally damage your plants.

PLANTING

Direct seeding is the most common way of planting watermelons. Plant two to three seeds per hill about 1-inch deep after all danger of frost has passed and soil temperatures are a minimum of 65 F, with the optimum being 70 to 85 F. Hills can be spaced 2 to 3 feet apart in the row with rows 6 to 8 feet apart (for regular-sized vines).

Growing transplants will gain a few days to a couple weeks of growing time; however, great care should be taken to be gentle with their roots when transplanting. Most seedless watermelon plants are planted as transplants due to the weak nature of their seedlings and the cost of the seed. Start transplants about two to three weeks before planting them outdoors after the danger of frost has passed (they will have two to three true leaves.). To minimize root disturbance, they can be started in peat pots so the entire pot can be planted. Be sure to cover up all of the pot with soil; otherwise, the pot material will wick moisture, dry out, and the roots won't be able to grow through the pot to enter the surrounding soil.

Pollination is important to successful fruit set. As with cucumbers, male and female watermelon flowers (which generally stay open for about a day) occur as separate flowers on the same plant. Bees must carry pollen from flower to flower to ensure fruit set. If you use row covers or other enclosed spaces to deter pests or to create a warmer growing environment, the covers should be opened at least part of the time during flowering to allow bees to enter. Apply pesticide very carefully if needed during this time–read and follow label instructions to protect the bees.

Watermelons are fairly drought tolerant but best growth occurs with adequate water. Irrigation should be deep due to watermelons' deeper root system. Overwatering when watermelon fruit are near harvest can cause fruit to split or reduce sweetness. Drip or soaker hose irrigation can help reduce the incidence of disease on watermelon leaves.

DAYS TO MATURITY

70–120 days.

HARVESTING

One indicator of harvest time is a yellowish undercolor spot where the melon lies on the ground (compared to a more white color when it is not ripe), and a dull appearance compared to a slick, shiny appearance prior to maturity. A dead tendril or curl near the point where the fruit is attached to the vine is used by some as an indication the fruit is ready for harvest. You can thump the fruit and listen for a dull sound. If the sound is more metallic, the fruit is not yet ripe. The best indicator is when the stem of the watermelon has shriveled—it's time to pick. Watermelons must be picked ripe since they do not sweeten or continue to mature once harvested.

Watermelons should be cut from their vines. Refrigeration of watermelon fruit at 55 to 61 F can extend storage time.

SOME COMMON VARIETIES

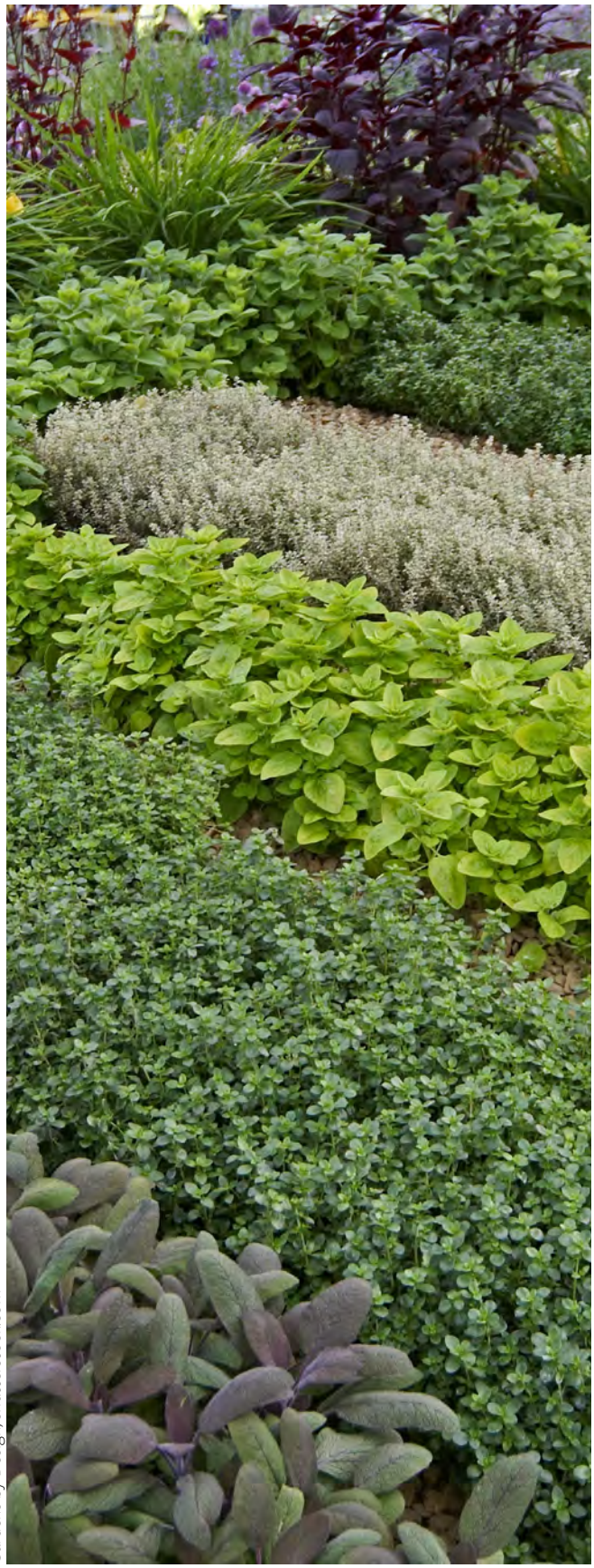
- Yellow Doll (68)
- Blacktail Mountain (70)
- Mini Love (70)
- Sugar Baby (85)
- Crimson Sweet (88)

INSECT PESTS

Look under the Cucumber section for information on common insect pests of watermelons, page 96.

DISEASES

Look under the Cucumber section for information on common diseases of watermelons, page 96.



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CHAPTER 3: HERBS

INTRODUCTION

A variety of herbs grow well in Wyoming. This section will cover a few of the more common ones. A longer list can be found in the UW Extension publication *Growing Herbs,* https://bit.ly/GrowingHerbs.

Herbs vary in their life cycles and climatic needs. For example, some herbs are annuals that can reseed themselves from year to year, such as dill and cilantro. Others are tender perennial herbs (rosemary and marjoram), which won't survive outdoors over the winter. They are best cultivated as annuals when grown outside or grown as container plants. A number of herbs are tough perennials. Some may even need to be controlled to keep in bounds. For example, mints spread through runners/stolon, which are lateral shoots that root as they grow, and chives can spread through abundant seed production.

Many herbs do not require a lot of effort to grow due to their adaptation to dry conditions and lack of plant issues such as insect pests, although these are always a possibility as the next section will outline.

INSECT PESTS AND HERBS

Culinary herbs don't have as many arthropod pests as typical vegetable food crops. Aromatic plants, like herbs, produce chemical compounds (phytochemicals) as a defense against animals that might otherwise eat them. The taste and aroma of these phytochemicals are why humans value herbs. We use a small amount of herb as flavoring for our food. The old adage "The dose makes the poison" probably applies to many phytochemicals produced by aromatic herbs. Unless a small insect larvae is adapted to feeding on an herb, eating it exclusively

could be fatal to the insect (they get a larger dose of phytochemical per body weight). As a result, many insect herbivores are likely to avoid herbs. Some organic gardeners mix in plantings of herbs with their vegetable crops to make it harder for the pest insects to locate the vegetables.

Pests of culinary herbs generally fall in three categories. The first type of pest are species adapted to eating aromatic herbs. An example is rosemary beetle (*Chrysolina americana*) that has spread all over Europe but hasn't arrived in North America, yet. The second type of pests are mobile insect herbivores, like grasshoppers and adult flea beetles, which feed on multiple species of plants in a day, thus diluting the impact of the defensive chemicals. The third type of herb pests are those that feed on the parts of an aromatic herb that have the lowest concentration of defensive chemicals. For example, green peach aphids avoid defensive chemicals contained in vacuoles within the plant's cells by feeding on an herb's phloem. Be sure to scout your culinary herbs for pests because there is a good possibility a particular species can thrive in your crop, despite some inherent pest resistance. Choose management actions compatible with the end use of your crop if you find a plant pest causing damage.

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BASIL

Ocimum basilicum

Basil is a great plant for indoor or outdoor areas. As a short-statured plant, usually 12 to 30 inches tall when mature, basil works great for containers or planted outside in larger areas. Basil is a tender annual herb and will not survive freezing temperatures.

With strong aromas and a unique flavor, basil is most often grown for culinary uses. Some varieties of basil are harvested for their use as essential oils. Basil plants have square stems, as do other members of the mint family. The many varieties of basil are sometimes difficult to identify.

GROWING CONDITIONS

Basil grows best with full sun and well-drained soils. Basil plants should be well-watered throughout the growing season. Plants grown in pots will tend to dry out quicker than plants grown directly in the garden. Irrigation will be required for plants that do not receive enough rainfall to avoid stressed plants.

Mazur Travel, shutterstock.com

Using drip irrigation will help growers avoid excessive watering and disease issues in the field.

PLANTING

Basil seeds can be directly planted into the garden after all threat of frost has passed or started indoors. Plant seeds in rows 12 to 24 inches apart and cover seeds no more than ¼ of an inch. Seedlings should be thinned to allow 6 to 12 inches of separation between plants once several inches tall. Basil is often started indoors and then transplanted outside due to our short seasons and cool temperatures across much of the state. Seeds should be planted indoors approximately six weeks prior to planting seedlings outdoors. Basil is sensitive to freezing temperatures. It should only be transplanted outside once all threat of a spring frost has passed or grown with protection. Basil can also be easily propagated from cuttings, place. Place them in water, and allow to develop roots. Once roots are visible, transfer to a soil filled container or directly into the soil outdoors.

HARVESTING

The leaves of basil are the plant part usually harvested for consumption. Leaves may be consumed raw or dried for later use. Freezing is another option for storing basil leaves. Basil can be pureed in a blender and then frozen with water in ice cube trays. These ice cubes can be stored in containers in the freezer and used later for cooking. Leaves may be harvested once plants begin to produce adequately sized leaves. Plants that become stressed or produce flowers may have more fibrous leaves and contain less flavor. Flowers can be removed to try to increase the energy the plant is putting into leaf growth. Plant leaves should be dried at relatively low temperatures, usually around 90 F. Dried leaves may have less flavor than the fresh or frozen form.

Basil can suffer cold chilling injury if held at too low a temperature. Other improper post-harvest handling and storage methods can cause leaf quality to quickly deteriorate. Proper commercial post-harvest

handling techniques and food safety information can be found on the University of California, Davis, Postharvest Technology Center website, http://postharvest.ucdavis.edu, and the Rutgers Ultra-Niche Crops Series, https://bit.ly/rutgers-basil-handling.

CULTIVARS TO TRY

There are five distinct groups under which basil varieties are classified.

Sweet

- Napoletano
- Romanesco
- Medinette

Genovese

- Emily
- Dolly
- Genovese

Bush

- Spice
- Green
- Bush

Purple

- Dark
- Emerald Wine
- Rubin

Scented

- Cinnamon
- Lemon
- Clove
- Thai

INSECT PESTS

Common early season pests of many crops can also affect the seedlings of basil. **Cutworms, garden slugs** and **flea beetles** are some of the widely distributed pests that can feed on basil early in the growing season. **Leaf mining pests** and **grasshoppers** usually occur mid-summer and continue later into the season. Grasshoppers from the genus Melanoplus such as the twostriped and differential species will feed on basil. The ubiquitous **green peach aphid** is one of several aphid species that can also feed on many culinary herbs. For additional information on many of these insects and control measures see the Integrated Pest Management section, page 42.

Cutworms and the larvae of some other species of owlet and underwing moths can damage basil and other culinary herbs. The larvae of these species hide in soil cracks and plant debris during the day, so they may go unnoticed; however, herb seedlings can be killed by their heavy feeding.
Charles Olsen, USDA APHIS PPQ, USDA APHIS PPQ, Bugwood.org

Multiple species of flea beetles from the genus *Phyllotreta* can feed on some culinary herbs. The feeding damage is typically little pits and holes chewed into the leaf surface. These small beetles can be all black, dark bronze, or striped in coloration.
James Coupland, FarmForest Research, Bugwood.org

The larvae of small leaf miner flies from the genus *Liriomyza* tunnel between the upper and lower surface of a leaf, enlarging the mine as they grow. Along with affecting plant growth, this kind of damage can make leafy produce, including herbs, unsaleable.
Charles Olsen, USDA APHIS PPQ, USDA APHIS PPQ, Bugwood.org

Spotted lantern fly *Lycorma delicatula* is a new invasive pest of many crops in the eastern U.S., including basil. Growers should keep alert and report any unusual pest they may spot on their crops, such as this one.
Lawrence Barringer, Pennsylvania Department of Agriculture, Bugwood.org

DISEASES AND DISORDERS

Physiological disorders (abiotic disorders)

Bolting is when plants begin to flower and go to seed prematurely. Basil begins to flower soon after planting. Pinch off flowers as soon as they appear to prolong quality leaf production.

Infectious diseases

Seedling diseases

Basil is susceptible to seedling diseases (**damping-off**) under high humidity and poor air circulation. Use sterile soil, clean pots and avoid overwatering when starting plants indoors.

Foliar and whole plant diseases

Fusarium wilt of basil is caused by the soil-borne fungus *Fusarium oxysporum* f.sp. *basilicum*. Early in the disease, infected plants will be stunted with yellowish leaves. In later stages of disease, brown streaks develop on the stems, vascular tissue becomes discolored, and stems may twist and leaves drop. Prevention is the best management strategy. Disease can become introduced to the soil from infected seed or transplants. Once established, this disease can survive in the soil for a number of years, so management would require a several year rotation that avoids basil and other members of the mint family.

Bacterial leaf spot is caused by the bacteria *Pseudomonas cichorii*. Symptoms include black or brown spots that appear on leaves and streaking on the stems. Introduced to fields from contaminated seeds and transplants, disease spread is favored by splashing water (overhead irrigation) and high humidity. Not likely to be a problem in Wyoming's environment, except early in the season before it gets too dry.

Root rots can be caused by excessive overwatering resulting in root death or by fungal infections such as *Rhizoctoina solani*. Roots will be brown and have a water-soaked appearance. Avoid over watering and plant in well-draining soils.

CHIVES

Allium schoenoprasum

Chives are a type of onion grown for their edible round green leaves. Chives are smaller in size than typical bulb onion varieties found in commercial supermarkets.

Garlic chives, *Allium tuberosum*, have flatter leaves, a more garlicky taste, and are grown in the same manner.

GROWING CONDITIONS

These perennial plants, about 10–12 inches tall, can be grown outdoors or indoors by a window or grow light. Chives need full to partial sun, with a minimum of 6 to 8 hours of full light recommended for proper growth. Chives will not grow well in excessively hot environments such as the south side of structures exposed to full sun at lower elevations.

Chives grow best in well-drained soils. Fertilization or the addition of compost is recommended for low-quality soils or if chive plants are exhibiting signs of inadequate nutrition. Struggling or overcrowded chives should be divided and replanted to a new area if needed. This should occur every three to four years. Chives grown indoors should be grown in pots that are well-drained, consistently watered, and with suitable soil.

PLANTING

Chives can be directly planted outdoors in the spring. Seed should be planted ¼-inch deep and then thinned (4 to 6 inches apart) when the seedlings have become established. They can also be increased by dividing plants. If allowed to flower, chives will reseed (sometimes prolifically). Control reseeding by removing the flowers before they produce mature seed.

Chives can also be started indoors and then transferred outdoors in clumps or groups consisting of four to six plants. Plants started from seed can take four to six weeks to grow large enough to be transferred outdoors.

HARVESTING

The flavor of chives is often considered to be milder than many varieties of larger onions. Chives are best used fresh and should be harvested by cutting the stems just above the soil surface. A serrated knife or scissors work well for this task. Chive leaves can be dried but lose much of their flavor. Freezing the leaves (often after cutting the leaves into pieces) helps preserve more of their flavor for home use. For those growing for sale, storage at 0°C (32°F) is required to optimize quality and storage life of many herbs. More post-harvest information on herbs can be found on the University of California, Davis,

krolya25, shutterstock.com

Postharvest Technology Center website. https://bit.ly/uc-veg-facts.

Chives are a great addition for growers looking for a relatively easy herb to grow. Their brightly colored flowers can also be used to garnish dishes.

CULTIVARS

- Dolores—thin and uniform leaves that are dark green
- Grolau—Swiss variety that is known for extra-long, thick, and dark green leaves
- Nelly—medium-sized leaves
- Staro—known for thick round leaves

INSECT PESTS

The plants in the genus Allium are grown for the flavor they add to many foods. As mentioned previously, the phytochemicals that give them their characteristic aromatic odor and flavor also deter some plant eating insects, however, alliums can be attacked by both specialist and generalist insect species. An example of generalist pests are the several species of grasshoppers in the genus *Melanoplus* that will eat the green tops. Specialist onion maggots (*Delia antiqua*) attack Allium species bulbs.

Delicate allium seedlings can be quickly killed by **cutworms**. Plants grown from sets can also be severely damaged. Good weed control in the field throughout the year should be used to discourage cutworm moths from depositing eggs. Many insecticides are labeled for cutworms but, for most of them to work, the plant has to be at least partially eaten by the pests (so the insecticide will be ingested by the cutworms). Reducing the population of the cutworms before planting with cultural management methods is a better control strategy. See cutworm management under the Integrated Pest Management section for additional information, page 45.

Onion maggot (*Delia antiqua*) adults are flighty, small gray flies that are hard to spot in an allium crop field.
Pest and Diseases Image Library, Bugwood.org

First generation **onion maggots** and **seedcorn maggot** (*Delia platura*) can damage allium seedlings. Management to reduce maggot populations with cultural practices that reduce pest pressure helps. An example of a cultural control would be destroying allium crop residue completely to deny insect pests overwintering habitat. Crop field rotation also helps because adult onion maggot flies are not strong fliers. They can't fly very far to infest new crops.

Onion thrips (*Thrips tabaci*) are tiny insects that start their infestation in the folds of and spaces between the new growths of allium plants.
Whitney Cranshaw, Colorado State University, Bugwood.org

Onion thrips (*Thrips tabaci*) can also live in alfalfa. They can migrate into allium fields when nearby alfalfa hay fields are cut. Thrips feeding damage results in leaf scarring reducing the value of green

onions and chives. Severe feeding also increases the occurrence of foliar diseases and reduces the effective leaf area to support vigorous growth.

DISEASES AND DISORDERS

Physiological disorders (abiotic disorders)

Center die-out occurs when chive clumps get too large and the center of the clump begins to die. In the spring, divide the plant and replant the healthy portion of the clump.

Infectious diseases

Seedling diseases

Chives are susceptible to seedling diseases (**damping off**) under the right conditions. See **Seedling damping-off diseases** in the Starting Plants from Seed Indoors section for more specifics.

Foliar and whole plant diseases

Pink root (*Phoma terrestris*) is a fungal-like disease that infects the roots of chives. Symptoms include roots that initially turn pink, then purple. Roots become transparent and water soaked. Infected plants become stunted with shriveled bulbs. Avoid planting chives in the same area continuously or in an area that had been planted to onion or other *Allium* spp.

Downy mildew is caused by the fungal-like pathogens *Peronospora parasitica* and *P. destructor*. Infected leaves turn a light tan to brown and under very moist conditions, a furry, greyish violet growth will be visible on infected leaves. Improve air circulation if possible. Under overhead irrigation situations, water early in the day to avoid wet leaves overnight. Clean beds in the fall to remove infected plant material and rotate the crop.

CILANTRO

Coriandrum sativum

Looking to grow a dual-purpose herb? If so, look no further than *Coriandrum sativum*. The leaves and stems of *Coriandrum sativum* can be harvested for consumption, which is known as cilantro. Seeds collected from *Coriandrum sativum* can be used as a second herb known as coriander. Cilantro is the common name used to describe the plant used for harvesting leaves and the name coriander is used when referring to the harvested seeds (or plant used for this purpose).

GROWING CONDITIONS

As an annual, cilantro can be a great addition for gardeners that are dealing with a short growing season. Plants are quick to mature, and multiple or succession plantings can provide gardeners with fresh cilantro throughout the growing season. Cilantro prefers sunny locations and well-drained soils. Plants in heavy soils that are often saturated will not be productive. Fertilization is only needed for very nutrient poor soils.

Lahore Qalandar57, shutterstock.com

Plants tend to "bolt" (send up flower heads) with hot temperatures. It is a good idea to select slow bolting type varieties to provide longer windows for harvesting leaves. Plants left to bolt produce umbels of small white flowers that attract some pollinators. Seeds are harvested and used when they have turned light brown. However, if you do not want the plants to reseed, you should remove the flowering heads before the seed is mature. In some cases, cilantro can take over if left unchecked.

Plants can be grown indoors as well. Provide similar growing conditions for plants grown indoors as plants grown outdoors. Maintaining cooler soil temperatures for indoor plants will reduce the chances plants will bolt.

PLANTING

Seeds should not be planted more than ½-inch deep in fertile soil. Seeds germinate around 21 days after planting. Plants should be spaced 8-10 inches between plants and in rows 15 inches apart. Mature plants will range from 1-3 feet tall. Succession plantings should be spaced three to four weeks between plantings. Succession planting is important if interested in harvesting leaves over extended periods of time.

HARVESTING

Harvest leaves when plants are at least 6 inches tall. Some gardeners will pinch or cut off the flower stem of plants to prevent the onset of bolting. Fresh leaves can be used fresh, or dried and frozen to be used later. If looking to harvest seeds for coriander, allow plants to fully mature and start to turn brown. When plants begin to turn brown, the seed heads can be cut and allowed to completely dry in a warm location that has low humidity.

For those interested in selling fresh cilantro, information on post-harvest handling for herbs can be found on the University of California, Davis, Postharvest Technology Center website. https://bit.ly/uc-veg-facts.

CULTIVARS TO TRY

- Leisure—slow bolting and high leaf production
- Delfino—fast growing and great for leaves and seeds
- Marino—slow bolting and quick growth
- Santo—slow bolting and dark green leaves
- Slow Bolting—best used for harvesting leaves

INSECT PESTS

Multiple climbing **cutworm species**, **alfalfa webworm**, and **parsley worm** feed on the foliage with chewing mouth parts. This is especially damaging on cilantro and parsley crops as that is the saleable part of the plant.

DISEASES

Cilantro seedlings can die due to **damping off.** See seedling damping-off diseases in the Starting Plants from Seed Indoors section for more specifics, page 27.

Powdery mildew is composed of a white fungal growth that can eventually cover all leaf surfaces. Plants are not killed, but yields are reduced. Favored by high humidity and moderate temperatures, spores are easily spread by wind. Infection typically occurs late in the season. Remove infested plant material or incorporate it well into the soil.

DILL

Anethum graveolens

Dill, a member of the carrot family (Apiaceae), is a great herb to add some height and beauty to the garden. This tall and vibrant plant is relatively easy to grow and will tolerate low nutrient soils. It can reseed itself profusely, so seed heads should be removed before they are mature if reseeding is not wanted. Dill is used for its aromatic flavors in fresh cooking or in flavoring preserved foods. Perhaps it is most famously known for providing the flavor of dill pickles.

PLANTING

Directly planting dill seeds into a garden soil is the best practice for establishing plants. Seeds should be planted ½-inch deep after the threat of frost has passed. Plants should be thinned to 12 inches between rows and 9 to 10 inches between plants. Plants will most often mature within four to six weeks. Successive planting through the growing season can ensure a constant crop. Seedlings will emerge after 1–3 weeks in the soil. Plants tend to "bolt" or prematurely produce a seed head when temperatures become very hot. This is usually air temperatures above 90–95 °F.

aniana, shutterstock.com

GROWING CONDITIONS

Dill can reach two to four feet tall when mature, depending on variety. Plants can be grown indoors using containers. Staking dill plants grown inside is common practice to prevent plants from falling over if they do not receive enough sunlight from windows. Plants will become "leggy" as they spend more energy trying to reach light instead of spending energy on stem structure. Dill plants need a minimum of 6 to 7 hours of full sun when outside. Indoor plants can benefit greatly from the addition of supplemental light from LED and other types of grow lights even if plants are grown next to a window. Soil should be kept moist during the growing season, but not excessively saturated. Plants do best in well-drained soils. Small amounts of fertilizer or the incorporation of compost should be added to nutrient deficient soils.

HARVESTING

Mature plants produce yellow flowers. If left to go to seed, dill will self-seed and start potentially unwanted volunteer plants. The fern-like leaves and seed heads can be harvested for use. The leaves are most often used fresh, while the seed heads can be used fresh or for preservation purposes. Leaves can be harvested almost as soon as they are of adequate size. Seeds and seed heads are harvested once seed have started to mature yet have not turned completely brown in color.

VARIETIES

- Bouquet—short stature variety and best for fresh use
- Dukat—strong flavor and slow to bolt
- Fern leaf—short in stature and known for higher leaf production than other varieties
- Monia —compact variety, best used for container gardening
- Tetra—very similar to Dukat variety

INSECT PESTS

Swallowtail larvae
Jim Occi, BugPics, Bugwood.org

Willow-carrot aphids cause a bronzing discoloration when feeding on dill foliage.
Whitney Cranshaw, Colorado State University, Bugwood.org

Anise swallowtails are beautiful butterflies similar in coloration to the black swallowtail butterfly. The caterpillars of this species will occasionally be found on dill. Larvae can cause rapid defoliation due to their voracious appetites. This species can produce multiple generations in warm climates, but generally only produce one generation per summer in Wyoming. **Willow-carrot aphids** and **tomato hornworms** will also feed on dill plants.

OREGANO AND MARJORAM

Origanum vulgare and *Origanum majorana*

Oregano is used for cooking as a fresh or dried herb. Marjoram (*Origanum majorana*) and oregano (*Origanum vulgare*) are often confused and are sometimes used interchangeably. These two herbs are in fact different plant species and thought by many to have a unique and distinct flavor for each species. Marjoram is considered less intense and less spicy in flavor than oregano.

PLANTING

Both oregano and marjoram do best when planted as a divided plant from an existing plant or purchased as an established plant from a nursery. Plants can be started from seed if the seed is from a reputable source. Seeds can tend to not be true to the parent plant in many cases. Seeds should be kept moist and planted very shallowly. Light is needed to start the germination process for seeds. Plants can reach 6 to 24 inches when mature. Provide 18 to 24 inches between plants if planted outside.

Artem Kontratiev, shutterstock.com

GROWING CONDITIONS

Plants started from seed or as transplants should be planted after the threat of frost in an area with full sun and well-drained soil. Plants will not be very productive if soils are not well drained and are constantly saturated during the growing season. Marjoram is a perennial plant hardy to USDA Zone hardiness 6. For Wyoming, plants will need to be brought indoors during the winter if they are grown in containers or started new each year if directly planted in the soil outdoors. The hardiness zone for oregano can vary depending on variety. Microclimates can be important to the success of overwintering oregano. Containers are commonly used for cultivating both oregano and marjoram. It is a common practice to pinch off any flowers or seed heads that form during the growing season to enhance the flavor of leaves. If left, flowers will be purple to white in color.

HARVESTING

The leaves are harvested for both oregano and marjoram. The leaves can be used fresh or dried for cooking. Fresh leaves should be used within a day or two of harvest. Dried leaves can be stored for around a year in proper conditions.

It is important to keep in mind there are many varieties of oregano available for ornamental use. These varieties are great for flower beds and attracting pollinators, yet they are not the best for culinary use.

VARIETIES

- Profussion® oregano—excellent flavor and more winter hardy than most varieties
- Greek oregano—excellent flavor and considered to be the true oregano
- Syrian oregano—bold flavors and considered to be spicier than other varieties
- Turkestan oregano—robust flavor
- Sweet marjoram—mild flavor and often used fresh

INSECT PESTS

Cutworms of various species are pests of oregano early in the spring. **Green peach aphids** can feed on the plant and leave behind honeydew, which can feed the growth of sooty molds making the crop unsalvageable. **Western flower thrips** (*Frankliniella occidentalis*) will feed on oregano leaves, discoloring them and leaving behind sticky black feces drops. **Two-spotted spider mites** (*Tetranychus urticae*) can also damage and discolor the leaves and produce the characteristic webbing. Monitor plants for sudden increase in spider mites if treated for aphids or thrips with some broad-spectrum insecticides. Outbreaks can occur if many of their predators are killed by a treatment. Selecting a pesticide that is less toxic to predator insects or is equally effective on mites is advisable. For additional information on many of these insects and control measures, see the Integrated Pest Management section, page 42.

PARSLEY

Petroselinum crispum

Parsley is in the same family as carrots (Apiaceae) and is similar to carrots in cultivation requirements. This biennial herb is best cultivated as an annual crop for Wyoming's climate. Parsley is a common herb used in many culinary capacities such as a spice for cooking or as an edible garnish depending on the variety.

PLANTING

Parsley seeds can take relatively longer periods of time to germinate (2 to 5 weeks). Seed germination can also be variable depending on seed age. Younger or newer seeds tend to have better germination rates than older seeds. It is a common practice to soak seeds in water prior to planting to decrease the time for seeds to germinate and increase the number of seeds that germinate.

Parsley seeds are small. Seeds should be planted very shallowly, around ⅛ – ¼ inch deep, in a well-drained soil. Seeds planted in containers indoors should be placed next to a window with lots of sunlight or grown under lights. Seeds planted directly in the garden bed outdoors should be planted after the danger of frost. The same is true if moving seedling transplants to an outdoor location. The tap root of parsley can be easily damaged when moving seedlings.

aniana, shutterstock.com

Parsley seeds can be mixed with radish seeds to help thin the number of seeds planted and provide a method for locating where seeds were planted.

GROWING CONDITIONS

Established plants should be thinned to 10 to 12 inches between plants and 18 to 20 inches between rows. Parsley grown in containers or in a garden bed outdoors should receive 6 to 8 hours of direct sunlight daily. Parsley will tolerate partial shade. Parsley roots should be kept well-watered, yet not to the point that soil is completely saturated. Well-drained soil is preferred. Incorporation of compost or the addition of fertilizer is beneficial. An equal part of N-P-K type fertilizer is suitable for both indoor and outdoor grown plants.

HARVESTING

The entire plant can be harvested. Common practice is to cut the entire plant approximately 1 inch above the soil surface. Harvested leaves can then be used fresh, frozen, or dried for later use. Dried parsley tends to lose most of its flavor. Fresh leaves should be kept at high humidity and between 32 to 35 F. Parsley leaves can also be frozen, either whole or chopped like other herbs. They can be spread out in a layer on a pan, frozen, and then bagged and left in the freezer. They can also be chopped and frozen in water or vegetable oil in ice cube trays and then bagged. Parsley, like most herbs, will be limp when thawed, so frozen herbs are best used for cooking.

VARIETIES

There are three common varieties of parsley.

Curly type parsley (*Petroselinium crispum*) is perhaps the most common and is used fresh (often as a garnish) or dried for cooking. Curly type parsley is around 7 to 15 inches tall when mature. More common varieties include: Banquet, Moss Curled, and Deep Green.

Flat leaf or Italian parsley (*Petroselinium neapolitanum*) is commonly used fresh for cooking purposes. It can also be dried for later use. Plants are taller and will mature around 24 to 36 inches. The most common variety is Plain Italian Dark Green.

Hamburg type parsley (*Petroselinium tuberosum*) is the least common type of parsley. This cultivar is used for its edible tap roots. The taproots can be used fresh consumption or as a spice for flavoring. Hamburg is the only variety.

INSECT PESTS

Parsley (*Petroselinum crispum*) and cilantro (*Coriandrum sativum*) are both in the carrot family of plants and share common pests. **Beet armyworn** (*Spodoptra exigua*) is the larvae of a small, gray moth that can't overwinter in Wyoming. Occasionally, it will disperse north on warm southern winds from endemic regions and damage crops. The **cabbage looper** is another caterpillar pest of many crops, but it is not hardy enough to overwinter. It also arrives on southern winds later in the growing season. The pale green caterpillar moves with the distinctive inch worm pattern of locomotion. The defoliation and contamination caused by these two insects and **black swallowtail butterfly caterpillars** make them serious pests if not detected early. A wide range of insecticides can be used on crops, but they need to be selected based on your control philosophy and the available pre-harvest interval.

Black swallowtail egg laid on parsley florets
Whitney Cranshaw, Colorado State University, Bugwood.org

Black swallowtail early instar larvae. The coloration and size makes the larvae look like bird droppings for camouflage.
Ansel Oommen, Bugwood.org

A fully developed black swallowtail larvae.
Whitney Cranshaw, Colorado State University, Bugwood.org

The ubiquitous **green peach aphid** and the **willow-carrot aphid** will also feed on these crops. These two aphids can vector several types of mosaic virus diseases to plants. This makes them much more harmful pests than if they only sucked sap and contaminated the leaf surfaces with honeydew (aphid excrement).

ROSEMARY

Rosmarinus officinalis

Rosemary is native to coastal regions of the Mediterranean where it grows as a perennial shrub. It is not generally regarded as perennial in Wyoming as it won't survive our cold winters, but it can be grown as a perennial in greenhouses, sunrooms, and even high tunnels. The genus name *Rosmarinus* actually means "dew of the sea." It is a woody shrub of varying height and width, depending on the variety. Fresh rosemary stems and leaves are frequently used in cooking. The leaves can also be dried and used as a culinary herb. Plants have various shapes and sizes, ranging from small mounds to 6 foot shrubs.

Diana Taliun, shutterstock.com

GROWING CONDITIONS

Rosemary grows best in warm temperatures and full sun. Irrigation should be moderate, unlike many other vegetables and herbs. The worst thing a grower can do is over-water their rosemary plants. Plants can tolerate soil pH between 5 and 8. They also tolerate a wide range of soil conditions, but do best in loose, well-drained soils.

PLANTING

Individual plants can be grown from either seeds or stem cuttings. Fresh seeds should be sown in a sterile, lightweight germination mix and not covered. The best temperature for germination is about 70 F. Plants grown from seeds tend to be very slow growing and variable, so growing from stem cuttings is usually preferred.

For cuttings, harvest 2 to 4 inch sections from new stem growth. Strip the lower leaves off, dip the bases of the cuttings in a rooting hormone, and stick cuttings in a sterile, lightweight rooting mix, at a temperature about 70 F. It will take cuttings about 3 to 6 weeks to root and another 2 to 3 weeks for roots to reach transplantable size.

Plants can be grown in containers or in the ground but are not winter-hardy in Wyoming.

MAINTAINING ROSEMARY

Plants prefer warm temperatures, low water, and only light fertilization. They can be pruned to encourage new shoot growth and older plants can be used for cuttings for new crops.

HARVESTING

Harvest stems before flowering occurs and routinely remove flower stalks. Stems can be either used fresh or can be dried. Drying tends to concentrate flavors and aromas.

CULTIVARS

- 'Tuscan Blue'
- 'Majorca Pink'
- 'Aureus'
- 'Arp'
- 'Albus'
- 'Prostratus'

INSECT PESTS

Two-spotted spider mites are the most commonly reported pest on this herb. Pesticide products selected for use have to be compatible with the plant's end use. For example, a low toxicity product like insecticidal soap would not be a good flavor to add to this herb if its residue remained on the leaves at harvest. Preventing too much water stress in hot and dry conditions that favor spider mites is a good preventative management strategy. For additional information on spider mites, see the Integrated Pest Management section, page 49.

DISEASES

Root rots–fungal diseases caused by *Pythium*, *Thielaviopsis* and *Rhizoctonia*–cause leaf yellowing and eventual death. Branches or entire plants may turn yellow or brown, and roots will generally be brown, depending on the causal organism. Over-watering will encourage development of root rots.

SAGE

Salvia officinalis

Salvia officinalis is the most common species of sage grown and used as a culinary herb. If left to bloom, sage plants produce purple to pink flowers and are attractive to pollinators. There are many plants with the common name of "sage." Most of us in Wyoming think of sage plants as the green to grey colored native plants found throughout Wyoming. There are, however, different species and varieties of sage grown as herbs and consumed by humans. These culinary herbs are not native to North America and are of the genus *Salvia*, whereas the native shrubs of Wyoming are of the genus *Artemisia*. Many species of *Salvia* are used for ornamental and culinary purposes throughout the world.

Andreja Donko, shutterstock.com

GROWING CONDITIONS

Sage is a perennial shrub that can be grown indoors or outdoors. For outdoor production, growers in most of Wyoming should choose cultivars of sage that are hardy to USDA Zone Hardiness 4. Plants grown indoors require plenty of light to grow well. Additional lighting may need to be added in some situations. These plants will need pots at least 10 to 12 inches in diameter to provide enough support for the sage plant once it reaches maturity, to prevent tipping over. Sage plants grow best in well-drained soils in full sun. Plants will not grow in overly wet soils or in shady areas.

PLANTING

New plants can be started by seeds or divisions from existing plants. Seeds should be planted after the threat of frost or started indoors. Seedlings can be transplanted outdoors after 6 to 8 weeks. Allow 24 inches between plants. Locating and purchasing seeds for each of the varieties listed below can be a bit difficult. Seed of unnamed strains is easier to find. Plants will reach two feet in height when mature.

HARVESTING AND MAINTENANCE

The leaves of sage are used for culinary purposes. Stems may become quite woody after 3 to 5 years of growth and decreased leaf production can sometimes occur as plants become older. For best leaf yields plants should be divided or replaced when plants become too woody and leaf production decreases.

Sage should be harvested by cutting 6 to 8 inches of the stem. The leaves can be removed from the stem for fresh consumption or dried for later use. If you don't plan on using harvested sage leaves soon, they can be dried and stored in the refrigerator for up to two weeks to produce a fresher taste than those that have been dried and stored for longer periods of time.

For those interested in selling fresh sage, information on post-harvest handling for herbs

can be found on the University of California, Davis, Postharvest Technology Center website. https://bit.ly/uc-veg-facts.

CULTIVARS

- Berggarten—green to silverish-gray leaves, leaves are very large, and more hardy than other species listed
- Golden Sage—Bright yellow leaves and only hardy to zone 6
- Icterina—yellowish green striped leaves
- Purpurea—purple-colored leaves and hardy to zone 6
- Tricolor—red, white, and green-streaked leaves and hardy to zone 6

INSECT PESTS

Salvia officinalis is pretty resistant to arthropod pests, however, **two-spotted spider mite** and **Western flower thrips** occasionally feed on it. Both the **green peach aphid** and the **foxglove aphids** (*Aulacorthum solani*) are occasionally a problem on various *Salvia* species. For additional information on these insects and control measures, see the Integrated Pest Management section, page 42.

THYME

Thymus vulgaris

Culinary, common thyme is about 1-foot high by 2 feet wide and is widely used in many dishes. Thyme is a native of the Mediterranean region of Europe and North Africa, and the flowers are attractive to bees. The genus *Thymus* is in the mint family, Lamiaceae, and includes many different species. *Thymus* x *citriodorus*, for example, is the very fragrant lemon thyme. Some species of thyme are more useful as landscape plants than for cooking. These include *T. pseudolanuginosus*, or woolly thyme, and *T. serpyllum*, or creeping thyme.

GROWING CONDITIONS

Thyme thrives under conditions of high light and moderate water, so let the plants dry a bit between watering. Species of thyme vary in winter hardiness. Common thyme is winter hardy in many areas of Wyoming, though it will need irrigation in winter when the soil is not frozen to avoid winter desiccation. Planting it in a location protected from winter winds can help as well. Soil should be in the 6 to 8 pH range, loose, and well-drained.

Diana Taliun, shutterstock.com

PLANTING

Thyme is generally grown from stem cuttings because the seeds are very erratic in germination. If a grower wants to use seeds, sow several seeds in each cell of a 288-cell plug tray, cover the seeds very lightly, and keep them at 70 to 72 F. Seeds should germinate in 6 to 10 days and will be ready to transplant to larger containers or outside in 5 to 7 weeks after sowing.

To use stem cuttings to create new plants, take 3 to 4 inch stem cuttings from active growth (not woody) in spring. Use a clean, lightweight growing mix to plant them in (sticking) and keep the cuttings at about 70 to 75 F. They should root in 3 to 4 weeks and should be ready to transplant about 5 to 6 weeks after sticking.

Thyme plants can be grown in containers or in the field.

MAINTAINING THYME

Lots of sunlight favors enhanced fragrance in thyme. Keep the plants on the dry side as well. Fertilization should be light. The plants can be encouraged to branch by pinching within a week or two after planting.

HARVESTING

Harvest stems just prior to flowering for best flavor. Keep plants from flowering by removing flower stalks as they appear. Stems can be used either dried or fresh. Drying tends to concentrate flavors and aromas.

CULTIVARS

- 'Argenteus'
- 'Silver Posie'
- 'Lemon'
- 'Dot Well's'
- 'Narrow Leaf French'
- 'Aureus'
- 'Golden King'
- 'Pinewood'
- 'Silver Queen'

INSECT PESTS

Eight species of aphid are known to feed on thyme but the **green peach aphid** and **potato aphid** (*Macrosiphum euphorbiae*) are the primary pest aphid species in North America. The leaf distortion reaction to the toxic saliva the potato aphid injects makes it the more harmful pest. In addition, both aphid species can vector plant diseases to thyme. Populations of **two-spotted spider mite** can flair up on these herbs in hot, dry, dusty conditions if they are moisture stressed. For additional information on these insects and control measures, see the Integrated Pest Management section, page 42.

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CHAPTER 4: FRUITS

FRUIT GROWING TIPS

Growing fruit trees, shrubs, or other perennials can be challenging in Wyoming but can also be very rewarding. There are some items to consider before you decide on the type of fruit plants you want to grow and where to put them. This tips section will help provide some important considerations that may show up again under each fruit section.

WHAT COULD GROW AROUND HERE?

Successful fruit growing is founded on a good knowledge of the growing area. Understanding the climate of your property will help determine which fruit species may have the best chance of survival and production. It is no secret that temperature limits fruit production in many parts of Wyoming. Extreme winter lows, late spring frosts, and short frost-free periods can all affect fruit production. Understanding your property (including locating any microclimates) can help you select the best planting areas and choose the right fruit varieties that will give your fruit plants the best chances for success.

LOCATION, LOCATION, LOCATION—FINDING A PLACE TO THRIVE

Protected locations often turn out to be the best areas for growing for a variety of reasons, particularly if these places can reduce drought and exposure to wind. Most native Wyoming plants have developed strategies for minimizing water loss during the growing season. Many introduced fruit plants do not have specialized leaves and plant cells for dealing with these conditions. Placing plants in areas where they are protected from the elements, including

wind events, will help reduce water loss. A protected location will also help keep plants insulated during colder temperatures and may help extend their potential growing season.

Fruit plants can be located in microclimates created by man-made structures. Proper location near a dwelling, downwind from a tree belt, or other natural features on a property can enhance their growth. Pay attention to when and where the wind blows, sun shines, snow piles up. Snow acts as an insulator from cold; however, tree branches can be snapped by the weight of snow drifts.

Slope and aspect play a key role when selecting a place to grow. Steeper slopes tend to have shallower soils and can be more challenging for maintaining consistent soil moisture. Flat or low-lying areas may tend to accumulate water and not allow enough air to reach plant roots. Colder air will also settle in low lying areas compared to slopes and benches.

Aspect is also important to consider since the aspect will determine potentially how hot or cold a site will be. South facing slopes will be much warmer than north facing slopes. This added heat might allow certain plants to receive enough sunlight and adequate temperatures for fruit production. This same site, however, might lead some fruit species to bloom earlier in the spring and put that plant more at risk of blooming during a spring frost, which can result in no harvest at all.

Many fruit tree and shrub cultivars from commercial growers are not adapted to Wyoming's cold temperatures and require long frost-free periods for production. When selecting fruit varieties, make sure they will withstand the lowest potential temperature for your area. For many locations in Wyoming, this means selecting either zone 3 or 4 plants as related to the USDA Plant Hardiness Zone Map https://bit.ly/USDA-Plant-Hardiness-Zones. For less winter damage or die off risk, we recommend planting zone 3 plants. It is often not the week of -10 F that kills a tree but the fluke cold snap when temperatures get to -40 F for several hours.

PLANT AND ROOT SELECTION

Fruit trees, shrubs, and forbs come in many different shapes and sizes. Trees and shrubs often prove the greatest challenge for future planning and care. When selecting plants, find species that will not outgrow your ability for care. This is most meaningful when discussing large fruit trees such as apple, apricot, pear, plum, and cherry. Today, many fruit trees have a particular variety of fruit that has been grafted onto a specific rootstock. The rootstalk is a plant of a different variety. It provides the roots and lowest part of the trunk when another variety is grafted onto it. The rootstock is very important; it determines the size of the mature tree, winter survival, and growth productivity.

Decreasing in size, trees can grow to the height of a standard tree, semi-dwarf, or dwarf. With dwarf being the smallest size, these tree sizes often make the most sense for backyards in urban areas. While dwarf sizes are great for maintenance, it is suggested these rootstocks are not as hardy as a standard rootstock and often have shorter lifespans. Standard trees can be planted if you have limited space, but a lot of intense pruning may be required each season to make sure it will not outgrow its space.

Once you purchase a fruit tree(s), proper planting is important. Damage from improper planting techniques may not show itself until after you have invested years of care. For proper tree planting techniques, check out these UW Extension Barnyards & Backyards articles https://bit.ly/tree-planting-2005 or https://bit.ly/tree-planting-2007.

PLANT CARE

Pruning is an important aspect of fruit tree and shrub care. Resources being allocated to a poorly placed or damaged tree branch can lead to the loss of fruit production. Pruning should be completed in

late winter or early spring before trees and shrubs have started to bud. Older trees can be pruned more heavily than younger trees. Keep in mind, tree branches at angles greater than 45 F are a lot stronger than narrow angled branches. For pruning strategies check out this Oregon State Extension publication, http://bit.ly/Pruning-Strategies.

A common strategy is to thin fruit on branches to optimize fruit growth, quality and production consistency. Thinning fruit can decrease the overall number of fruit produced while increasing the size and quality of the remaining fruit. It can also help promote bud formation for the following year. To accomplish proper thinning, remove immature fruit after the tree is done blooming and you can see fruit developing. Generally this should be done within 30 days of the end of the bloom, when fruit is under ½-inch in diameter. Save the healthiest looking fruit during thinning and avoid damaging the blossom spurs. Sometimes in Wyoming adverse weather events do the thinning for us.

Apples, pears, plums, apricots and peaches are most often thinned to a spacing of 6 to 8 inches between fruits along a fruiting branch. The "king blossom" or the center blossom/fruit is most commonly kept when thinning apples and pears. Tart cherries do not need to be thinned. Some fruit varieties have some degree of self-thinning. Premature fruit drop occurs naturally for some such as plums, peaches and cherries. Plan thinning accordingly for these fruits.

Supplemental irrigation water for fruit plants is required in most areas of the state. Knowing your soil texture is important when considering the amount and timing of water applications. Adding three to four inches of mulch from the base of the tree to the outer drip zone of the tree canopy is important. The mulch helps conserve water during dry periods and also helps reduce competition from weeds, grass and other plants for resources. It also helps protect trunks from equipment damage. Plant roots need to be kept moist throughout the entire root profile. Deep watering is highly encouraged. Avoid putting lots of mulch next to the trunk of trees since this can lead to potential rotting issues and provide cover to rodents that will eat the bark.

PREVENTING SUNSCALD

Many fruit tree types are susceptible to sunscald in winter. Sunscald damages the trunks of these trees. Sap moves within a tree during the warmer part of the day, and then cannot be released back to the roots by the time temperatures begin to freeze, ultimately damaging the cells of the tree trunk. To avoid this, paint the entire trunk or at least the south facing side of the trunk with an interior white latex paint. The white paint is reflective and will reflect enough sunlight to keep the trunk cool enough to prevent sunscald. Trees can also be wrapped with soft white tree tape to help prevent sunscald.

DISEASE AND PREDATOR CONTROL

Unfortunately, there are many other challenges facing fruit production besides the Wyoming climate and soils. Small and large animals, bacterial infections, and insects all can have negative impacts. Maintaining a healthy fruit plant is the first step in dealing with potential stresses a plant might face.

Small mammals–Add ¼-inch mesh wire around the base of trees to prevent voles from girdling the bark of the tree while they search for food under the snow during winter. Pocket gophers are also a pesky grazing problem. Instead of eating stems, these rodents eat the root system of trees. Poisons are often the most effective control for voles and gophers depending on the situation. Please refer to https://bit.ly/voles-2015 and https://bit.ly/gophers-2019.

Large animals–Place taller fencing around the perimeter of orchards or small fruit locations to prevent grazing from larger mammals such as deer, elk, and moose. Deer will browse on limbs, eat the fruit and rub on trunks or branches. This rubbing can destroy fruit trees or create wounds for disease entry. Please refer the section

on Keeping Critters Out, page 55, for more information on fencing out large animals. Netting might be needed to prevent birds from eating fruit before it becomes ripe. The larger the fruit tree, the more challenging netting tends to be.

For some mammals, such as squirrels and raccoon, fencing is not always feasible. In some cases, fruit is harvested early. Electric fence can help deter some of these types of critters. You may want to reconsider planting fruit crops if you live in areas with many bears. Not surprisingly, fruit crops can attract bears to a property.

More information related to disease and insect issues are included with each fruit section. Remember, a healthy plant is the first step for prevention of many pests and diseases. Fruit production in Wyoming can be challenging. This information will help get you started in the right direction for successful fruit production in your backyard or acreage.

CURRANTS AND GOOSEBERRIES

Ribes spp.

Currant and gooseberries are well-suited for Wyoming's climate. These perennial shrubs are in the *Ribes* genus and provide growers with a fair number of cultivar options. While there are many native species of *Ribes* in Wyoming, the common cultivars have been developed from species native to Europe. Berries can be sold and used for fresh eating, cooking, and preserving.

GROWING CONDITIONS

Both currants and gooseberries can be used in commercial production. Most currant and gooseberry cultivars are USDA hardiness zone 3 or 4, which makes them ideal for Wyoming. Look for areas with full to partial sun. Plants can handle full sun but are adaptable and can survive in shaded areas as well. Since plants bloom very early in the season, those in areas at high elevation or low-lying areas might consider planting on the north side of buildings to delay the blooming of plants, which helps avoid damage to blossoms from frost. Adding several inches (2 to 4) of mulch at the base of plants is useful for reducing competition from weeds and grass, helping maintain moisture for plant roots, and reducing injury from mowers and weed eaters.

Gunimunds, shutterstock.com

PRODUCTION

Plants bloom early in the spring and produce fruit from the middle of July to early August. Most currants will produce fruit in a 1-to-2 week window, while gooseberries produce over a longer 3-to-4 week period. Soils that are well-drained, remain cool through the growing season and have adequate moisture are best. Plants can grow in slightly acidic and alkaline soils. Incorporating organic matter into the soil before planting can be useful. Also consider adding a moderate level of fertilizer or organic matter around plants once they have established; however, currants and gooseberries have moderate nutrient needs so do not over-fertilize.

Currants and gooseberries will produce fruit after two years and usually take three to five years to reach a mature size. Mature currant plants are 3 to 5 feet in height. Plants should be spaced 3 to 5 feet apart in rows 6 to 8 feet apart. This will allow room for spread and access for harvesting berries. Gooseberries should be spaced 3 to 4 feet apart in rows 6 to 8 feet apart. Both species should be pruned to help with shape and fruit production. Instead of pruning the ends of branches off, look to remove the entire length of older branches to maintain plant vigor. Aim to maintain 1, 2 and 3-year-old branches on plants for best production. Plants should be pruned during the dormant season (November to March).

VARIETY SELECTION

Varieties of currant and gooseberries can be selected based on color, taste, disease resistance, and presence of thorns. Black, red, pink, and white are the most common colors of berries. The size of berries is relatively small compared to some fruits such as strawberries, but the quantity produced from mature bushes can be quite large. A mature currant or gooseberry plant can produce 5 quarts of fresh fruit. Berry flavor also varies between species. Tartness is often the biggest factor when selecting for taste. Currant stems lack thorns, while gooseberries generally have small thorns. There have been fewer varieties of gooseberries developed due to the presence of thorns. Harvest berries when they are large and/or the proper color. Some types of gooseberries are harvested before they are fully ripe to allow them to slowly ripen and increase flavor.

Black currants

- 'Ben Sarek' (highly resistant to blister rust, but susceptible to mildew)
- 'Titania' (highly resistant to mildew and blister rust)
- 'Consort' (highly resistant to blister rust)

White currants

- 'White Imperial' (very mildew resistant)
- 'Blanca White' (very mildew resistant)
- 'Primus White' (susceptible to mildew)

Red currants

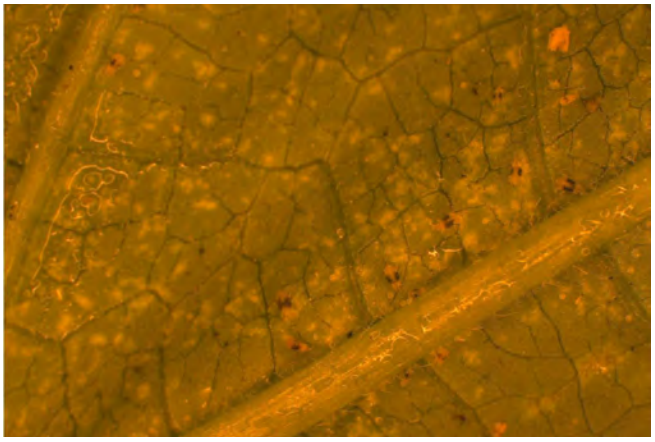
- 'Red Lake' (mostly resistant to blister rust but susceptible to mildew)
- 'Rovada' (resistant to mildew and leaf spot diseases)
- 'Tatran' (very resistant to mildew)

Gooseberries

- 'Pixwell' (pink) (mildew resistant)
- 'Invicta' (resistant to mildew but not leaf spot)
- 'Poorman' (very resistant to mildew)

INSECT PESTS GOOSEBERRIES, CURRANTS AND JOSTABERRIES

Affecting vegetative growth (Pests that chew leaves or pierce and suck plant juices)

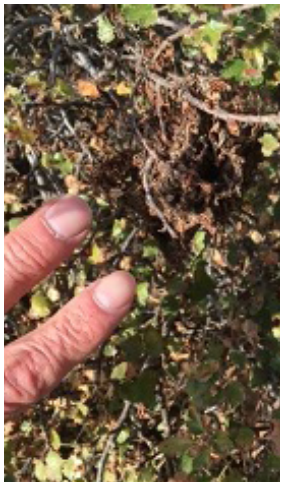


Twospotted spider mite adults and eggs
Tracy Wootten, University of Delaware, Bugwood.org

Ribes species plants are among the many plants attacked by the **twospotted spider mites.** Eliminating water stress, limiting dust on the plants, which harms spider mite predators, and proper fertilization are all cultural controls that can help keep twospotted spider mites in check. There are both organic and inorganic miticides labeled for use on *Ribes* spp plants. Using pesticides specific to mite control, miticides (rather than broad-spectrum products), can have a reduced impact on insect predators of the mites.

Currant aphid damage
Whitney Cranshaw, Colorado State University, Bugwood.org

Currant aphid (*Cryptomyzus ribis*) is a single host plant species that overwinters as eggs on Ribes species plants, and the subsequent spring and summer aphid generations are wingless and reproduce asexually. Sooty mold can grow on the honeydew (excrement) these aphids produce. This mold can damage fruit quality and stress the infested plant.



In the pictures above the mass of caterpillars did defoliate part of this wax current bush, but the plant put on a new set of leaves, and the debris-filled tent is the only evidence of their presence by late summer.

Scott Schell, University of Wyoming Extension

Western tent caterpillar (*Malacosoma californicum*) is a native insect that overwinters as egg masses on the branches of host trees and shrubs. Their populations are suppressed to noneconomic levels most years by environmental conditions, diseases, and predators. They are susceptible to many control products labeled for leaf feeding caterpillars. Don't cut the branches with tents out as a control measure (unless you were planning on pruning anyway). With the same amount of effort, you can wipe them off by hand (and throw into a container of soapy water) or spray an insecticide and preserve the plant. The infested branch will grow a new set of leaves after the caterpillars are gone.

Imported currantworm

Whitney Cranshaw, Colorado State University, Bugwood.org

The **imported currantworm**, aka currant sawfly (*Nematus ribesii*), have six pairs of abdominal prolegs they use for grasping the leaves behind the six thoracic legs they keep for walking as adult sawflies.

Currant spanworm

Whitney Cranshaw, Colorado State University, Bugwood.org

The **currant spanworm**, (*Itame ribearia*), is a caterpillar that will feed currant and gooseberry leaves. The caterpillars are spotted similar to the imported currantworm; however, they only have two pairs of abdominal prolegs near the end of the abdomen that give them the distinctive looping walk of the spanworm/inchworms.

Sumac flea beetle
Joseph Berger, Bugwood.org

The **sumac flea beetle** (*Blepharida rhois*) will feed on shrubs in the in the genus *Rhus* as well as currants (*Ribes* spp). The coloration of this jumping beetle is very variable.

Gooseberry fruitworm
Donald Hobern, CC BY 2.0, https://creativecommons.org/licenses/by/2.0, via Wikimedia Commons

Gooseberry fruitworm (*Zophodia grossulariella*) is a small moth that uses the almost ripe berries of currants and gooseberries as food for its larvae. The rapidly growing caterpillars need several berries each to complete development. Larvae tie the fruit and adjacent leaves together with silk as they exit the consumed berry.

Currant borer
Whitney Cranshaw, Colorado State University, Bugwood.org

Currant borer (*Synanthedon tipuliformis*) larvae tunnel down the path of the canes in June. The feeding damage causes the foliage to yellow at first, but will kill the cane eventually. The only control is removal and destruction of the infested canes before the larvae overwinter, pupate, and emerge the following spring.

Rose stem girdler
Whitney Cranshaw, Colorado State University, Bugwood.org

Rose stem girdler/ bronze cane borer also attack *Ribes* species plants. (See information on this pest in the Raspberry crop section for management options, page 222.)

Insect pest affecting the saleable parts directly

The currant fruit fly (*Euphranta canadensis*), gooseberry fruitworm (*Zophodia grossulariella*), and the spotted wing drosophila will all attack the *Ribes* fruit. The use of insecticides labeled for application to protect the fruit with the appropriate pre-harvest interval is the primary management method for these three pests. The variety of pesticides are limited on currants and gooseberries. Some formulations of pyrethrins allow use on these crops and are also effective for imported currantworm control.

A very detailed publication entitled “Growing Currants, Gooseberries & Jostaberries in the Inland

Northwest & Intermountain West" was published by University of Idaho Extension in 2009 and can be viewed online at https://bit.ly/UID-currants.

DISEASES AND DISORDERS OF CURRANTS AND GOOSEBERRIES

Physiological disorders (abiotic disorders)

Dormant ("blind") buds fail to grow out in the spring. Some early flowering varieties are susceptible to freezing temperatures in the spring. Select appropriate varieties for your local conditions.

Infectious diseases

Affecting both currant and gooseberries, **powdery mildew** is caused by the fungus *Podosphaera mors-uvae*. Powdery white fungal growth initially appears on the oldest leaves but then spreads to cover all leaf surfaces, green shoots, and fruit. Later in the season, small black fruiting structures can form on twigs, canes, and fruit. Plants are not killed, but yields are reduced and can be unmarketable. Favored by high humidity and moderate temperatures, spores are easily spread by wind. Infection typically occurs late in the season, so fungicide control is generally not needed. Prune and thin bushes to provide better air circulation. Remove infested plant material or incorporate it well into the soil.

Anthracnose is a fungus that affects leaves of gooseberries and leaves and fruit of currants during periods of extended warm, rainy weather. Small, dark-brown spots may develop on leaves, which can cause foliage to yellow and drop prematurely. On currants, fruit may develop small black specks and fruit can crack open and drop. To manage, remove and destroy dead leaves from under bushes. Prune and thin bushes to provide better air circulation.

Currants and gooseberries can serve as an alternate host to the fungal pathogen **white pine blister rust**. Spores travel from infected 5-needle pines in the spring (up to 300 miles) to infect plants in the *Ribes* family. Warm, moist conditions are required for infection. After infection, tiny yellowish spots become visible on the upper leaf surface while on the underside, yellow-orange blister-like fruiting bodies appear. These spores can continue to infect *Ribes* sometimes resulting in premature defoliation. By late summer, threadlike growths (yellow-brown in color) develop near these initial infection sites and produce spores that infect 5-needle pines. The best management strategy is to plant disease-free and resistant plants from the start. Not much can be done if infection occurs.

GRAPES

Did you know that grape production occurs in every state in the United States? Even here in Wyoming. Wyoming's production is primarily for homeowner use, though there is some small scale commercial production. There are even native or wild grapes (*Vitis riparia*) found in Wyoming, though these are not usually desired for cultivation because of low yield and poor berry quality.

There are several uses for grapes, including fresh eating, wine, juice, dried (raisins), and jellies. Grapevines are a woody perennial vine cultivated for numerous years. There are vines in Europe that have been under cultivation for over a hundred years.

Jeremiah Vardiman, University of Wyoming Extension

GROWING CONDITIONS

So what does one need to know about grapes to be successful in Wyoming? Often overlooked, site location and support of the vines (trellis or similar structure) are two important factors that will affect the survivability and yield of the vines, even if the correct variety is planted.

Three environmental factors limit Wyoming's grape production: harsh cold winters, late and early frosts, and short growing seasons. Grapes do not tolerate cold temperatures, especially during the growing season. Grapes should only be planted in areas of Wyoming that have frost free periods. Of course, the longer the frost free period the better.

In addition to the frost-free period, selecting a vineyard location that has a conducive microclimate for grapes is key. Most often this is on a southern or southeastern exposure, especially when planted near buildings, shelter belts, or on a hill. This exposure usually assures direct sunlight, a warmer microclimate, and drier sites than a northern aspect.

Interestingly enough, vineyards can often be established on sites considered unsuitable for other crops. Well-drained soils are the most desirable for growing grapes. A soil that provides a balance of good drainage while still having an adequate moisture holding capacity would be ideal; however, grapes can be grown over a wide variety of soils and wide range of soil conditions. Grapes perform poorly or do not survive when their roots are constantly saturated with water.

The trellis or support structure is the next consideration. A durable structure is needed to support the vine whether growing one vine or acres. Remember these vines can grow for many years and get larger and heavier as the age of the vine increases. It is recommended the trellis is built so the top is 5 or 6 feet tall and in full sun.

VARIETY SELECTION IS CRITICAL

There are five important species of grapes usually considered for cultivation. These are the European Bunch Grape (*Vitis vinifera*), Muscadine Grape (*Vitis rotundifolia*), Summer Grape (*Vitis aestivalis*), Fox Grape (*Vitis labrusca*) and River Bank Grape (*Vitis riparia*). The Fox Grape and River Bank Grape are the only two species that can handle Wyoming's cold climate. Note that the Fox Grape can suffer from nutrient deficiencies in high pH soils and may only work in certain areas in Wyoming. The recommended varieties for Wyoming would be cold-hardy hybrid grapes that have the River Bank Grape and possibly European Bunch Grape in their parentage.

Selecting the correct grape variety includes several considerations. The first is cold hardiness, which is usually the coldest temperature the variety can tolerate. Colder temperature varieties have a better chance of survival. Other considerations would be the use of the grapes (wine grapes may not be desirable for fresh consumption), color of berries or color of end product (white versus red), and desired flavor or aroma (especially for wines).

PLANTING

Grapevines should be planted in the late spring to early summer when the chance of a late frost is minimized. For example, this would be around the end of May to the middle part of June for Sheridan. Planting during this time period (rather than later) gives the vines all season to grow and establish. This will give the vines the best chance of surviving their first winter.

Before planting, measure and mark out the desired spacing for the new grapevines. This spacing varies by variety. Once these are marked, dig a hole slightly deeper and wider than the roots when naturally extended, without bending or curling the roots. The crown of the plant should be at the soil surface when the vine is properly planted. Grapevines planted too shallowly or too deeply will be less likely to survive.

If you determine your soil needs to be amended with compost, it should be mixed with the soil that will refill the planting hole. Backfill the hole while holding the plant in place. Once the hole is completely backfilled, water the vine well.

MANAGEMENT

Climatic factors, variety, and management of the vineyard all play a part in the potential yield of the vines. After a site and variety is selected, these factors cannot be manipulated for better yield. Management of the vine is the only factor controllable to some degree. This includes training and pruning of the vineyard, canopy management, irrigation and fertilization, and pest management. Vineyard management includes training vines to 5 or 6 feet in height, pruning once a year, and not allowing them to produce fruit the first three to five years of its life.

Training the vines to 5 or 6 feet keeps the new buds and next year's fruit production above the coldest air, which is next to the ground. Pruning keeps the vines growth under control and manageable, while also increasing berry size and quality. Pruning is typically done while the vine is dormant, a window between the coldest portion of the winter and before bud break (March to early May). Because of the uncertainty of Wyoming's winter and spring, pruning can be done after bud break to visibly see how much of the vine has survived the winter, though this is not ideal.

One of the most significant management techniques that can help the vines survive Wyoming's short growing seasons, frosts, and cold winters is to push for the biggest, healthiest vines possible. This is achieved by pinching flowers off (removing them) as they develop on the vine for the first three to five years. Keeping the vine from producing fruit this way conserves the vine's energy for root, trunk, and shoot development, which results in a more robust and vigorous vine. Having this robust and vigorous vine also benefits fruit yield and quality when the first crop is produced.

DAYS TO MATURITY

Days to maturity is dependent on grape variety. Short season grape varieties perform the best in Wyoming. These varieties need approximately 100 to 140 frost free days.

HARVESTING

Grapes need to completely ripen on the vine before they can be harvested. Harvesting parameters can vary between table and wine grapes. In case of table grapes, higher sugar levels are desirable at the time of harvest. Sugar content of berries can be measured using an instrument known as a refractometer. To use this instrument, harvest some of the berries you would like to test. Squeeze a drop of juice from the berry and place it on the panel of the refractometer. Digital and analog versions of the refractometer are available that will provide a reading known as **total soluble solids** (**TSS**). TSS in fruit juice predominantly consists of sugars along with acids and other compounds. TSS readings are expressed in degree Brix. Table grapes are generally harvested at TSS levels of 20 Brix and upward (berries of some cultivars accumulate up to 25 Brix). Wine grapes are harvested at TSS levels of 17 to 21 Brix and are selected for the uniqueness of the wine desired.

Other important considerations for harvesting table grapes include uniform color development and change in the color of the rachis (the part of the stem containing all the berries). In case of white cultivars, berry color changes from green to different shades of yellow-green and yellow. In dark colored varieties, uniform red or dark black color is observed in berries following ripening.

Harvesting early in the morning helps in keeping the fruit at a low temperature and ensures better quality and post-harvest storage. If harvesting for sale, great care should be taken while harvesting and post-harvest handling of clusters to maintain their attractiveness and luster. Remove any shriveled, diseased, and insect damaged berries from the clusters during cooling.

VARIETIES

Cold-hardy hybrid grapes to try: Frontenac, Frontenac Gris, Marechal Foch, Prairie Star, Bluebell and Valiant. Also, Saint Theresa and Beta.

For more detailed information on grape production in Wyoming, please read the publication "Wyoming Grape Guide" which can be found online at http://bit.ly/BBfruitgrowing.

INSECT PESTS

There is great potential for grape production in Wyoming with the development of varieties that were selected for coping with short, frost free periods. The lack of large areas with wild grapes provides another advantage by reducing pest insects that specialize on the plant. This is fortunate, but it doesn't mean that it is impossible for a grape specialist pests, like the glassy winged sharpshooter, to show up in a Wyoming vineyard. You will still need to monitor for vineyard pests on a regular schedule. A grower should also be very cautious about the importation of plant material that could harbor plant diseases or insect pests into your growing area.

Your individual production philosophy and the end use of the grapes will determine what pesticides can or can't be used legally if you discover economically damaging populations of pests. Identification of the pest is the first step of IPM. The second step is determining whether the pest damage can be economically treated. Pest damage that threatens the long-term health and productivity of the vines and the saleable portion of the plant are most likely to be worth treating. Wyoming doesn't have some of the most damaging pests of grapes, yet; however, regular scouting of your vineyard to detect and manage pest problems before they become severe cannot be overemphasized.

Pests that attack grape roots and/or woody parts

Galls on grape leaves from grape phylloxera
Whitney Cranshaw, Colorado State University, Bugwood.org

Grape phylloxera (*Daktulospharia vitifoliae*) is a small insect related to aphids that spends most of its complex life cycle feeding on grape roots. It is most visible when the gallicole stage of the insect forms galls on grape leaves. This insect pest is infamous because it almost destroyed the wine industry in Europe by 1900 when it was accidentally introduced in 1860 with American grape vines. The American grape plants were imported to improve powdery mildew resistant in European species of *Vitis*. Three American grape species are resistant to phylloxera, and their rootstock must now be used for grafting susceptible grape species vines worldwide.

A mating pair of grape root borers.
H C Ellis, University of Georgia, Bugwood.org

Grape root borers (*Vitacea polistiformis*) are found all over the eastern Unites States and hopefully will not spread to Wyoming. The larvae of this pest tunnel into the roots, eventually chewing their way out of the grape's crown. Diagnosis requires digging up dying grape vines and examining the roots.

Grape pests that chew leaves or pierce and suck plant juices

Apple flea bettle
Joseph Berger, Bugwood.org

Apple flea beetle damage
Whitney Cranshaw, Colorado State University, Bugwood.org

Apple flea beetle (*Altica foliaceae*) adults and larvae will defoliate grapes and many other plant species. The iridescent green adults that overwinter in plant debris are strong fliers. They seek out suitable host plants and deposit pale orange eggs on their leaves. The larvae that hatch are black grubs that skeletonize the leaves from the underside.

The variegated cutworm (*Peridroma saucia*) in this photo feeding on hemp is a common species of climbing cutworm in Wyoming.
Whitney Cranshaw, Colorado State University, Bugwood.org

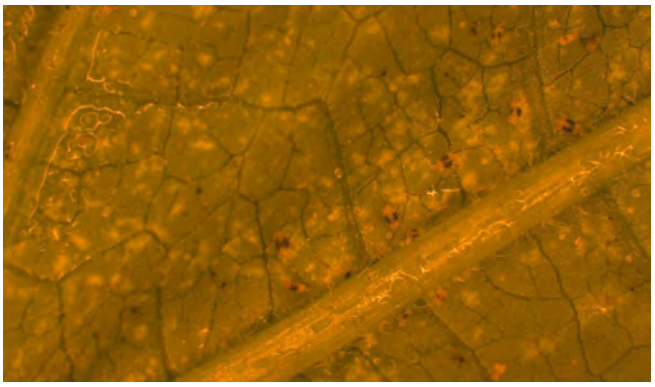
Climbing cutworms is a catch-all term for the larvae of multiple species of noctuid moths. The larvae are most active at night or overcast days and will climb up on a wide variety of host plants to feed.

Severe leaf injury symptoms. Green areas are where leafhopper eggs were laid and are largely avoided by nymphal feeding
Whitney Cranshaw, Colorado State University, Bugwood.org

The widely distributed **Virginia creeper leafhopper** (*Erythroneura ziczac*) can also severely damage grape leaves with their piercing beak, which they use to extract the plant cell contents.

Cottony maple scales
Raymond Gill, California Department of Food and Agriculture, Bugwood.org

Cottony maple scale (*Neopulvinaria innumerabilis*) is able to utilize grapes and many other plants as hosts. These insects feed on the plant phloem and produce copious amounts of honeydew, which attracts ants and also results in sooty mold growing on the plants and grape clusters. Pruning can be used to control them if the scales are mainly on the vines. Horticultural oil applications can be used for their control if they are found on the main grape trunk and cordons.



Twospotted spider mites adults and eggs
Tracy Wootten, University of Delaware, Bugwood.org

Ubiquitous web spinning **spider mites** such as the twospotted and McDaniel species (*Tetranchyus urticae* and *T. mcdanieli*) can cause damage in vineyards usually in response to hot, dry, and dusty climatic conditions. Alternatively, spider mite populations can flare after a pesticide application for other grape

pests that unintentionally reduces their predators' populations. A hand lens may be necessary to see the mites when scouting. The action threshold for treatment is usually around 15 mites per leaf, but they can rapidly increase to damaging numbers in favorable conditions.

Damage caused by root weevils.
Jim Baker, North Carolina State University, Bugwood.org

Root weevils (*Otiorhynchus sulcatus*)—The root damage caused by the larvae of these beetles can apparently be tolerated by grape vines. Detection of these pests is usually accomplished by observing the characteristic leaf edge notching done by the nocturnal adult weevils. The feeding damage by adult weevils on buds, berries, and cluster stems is the worst damage they inflict on grapes. This pest is covered in greater detail in the raspberry section, "Raspberries" on page 222.

Grasshoppers (multiple species) The weedy areas of fence lines, borrow ditches, and around outbuildings are preferred by the pest grasshopper species for their overwintering eggs. Scout the habitat that pest grasshopper species use for egg pod deposition starting in mid-May and continue on a weekly schedule until mid-July. Treat these areas with poisoned grasshopper bait or sprays as they hatch. The goal of management is to treat the source of the pests outside of the vineyard to prevent invasion later in the summer as the grasshoppers become more mobile. See grasshopper management under the Integrated Pest Management section for more information, page 47.

Damage caused by grape erineum mites.
Lesley Ingram, Bugwood.org

Grape erineum mites (*Colomerus vitis*) are microscopic, and the "blister like" malformations on the leaves are the visible sign left by their feeding activity on the leaf. They cause little harm at low population levels and are often controlled if sulfur is applied to the leaves for disease control.

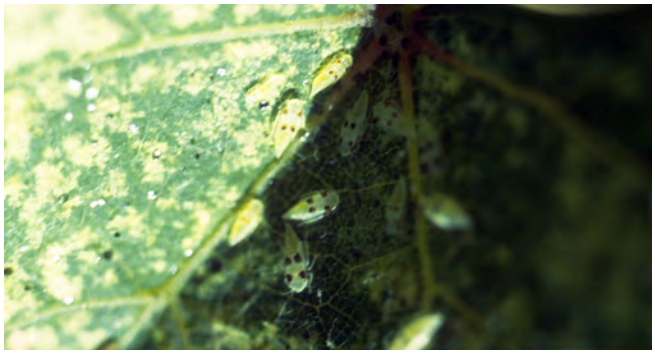
Western grape leaf skeletonizers
Whitney Cranshaw, Colorado State University, Bugwood.org

Western grape leaf skeletonizer (*Harrisina metallica*) caterpillars are brightly marked and often feed in groups on the surface of the leaves. Many insecticides labeled for leaf feeding caterpillars on grapes are available. Follow the label and know the field re-entry period and pre-harvest interval labeling for any product you choose to use.

Achemon sphinx
Whitney Cranshaw, Colorado State University, Bugwood.org

Large **Achemon sphinx** (*Eumorpha achemon*) **caterpillars** are common on Virginia creeper ornamental plants but can also utilize grape leaves for food. Their number and density in the vineyard determine their pest status, but the large insects can eat a lot leaves.

Insect pests affecting the saleable parts directly



Nymphs of the western grape leafhopper on a grape leaf.
Eugene E. Nelson, Bugwood.org

Grape leaves are not commonly considered a saleable product of a vineyard, but some Mediterranean cuisine utilizes grape leaves and they could be a potential cash crop at farmer's markets as vigorous plants can easily withstand light defoliation. **Western grape leafhopper** (*Erythroneura elegantula*) nymphs' piercing sucking mouthparts can inflict damage on the surface of grape leaves. These insects can jump quickly (and adults can also fly off the leaves) so sometimes they are hard to see closely. The leafhoppers have multiple generations through the growing season.

Grape berry moth
Mark Dreiling, Bugwood.org

Grape berry moth (*Paralobesia viteana*) can have multiple generations per growing season with the first generation feeding on the blossoms and small berries. The second generation caterpillars tunnel directly into the grapes. Both generations tie the grape clusters together with silk webbing.

European grapevine moth larvae
Todd M. Gilligan and Marc E. Epstein, TortAI: Tortricids of Agricultural Importance, USDA APHIS PPQ, Bugwood.org

European grapevine moth (*Lobesia botrana*) is a new invasive pest of grape initially found in California in 2009 and declared eradicated in 2016. Their larvae hatch at the same time the grape clusters are developing. When the berries form they eat into the grapes. Hopefully, this damaging pest will never be reintroduced to the United States again, but it should be watched for.

Spotted wing drosophila larvae and adult
Hannah Burrack, North Carolina State University, Bugwood.org (both)

Spotted wing drosophila is an invasive fruit fly that is usually more damaging to thinner skinned berries than grapes; however, allowing ripe grapes to "hang" to benefit juice chemistry can also thin the fruit's skin, which can allow this pest to utilize the grapes. The spotted wing drosophila can then rapidly proliferate in a vineyard and ruin the harvest. (See the Integrated Pest Management section for additional information on this pest, page 52.)

Wasp on a grape.
Bicanski, pixnio.com

Yellowjacket wasp species and **European paper wasps** will feed on ripening grapes. Earlier in the growing season they can be beneficial predators of leaf feeding caterpillars in a vineyard; however, that benefit has to be weighed against fruit damage and worker safety. Effective traps are available to suppress yellowjacket populations starting in the spring. However, the lures used in yellowjacket traps are not attractive to European paper wasps.

Brown marmorated stink bugs
Gary Bernon, USDA APHIS, Bugwood.org

The **brown marmorated stink bug** (*Halyomorpha halys*) was not known to be in Wyoming, as of 2018, but it is found in some surrounding states. This pest will feed on grapes, wounding the fruits which allow decay to start. The bodies of the insects can also contaminate the harvested grape clusters, which can taint the flavor of wine.

DISEASES

Bacterial diseases

A major bacterial pathogen of grapevine is *Agrobacterium vitis*, which causes **crown gall disease**. The pathogen gains entry into vines through damaged tissues that may occur from a freeze or mechanical damage during cultural operations.

Pierce's disease is an important bacterial disease spread by sharpshooter insects. The pathogen is known to live and proliferate in the xylem (water conducting tissues) system of grapevines. As a result, the xylem vessels become clogged and unable to transport water and dissolved nutrients to different vine parts. As a result, grapevines exhibit symptoms typical of drought such as leaf scorching, islands

of brown tissues on shoots, and poor berry set. Grapevines severely infected with Pierce's disease eventually die to the ground leaving the roots alive, which leads to severe suckering and new shoot production from the crown. Grapevines infected with crown gall and Pierce's disease need to be uprooted from the vineyard and burnt. Make sure planting stock is purchased from nurseries that sell certified disease-free vines since the bacterial pathogens can be spread when infected grapevines are used as a source to propagate new plants.

Fungal diseases

Grapevines are also affected by several fungal diseases that, if unchecked, can cause anywhere from 20 to 100 percent reduction in yield. Fungal pathogens are known to infect above- as well as below-ground parts of the vine. Most fungal pathogens thrive in hot and humid conditions that are not frequently observed in Wyoming during the growing season. Fungal pathogens that may be seen in Wyoming are downy and powdery mildew, anthracnose, black rot, and botrytis.

Downy mildew appears as a fluffy white growth on the lower side of leaves. The fungus also infects developing flower and berry clusters. Infected tissues turn black, and complete defoliation is observed in severe cases. The fungus remains dormant during the winter on dead tissues and in vineyard debris and infects vines when conditions are favorable.

Powdery mildew is one of the most devastating fungal pathogens infecting grapes worldwide. The fungus produces a powdery growth on leaf tissues, flowers, and developing berries. Infected leaves turn yellow and eventually fall off. Berry clusters affected prior to veraison (when grapes start to change color) will develop poor color, uneven ripening, and are not suitable for consumption or wine production.

Anthracnose, also known as bird's eye spot disease, infects grapevines under warm and humid conditions. The fungus affects foliage, flowers, and fruits, and severe infection results in tissue death and defoliation. The fungus remains dormant in vineyard debris and infects vines when conditions are suitable.

Black rot occurs during high humidity conditions. These conditions generally only occur in Wyoming after unusually large amounts of rainfall. The fungus produces brown lesions on leaves, shoots, and developing berries, and carries over to the next season by over-wintering on vineyard debris.

Botrytis, commonly known as soft rot/storage rot disease, infects young shoots, flowers, and developing berries. The fungus may remain dormant until harvest and then infects ripe berry clusters in storage and transit, producing a grayish fluffy growth. Berries damaged from insect attack may become infected and serve as an inoculum for spreading the pathogen to healthy berries. The fungus remains dormant in berry clusters left hanging in the vineyard following harvest and becomes active during favorable conditions.

A group of fungal pathogens infect grapevines causing a complex known as "**trunk diseases**." These include *Eutypa*, *Phomopsis* and *Botryosphaeria*. These pathogens affect the vascular system and can result in the death of spurs, cordons, and trunks. The disease symptoms typically appear as wedge-shaped discolorations in a cross section of the infected vine (trunk, cordons, and canes). Trunk diseases may be spread during pruning of infected vines.

Fungal pathogens can be effectively managed by a combination of cultural techniques such as maintaining clean vineyards, removing weeds that may serve as alternate hosts for fungi, and monitoring the climate to predict conditions favorable for buildup of fungal pathogens. Chemical control measures using fungicides are effective at preventing the infection process when used at the right concentrations and following appropriate chemical rotations to prevent development of fungicide resistance in vineyard.

Viral pathogens

Viral pathogens are a serious threat to the grape industry in the United States. Among the important viruses, **leafroll associated virus**, **grape fanleaf virus,** and **red blotch** are important pathogens. Viral pathogens are most commonly spread when infected mother vines in a nursery are used as a source material for propagating new vines. Some viruses can also be spread by mealy bugs and nematodes. Viruses may remain latent in infected vines for a long period of time before they express themselves. Infected grapevines exhibit poor vigor and ultimately reduced yields. Additionally, fruit produced from infected vines may not accumulate the usual amount of sugars and pigments, thereby lowering the quality of the fruit. Prior to purchasing vines, please check with the nursery to determine if the planting material is certified disease-free.

Good references for grape producers

- *Midwest Fruit Pest Management Guide*, Purdue University, https://bit.ly/purdue-fruit-pest
- *Growing Grapes in the Home Garden* , University of Minnesota Extension, https://bit.ly/unm-growing-grapes
- *Colorado Grape Growers Guide*, Colorado State University Extension, https://bit.ly/csu-grape-growing
- *Pest Management Guide for Grapes in Washington*, Washington State University Extension, https://bit.ly/wsu-grape-pests
- *Grape Phylloxera: Biology and Management in the Pacific Northwest*, Oregon State University Extension, https://bit.ly/osu-grape-phylloxera. Great publication on grape phylloxera, especially chapter 7.
- What Lies Beneath: Grape Root Borer in Eastern Vineyards, Entomology Today, https://bit.ly/ent-today-grape-root-borer
- *Climbing Cutworms*, https://grapes.extension.org/climbing-cutworms/
- *Integrated Pest Management for Brown Marmorated Stink Bug in Grapes*, Stop BMSB, https://bit.ly/BMSB-grapes
- *Web Spinning Spider Mites*, Utah State University Extension, https://bit.ly/usu-spider-mites

RASPBERRIES

Raspberries are considered cane fruit. Cane fruits include raspberries, blackberries, boysenberries, Marionberries, Loganberries, and Tayberries. Reliable cane fruit production in most parts of Wyoming may be limited mainly to summer-bearing and fall-bearing red and yellow raspberries. Other cane fruit including most blackberries, black raspberries, purple raspberries, Boysenberries, Marionberries, and Loganberries need warmer temperatures to thrive. Some research into varieties and a good knowledge of your property and available microclimates will help you decide whether to experiment with these types. There are many varieties of red and yellow raspberries that thrive and produce reliable yields for many years.

Vlad Siaber, shutterstock.com

GROWING CONDITIONS

Raspberry plantings may last for 15 or more years, so careful consideration of where to locate these plants is time well invested. When selecting a location, keep in mind raspberry plants prefer to grow in full sun, in organic-rich soils with regular water and fertilizer applications throughout the growing season. Common causes of unproductive raspberry plantings include lack of adequate sun, nutrition, and moisture.

The plant's spreading root system survives for many years sending up canes each spring. Those canes are biennial, meaning they can live for two years.

This excerpt from the publication Raspberry and Blackberry Production Guide for the Northeast, Midwest, and Eastern Canada, NRAES-35, Lori Bushway, Marvin Pritts, and David Handley, technical editors, and published by NRAES (2008). https://bit.ly/msu-raspberry-production covers how these canes grow.

> *Bramble plants produce new canes (primocanes) every year. Primocanes grow rapidly during spring and early summer. During the summer, axillary buds may break on primocanes and form lateral shoots, especially in primocane-fruiting raspberries and tipped black raspberries and blackberries. Most of these lateral shoots occur on the top one-third of the primocane. In primocane fruiting types, these lateral shoots will contain flowers that initiate sequentially from the top to the bottom of the cane. If the growing season is sufficiently long, fruit can be harvested from the upper portion of these canes in the late summer and through the fall. During late fall, the buds below the primocane-fruiting zone continue to differentiate into flower buds, but these buds do not normally grow until after winter. In spring, axillary buds on the lower portion of the cane flower and produce a summer crop. Because of this unique growth habit, primocane-fruiting types can be managed to produce two crops per year—one in the summer from the floricanes (second-year canes) and the other in the fall from the primocanes. The term*

"everbearer" is sometimes used to describe this type, although this name is not an accurate description of the growth habit. In floricane-fruiting types, as temperatures drop and day lengths shorten in the fall, flower buds begin to form in the axils of leaves, but the buds do not break. With the further onset of cold temperatures, canes stop growing and eventually go into a state of rest called dormancy. At this point plants need an extended period of time exposed to temperatures between 25°F and 40°F (often eight hundred hours or more for raspberries, three hundred hours or more for blackberries). If this period of chilling temperatures has occurred, the buds will break when growing conditions become favorable in the spring. If chilling is insufficient, buds will remain dormant despite the return of warm weather. Chilling requirements vary considerably among cultivars. Long chilling requirements of some cultivars may limit their production in very warm climates. Conversely, cultivars with short chilling requirements may be injured in cold climates if they begin spring growth during a winter warm spell. After the buds break in the spring, the lateral shoots will grow, producing both leaves and flowers. The most fruitful lateral shoots are those in the middle three-fifths of the cane. After fruiting, the entire cane senesces and dies. While these second-year canes (floricanes) are flowering, first-year canes (primocanes) are growing from the crown or roots.

Most blackberries and other cane fruits produce fruit only on floricanes, so growers must keep those canes growing for two seasons before a crop is harvested. Extremely cold temperatures and drying winds can kill overwintering primocanes (and therefore floricanes do not develop) in Wyoming, and for this reason floricane producing varieties may not be reliable in some locations. Additionally, in colder areas of Wyoming, it is not uncommon for an early fall freeze to prevent fruit ripening on fall-bearing varieties. Summer-bearing and fall-bearing varieties that produce in July, August, and September are the most reliable producers.

Growers may be able to get a second yield from their raspberry canes in some locations in Wyoming,. Primocanes left to overwinter should be trained to a trellis to keep them upright. The canes that survive become floricanes and produce flowers and fruit lower on the cane before the newly emerged primocanes flower and produce fruit.

PLANTING AND CARE

Amend soil prior to planting with compost to increase organic matter content of the soil. Dormant bareroot plants can then be planted as soon as the soil can be worked. Transplant container grown plants with foliage after the risk of snow and freezing temperatures has passed. Plants can be spaced 18 inches or greater apart in rows with 4 to 8 feet between rows (depending on equipment needs). Hand-water immediately after planting, then install a drip irrigation system for the most efficient irrigation. Run two drip-lines 12 inches apart the length of the row, one line on both sides of the plants. Water new plantings daily, gradually cutting back to two to three times per week. Drip irrigation is ideal for raspberry plants because water is directed at the rootzone and it keeps water off the foliage helping avoid foliage diseases. Apply mulch 2 to 4 inches thick throughout the entire planting to help the soil conserve moisture and to suppress weeds. The drip line should be installed before the planting is mulched so water drips directly into the soil. Or prior to planting as subsurface drip directly into the root zone. Focus on establishing a healthy planting the first year. Plan to harvest only a small amount of fruit the first year. Second year and beyond, yields can be productive.

FLOWERING AND FRUIT DEVELOPMENT

Raspberry and Blackberry Production Guide for the Northeast, Midwest, and Eastern Canada, NRAES-35:

A typical raspberry flower opens to show five small sepals and five small petals, while blackberry petals can be quite large and showy. Many stamens are arranged around a center cluster containing many

individual pistils inserted on the receptacle. For pollination to occur, pollen grains must be transferred from the stamen (male part) to the pistil (female part) of the flower. Brambles are self-fruitful, so pollen need only be transferred within the same flower to result in fruit set. Honeybee colonies usually are not required for brambles, because the flowers produce huge quantities of nectar that attract both wild and domesticated bees. If honeybee colonies are used, two hives per acre are recommended. Each of the 100 to 125 pistils of a bramble flower contains two ovules. About one month after pollination one of the two ovules will ripen into a mature seed and the other into a fleshy drupelet surrounding the seed. Between 75 and 125 drupelets comprise a mature raspberry. Raspberries are thus considered aggregate fruits in which each individual drupelet has the same basic structure as a peach, plum, or cherry (botanically these larger fruits are called "drupes"). Considerable variation in fruit size exists, with a range from one to more than ten grams. In the raspberry, the drupelets separate from the receptacle (torus) at harvest, yielding a hollow, thimble-shaped fruit, while in blackberries the torus remains inside the harvested fruit and is eaten along with the true fruit portion.

HARVESTING

When fruit begins to ripen, harvest two to three times a week to ensure fruit is picked at peak ripeness. Raspberries are ready to harvest when you pull lightly on the berry and it slips easily from the white calyx. Growers can quickly learn to recognize the color and firmness of a ripe raspberry, depending on varietal characteristics. Continue to harvest through the first hard freeze. To improve shelf life and to prevent storage diseases, avoid harvesting berries when wet. Berries are best when unwashed and eaten fresh. If you must wash them, be prepared to process them. Do not allows berries to sit in water. Place berries in shallow containers as they crush easily and refrigerate or process quickly after harvest.

VARIETIES TO TRY

Yellow fall-bearing (primocane)

- Anne (4 — indicates USDA Hardiness Zone)
- Fall Gold (4)
- Double Gold (4)

Red summer-bearing (floricane)

- Boyne (3)
- Canby (3)
- Latham (4)
- Liberty (3)
- Nordic (4)
- Prelude (4)

Red fall-bearing (primocane)

- Amity Red (3)
- Autumn Bliss (4)
- Crimson Giant (4)
- Heritage (4)
- Himbo Top (4)
- Joan J (4)
- Polana (3)
- Redwing (4)
- September (3)

RASPBERRY AND OTHER CANE FRUIT INSECT PESTS

Wyoming's harsh climate and small to non-existent populations of wild plant hosts of some of the cane fruits means growers should have fewer of these pests to deal with on an annual basis. Make sure you are very careful not to bring in pests you don't already have when importing plant material onto your property. The following pests do occur in Wyoming and can cause serve injury on the plant's woody tissue or the fruit. Foliage pests should also be scouted for and treated if they are nearing economic damage thresholds, but they are not as damaging as the pests of canes, roots, and fruit.

Raspberry crown borer
University of Georgia Plant Pathology , University of Georgia, Bugwood.org

You have to dissect the infested crowns of Rubus spp. plants to find the larvae of the raspberry crown borer (*P. marginata*).
University of Georgia Plant Pathology , University of Georgia, Bugwood.org

At first glance a **raspberry crown borer** (*Pennisetia marginata*) appears to be a wasp capable of inflicting a sting, which is exactly the impression this defenseless species of clearwing moth family Sesiidae wants to give to potential predators.

Bronze cane borer also know as the rose stem girdler
Whitney Cranshaw, Colorado State University, Bugwood.org

The **bronze cane borer** (*Agrilus rubicola*), also known as the rose stem girdler, is from the metallic wood boring beetle family Buprestidae. The adult stage feeds lightly on the plant foliage, but the larvae feed

COMPREHENSIVE LIST OF POSSIBLE PESTS OF CANE FRUITS

- Aphids (several species)
- Armyworm and cutworm species
- Brown marmorated stink bug (not in Wyoming, yet)
- Cane maggot
- Dryberry mite
- Flat-headed cane borers (two species)
- Leafrollers (two species)
- Cane fruit looper
- Lygus bug (two species)
- Obscure root weevil
- Raspberry beetle
- Raspberry crown borer
- Redberry mite
- Root weevils (three species)
- Rose leafhopper
- Bronze cane borer also known as the rose stem girdler
- Leaf-rolling sawfly
- Raspberry sawfly
- Slugs
- Snowy tree cricket
- Twospotted spider mite
- Yellow spider mite
- Spotted wing drosophila
- Consperse stink bug
- Strawberry crown moth
- Western flower thrips
- Winter moth
- Woods weevil
- Yellowjackets (multiple species)
- European paper wasp.

under the bark of the canes eventually girdling and killing them.

Rough strawberry weevil photographed on penny to illustrate small size.
Whitney Cranshaw, Colorado State University, Bugwood.org

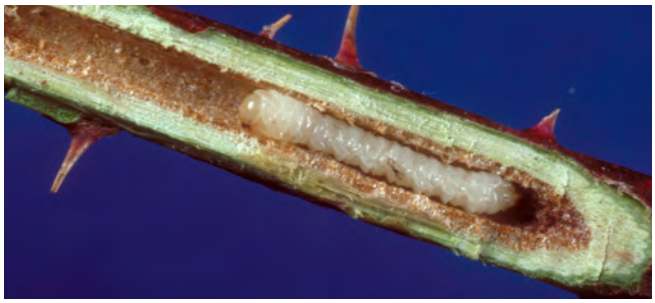
Larvae of black vine weevil (*Otiorhynchus sulcatus*) infesting the root of a common hop plant looks similar to all of the other root weevil species. The larvae are all soil dwelling, legless, with chewing mouth parts that physically damage roots while feeding, which can allow plant pathogens in the soil to infect the plants.
David Gent, USDA Agricultural Research Service, Bugwood.org

The larvae of several species of invasive **root weevils** in the genus **Otiorynchus** can damage most species of fruit producing shrubs. The **rough strawberry weevil** (*O. ovatus*) illustrates the small size and typical adult body form of these nocturnal leaf feeders. The black vine weevil and strawberry root weevil look very similar and have comparable life histories.

Red-necked cane borer
Johnny N. Dell, Bugwood.org

The damage on these raspberry canes shows the typical swelling from internal damage that could be caused by the under bark chewing the bronze cane borer or red-necked cane borer larvae inflict.
James Solomon, USDA Forest Service, Bugwood.org

The **red-necked cane borer** (*Agrilus ruficollis*) life cycle is nearly identical to bronze cane borer and is widespread in eastern North America, but there is no reason it won't show up in Wyoming eventually.



The larva of rose stem sawfly (*Hartigia trimaculata*) feeding in the pith of a cane.
James Solomon, USDA Forest Service, Bugwood.org

Adult rose stem sawfly
Whitney Cranshaw, Colorado State University, Bugwood.org

The adults of the **rose stem sawfly** are small slender insects with dark blue-black wings. The first generation of sawflies emerges from pupation inside of canes near the base of the plant in early spring to mate. The female sawflies then insert eggs into the tips of the canes that will feed on the pith and rapidly develop into adults that will produce the second, overwintering generation.

COMMON REGIONAL PESTS OF THE CANES, CROWNS, AND ROOTS

Raspberry crown borer

Insect borers cause damage in very vital plant tissues as compared to insects that eat just the leaves. Borer damage is much more likely to kill the plants. The raspberry crown borer (RCB) (*Pennisetia marginata*) larvae severely damages crowns and roots of raspberry plants. This insect is a member of the clearwing moth family Sesiidae. Many of the adults of this family mimic the appearance of wasps for protection from predation. The larvae are capable of chewing tunnels into the woody tissue. Living inside the plant makes the larvae invulnerable to many pesticides.

RCB requires two years to complete its life cycle. The adult moths appear in mid-summer and can be seen during the day resting on the leaves of the plants. Eggs are individually placed on the undersides of leaves. Upon hatching, the tiny white caterpillars migrate to the base of the canes. Here, they either excavate a small blister-like cavity under the bark near the base of the stem or find a protected place under loose bark to overwinter. In the spring, the larva resumes activity and usually tunnels into a new cane and girdles it before returning to the crown and root tissue. The second winter is spent in the upper root. By the second summer, the crown area can be extensively tunneled and severely damaged. A plant's entire crown may be damaged. The following description is accurate and concise:

> *"Damage from raspberry crown borer can often be confused with root rot and wilt diseases. The first indication of injury is the withering, wilting, and dying of the cane foliage, often with half-grown fruit still attached. Damaged canes will often break at the damaged area when pulled, revealing the larva inside. In severe cases, the infested plant may die. The crown must be dug and opened to find the larva infesting it."* (*source:* https://ipm.cahnr.uconn.edu/raspberry-borers/)

Control

Removal and destruction of infested plants before the new adults can emerge and reproduce is recommended. Drench applications of insect parasitic nematodes of the genus *Steinernema* around the base of the plants before the larvae can chew their way into the plant crowns can help reduce the population of RCB and several other root feeding pests. These nematodes are available from various vendors of biological control organisms and organic pesticides.

Timing is critical for topical pesticide applications to control RCB. Caterpillars are only vulnerable to pesticide applications for a limited time. Sprays must be applied to the first stage RCB caterpillars before they move down to the crowns and chew their way into the plants. The label instructions on the chosen pesticide must be followed to protect pollinators and pre-harvest interval must be followed to protect the consumers of the fruit.

Flat-headed cane borers

The **bronze cane borer** (*Agrilus rubicola*), and the **red-necked cane borer** (*Agrilus ruficollis*), are two species of metallic wood boring beetles that attack raspberry plants and primarily damage canes above ground by tunneling under their bark. In Wyoming, the bronze cane borer is the more common pest; however, if red-necked cane borers are accidentally introduced by planting infested raspberry plants, they could potentially establish. Wild raspberries can harbor these pests. Due to our lack of wild raspberry plants adjacent to farmlands, currently, Wyoming growers can have cane fruit fields isolated from these pests. It is very important new pests are not accidentally introduced on your property when importing plant material.

The bronze cane borer beetle is slender and has an iridescent bronze to copper sheen and is between ⅓ and ¼ inch in body length. The red-necked cane borer beetle is similar in appearance to the bronze species but is closer to ¼-inch long, with a reddish-colored "collar" that contrasts sharply with its black head and wing covers. The life cycle of the two species are nearly identical (see table below). Adult cane borers are present from May to early August. They feed along the edges of the leaves and can be observed crawling on the raspberry leaves during the day. Female beetles deposit whitish, scale-like eggs along the bark of the new canes starting in late May to early June. The larvae hatch from the eggs and chew their way under the cane's bark. They do not girdle the cane as the raspberry cane borer does, but later the tunneling of the larva causes a symmetrical swelling to form on the infested cane. In early August, the larvae tunnel into the cane's pith. The bronze borer larva is full-grown by fall and remains in the tunnel during the winter, and pupates in the spring. New adults emerge beginning in May, weather dependent.

Control

Remove all canes that show swelling from the borer larvae feeding and destroy them by burning, landfill burial, or chipping and composting the infested material. Insecticides directed at adults beetles can be applied on the plants pre-bloom to just before blossoms open to protect pollinators. The length of the insecticide residual control product chosen should try to cover the period of active feeding by the adult beetles to save on cost and labor.

Life cycles of common cane fruit borer pests and the approximate calendar dates important for control of serious pests of cane fruit plants.

<table>
<tr><th></th><th></th><th>April</th><th>May</th><th>June</th><th>July</th><th>Aug.</th><th>Sept.</th><th>Fall & Winter Months</th></tr>
<tr><td rowspan="2">Raspberry Crown Borer 2 year life cycle</td><td>1st year</td><td></td><td colspan="2">2 yr. old larvae pupate</td><td colspan="3">Adult moth mating with egg production and hatch</td><td>Larvae overwinter on cane bases 1st year</td></tr>
<tr><td>2nd year</td><td></td><td colspan="5">Larvae resume feeding and bore into canes causing swellings on canes at the crown</td><td>Larvae spend second winter in the cane crowns</td></tr>
<tr><td rowspan="2">Bronze Cane Borer annual life cycle</td><td rowspan="2"></td><td rowspan="2">Larvae ends diapause and pupates</td><td colspan="3">Adult beetle leaf feeding and egg production</td><td colspan="2"></td><td rowspan="2">Larvae overwinter in the pith near the crown</td></tr>
<tr><td></td><td colspan="4">New larvae tunnel under cane bark causing visible damage by late July</td></tr>
</table>

Rose stem sawfly

The **rose stem sawfly** (*Hartigia trimaculata*) is a plant feeding member of the Order Hymenoptera that can be found in Wyoming and is widespread because it also attacks wild and domestic roses in addition to cane fruit plants. The larvae of this insect bores into the canes and eventually girdles them causing the plant tissue beyond the feeding site to wilt and die. This pest produces two generation per year, so plant damage can rapidly escalate.

Control

Cultural control by pruning out the canes infested by the first generation is the primary method to minimize the damage caused by this pest. The infested canes need to be cut back to just below where the larvae began tunneling in the pith to ensure the insect is removed. The pruned out infested canes need to be destroyed to kill the larvae. Foliar pesticide applications for controlling the adult populations of this pest haven't been shown to be very effective.

Root weevil species

Another subfamily of insect that is widespread in Wyoming and can damage cane fruits and many other tree and shrub species are the broad-nosed weevils from the Subfamily Entiminae. The larvae of all of these invasive species in the genus *Otiorhynchus* are collectively referred to as root weevils. The larvae feed on the outside of the roots and can severely stunt the growth of plants. New transplants are especially vulnerable to the root damage. **Black vine weevil**, **strawberry root weevil,** and **rough strawberry root weevil** are known to attack many fruit bearing plants. The characteristic small square notches in leaf edges done by nocturnal feeding adult weevils is often the first thing that reveals their presence. The best way to diagnose them as the cause of failing plants is to dig them up and examine the roots in late summer. Examination of the soil close to the roots of infested plants can reveal the legless white root weevil larvae and their feeding damage.

Control

The adult root weevil beetles are leaf feeders when they emerge from the soil in the spring. Foliage-applied pesticides such as the fungal pathogen *Beauveria bassiana*, biopesticides containing active ingredients such as spinosad, azadirachtinn, and many synthetic pesticides can be applied to plants before they start blooming to kill the adult root weevils feeding before they start producing eggs. Each root weevil can produce hundreds of eggs, they are all female and reproduce via parthenogenesis. A very high level of adult root weevil mortality is needed to suppress the larvae population and reduce root damage. Entomopathogenic nematodes can also be applied in drenches to the soil around the plant crowns to kill the root weevil larvae. *Heterorhabditis bacteriophora* nematodes can be effective if soil moisture and temperature are suitable for them. *Steinernema carpocapsae* and *S. kraussei* are two other species of insect parasitic nematodes that will work in cold climate soils. The insect fungal pathogen *Metarhizium anisopliae* is available in a pesticide labeled for drench application against root weevil larvae in the soil. It can also be applied to the foliage for adult root weevil suppression; however, due to *M. anisopliae* spore's deactivation under UV light exposure, its residual control on leaves is very brief in high altitude sunlight.

Occasional foliage pests

A close-up of a roseslug sawfly larva eating down to the lower leaf surface and leaving behind the veins. They are frequently pale green in color, and you can see in their body faintly.
John A. Weidhass, Virginia Polytechnic Institute and State University, Bugwood.org

Roseslug sawfly

Roseslug sawfly (*Endelomyia aethiops*) adults are small, less than a ¼ inch long, dark colored, non-stinging wasps whose larvae skeletonize rose and raspberry leaves by eating the upper leaf surface and interior cells, leaving the bottom of the leaf intact. Before pupating the larva will be close to ½ inch long. In a dry climates the surface of the leaves left uneaten eventually dry out and flakes away. The larvae look similar in body form to caterpillars but can be distinguished as sawflies from caterpillars by having more than four sets of prolegs on the abdomen behind the three pairs of what will be thoraxic legs, just behind the head.

Control

The weak sawfly larvae can be physically hosed off plant leaves with water. Once on the ground they can't climb back on the plant. Horticultural oil and insecticidal soap solutions are low-toxicity biorational insecticides, which are labeled for use on foliage feeding pests like these sawlies. Currently available *Bacillus thuringiensis* (Bt) products such as Bt *kurstaki* and Bt *aizawai* are **NOT** effective on larval sawflies. If the defoliation is greater than 50 percent, broad spectrum insecticides can be used but label precautions need to be followed to protect insect pollinators if the plants are blooming.

Twospotted spider mites (TSSM) (*Tetranychus urticae*) are less than 0.5 mm long as adults but attack a huge number of crop plant species.
Frank Peairs, Colorado State University, Bugwood.org

Twospotted spider mites

Twospotted spider mites (TSSM) (*Tetranychus urticae*) are so small you often notice the leaf discoloration caused by them sucking the plant cell contents out and the silk webbing they put on the leaf surface before you actually see the mites themselves. TSSM feed on many different crop plants and are usually present in low numbers in all fields. When pesticides, such as carbaryl products for example, are used to control other plant pest species, the insecticide may not kill TSSM; however, it can unintentionally devastate TSSM's insect predators such as minute pirate bugs. The population of TSSM can then expand unchecked and cause significant injury. This is another reason to monitor the results of all pesticide applications. This can also happen when crops are grown in high tunnels as the TSSM's primary predators may be unintentionally excluded.

Insuring crop plants are not water stressed can help them cope with TSSM feeding damage. If feasible with your production system, overhead watering of the plants can physically dislodge TSSM. Minimizing dust from adjacent field and roads also reduces TSSM populations. There are mite specific pesticides with ingredients such as bifenazate, acequinocyl, and etoxazole currently labeled for cane fruits; however they also must be registered for use in Wyoming. These mite specific active ingredients have reduced impact on the insect predators of TSSM. Field releases of beneficial predatory mite species, reared commercially, can also work to suppress TSSM populations. The predatory organisms work best for suppressing TSSM populations that have not yet reached economic thresholds.

PESTS THAT ATTACK THE FRUIT

A pest monitoring trap like this one designed for spotted wing drosophila can help you determine when to initiate management actions to optimize results.
Hannah Burrack, North Carolina State University, Bugwood.org

Spotted wing drosophila

The spotted wing drosophila (SWD) (*Drosphila suzukii*) is a relatively new invasive pest in Wyoming. It is different from other endemic fruit fly (Drosophilidae) species in that the female can insert her eggs into ripening, undamaged fruit with a serrated ovipositor. The rapidly developing larvae quickly make the infested fruit worthless. Unfortunately, cane berries are favored hosts of this pest. If your farm doesn't have SWD already, try to keep it that away by not allowing plant material, like fruit, from SWD endemic regions that might harbor this pest on your property. Infested fruit will lose its sheen, turgidity, and the calyx will be stained with juice when fruit is harvested. Another way to determine if you have an infestation is to drop suspect fruit into a container with 70 percent alcohol, larva will be readily visible leaving the fruit.

Control

If you have SWD, then trapping with sticky yellow cards or species specific traps should be used to monitor their population levels through the growing season. The trap data can help you decide when to treat SWD and determine the efficacy of the treatment. Maintaining an open canopy in your berry patch via pruning can make environmental conditions less favorable for SWD. SWD prefer shady and humid conditions created by thickly growing plants. An open plant canopy also makes it easier to get good coverage during pesticide applications. Removal and destruction of infested fruit plus the aggressive rapid harvest and cold storage of good fruit is recommended. Applications of labeled pesticides to suppress SWD populations should only be used during the times in the field when pollinators are not active on flowers. You must follow the pre-harvest and field re-entry intervals listed on pesticide label after applications. Alternate the pesticide active ingredient mode of action classes you use to reduce the possibility of resistance occurring in SWD populations. For organic growers this can be difficult as pyrethrum and spinosyn are the only two active ingredients that have qualifying organic formulation. Already, reports of poor control of SWD with pyrethrum products are being made by fruit growers in Michigan. Reliance on multiple applications of broad spectrum insecticides, whether organic or synthetic, may cause two-spotted spider mites or other pest populations to explode. The predators of the spider mites that usually keeps them in check are vulnerable to the same broad spectrum insecticides currently labeled for SWD.

Commercial or homemade traps placed in the early spring around fruit production fields can capture the new queens while they forage for their first cohort of daughters. This can reduce the numbers of worker wasps raiding fruit later in the summer.
Whitney Cranshaw, Colorado State University, Bugwood.org

A yellowjacket flying up to a raspberry already being feed upon by two European paper wasps.
Bachkova Natalia, shutterstock.com

Yellowjackets and European paper wasps

Yellowjacket wasps and the invasive European paper wasp will attack ripening berries and other fruits as a source of carbohydrates in the summer. The damaged fruit becomes unsaleable, and the stinging wasp activity makes harvesting the ripe fruit more of a challenge and potentially hazardous for those allergic to stings. Commercial traps baited with heptyl butrate are effective for catching *Vespula* species yellowjackets but ineffective for European paper wasp (*Polistes dominula*). The European paper wasp is attracted to fermenting fruit and plans for drowning traps and a bait recipe with 2 fluid ounces fruit juice to 20 fluid ounces water, ¼ teaspoon active dry yeast, and ¼ teaspoon dish soap are available from Utah State Extension. Two-liter plastic pop bottles with their tops cut off and inverted are baited with the solution and then hung up around the perimeter of the fruit production area. The number of traps needed varies with pest pressure and location. Utah State Extension entomology Professor Diane Alston has posted a video that details the paper wasp trap construction and placement on YouTube.

Grasshoppers

(More detail on grasshopper control can be found in the Integrated Pest Management section, page 47.)

Several species of crop pest grasshoppers will feed on the leaves of cane berries and much worse, from an economic damage standpoint, the fruit itself. Treating grasshoppers early in the habitats they originate from is the best type of management strategy. The ideal goal is to prevent grasshoppers from migrating to your berry patch. Many control options for grasshoppers exist for non-crop habitats and are usually much less expensive than pesticide products labeled for use on cane fruit crops.

Control

Adult grasshoppers are highly mobile and will travel a long way to find food. If grasshopper swarms invade your fields when cane fruit is ripening, they will feed on it. In the period just before fruit harvest it is difficult to manage adult grasshoppers. Insecticide products labeled with a short pre-harvest interval may not provide good control of adult grasshoppers. Another confounding problem with insecticide treatment is that grasshoppers are cannibalistic and are attracted to the odor emitted from decaying bodies. This could attract even more grasshoppers to the crop.

Some horticultural products are advertised as having grasshopper repellent and/or anti-feeding properties. Products making these claims may contain ingredients such as garlic extracts, capsaicin, denatonium benzoate, and soaps that could impart

an off taste or odor to plants and fruits treated. An odor free pest deterring product with low to no toxicity and high repellency to grasshopper would be ideal. You don't need to kill them if the grasshoppers aren't eating your plants and fruit. Small-scale field trials conducted on non-fruiting shrubs showed azirdirachtin, which is extracted from neem tree leaves, was the only effective short-term grasshopper repellent of the limited number of products tested. Until more effective and properly labeled grasshopper repellant products are developed, using row covers to exclude grasshoppers from ripening berry crop is the only sure way to protect the fruit.

DISEASES AND DISORDERS

Physiological disorders (abiotic disorders)

Sunscald or Tip burn

The clear sunny skies typical of Wyoming in the summer can result in sun damage in the form of sunburn. Symptoms include yellow or browned leaves on tissue exposed to unfiltered intense sunlight. Affected fruit may appear white in spots, especially on the side with the most sun exposure. To manage, protect plants from intense sun with a temporary shade cloth. Some of the varieties mentioned have larger leaves and fruiting habits that will keep the berries protected from sunscald. These same qualities can make berry harvest more challenging.

Wind injury

Injury from wind in Wyoming includes leaning plants, broken canes; and wind-burned foliage. To reduce wind effects, adequately tamp soil down around roots with watering at planting to ensure good contact of roots with the soil. This helps to avoid plant movement and possible injury and uprooting during wind events. For small plantings, construct a trellis to help support an upright growth of canes, which would avoid breakage issues. Remove wind burned or damage tissue to promote healthy, new growth. Canes infested with larvae of the flatheaded borers mentioned above will often snap off or lodge due to insect damage.

Infectious diseases

Foliar diseases

Powdery mildew is a fungal disease that overwinters in cane tips and buds and emerges during humid and cool to warm weather periods during the growing season. Symptoms are a whitish-grey, powdery mold-like growth or felt-like patches on leaves, buds, and canes. Leaves may crinkle and curl upward. Manage with disposal of infected tissue to reduce inoculum and prune to improve airflow if stand is overcrowded. Fungicides are successful if applied at first signs of disease.

Raspberry anthracnose is a fungal disease that can affect both black and red varieties. Symptoms can appear on canes, leaves, and sometimes fruits at any time of the season but typically follow periods of cool, wet weather. Symptoms on stems (most common) appear as scattered small, roundish purple spots (often about 3/8 inches in diameter). Over time, spots can merge and girdle the canes resulting in cane death. Mature stem lesions develop ashen-colored, sunken centers with raised purple margins. Lesions on leaves are smaller (1/8 inch) and more irregularly shaped, and over time enlarge and develop grey centers with a reddish purple border. These centers may fall out, giving the spots a "shot-hole" effect.

Whole plant and root diseases

Cane blight is caused by the fungus *Kalmusia coniothyrium* (formerly *Leptosphaeria coniothyrium*). This fungus overwinters on old cane stubs and near wounds on infected fruiting canes. This pathogen is a wound invader so it is rarely a problem in hand-harvested fields. Symptoms of cane blight usually appear in the early summer after blossoming and leaf emergence, in association with wounds from pruning or harvesting caused the previous year. Look for dark brown to purple cankers on the canes and tissue death above, if the cankers encircle the cane. In wet weather, the black specks (fungal fruiting bodies) in the cankers will ooze spores that when dried gives the canker a silvery appearance. Infected canes are often brittle and snap off in windy conditions. To manage, adjust irrigation to avoid wet plants for long periods.

Avoid over-fertilization, as this leads to succulent new growth more prone to breakage and wounding by insects. Control insect pests that can cause wounds. Sanitation is very important. Remove and destroy diseased primocanes and spent floricanes in the dormant season, and disinfect pruning tools between cuts (30 seconds in 10 percent bleach or 70 percent alcohol).

Fire blight is caused by the bacterium *Erwinia amylovora*. This bacterium infects many species in the rose family and is especially a problem in apple, pear, quince, and crabapple; however, all strains of the bacterium do not infect all species of the rose family. For example, the bacterium strain that infects raspberry does not infect apples, and the apple strain does not infect raspberry. The exception is "Boyne" raspberries, which can be infected by the apple strain. The most prevalent symptom is that infected cane tips become blackened, die, and resemble a "shepherd's crook." Under high humidity, cream-colored bacterial ooze may appear on infected canes. Infection continues down the cane and leaves may wither and die. Infected fruit will not mature and will become brown and dry up. Disease favors new growth and is transmitted by rain, wind, and insects. Management is mostly through preventative measures. Plant only certified, disease-free plants. Remove and destroy infected canes as soon as you see them. Prune cuts should be 8 to 12 inches below visibly diseased tissue and disinfect pruning tools after each cut (see above). Avoid over-fertilization as vigorous, succulent tissue is most susceptible.

Verticillium wilt, a fungal disease caused by *Verticillium dahlia*, is mostly a problem on black raspberry and rarely found in red raspberries. New canes wilt in mid-summer and bluish stripes of infected tissue may extend up the canes from the ground. Foliage can take on a scorched appearance and leaf blades drop leaving the petioles still attached. Initially, only part of plant may be affected and as the disease progresses, the whole clump may die. Nothing can be done once plants are infected. Prevention of establishment and movement are the best defense since this disease is very difficult to eradicate once introduced in the field. Defense strategies include removal of infected plants and neighboring plants to reduce spread, and care to avoid tracking soil from infested areas to clean areas. In extreme cases of infested fields, there are preplant soil fumigation products available, but they are costly and require special application equipment.

SERVICEBERRY (AKA SASKATOON OR JUNEBERRY)

Amelanchier alnifolia

Serviceberry or **juneberry** (*Amelanchier* Spp.) is a native shrub of Wyoming. The common name juneberry is most often used when describing horticulture varieties and cultivars of *Amelanchier*, while serviceberry is more commonly used to describe native species of *Amelanchier*. The commercial varieties of serviceberries available are not the same as the serviceberries found in the wild. While the fruits from wild plants can be collected, the commercial cultivars available for home gardens and orchards have been carefully bred for larger berries, more consistent crops and more uniform ripening time. The majority of commercial cultivars have been derived from *Amelanchier canadensis* (not native to Wyoming) and *Amelanchier alnifolia* (native to Wyoming).

Juneberries are an alternative to blueberries for many growers due to their tolerance of neutral and alkaline soils. The berries of juneberries tend to contain less liquid and are often known as being drier or less juicy than blueberries.

Iva Vagnerova, shutterstock.com

Plants are self-fertile but will benefit from a second juneberry for increased yields. Look to harvest berries when they are dark purple in color and full. Berries hang in clusters. Juneberries are a favorite of many bird species so covering plants with netting or regular and frequent harvesting of fruit is important to prevent yield losses. Fruit thinning is not recommended.

GROWING CONDITIONS

Juneberries can be a great addition to home gardens or orchards. Cultivars can be selected to fit in small or large spaces. White blossoms cover plants each spring, and the leaves of most cultivars turn a brilliant red or orange color in the fall. Plants can be a short or tall depending on the cultivar. Shorter species can be 5 to 6 feet tall and 20 to 25 feet tall for larger cultivars. Specific species of Juneberry should be spaced accordingly to mature height and overall size.

Well-drained soils high in nutrients are best for Juneberries. Plants will benefit from the addition of water during warmer temperatures but prefer soils that are not consistently saturated. Plants grow well in full sun and are very cold tolerant making them a great addition for most locations in Wyoming.

PLANTING

New plants can be started from seed, sprouts, root cuttings, or dividing the crowns of established plants. Plants started from seed and root cuttings tend to take several more years to reach the point where they start producing berries compared to plants started by crowns. Establishing new plants from sprouts can be difficult. Sprouts need to be transferred into sandy soil and kept well-watered. Sandy soil helps allow roots to grow quickly and makes it easier to remove the plants to be transferred to a final permanent planting location once large enough. It should be noted new seedlings started from seed may not be identical to the parent plant.

VARIETIES

- Autumn Brilliance—20 to 25 feet tall, great fall colors, sweet fruit and very productive
- Northline—high yields, vigorous grower and large berries
- Pembina—very productive, vigorous grower and produces large fruit
- Smokey—bush growth type, large berries, mild flavor, lots of suckering and very productive
- Success—very old variety, 6 to 8 feet tall, sweet berries and shape is upright
- Thiessen—12 to 14 feet tall, large fruit, good flavor and moderate suckering

INSECT PESTS

Serviceberry (*Amelanchier alnifolia*) is native to North America so many native insect species evolved to feed on it; however, these potential pests also have native predators and parasitoids that will suppress them if habitat in and around the serviceberry orchard fulfills their needs. The beneficial insect's habitat needs may be as simple as nectar sources for the adult parasitoid wasps to feed on or suitable plant material, such as leaf litter or hollow stems, for pupation habitat and overwinter survival of the predators.

Serviceberry is a member of the rose plant family so many introduced invasive pests will also feed on it. The list of possible pests includes plum and apple curculio snout beetles, wooly elm aphid, Saskatoon bud moth, two species of leaf feeding sawfly, thrips, mites, shoot borers, and several species of tree fruit leafrollers. Because serviceberry isn't a common orchard crop, few or no pesticides are labeled for control for some of the pests. Starting your serviceberry orchard with healthy, pest-free plant stock is important for success.

Pests that attack serviceberry roots and/or woody parts

Wooly elm aphids (*Eriosoma americanum*) feed on the roots of serviceberry plants and can cause severe damage. The following photo shows untreated serviceberry to the left of the wire flag compared to treated plants to the right of the flag. **Wooly apple aphids** (*Eriosoma lanigerum*) will also feed on the roots of serviceberry, but the treatment is the same for both species.

Untreated plants, left of flag, next to treated plants.
Whitney Cranshaw, Colorado State University, Bugwood.org

Pests that chew leaves or pierce and suck plant juices

Hawthorn lace bug adult.
Jim Baker, North Carolina State University, Bugwood.org

The **hawthorn lace bug** (*Corythuca cydoniae*) feeds on the foliage of the serviceberry and at high population levels can cause the leaves to fall off. Their piercing beak mouth sucks the cell contents out of the leaves. These widely distributed insects overwinter as adults and become active in the spring and can produce two generations per summer.

The caterpillars of **Saskatoon bud moth** (*Epinotia bicordana*), **yellow-headed fireworm** (*Acleris minuta*), **eye-spotted bud moth** (*Spilonota ocellana*), **leafcrumpler** (*Acrobasis indiginella*), **gold-striped leaftier** (*Machimia tentoriferella*) and **Sparganothis fruitworm** (*Sparganothis sulfureana*) all feed on the berry buds and can cause significant damage. Contact or stomach insecticides, including the biopesticide *Bacillus thuringiensis* serotype *kurstaki* (Btk) products labeled for caterpillars on fruit trees, can be used against these pests when natural predation fails to keep their populations in check.

Several species of **tree fruit leafrollers** from the Tortricidae moth family also attack serviceberry. The caterpillars of these moth species gather the leaves together and tie them with silk to form shelters to feed inside of. **Pandemis leafroller** (*Pandemis pyrusana*), **obliquebanded leafroller** (*Choristoneura rosaceana*), **fruittree leafroller** (*Archips argyrospilus*) and **European leafroller** (*Archips rosanus*) are the most damaging species because they can injure developing fruit and leaves. The shelters these insects make for themselves can make it difficult to control them with insecticide sprays. More detail on these leafroller species and their management is in the Fruit Tree Insect Pests section, page 265.

Insect pest affecting the saleable parts directly

A plum curculio adult.
E. Levine, The Ohio State University, Bugwood.org

Plum and apple curculio snout beetles (*Conotrachelus nenuphar* and *Anthonomus quadrigibbus*) are small (less than 1/5-inch long) insects with elongated mouthparts they use to chew cavities in the fruits of many plant species to feed and make cavities to deposit eggs.

The **Saskatoon sawfly** (*Hoplocampa montanicola*) and several other species in the genus *Hoplocampa* feed heavily on the plant's developing fruit, reducing yield and quality. The larvae look like caterpillars but belong to the Order Hymenoptera. This makes them immune to the Btk based biopesticide products developed for lepidopteran pest caterpillars.

Tarnished plant bug adult.
Russ Ottens, University of Georgia, Bugwood.org

Tarnished plant bugs (*Lygus lineolaris*) and other species in the genus are distant relatives of the hawthorn lace bug but lack the "lacey" front wings. The *Lygus* species bug are very common and can be quite abundant on many types of crops, including alfalfa. Only the adult *Lygus* species bugs are considered a pest of serviceberry. They choose other crops for egg deposition; however, the tarnished plant bugs feed heavily on the bud and flower stages of serviceberries and can cause severe reductions in fruit yield. Monitoring for the pests at the green tip and balloon floret stage and applying a labeled contact pesticide may be required to protect the berry crop.

Cherry shoot borer moth.
Ilona Loser, www.discoverlife.org

Cherry shoot borer (*Argyresthia oreasella*) is a native insect that can utilize serviceberry and choke cherry. The eggs spend the winter on the plant's fruit buds. The eggs hatch in early spring and bore into the forming fruit inflorescences, causing them to wilt and fall off. The mature larvae drop to the ground to pupate and emerge as tiny gold and white moths in the summer. They mate and deposit eggs that will overwinter in the bracts of the forming buds.

An excellent reference for serviceberry production

http://bit.ly/SaskatoonBerryProduction

STRAWBERRIES

Strawberries are spreading, perennial plants, enjoyed for their sweet fruit. While strawberry plants can live and grow for many years, most strawberry patches stay productive for three to five years before yields decline significantly. Since they multiply via runners, production decline is likely due to overcrowding of plants in the growing space. There are three different types of strawberries grown. Each type produces differently, and growers will care for the plants differently. The three types of strawberries are June-bearers, everbearing, and day-neutral.

GROWING CONDITIONS

The most common strawberry variety grown in Wyoming is Fort Laramie, an everbearing variety. This is a variety developed in Wyoming and is known for its cold hardiness and reliable production. Many other strawberry varieties are hardy to zones 5 or 6 and are not good choices for outdoor production in Wyoming. Growing strawberries in high tunnels greatly increases the number of varieties to choose from. If you are growing outdoors and plants will be left uncovered, or covered only with mulch over winter, choose varieties hardy to zones 3 or 4, depending on where you live. Grown in high tunnels, growers can choose strawberry varieties hardy up to zone 5.

Tim UR, shutterstock.com

June-bearers produce one crop per year, usually in late June or early July. Flowers begin to develop shortly after new leaves appear in spring. Because of Wyoming's unpredictable, yet reliable cold snaps at higher altitudes, June-bearers are susceptible to complete crop loss from one cold night while the plants are flowering. The center of frozen or frosted flowers will turn black, known as "black-heart." These flowers will abort and not produce fruit. Growing June-bearers in a high tunnel is recommended for higher elevation areas. High tunnels will protect plants from mildly cold weather while the plants are flowering, and will provide winter protection.

If growing under a high tunnel is not an option, and you live in a low elevation area in Wyoming, you may be able to grow June-bearers outdoors. June-bearing strawberries will not do well in high elevation areas with extremely cold winters. To improve the chance of successful harvest, apply straw mulch on top of strawberry plants in fall and leave on the plants for several weeks after other plants begin to leaf out in spring. The mulch will delay vegetative growth and flowering of the strawberries, reducing the risk of cold temperature damage to the flowers in the late spring/early summer. Remove mulch after night temperatures are consistently above freezing. This will delay fruit production into July.

JUNE-BEARER PLANTING AND CARE

June-bearers are heavy runner producers. Growers will use those runners to fill in the rows after

planting. Begin in spring by planting bare-root plants every 18 to 24 inches and space 36 to 48 inches between rows. Plants will quickly develop leaves, flowers, and runners. It is very important for growers to remove all flowers during the first year. Although this results in no fruit development the first year, it allows the plants to put more energy to root and vegetative growth and increases yields in future years. Allow runners to fill in the space between plants. Once the strawberry patch reaches a density of five to six plants per square foot, remove all other runners. Allowing the runners to fill in the rows creates a dense groundcover called a matted-row, which maximizes space and helps suppress weeds. Individual June-bearing varieties produce fruit for about 10 days; an extended harvest period can be achieved by selecting varieties with early, mid-, and late season production times. Doing this, one can extend the harvest from early June through the middle of July.

After the second year, begin renovation of the strawberry patch. Annually, about 10 to 14 days after the last fruit is harvested, mow off all above ground leaves at about 2 inches from the soil surface. Mowing seems to be a drastic measure and the first time you do it you will wonder what you have done, but this process cleans up the patch and removes all the old nonproductive leaves. New growth will continue, and plants will look great in about 10 days. After mowing, cultivate (or rototill) strips 12 to 18 inch wide through the strawberry patch and leave 12 to 18 inch strips of plants.

After renovation, fertilization needs to be applied monthly after fruit harvest. Applying fertilizer prior to fruiting will result in mushy fruit. Complete a soil test to understand the fertilization requirements, divide the total fertilizer into thirds and apply 1/3 of the total amount in July, 1/3 in August, and 1/3 in September. You are feeding the plant, and the plant is creating blossoms for the following season.

One management option is to allow runners to replace the plants that were removed by the cultivation. In alternate years, cultivate strips with older plants, and allow runners to fill in. This practice keeps plants alive for two years before they are cultivated and replaced with new runners. Ignoring this step will result in overcrowding and decline in yields.

June-bearing plants grown outside must be mulched over winter using clean straw mulch (no pesticide residue). Usually, a layer 6 inches deep will provide enough insulation without smothering, and the majority will stay in place under pressure from Wyoming winds. Timing of placement is critical and needs to occur after the plants go into winter dormancy. Mulch application usually is around Thanksgiving. Timing of spring removal is also important as one needs to avoid the spring freezes or frost events. Late April to early May is a good time to consider mulch removal for parts of the state. Rake the mulch between the rows and use for weed suppression. Timing should be adjusted based on your elevation.

EVERBEARING AND DAY-NEUTRAL PLANTING AND CARE

Everbearing strawberries will produce two substantial yields each year, usually in July and again in August-September. Some everbearing varieties produce a continuous crop from September until frost.

Day-neutral varieties produce flowers and fruit throughout the entire growing season. Generally, the berries range in size from small to large. Total yields are reportedly less than June-bearers, but they produce fruit over a longer period of time and are more reliable in Wyoming. These varieties produce few runners, so growers plant more densely and do not rely on runners to fill in the rows. Temperatures above 90 F will temporarily reduce flower production and yields. Often, peak yields occur during late summer and fall.

Everbearing and day-neutral varieties are planted at 12-inch spacing in double or triple rows. Leave an

aisle 3 feet wide between double or triple rows. All runners are removed as they develop. Remove the first flush of flowers that develop after planting (do this for one to two weeks). Allow following flowers to develop. Fertilize monthly with a 3-4-4 fertilizer. Water every day or every other day throughout the growing season. Maintain the strawberry patch for three to five years and then replant. Production declines in older strawberry patches.

HARVESTING

Harvest every other day once berries start ripening. Harvest red, ripe fruit, cap and all by gripping the berry in your hand with the stem pinched between two fingers. Gently pull to snap the stem being careful not to uproot the plant by pulling too hard. Take two buckets with you to pick. One for good strawberries, and the other bucket to remove damaged or diseased fruit (this will help reduce the spread of disease). Grown outdoors, expect to harvest day-neutral varieties July-September. Grown in a high tunnel, expect to harvest from June-October.

Remove all foliage after plants have gone dormant. Cut stems to 1-2 inches, leaving the crown of the plant alone. Water one to two times a month during the dormant season. Heavily mulch outdoor plantings to protect plants from drying winter winds and extreme cold. Remove mulch in spring.

STRAWBERRY VARIETIES

June-bearing varieties

- Honeoye
- Guardian
- Kent
- Redchief
- Delite
- Jewel
- Mesabi
- A.C. Wendy
- Cabot
- Blominden Gem
- Catskill and Geneva

Everbearing varieties

- Quinalt
- Ogallala
- Fort Laramie

Day-neutral varieties

- Tribute
- Tristar
- Fern
- Sea Scape
- Charolette

INSECT PESTS

There are many potential insect and mite pests of strawberries. The possible pests include root weevils, strawberry crown miner, flea beetles, lygus bugs, garden slugs, sap beetles, gray millipedes, stink bugs, European earwigs, yellowjacket wasps, grasshoppers, plant mites, and multiple species of aphids. In Wyoming, the risk to strawberry production is probably lower from the pest species that are specialists on the plant, such as strawberry crown moth, that have yet not become established here. Start your strawberry patch with plant material free from pests not already in your area. However, you should still monitor (scout) your berry patch for uncommon pests, too.

Millipedes damaging ripening strawberries. Large populations of millipedes can develop on organic matter in the soil that isn't fully decomposed. Ripe fruit shouldn't be left in contact with the earth or damp mulch to prevent millipedes from infesting it.
Whitney Cranshaw, Colorado State University, Bugwood.org

Root weevil species

Strawberry root weevil (*Otiorhynchus ovatus*)

Whitney Cranshaw, Colorado State University, Bugwood.orgAnother subfamily of insect widespread in Wyoming and can damage many different plant species are the broad-nosed weevils from the Subfamily Entiminae. The larvae of all of these invasive species in the genus *Otiorhynchus* are collectively referred to as root weevils. The larvae feed on the outside of the roots and can severely stunt the growth of plants. New transplants are especially vulnerable to the root damage. Three species, the common names of which are **black vine weevil**, **strawberry root weevil,** and **rough strawberry root weevil**, are known to attack many fruit bearing plants. The characteristic small square notches in leaf edges done by nocturnal feeding adult weevils is often the first thing that reveals their presence. The best way to diagnose them as the cause is to dig up failing plants and examine the roots in late summer when the grubs are most numerous. Feeding damage from the legless white root weevil larvae can be found by examining the soil close to the roots of infested plants.

Control

The adult root weevil beetles are leaf feeders when they emerge from the soil in the spring. Foliage-applied pesticides such as the fungal pathogen (a fungus which causes disease in other organisms, in this case a beetle) *Beauveria bassiana*, biopesticides containing active ingredients such as spinosad, azadirachtinn, and many synthetic pesticides can be applied to plants before they start blooming to kill the adult root weevils feeding before they start producing eggs. Each root weevil can produce hundreds of eggs. They are all female and reproduce via parthenogenesis. A very high level of adult root weevil mortality is needed to suppress the larvae population and reduce root damage. In addition to the adult root weevil control efforts, nematodes that attack root weevil larvae can be applied in drenches to the soil around the plant crowns to kill the larvae. *Heterorhabditis bacteriophora* nematodes can be effective if soil moisture and temperature are suitable for them. *Steinernema carpocapsae* and *S. kraussei* are two other species of insect parasitic nematodes that will work in cold climate soils. The insect fungal pathogen *Metarhizium anisopliae* is available in a pesticide labeled for drench application against root weevil larvae in the soil. It can also be applied to the foliage for adult root weevil suppression. However, due to *M. anisopliae* spore's deactivation under UV light exposure, its residual control on leaves is very short in high altitude region sunlight.

Aphids

Green peach aphid (*Myzus persicae*), **melon aphid** (*Aphis gossypii*), **potato aphid** (*Macrosiphum euphorbiae*), **strawberry aphid** (*Chaetosiphon fragaefolii*), **shallot aphid** (*Myzus ascalonicus*), and,

found on the roots, the **wooly apple aphid** (*Eriosoma lanigerum*), are the main species that will feed on strawberries. Light aphid infestations on leaves with observed predator activity are considered to cause sub-economic damage (may not be worthy of any control efforts). Shallot aphid can transmit strawberry mottle virus, and a root infestation of the wooly apple aphid can cause plants to dieback. Insecticide treatments for aphids can sometimes result in flareup of spider mite populations, so the benefits of control measures should be weighed against the risks and pest scouting should continue after any management actions are taken.

AFFECTING VEGETATIVE GROWTH (PESTS THAT CHEW LEAVES OR PIERCE AND SUCK PLANT JUICES IN LEAVES OR STEMS)

The **twospotted spider mite** is a common strawberry pest. Reductions in mite predator populations, plant management, and environmental conditions such as dust on the leaves (which inhibits common mite predators) and water stress play an important role in managing spider mite populations. Preventing the damage the mites can inflict on forming berries is the priority. The release of the numerous predator species of mites available for purchase should be done before the pest mite populations' reach economically damaging levels. Release of purchased biological control agents can also follow up a pesticide application that will reduce the naturally occurring predator populations. (More details on twospotted spider mite management can be found in the Raspberry section, page 222). Currently available miticide labels should be consulted and followed to ensure your crop is protected and safe for consumers.

Strawberry leafroller (*Ancylis comptana*) is an occasional pest of strawberry. The caterpillars feed on leaves. It has been found as far west as Colorado, so it could occur in Wyoming. The adult moths are small with distinct gray, tan, and white forewing markings. Strawberry leafroller larvae use silk to spin webs and roll leaves while consuming leaf tissue. Beneficial jumping spider species will sometimes make silk retreats in strawberry leaves but don't roll the leaves.

Adult strawberry leafroller
Mark Dreiling, Bugwood.org

Strawberry leafroller larvae
Stephen Ausmus, USDA Agricultural Research Service, Bugwood.org

Western flower thrips
Frank Peairs, Colorado State University, Bugwood.org

Western flower thrips (*Frankliniella occidentalis*) are tiny insects that damage plants by puncturing the cells and sucking out the contents. When they feed on strawberry blossoms, the resulting berries may be distorted, harming crop value. The adults overwinter in the field and reproduce quickly in the spring. They can also migrate to growing areas by flight. All of these factors make them difficult to control as the flowers cannot be treated without harming necessary insect pollinators. Cultural control via the planting trap crops of flowering plants (borage, lupin, etc.) adjacent to strawberries can be done. The trap crop can then be destroyed to kill the less mobile larvae of the western flower thrips.

Damage from cyclamen mites
Jody Fetzer, Maryland National Capital Park and Planning Commission, Bugwood.org

Cyclamen mite (*Pytonemus pallidus*) is much smaller than the more common twospotted spider mite. The stunted and curled leaves it produces may be the only thing noticed while field scouting. Some magnification is necessary to see the tiny mites causing the damage. Use mite-free planting stock to help prevent infestations of this pest.

Strawberry crown miner
Natasha Wright, Braman Termite & Pest Elimination, Bugwood.org

Strawberry crown miner (*Tyloderma fragariae*) is a small beetle (⅕-inch long) from the weevil family whose larvae develop inside tunnels chewed into the crowns of plants. Infested plants should be removed and destroyed to kill the larvae inside the crowns.

INSECT PEST AFFECTING THE SALEABLE PARTS DIRECTLY

Plant bugs

A nymph of a tarnished plant bug (*Lygus lineolaris*) feeding on a broccoli flower with its piercing beak. All of the *Lygus* species plant bugs prefer to feed on flowers, buds, and fruit tissues. The resulting reaction by the plant to their saliva makes them very damaging pests.
Allen Cohen, USDA Agricultural Research Service, Bugwood.org

The **tarnished plant bug**, *Lygus linalaris,* uses a piercing and sucking beak mouthpart to damage strawberries by feeding on the flowers and developing fruit. When they feed on a developing strawberry fruit, the injury can result in a deformed berry called a "nubbin." Tarnished plant bugs are widespread and feed on many common plant species. They overwinter in the winged adult life stage and are capable fliers that can rapidly infest a field in the spring. Tarnished plant bugs do well in alfalfa fields and when the hay is harvested, they can move long distances to find new crops to feed on.

Control

The *Lygus* species insects' affinity for alfalfa can be used against them. Strips of alfalfa comprising just two to three percent of the area of the strawberry field can be planted. The strips of alfalfa are allowed to flower and mowed just enough to encourage continual flowering during the development of the strawberry crop. The alfalfa can be vacuumed for mechanical control of the lygus bugs or treated with pesticide to kill them to keep them from spreading to the strawberries. Microbial pesticides labeled for use on lygus bugs, such as formulations of the insect fungal pathogen *Beauveria bassiana,* can be used economically. You can save money through this method by treating only the trap crop and not the entire field of strawberries. Pesticides that are not broad spectrum contact types will have lower impact on beneficial insects in the field. An example of beneficial insects that use alfalfa would be parasitoid wasps that attack aphids. The adult wasps will use the flowering alfalfa for nectar and shelter. Black-eyed peas have also been used as an annual type trap crop substitute for alfalfa in strawberry fields.

Spotted wing drosophila

Spotted wing drosophila (SWD) (*Drosophila suzukii*) will insert eggs into ripening, intact strawberries. The resulting maggots rapidly destroy the fruit. The timing of your strawberry harvest and the population density of adult SWD present in your field will determine the amount of fruit loss. In Wyoming's relatively cool summers, SWD populations generally increase throughout the entire growing season. Because it takes a while for SWD populations to get going, SWD is usually not an issue with June-bearing strawberries, it can become a problem for the late season everbearing or day-neutral varieties. In regions where daily high temperatures get above 95 F, reproduction slows and a temporary decrease in SWD population occurs.

Control

SWD is a new pest in the U.S. that attacks a broad range of high value crops. A lot of research is being conducted to develop cost-effective IPM. The use of monitoring traps to trigger insecticide treatments to reduce SWD populations is critical to reduce damage in either organic or conventional production. A consortium of universities across the country, funded by USDA-NIFA, are working on sustainable spotted wing drosophila management. https://swdmanagement.org/. The results of this research initiative will hopefully prove useful. Until then, the

following steps can be taken to protect small fruit crops:

- If the pest is not present already, quarantine your farm (do not allow fruit to be brought on the property) to prevent SWD from being accidentally introduced on infested fruit.
- If you have SWD already, use traps to monitor for population build up in your crop fields to trigger pesticide treatment. See this Utah State bulletin for detailed information of monitoring methods, http://bit.ly/SWD-Monitoring .
- Harvest and put ripening fruit in cold storage as soon as possible. Cold temperature arrests the development of the SWD larvae.
- Don't allow fallen fruit of any sort to accumulate in the vicinity of the crop fields. SWD has been found to successfully reproduce in common ornamental plant fruit such as European cotoneaster berries and fallen, overripe crab apples.
- Open the canopy of your crop through pruning to increase temperature and decrease humidity to make it less habitable for SWD, if applicable.
- Crop covers of fine mesh material can be used to exclude SWD from vulnerable ripening fruit after pollination.
- Apply pesticide targeted to reduce SWD population before critical fruit ripening periods. Thorough application within the leaf canopy with any type of pesticide used is necessary to get good control. Follow pesticide mode of action rotation practices to prevent resistance in your local SWD population.

Sap beetle

Sap beetle adult
Joseph Berger, Bugwood.org

Sap beetle species (*Carpophilus* spp) can damage ripe fruit but are usually attracted to fields by the odor coming from overripe, damaged, or rotting fruits. Don't allow fallen fruit to accumulate in the fields and keep to a frequent harvest schedule to avoid having problems with sap beetle species.

DISEASES AND DISORDERS

Physiological disorders (abiotic disorders)

Winter injury

Winter injury occurs when ice crystals form in the strawberry plant crown tissue causing cellular damage, resulting in lethal or sub-lethal injury. Winter injury can also occur when plants are subjected to alternating freeze thaw cycles that can heave plants, exposing the crowns to the air. When temperatures in the crown drop below 10 F, crown tissue can become injured. Plants affected are slow to respond in the spring or crowns turn brown-black and the plant does not recover. Surviving plants are more susceptible to insect and disease damage. To reduce winter injury, mulch plants in the late fall with hay, straw, or leaves to protect crowns. A blanket of snow will also work as a mulch, but not a covering of ice. Avoid heavy nitrogen applications in the fall since plants will not harden off properly and will be more susceptible to damage.

Frost injury

Flowers, buds, leaves, and immature fruit can be damaged by cold. The critical temperature for frost injury is dependent on climatic conditions, variety, and stage of growth. Flowers are most sensitive right before and during opening with critical temperatures below 28 F. Symptoms include blackened floral parts (with reduced fruit set), edge die back of leaves, and misshapen fruit. Large operations minimize frost injury by applying overhead irrigation (freezing water releases heat) until temperatures improve. Another technique is to cover plants with plastic row covers or frost "blankets" until the cold period passes.

Poor pollination

Poor pollination is characterized by poor fruit set, low yields, variable achene (seed) size, and misshapen fruit. Caused by unfavorable environmental conditions (cold, wet weather), prolonged periods under protective covers during blooming, and reduced pollinating insect activity. Damage created by poor pollination is often confused with nutrient deficiencies, damage to flowers by insects (thrips, mites, tarnish plant bug), and some diseases like botrytis (gray mold) and powdery mildew. To manage, remove crop covers as soon as possible when conditions improve and avoid insecticide applications when bees and other pollinators are active (mid-day).

Sunscald

High temperatures and sun over-exposure to the strawberry fruit causes sunscald. Berries growing on the south or west side of rows are most affected. Symptoms appear on the upper exposed side of the fruit near the stem attachment. After a brief period of the fruit becoming pale and water-soaked, this eventually dries down to a distinct, firm, bleached lesion ranging in color from pink to off-grey. Can be confused with the disease leather rot.

Infectious diseases

Foliar diseases

Leaf spot, caused by the fungus *Mycosphaerella fragariae*, is a common foliar disease of wild and cultivated strawberry. Symptoms of leaf spot can occur on leaves, fruits, petioles and runners. Lesions are small ⅛- to ¼-inch diameter spots that are initially deep purple to red in color and over time develop tan, grey centers with the distinct reddish purple to brown borders. Lesions on fruits are shallow black spots (¼ inch in diameter) surrounded with brown-black leathery tissue. Disease is most active at 65 to 75 F and periods of wet weather. Management is best achieved through prevention. When establishing a new strawberry patch, plant disease-free nursery stock and consider a resistant variety. Removal of diseased plant tissue is beneficial as the fungus survives on diseased strawberry tissue. For June-bearing plants, mowing after plants have finished fruiting will remove old infected leaves. Mowing is not suitable for everbearing or day-neutral strawberry plant types. Use drip irrigation if possible to minimize leaf wetness. When using overhead irrigation, use shorter sets or irrigate at times that promote rapid drying of foliage. Fungicides can be used in severe cases but are not normally necessary.

Powdery mildew is caused by the fungus *Sphaerotheca macularis* f.sp. *fragariae*. Symptoms include the rolling of leaves in the late summer and fall and sometimes powdery growth on the leaves, flowers, and fruit. Small pepper-like black specks (fungal fruiting bodies) can appear on the undersides of infected leaves in the fall. Fungus overwinters in infected plant material so practice sanitation as outlined above for leaf spot. Resistant cultivars are available and recommended in problem areas. Fungicides can be used with some success in extreme cases.

Leaf scorch is caused by the fungus *Diplocarpon earlianum* and causes small, irregular purple spots on leaves. Unlike with leaf spot discussed above, these lesions are purple throughout with no well-defined border. Lesions may grow together to form larger affected areas on the leaf. In severe cases, infected leaves turn brown and leaf edges curl up giving them a scorched appearance. Like leaf spot, the leaf scorch fungus survives in diseased plant tissue and thrives in wet warm conditions, and spreads through wind

and water splash. Management is through removal of diseased tissue and irrigation management to avoid prolonged periods of leaf wetness. Resistant varieties and fungicide options are more limited with this disease.

Whole plant and root diseases

Fruit rot and blossom blight can be a serious fruit disease caused by the fungus *Botrytis cinera* also known as gray mold. The fungus survives in diseased plant tissue and can also exist as a saprophyte in the soil for limited periods. Infection is favored by cool, humid conditions. The flowers typically become infected first, then the disease can spread to developing fruit. Infected fruit will become water soaked in appearance and covered in a characteristic gray-fuzzy spores that can easily become airborne or dispersed by water droplets. Infection can also occur when fruit touches the soil or an infected plant part. Frost injury to developing fruit can predispose it to infection. Practices that reduce humidity in the field are beneficial in lessening impact of this disease. Proper spacing of plants, controlling weeds, and planting in full sun locations can help reduce in-field humidity. Since the fungus thrives in diseased plant residue, sanitation at the end of the season is a must. Sanitation during the season includes removing overripe or diseased berries promptly from the field. Clean straw mulch added in the spring can help keep berries off the soil. Some strawberry varieties are less susceptible to fruit rot than others.

Leather rot disease occurs occasionally in strawberry fruit and is caused by the fungal-like organism *Phytophthora cactorum*. Infections start out as tan-brown patches on green fruit and purple-brown areas on ripe fruit. Infected fruit eventually develop an overall brown leathery texture then shrivel. Infected fruit have a distinct odor and can impart a bitter taste to jams and jellies. Disease can occur at all stages and thrives in warm, wet conditions, especially in areas where water pools after rain/irrigation. To manage, choose a planting site that is naturally well drained, or add organic matter to soil and redirect water away from the area. Consider planting strawberries on raised beds to improve drainage. Use straw mulch to keep berries from contacting the ground or puddled water. Avoid overhead irrigation or, if that's not an option, irrigate at a time of day when leaves dry quickly. Additionally, frequently remove overripe and diseased berries from the field.

Black root rot is caused by a disease complex of various soil-borne fungal pathogens, nematodes, and environmental stresses. These stresses can be drought, winter injury, excessive fertilizer application and excessive soil water. Symptoms are often observed in the spring and characterized as wilted plants with brown and/or distorted leaves and black roots. When plants are dug up, roots tips are rotted, or fine lateral roots are missing or dead. Irregular black patches may be visible on the normally fleshy white roots. In beginning stages, the inner part of the root will still be white but eventually the root in cross section will be all black. Disease is favored by wet soils and soils low in organic matter. Proper site selection such as soil with good drainage, improvements to soil organic matter, and water management are important management tools for this disease complex.

Red stele root rot is caused by the fungal-like soil-borne organism *Phytophthora fragariae* var. *fragariae*. This disease is most problematic in heavy clay soils saturated with water. Diseased plants, which are usually infected in late winter and spring, appear stunted and eventually die. Younger leaves may have a bluish discoloration. The defining symptom of this disease is when an affected root is cut length-wise, the center, or the stele region, will have a rusty-brown discoloration rather than the normal yellowish-white color. Sometimes the red stele becomes evident when the root tip rots away leaving the reddish-brown stele region open to view. Once established in a field, the pathogen can produce spores that can survive for 20 years. To manage, select fields with good drainage, minimize soil compaction, and improve soil tilth with organic amendments. Infected planting stock is the primary method of introducing this disease to new sites, so always start with healthy disease-

free planting stock. There are varieties with some resistance. Fungicide treatments can be an effective tool to manage this disease.

BLUEBERRIES

Blueberry (*Vaccinium* spp.) plants are perennial woody shrubs. Blueberries require acidic soil (optimum range is 4.5-5.2 pH) and show iron deficiency symptoms quickly as soil pH moves above this range. Wyoming's soils tend to be neutral to alkaline and rarely acidic. For this reason, blueberries are not suited for in-ground production in Wyoming. Growers wanting to try blueberries on a small scale should grow them in large containers with an acidic potting soil mix. Containers should be large enough to accommodate the plants, think 5 gallons or larger. Peat moss, compost, and coir are good choices for potting material. As our water sources in Wyoming are also often alkaline, fertilizers for acid-loving plants like rhododendron and azalea will help maintain the potting mix acidity and will work for blueberries. Soil testing will be required to assure pH is in appropriate range.

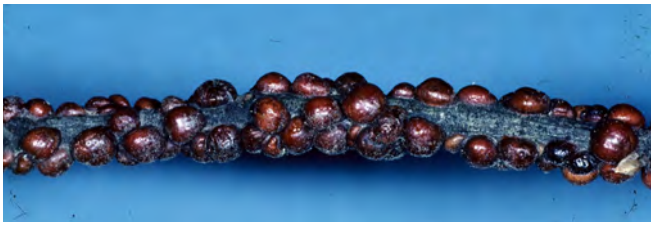
Tim UR, shutterstock.com

If looking for a blueberry substitute more suited to Wyoming conditions you may want to check out serviceberries (*Amelanchier* spp.), which have a somewhat similar flavor to blueberries but may be blander and have a different texture. Taste some to determine if they are of interest to you.

INSECT PESTS

As mentioned, the delicious blueberry requires acidic soil conditions for production. If you have acidic soil for your berry patch, the good news is that many blueberry host specific pests should not be present in Wyoming to attack your crop. However, the bad news is blueberries are also susceptible to many widespread common plant pests.

Pests that chew leaves or pierce and suck plant juices



European fruit lecanium
Lacy L. Hyche, Auburn University, Bugwood.org

Coccid soft scale species suck sap (phloem) from plants, which reduces their vigor and can cause dieback. The **European fruit lecanium** (*Parthenolecanium corni*) is one of the most common and widespread species that will feed on blueberry plants. The honeydew waste (excrement) that soft scales produce can contaminate fruit and attract secondary pests such as sap beetles and yellow jacket wasps. Good pruning practices can reduce scale insect problems as removal of the attached female scales and the overwintering eggs they produce can reduce the infestation the following year.

Obliquebanded leafroller larvae
Todd M. Gilligan and Marc E. Epstein, TortAI: Tortricids of Agricultural Importance, USDA APHIS PPQ, Bugwood.org

The **obliquebanded leafroller** (*Choristoneura roseceana*) is a native species of moth that occurs throughout southern Canada and the United States. Beside blueberries, it infests apples, pears, cherries, plums, peaches, roses, raspberries, gooseberries, currants, strawberries, and many weeds. The first generation larvae will start to roll leaves to feed inside of in late May. If they roll the leaves around the developing berries, their chewing mouth parts will also scar the developing fruit. Getting labeled insecticides on caterpillars can be hard once they are inside rolled leaves.

Pests attacking the roots

The **black vine weevil** is the most common root weevil on blueberries, but the **strawberry root weevil** and **rough strawberry root weevil** can also be found attacking the plant roots. The characteristic leaf notching caused by the feeding of the adults weevils is of little consequence to the plant. But the larvae will feed on the roots for months. This can stunt or even kill young blueberry plants. See the Raspberry section for more detail on their management, page 222.

The **blueberry mealy bug** may not be here in Wyoming, yet. However, if you observe serious decline in your plant's health with no other discernable aboveground cause, you should examine the roots for the presence of small, flattened, wingless insects with a white waxy coating. They feed on the plant's sap. Ant activity usually occurs with the mealy bug infestations as ants protect them from predators. The ants are interested in the honeydew the mealy bugs excrete as a waste product.

Pest affecting the saleable parts directly

Spotted wing drosophila, **green** and **consperse stink bugs**, and multiple species of **yellowjacket** wasps will feed on blueberry fruit. The stink bugs will feed on the unripe fruit with their piercing, sucking mouth parts. The spotted wing drosophila, yellowjacket wasps, blueberry maggot, and cranberry fruitworm prefer to attack fruit starting to ripen.

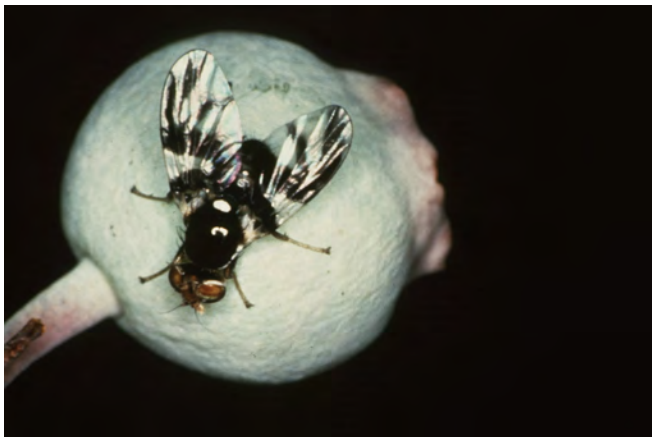
Consperse stink bug
Steven Valley, Oregon Department of Agriculture, Bugwood.org

Consperse stink bugs (*Euschistus conspersus*) and similar looking but differently colored **green stink bug** (*Chinavia hilaris*) are two of the most common

stink bugs that will damage developing fruit while feeding on them with their beaks (mouth parts).

Obliquebanded leafroller
Mark Dreiling, Bugwood.org

Obliquebanded leafroller (*Choristoneura rosaceana*) are small "boat" shape moths that emerge from June through July. In Wyoming's fruit growing regions, a second generation of larvae will be produced that will overwinter on the bark of host plants. Monitoring traps with pheromone attractant can be used to determine if their population has reached economically damaging levels.



Blueberry maggot adult
Jerry A. Payne, USDA Agricultural Research Service, Bugwood.org

Blueberry maggots (*Rhagoletis mendax*) feed inside the fruit, similar to the spotted wing drosophila. It is a major pest of blueberry crops in the eastern United States. For isolated, small plantings it may be possible to reduce populations of adult blueberry maggots to non-economic numbers by using a large number of yellow sticky trap cards in and around the blueberries.

Cranberry fruitworm
University of Georgia Plant Pathology , University of Georgia, Bugwood.org

Cranberry fruitworm (*Acrobasis vaccinii*) larvae enter fruit, feeding on flesh; as they develop, they move from one berry to another within a fruit cluster. They are common pest from Nova Scotia to Florida. As their common name suggests, they are a serious pest of cranberries, too. The larvae also soil the undamaged berries with frass and webbing.

Additional references

Detailed blueberry pest management information can be found in the Blueberry Insect Pest Identification Guide at eXtension.org, https://bit.ly/blueberry-insects.

APPLES

Malus domestica

Cold hardiness is an important consideration when it comes to growing perennial fruit trees or shrubs in Wyoming. Apples are the most cold-hardy among fruit trees. The results of a recent genetic analysis of apples indicate they originated in Central Asia, where the domestic fruit's wild ancestor, *Malus sieversii*, can still be found growing in the Altai Mountains of the Republic of Kazakhstan. The area where apples originated is a high altitude, midcontinent region similar in geography to Wyoming. With hardy apple varieties, suited to our harsh climate, the work of establishing a productive orchard in Wyoming seems less daunting. In fact, an orchard started in 1870 near Lander had, at its peak, more than 3,000 trees. More detail on this fascinating part of history can be found at http://bit.ly/WyoAppleProject.

Mirelaro, shutterstock.com

Many of the thousands of apple varieties out there will survive Wyoming's cold winters. And you can't choose just one. Apples require cross-pollination, so you will need to plant at least two varieties for pollination to occur and for fruits to develop. If you are growing apples in areas where apples and crabapples are common, nearby plants not on your property may serve as pollen sources. Crabapples are good pollinizers for apples if their bloom periods overlap.

Apple trees do require care and patience. It may take three to five years after planting an apple tree before you pick any fruit from the tree. A well-maintained apple tree may produce fruit for over 20 years. Tree selection is the first important decision, with cold hardiness and rootstock being important factors to consider. As mentioned previously, growers at higher elevation areas in Wyoming should look for USDA zone 3 trees, and realize that zone 4 trees may be borderline hardy. The lower elevation areas of the state may be able to grow trees up to zone 5 hardiness rating.

Growers should learn how to properly prune and how to identify and control pests to maximize yields. Annual pruning as well as insect and disease management are important factors in fruit quality and quantity when growing apples.

ROOTSTOCK

Oftentimes apple varieties are grown by grafting the desired variety onto the bottom portion (a short section of trunk and roots) of another apple variety (aka a rootstock). Rootstocks can have a big effect on disease resistance and the ultimate size of the tree.

Selecting rootstock for your apple trees may be a little confusing. There are many options out there for varieties that can be used as rootstock; however, unless you know how to graft, you'll want to purchase trees already grafted to rootstocks. Your options will be limited to what is available from the nursery.

Dwarf rootstock will produce apple trees that grow 8 to 10 feet tall, which is ideal if space is limited. Pruning and harvesting can be done from the ground rather than using a ladder. Dwarf trees may require staking or trellising to support the trees, which may otherwise topple over from the weight of the fruit. They also may be a little less hardy than standard trees.

Semi-dwarf rootstock will produce trees that grow 15 feet tall and wide. Semi-dwarf trees are often good choices for commercial production.

Apple trees on standard rootstock may grow 25 to 50 feet tall. Standard trees will eventually start producing most of their apples towards the tops of the trees where they are harder to reach for harvesting.

Spacing

Apple trees on dwarfing rootstocks are typically planted with 11 to 12 feet between rows and 5 feet between plants within the row. This will increase with larger trees. The idea is to increase the speed the available land area fills with canopy. This will maximize the photosynthetic capacity of the trees so they produce fruit and profits sooner.

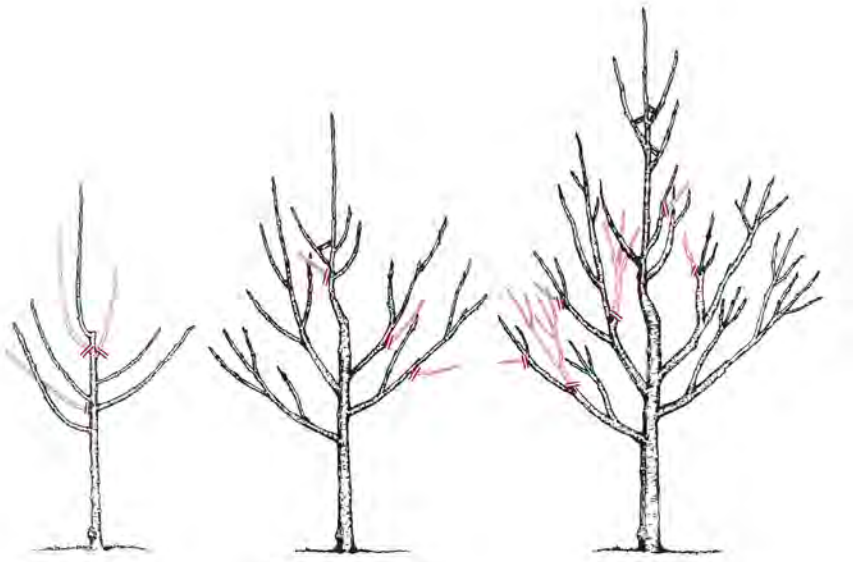
Disease resistant rootstock

You may not be able to choose the exact rootstock from the nursery, but it is worth asking if anything is available on fire blight resistant rootstock. Rootstock not only determines the size of the tree, but also the tree's susceptibility to diseases like apple scab and fire blight.

PRUNING

Start training apple trees through pruning at planting time, and prune annually throughout the life of the tree. Pruning is one of the most important maintenance practices required to get good yields, to manage diseases, and to control the size of the trees. Without proper pruning and fruit thinning, apples tend to over-produce, meaning they produce a lot of apples but they are small and lack flavor. Properly pruned trees will have fewer, but larger, apples with higher sugar content and better flavor.

Apples should be trained to a central leader with properly spaced lateral branches off the main trunk (central leader). If a young tree does not have any lateral branches, top the tree at 3 to 4 feet tall to encourage branches to emerge below the pruning cut. Once branches have emerged, select three to five branches that are 3 to 4 feet above the ground. These will become the lowest permanent branches on the tree. Wide branch angles between the trunk and a branch are desirable. Leave one upright branch to become the central leader. Remove everything else below these lower branches, including root suckers. These lowest branches are called scaffold branches and should be spaced evenly around the trunk. As the



Central leader pruning

tree grows, select three to five more branches 2 to 3 feet above the scaffold branches. These will develop the next scaffold whorl of branches. A mature semi-dwarf apple tree will have three scaffold whorls with the lowest branches being the longest and the upper branches the shortest, giving the tree a pyramidal shape. For more information on pruning, see *Barnyards and Backyards* magazine article "Apple, pear trees can survive and thrive in Wyoming," https://bit.ly/wy-apples-pears.

FLOWERING AND FRUIT PRODUCTION

Apples flower and produce fruit on spurs. Spurs are short lateral branches usually 1 to 2 inches long. These spurs grow on 2-year-old wood. It is important you keep this in mind when pruning. Make sure you are leaving plenty of spurs on the tree when you prune. Also, be careful when harvesting apples not to accidentally pull the spurs off with the apples.

VARIETIES TO TRY

- Snowsweet
- Zestar
- Honeycrisp
- Cortland
- Haralred
- Lodi
- McIntosh
- State Fair
- Jonathan
- Wealthy
- Yellow Transparent
- Wolf River
- Ben Davis
- Enterprise
- Liberty
- Freedom

APPLE PESTS

See Fruit Tree Insect Pests section, page 265.

DISEASES AND DISORDERS OF APPLE AND PEAR

Physiological disorders (abiotic disorders)

Environmental disorders of apple and pear include **bitter pit** and **cork spot** caused by nutrient calcium imbalances. Bitter pit and cork spot, which is more common in apple than in pear, is characterized by external and internal darks spots that develop in the fruit late in the season or in storage. Manage by avoiding excess fertility, which results in excessive tree vigor (because shoots then compete with fruit for calcium).

Infectious diseases

Fire blight is caused by the bacterium *Erwinia amylovora* and can be a problem under warm, wet conditions during flowering. This bacterium infects many species in the rose family, which includes most fruit species in Wyoming, and is especially a problem in apple, pear, quince, and crabapple. Various strains are somewhat host-specific.

Symptoms include a scorched, blackened appearance of leaves, blossoms, and new terminal shoots. Affected young tissue will curl exhibiting a "shepherds crook" symptom. Under warm, humid conditions small amber droplets of bacterial ooze can appear on affected tissue and overwintering cankers. Disease favors new growth and is spread by wind, rain, and insects.

Management is mostly preventative. Avoid over-fertilization, which promotes susceptible, succulent tissue. During the dormant season, remove infected twigs and branches to prevent the bacterium from overwintering and spreading to the main trunk. Remove and dispose of diseased fruits.

Pruning cuts on disease branches should be made 8 to 12 inches below the obvious infection. If pruning must be done during the growing season, sterilize the pruning blade between cuts with a 10 percent bleach solution or a commercial disinfectant. Consider a

resistant variety for new plantings if fire blight is a consistent limiting factor in your area.

Apple and **pear scab** are caused by different but closely related fungal diseases that have similar symptoms and management guidelines. Both diseases cause foliar spotting of leaves and scabbing of the fruit. The pathogen overwinters on diseased leaves on the ground. During periods of rain or sprinkler irrigation in the spring, spores are released to infect leaves, blossoms, or developing fruit. Disease can continue to spread until conditions become too dry. Typically, these diseases are only a problem during cool, wet springs (55 to 75 F with 9+ hours of leaf wetness for initial infection). To manage, remove and dispose of infected leaves after they have fallen. Avoid prolonged wetting of foliage if using sprinklers. Chemical control is only necessary under extremely wet conditions and typically not warranted in Wyoming.

Apple and pear are also susceptible to various fungal rust diseases caused by *Gymnosporangium* species. These diseases can include **cedar apple rust** (apple) or **cedar-hawthorne** (apple and pear). These pathogens are unique in that they require an alternate host, Juniperus species (cedar), to complete the life cycle.

Disease symptoms on apple/pear are prominent yellow-orange foliar lesions. As the disease develops, on the underside of the leaf these lesions will develop noticeable orange-yellow protuberances (fungal fruiting body). Spores produced by these lesions only infect the juniper, which produces orange to brown gelatinous galls (¼- to 1-inch diameter) known as cedar "apples" the following spring. These in turn produce spores that infect apple/pear. The diseases are considered mostly cosmetic, and control is typically not warranted. Remove the cedar apples from nearby junipers before they release spores in the spring to reduce apple and pear infection.

Powdery mildew of apple and pear is caused by the fungus *Podosphaera leucotricha*. This disease can reduce tree vigor, flower bud production, and fruit quality. The fungus overwinters in dormant terminal bud tissue causing systemic infections on new shoots in the spring. These infected buds produce stunted growth and twisted leaves with a silver-grey covering of infectious spores. Infected buds are also more susceptible to winter kill when winter temperatures dip below -18 F.

Secondary disease spread is possible affecting leaves and fruit under conditions of high humidity. Unlike most fungal diseases, leaf wetness is inhibitory to powdery mildew spore germination, but germination does require high humidity. Diseased leaves will twist and can be covered in a whitish-grey, powdery mold-like growth. Fruits will develop russeting in affected areas. To manage, remove infected buds during the dormant season. Infected buds may be a little smaller and have whitened terminal buds.

Use proper pruning to avoid crowded canopies, effectively increasing air movement and lowering humidity within the canopy. For sites with perennial powdery mildew problems, investigate resistant cultivars that may be adapted to your area. Fungicide applications during fruit development may protect fruit from russeting, but disease pressure in Wyoming rarely would warrant this.

PEARS

Despite what many think, pears should not be ruled out for growers and gardeners in Wyoming. This tasty fruit fits well in many larger spaces in backyard gardens or on larger properties. Like many other fruit trees, pear trees require two varieties for good pollination, so space will be needed for both trees. There are many cultivars available suited for growing in USDA Zone's 3 and 4.

PLANTING

Plant pear trees where two different varieties can be in close proximity of each other for maximum pollination. Maintain around 20 feet between trees, so they do not overcrowd each other for space and resources such as sunlight and water. Remember pear trees can grow 20 to 25 feet tall so avoid planting too close to buildings or under power lines. Plant trees in suitable soils which are high in nutrients and well drained. A soil test prior to planting can help determine any soil amendments that might be needed.

Swetlana Wall, shutterstock.com

Trees can be purchased as bareroot plants, in containers, and occasionally as balled and burlapped plants from local nurseries. Varieties purchased via the internet will most often be shipped and sold as bareroot trees. Bareroot trees, while easier to ship, will generally take more time before they begin to produce fruit compared to container trees. Like apples, pears can be purchased with different rootstocks. Most of the rootstocks used for pears tend to be standard or full sized.

PRUNING

Young trees may need to be pruned to initiate a correct growth form. Pears should be pruned using the central leader method. The goal of this method is to achieve a strong and sturdy central leader that supports four to five scaffold branches. Select scaffold branches with proper angles. Some smaller branches on young trees can be trained to angles between 45 to 60 degrees in relation to the trunk of the tree using limb spreaders, twine, or weights. Many pears trees tend to grow in an upright or columnar fashion, so training branches for proper angles that will support fruit production and snow loads during the winter is important.

FRUIT PRODUCTION

Carefully choose the variety of pears to plant. While researching varieties, pay attention to their winter hardiness, timing of bloom, fruit characteristics and other traits. For example, for best fruit quality, some varieties' fruit should be picked prior to ripening on the tree and allowed to fully ripen in cool storage (http://bit.ly/Picking-Storing).

How you plan to use the fruit should also be considered. Some varieties of pears are better for fresh eating, while other more suited for canning and storage. One of the primary items to consider

is whether a variety will have a good chance of producing mature fruit in Wyoming's growing season.

Care during the growing season is important. Pears can be damaged or bruised easily. Fruit thinning can help increase the size and quality of fruit produced. Temperatures should be monitored closely in the fall if late maturing varieties are being grown. Early freezes can ruin fruit harvest.

VARIETIES TO TRY

- Cabot—Good for fresh eating, September maturity date, and medium-sized fruit
- Celine—Good for fresh eating, late ripening, and should be picked to allow for ripening in cold storage
- Flemish Beauty—Late ripening and great for fresh eating
- Luscious—Large fruit great for fresh eating and mid to late maturing dates
- Patten—Large fruit great for fresh eating and is late maturing
- Savignac—medium-sized fruit, very hardy, and good for fresh eating
- Summercrisp—early maturing, good for storing, and can be eaten when still green
- Ure—small fruit for fresh eating, September maturity, and very cold hardy

PEAR PESTS

See Fruit Tree Insect Pests section, page 265.

DISEASES AND DISORDERS

See Apple section, page 255.

STONE FRUITS

Stone fruits (plums, cherries, peaches, apricots, and others) get their name as one might think—the large hard seed in the center of the fruit. Many of the stone fruits available can survive and produce a fruit crop in various locations in Wyoming.

Cold hardiness and early spring frost periods are the major challenges with stone fruits. Variety selection is a very important tool that can be used to address these challenges. Varieties found in the supermarket most often have USDA cold hardiness ratings of zone 5 to 9; however, zone 3 and 4 varieties are better suited for Wyoming. Spring frosts can limit the amount of fruit produced since stone fruit trees bloom and flower early in the year. Fruit blossoms tend to be more susceptible to cold once they open, and spring frosts can cause open flowers to abort, reducing or eliminating fruit set. Choosing varieties that bloom a little later can help growers avoid these frosts; however, the varieties must also be able to produce ripe fruit in the time remaining before the first frosts of fall. When choosing varieties, growers should also keep in mind two different varieties of each kind of stone fruit are planted for optimal pollination unless a variety is described as self-pollinating. The two varieties chosen should bloom at the same time.

Tatiana Volgutova, shutterstock.com

Pruning is important for stone fruit trees. Pruning is best completed during late winter when trees are still dormant. Minimal pruning should occur with young trees, but gradually increase as trees mature. Pruning should remove old or dead branches, remove branches to better develop tree structure, and remove suckers and water sprouts that take energy away from fruit production. For more information related to pruning, please refer to the *Barnyards and Backyards* website, www.barnyardsandbackyards.com and https://bit.ly/osupruning.

Stone fruit trees can be purchased at many local nurseries as potted or balled and burlapped trees or ordered as bare rootstock. Well-drained soils are ideal for stone fruit trees as they might experience root rot if planted in poorly drained soils. Soil nutrient management is also an important consideration. A soil test prior to planting can help determine any nutrient deficiencies present in the soil. Finally, proper tree planting is crucial for the longevity of tree health. More information related to planting trees properly can be found on the *Barnyards and Backyards* website, at https://bit.ly/tree-planting-2007.

PLUMS

Plums are potentially one of the more well-suited stone fruits for Wyoming's climate. In fact, *Prunus americana* is a native plum that grows as a large shrub or small tree in Wyoming and produces small, edible fruits.

In general, plums are not self-pollinating and require a second tree for fruits to set. A few plums are self-pollinating yet benefit from the additional pollination from a second tree for an increase in the number of fruit. Three groups are used to separate plums based on growth and pollination characteristics. Plums benefit the greatest from cross pollination with a different variety or cultivar of plum in the same group. A variety from a different group will not provide suitable pollination. You can often find charts on nursery websites that will help you select appropriate pollinizer varieties.

American plums

American plums are cultivars developed from the native plum of the United States, *Prunus americana*. Cultivars in the American plum category are well suited for Wyoming's climate with many of the cultivars listed as zone 3 or 4. Plums tend to be small in size compared to the European and Japanese plum varieties. The actual size of the tree will also tend to be smaller than the other two groups. American plum varieties can be pruned using the central leader method or the open-center pruning method. American plums may also be more tolerant of high pH soils than plums in other categories.

European plums

European plums are cultivars developed from plums that originally came from Europe. The size of mature fruit tends to be slightly larger for European plums compared to American plums. USDA zone 3 and 4 varieties are available for European plums, which make them a viable option for growers in Wyoming. It is suggested European plums have higher sugar content than American varieties, which makes them better suited for drying. Trees should be pruned to maintain a central leader with lateral branches that have angles of attachment greater than 45 degrees.

Japanese plums

Japanese plum varieties are more common in the marketplace. Most of the varieties in this group are not suitable for Wyoming's climate since they are zone hardiness 5 and greater. There are many Japanese and American hybrids. Japanese plums and their hybrids might be suitable for warmer regions of the state that have micro-climates to support zone 5 trees.

Plum traits

Plums vary in size with 10 to 20 feet as a maximum height for most varieties. Tree should be spaced 10 to 15 feet apart or farther depending on the variety and amount of space required for travel and work between trees. Pruning should occur annually with removal of up to 20 percent of the branches for mature trees. Spurs on branches 3 to 5 years old is the main source for fruit production with very little produced on 1-year old wood. Prune to remove unproductive dead or old branches. Pruning also helps improve the structure of the tree. Suckers and water sprouts should be removed during the pruning process. These branches are new growth that started at the beginning of the growing season and demand resources from the tree that could instead go to fruit production.

Mature plum fruits vary in size, shape, and color. Colors can be dark to light purple, blue, red, yellow, or almost black. The flesh is most often yellow in color but can be shades of green or red as well.

American and European varieties produce a plum that is 1 to 2 inches in diameter. Annual fruit thinning may be needed for some trees to produce consistent, ample size fruits. Thinning should occur soon after fruits have started to grow and fruit should be spaced 4 to 6 inches apart on branches. European plums generally benefit more from thinning than American varieties.

For pollinating purposes varieties must be pollinated by a different variety within the same group. As mentioned previously, some nursery websites provide charts that will help you select appropriate pollinizer varieties.

Varieties to try include
American hybrids (*Prunus americana*)–Many of these are hybrids with Japanese varieties.

- Blackice—large fruit, dark purple-black skin
- Underwood—large fruit, dark-red skin
- Toka—medium-sized fruit
- LaCrescent—medium-sized fruit, yellow skin
- Pipestone—large fruit, red skin
- Waneta—large fruit, yellow and red skin
- American Plum—very small fruit

European (*Prunus domestica*)

- Green gage—small fruit with green skin and very sweet
- Northern blue—medium-sized fruit
- Hildreth—small fruit, but very sweet
- Mount Royal—sweet, yellow-green flesh

APRICOTS

Apricots are very closely related to plums. In fact, there are some apricot and plum hybrids commercially available (pluots, apriums, and plumcots). Apricot trees are well suited for Wyoming's climate and can be found in many communities and regions around the state. Unfortunately, due to the early blooming traits of apricots, annual crops of fruit can be very hit-or-miss. A yearly crop of fruit is almost unheard of for many colder regions of Wyoming that experience late spring frosts.

Cultivars are available for USDA cold hardiness zones 3 and 4. Plant trees in areas with suitable soils where trees can be spaced 20 to 25 feet apart. It is helpful to locate them in microclimates that will help them avoid late spring frost periods when blooming. Microclimates on the north aspects of a building, for example, can delay when trees bloom to avoid these frosts. Apricots require cross pollination from a different variety of apricot for proper fruit set and optimal production.

Pruning should be completed during the later portion of the winter. Older and more mature trees are usually pruned to increase production of fruit since apricots are most often produced on stems 1 to 5 years old. An open vase pruning style is suggested for apricot trees to increase light infiltration to lower branches for increased fruit production, and pruning should be started when trees are young.

Fruits of mature apricots are orange, yellow, red, or a combination of these colors. Mature trees can potentially produce large yields that can be eaten or sold for fresh use or stored for future use. Fruits should be thinned during the early part of the growing season to 4 to 6 inches between fruits.

Varieties to try
- Sungold—later blooming than most varieties, with large fruit
- Mandan—large fruit and cold tolerant
- Moongold—large fruit and blooms fairly resistant to frost events
- Chinese (Mormon)—small to medium-sized fruit, with blossoms that withstand some light frost events
- Westcot—large size fruit with tolerance to cold climates

CHERRIES

Cherries can make a great addition for home gardens and properties in Wyoming. Unfortunately, the sweet cherries common at the supermarket are not hardy enough for most of Wyoming. Tart cherries are more suitable for Wyoming and can tolerate Wyoming's climate in many areas of the state.

Commercial cultivars of tart cherries are larger in size than the native chokecherries. Tart cherries are most often bright red in color when mature. These types of cherries are best used for baking purposes, jams, and occasionally fresh eating. Mature cherry trees come in a range of sizes depending on the variety. Some cultivars are grafted to different rootstocks

that ultimately determine the size of mature trees. Many full-size or standard tart cherry trees will reach 20 to 25 feet when mature. Tart cherries can be found at local nurseries or ordered as bare root trees. Just like other stone fruits, late frost periods can be a challenge for tart cherries. Luckily, the blooming time frame for cherries generally occurs after plums and apricots. Trees located on the south side of buildings and structures tend to bloom sooner and may be more prone to frost damage.

Varieties of tart cherry are often selected based on taste (including varying levels of sweetness), fruit size, and mature tree size. Tart cherries are self-fertile, which make the addition of a second cultivar not always needed. A second tree can help increase the number of cherries for some varieties. Anticipate the spacing between trees based on the mature tree size. Dwarf trees can be spaced 8 to 15 feet apart whereas mature standard trees should be spaced 20 to 25 feet apart. Make sure cherry trees are located in areas that receive full sunlight as decreased tree health can occur in shaded areas.

Pruning should occur in late winter. An open vase or multileader is most often recommended for tart cherries. Light penetration is important for proper bud formation. Fruit is formed on branches and stems that are 2 years old or older. Trees that have not been pruned properly may potentially produce decreased fruit yields.

Spotted wing drosophila fruit fly can be a major challenge to commercial production of cherries. For more information, see Fruit Tree Insect Pests section, page 265.

Cherry trees are also often susceptible to sun scald. See page 205 for more information.

Cultivars

Here are some varieties of tart cherries to try in Wyoming's climate.

- Bali—originated from Alberta, 1-inch size fruit
- Northstar—natural dwarf introduced from the University of Minnesota, good for fresh eating or baking
- Meteor—another introduction from the University of Minnesota, potentially more productive than Northstar, and is a natural dwarf
- Montmorency—potentially the most common pie cherry, grows the largest of the varieties listed and has excellent fruit
- The University of Saskatchewan Fruit Program has recently introduced some (sweeter) new varieties of dwarf sour cherries into the market (originally developed for commercial production in Canada). They have been tested in North Dakota. To see the results (including Spotted wing drosophila fruit fly issues) visit http://bit.ly/NDSU-Cherries.
- Balaton—introduced from Hungary, larger size tree, and is said to have very sweet tasting cherries
- Nanking—very short in stature and is most often a shrub, excellent tolerance for Wyoming's climate, and has small fruit that are very tasty
- Kristin—a sweet cherry that shows promise for Wyoming, yet requires cross-pollination from a different variety. Fruits are dark red to black in color and around 1-inch.

CHOKECHERRY, SAND CHERRY, AND PIN CHERRY

Wyoming is host to three native species of cherry. The fruits of chokecherry (*Prunus virginiana* var. *melanocarpa*), western sand cherry (*Prunus pumila* var. *besseyi*), and pin cherry (*Prunus pensylvanica*) are much smaller in size compared to cherries found in the produce section of commercial grocery stores and are often much more astringent in flavor.

Chokecherry, sand, and pin cherry can be used in landscaping or serve as windbreaks around structures and do not necessarily need to be planted in a typical orchard design. These three species can be a great

addition due to their cold hardiness, tolerance of Wyoming soils, relatively low maintenance requirements, and beautiful white to pink colored flowers in the spring. Chokecherry is perhaps the most common of the three native cherry species available for purchase. Pin and sand cherries are more commonly purchased through tree conservation programs and are not always found at nurseries.

Known for aggressive suckering, chokecherries can take over areas if left unchecked in ideal growing conditions. There are different varieties of chokecherry available that have different maturity size, fruit quality and quantity, non or minimal suckering, and leaf and berry color. Trees can reach 15 to 20 feet when mature. Fruits hang in clusters and are most often dark purple to black in color. Orange, yellow, and red are less common fruit colors. Fruit is most often ripe in late August or early September.

Western sand cherries are shorter than chokecherries. Most sand cherries will rarely grow taller than 6 to 7 feet. Their shorter stature and size make sand cherries a viable option for growers with limited space. Sand cherries prefer full sun, well drained soils, and supplemental irrigation. Their berries can range from very pleasant tasting to so astringent that few people would want to eat them. This unpleasant taste persists even when the fruit is cooked for jam.

Pin cherry is similar in size and shape to chokecherry. This tree produces bright red to burgundy colored berries. Trees can be planted in similar fashion and with similar considerations to chokecherries. Pin cherry can serve as an ornamental tree as well and is known to reach large sizes in the habitats of the eastern United States.

Growing conditions

Most varieties of chokecherries are suitable for a wide range of soil types and will benefit from the addition of irrigation. Supplemental irrigation during hot summer temperatures can help increase plant health and fruit quality. Chokecherry can be planted in windbreaks, landscaping, or used as ornamental trees for urban areas.

Harvesting and uses of fruit

While the berries of chokecherry and pin cherry are quite small (sand cherries are generally a bit larger), they are often prolific and are most often used in jellies, syrups, and for juice. It is important to note the pits of the cherries are listed as poisonous. The pits, leaves, and bark of chokecherry should not be consumed.

Cultivars of chokecherry to try

- Canada Red—dark purple leaves, some suckering potential, and shape more like a tree
- Common chokecherry, *Prunus virginiana* var. melanocarpa—tends to form clumps, often shorter than Canada Red, and very fast growing
- Boughen's chokeless—sweeter fruit than most varieties, large berries, and shrub formation
- Maskinonge—similar taste to Boughen's chokeless, does not sucker very much, and short stature

PEACHES

Peaches are probably the most challenging of the stone fruits to grow in Wyoming. Although peaches bloom later than apricots, there are not many peach varieties cold hardy enough for much of the state. There are a couple of options for areas that can support zone 4 trees.

Peaches like other stone fruits prefer soils that are well drained, of high fertility, and are not saturated throughout the growing season. A soils test prior to planting is highly recommended to detect potential nutrient deficiencies. Peach trees will greatly benefit from microclimates and protected areas. A minimum of eight hours of direct sunlight is required for proper growth.

Plant trees 15 to 20 feet apart. Deep watering is the best method for ensuring adequate water is made available to the tree throughout the entire root zone.

COMMON TREE FRUIT PESTS

The most common Intermountain West tree fruit pests based on Utah State University research guidance. The pests are organized by the tree fruit crop they can attack and then the type of damage they can do to the crop. A "D" for direct impact on the marketable part (in this case fruit), or an "I" for indirect harm to the crop via harm to the tree, which reduces yield and/or fruit quality. Some pests, such as San Jose scale, can do both depending on the intensity of the tree's infestation.

Apple	**Pear**	**Cherry**	**Peach/ Nectarine**	**Apricot**	**Plum**
Green Apple Aphid I	Pear Psylla D	Black Cherry Aphid I	Green Peach Aphid I		
Rosy Apple Aphid I & D		Western Cherry Fruit Fly D	Peachtree Borer I		
Woolly Apple Aphid I			Peach Twig Borer D		
Apple Maggot D					
	Pear/Cherry Slug Sawfly I				Pear/Cherry Slug Sawfly I
Fruit Cat-facing insects: Stink, Lygus, and Boxelder Bugs D					
Codling Moth D					
European Earwig D					
Flatheaded Borers I					
Pearleaf and Appleleaf Blister Mites (Phytoptus species) I					
White Apple and Rose Leafhoppers I					
Fruittree Leafroller D					
Root Weevils (*Otiorhynchus* species: Black vine, Strawberry, and Lilac species may become established in orchards) I & D					
Rust Mites I Peach Silver/Plum rust mite and Apple rust mite (*Aculus* spp.) Pear rust (*Epitrimerus pyri*)					
San Jose Scale D & I					
Spider Mite species I					
Root Borers I					
Western Flower Thrips D & I					
Grasshoppers D & I					

Sprinklers are usually not effective for deep watering and ones that get water on tree leaves should be avoided to prevent diseases within the canopy of the tree.

Aside from Wyoming's less than ideal climate for growing peaches, pruning is potentially the next biggest hurdle. Peach trees should be pruned not only for disease and structure management, but to also provide the best opportunity for fruit production. Fruit is produced on branches and stems that are 1-year-old. A balance needs to be achieved to provide enough older branches for leaf production and the correct amount of 1-year-old stems for adequate fruit production. Too many fruiting stems will result in decreased plant growth, weak branches, and smaller peaches. Conversely, too few will lead to minimal fruit crops.

An open vase design is the best structure for peach trees. This structure helps provide adequate light to promote bud formation and fruiting branch development. Training via pruning should occur when trees are young to create the proper shape. Pruning should occur annually, while keeping in mind pruning that is too heavy can stunt tree growth.

The timing of pruning can be a challenge. Some believe pruning can actually decrease the cold tolerance and resistance of trees. This means pruning should occur late (or early) enough in the year that trees are not too greatly affected by cold temperatures, yet not too late that trees have started to bud and leaf out. Summer pruning can help remove unwanted upright branches to increase light and air flow through the tree. Summer pruning can also remove diseased or dead branches.

Unlike other pruning methods mentioned earlier in the stone fruit section, pruning for peaches primarily focusses on managing 1-year-old wood. To help promote the strength of branches and reduce potential for breaking, thinning cuts are used to remove excess stems or branches. Heading cuts help strengthen branches by removing the ends of branches so energy reserves are used for increasing branch circumference and not branch elongation. Finally, stub cuts are implemented to achieve new growth points for branches to produce fruit bearing branches (1-year-old branches). A balance needs to be achieved between fruit production and structurally sound branches. Please visit these resources for more information regarding peach tree pruning and considerations, https://bit.ly/usu-training-peach-trees.

Peaches may need to be thinned via pruning or when the fruits are young to ensure sweetness and adequate size. Fruits may be yellow, orange, red, or a combination of these colors when ripe. It is important to let fruits completely ripen while on the tree for best flavor. Fruits become ripe when the flesh becomes soft. Fruits may ripen from late July through early September.

Varieties

- Contender—known for cold tolerance and the ability to produce fruit in cold climates
- Reliance—a potential option for certain areas of Wyoming
- Cresthaven—cold tolerant, but less so than Contender and Reliance
- Redhaven—cold tolerant, but less so than Contender and Reliance
- Intrepid—cold tolerant, but less so than Contender and Reliance

FRUIT TREE INSECT PESTS (APPLES, PEARS, CHERRIES, PEACH/NECTARINE, APRICOTS, PLUMS)

Apple and pear trees can be attacked by many of the same pest species. The codling moth and the woolly apple aphid are two of the most frequently encountered pests in Wyoming. Both pests also utilize decorative crabapple tree fruits. Crabapple trees are rarely managed to suppress these pests.

Proximity to crabapple trees or neglected apple trees can produce many codling moths that can invade your orchard. The codling moth attacks the fruit

so it doesn't impact the tree's health but it causes major damage to the harvest. Multiple, properly timed, sprays of insecticides are required to control codling moth. There are many labeled pesticides for use on this pest. Rotating the mode of action of the products selected to prevent insecticide resistance is important. It is also recommended to utilize insecticides that are moth specific or considered "soft" on non-target pests as part of the product rotation.

The use of pesticides that don't hurt pollinators is critical to protect them when they are visiting flowers in the orchard. Sometimes an unintended result of good codling moth control is a flare up of spider mites on the trees. This happens when predatory insects that usually suppress spider mites are killed unintentionally by insecticide applications. Apple bags can be used as a form of cultural control that physically protects the forming fruits from codling moth and other pests. It is an option that can be explored, especially if high-quality, pesticide-free apples can bring a grower a premium price at market.

As discussed previously, select varieties of cherries, peaches, apricots, and plum trees can grow well in microclimates found in Wyoming. These stone fruit species share many of the same regional pests as apples and pears. The table of common tree fruit pests, see page 264, can help you determine the cause of arthropod plant damage you might observe in you orchard.

Green apple aphids
Kansas Department of Agriculture, Bugwood.org

Green apple aphid (*Aphis pomi*), unlike many aphid species that have different winter and summer host plants, spends the entire year on apple trees. Their feeding activity doesn't cause the leaves to curl but stresses the tree and results in damage from accumulations of honeydew.

A nymph pear psylla (*Cacopsylla pyricola*) feeding on a pear leaf and producing lots of honeydew excrement.
Whitney Cranshaw, Colorado State University, Bugwood.org

Pear psylla adults look more like tiny cicadas than aphids. They can damage fruits with honeydew residue, and their saliva contains a plant toxin and can cause "psylla shock" in trees. Pear psylla is a vector of a disease organism that causes "pear decline," which can kill susceptible cultivars.

Black cherry black adults and brown immature aphids feeding on a sour cherry tree leaf.
Whitney Cranshaw, Colorado State University, Bugwood.org

High density populations of **black cherry aphids** (*Myzus cerasi*) can stunt the growth of young trees.

Green peach aphid
Whitney Cranshaw, Colorado State University, Bugwood.org

Green peach aphid (*Myzus persicae*) caused leaf curling damage on this peach tree. This widespread aphid species will also feed on apricot and nectarine trees. High density populations of this pest can cause reduced fruit crop yield before the aphids move to numerous species of herbaceous summer host plants.

Rosy apple aphid
Whitney Cranshaw, Colorado State University, Bugwood.org

Rosy apple aphid (*Dysaphis plantaginea*) feeding can cause leaf curling and small deformed fruit. It will also attack pears. By early July, this species moves from fruit trees to narrow and broad leaf plantain (*Plantago* spp.) plants, and the pests don't return to the trees until early fall to lay eggs. Controlling this weed reduces the aphids' summer habitat.

Western cherry fruit fly on yellow sticky trap
Whitney Cranshaw, Colorado State University, Bugwood.org

The striped pattern on the wings of this **Western cherry fruit fly** (*Rhagoletis indifferens*) caught on a yellow sticky card trap are a diagnostic character of this pest. This native pest uses all species of cherry fruit for its larval habitat. It is a weak flier so every effort to keep this pest from establishing in new, isolated, orchards is useful. Growers should prevent the introduction of possibly contaminated cherries to their properties.

Peachtree borer larvae on a peach root
Eugene E. Nelson, Bugwood.org

Peachtree borer (*Synanthedon exitiosa*) larvae chew on the roots of peach, nectarine, apricot, and plum trees. The adult insects are from the clearwing moth family and they mimic wasps in shape and coloration as a protection from predators.

The **wooly apple aphid** (*Eriosoma lanigerum*) is usually only a serious problem for stressed trees. They can be found on limbs and roots. When they attack the trees above ground, the clustered aphids, which are covered with white, fibrous wax, are noticeable and distinctive. These aphids prefer to feed on root suckers and around the edges of pruning cuts and bark wounds.

The larvae of the **peach twig borer** (*Anarsia lineatella*) moths will infest developing peaches and apricot fruits and the shoots on the limbs of the trees.

Apple maggot fly adult
Central Science Laboratory, Harpenden, British Crown, Bugwood.org

Apple maggot (*Rhagoletis pomonella*) flies use developing fruit for their larva's habitat. Despite their common name, this pest is capable of utilizing the fruit of many different plants for its larvae, including the ubiquitous crabapple.

Pear slug sawfly on a peach leaf
Jerry A. Payne, USDA Agricultural Research Service, Bugwood.org

Pear/cherry slug sawfly (*Caliroa cerasi*) larvae look very much like small slimy slugs, but they are a member of the insect order Hymenoptera (this order also contains wasps, bees and ants). The feeding activity of the second and sometimes the third generation (rare in Wyoming's climate) larvae can impact the productivity of pear, cherry, chokecherry, and plum trees via leaf damage. These pests are common on other rose family plants and should be controlled to prevent spread to fruit producing crops.

Cat-facing injury on pears
Whitney Cranshaw, Colorado State University, Bugwood.org

Multiple species of bugs with piercing sucking mouth parts can cause "cat-facing" injury on developing fruits like these damaged pears. **Consperse stink bug**, *Lygus* species bugs, and **boxelder bugs** are common pests in Wyoming and capable of this

type of fruit damage by feeding with their piercing mouthparts.

Codling moth
Scott Bauer, USDA Agricultural Research Service, Bugwood.org

A **codling moth** (*Cydia pomonella*) resting on pear fruit appears harmless, however, the larvae of this small, nondescript, insect is a major pest of both pear and apple fruit. They don't threaten the health of the trees, but they can ruin the commercial value of a fruit crop.

Euopean earwig adult
David Cappaert, Bugwood.org

European earwigs (*Forficula auricularia*) are omnivorous and will feed on developing tree fruits at night in orchards. Modifying the habitat conditions that provide this pest daytime shelter in the orchard helps to reduce their populations. Treating the trunks of trees with contact activity insecticides can protect ripening fruit from this nocturnal pest.

Flatheaded apple tree borer larva
James Solomon, USDA Forest Service, Bugwood.org

Flatheaded apple tree borer adult
Kansas Department of Agriculture , Bugwood.org

Application of labeled insecticides to the tree bark, timed to kill the borers hatching from eggs deposited on the bark, is the most effective way to manage the **flatheaded apple tree borer** (*Chrysobothris femorata*) beetle. This treatment prevents the new larvae from getting under the bark where it can eventually cause extensive damage to the cambium layers inside. Healthy trees without bark wounds are less susceptible to selection by the adults of this pest.

Appleleaf blister mite damage
Whitney Cranshaw, Colorado State University, Bugwood.org

Appleleaf blister mite (*Eriophyes mali*) and the closely related **pearleaf blister mite** (*Eriophyes pyri*) are very small and require high optical magnification to be seen. The appearance of the leaf blisters and

knowledge of the plant species affected is usually sufficient to identify the pest. Severe infestations can also damage fruit skins, making them unmarketable. Severe infestations of blister mites can also cause leaf drop, reducing tree health.

White apple leafhopper
University of Georgia Plant Pathology , University of Georgia, Bugwood.org

White apple leafhopper (*Typhlocyba pomaria*) (above) and rose leafhopper (*Edwardsiana rosae*) (below) look very similar to the naked eye.

Rose leafhopper
Whitney Cranshaw, Colorado State University, Bugwood.org

These two pests can utilize all of the common tree fruits species for food. The **rose leafhopper** has three generations per year and uses rose plants to host the overwintering egg stage. **White apple leafhoppers** have two generations per year and overwinter as eggs in the bark of the fruit trees. The damage to the leaves can be extensive and causes depletion of the tree's energy reserves and harms its health.

Fruittree leafroller larva
USDA Forest Service - Region 8 - Southern , USDA Forest Service, Bugwood.org

Several species of small moths have caterpillars that use leaves to create shelters in which they feed (the shelters provide protection). The **fruittree leafroller** (*Archips argyrospila*) is the most common species in Wyoming. Pre-bloom leafroller caterpillar feeding within fruit clusters results in fruit abortion or deeply scarred fruit. All species of fruit trees, along with many native and introduced trees and shrubs, can host this pest. Management of the overwintering generation's larvae can be done with pre-bloom insecticide treatments applied for other tree fruit pests. If targeting only fruittree leafrollers, pesticides containing the *Bacillus thuringiensis kurstaki* derived active ingredient are an effective selective insecticide option.

Black vine weevil adult
Cheryl Moorehead, Bugwood.org

Black vine weevil, (*Otiorynchus sulcatus*), **strawberry root weevil**, (*Otiorynchus ovatus*) and **lilac root**

weevil, (*Otiorhychus meridionalis*) populations can establish in orchards. The root feeding by the larvae is especially harmful to young trees and transplants. The leaf feeding by the nocturnal adult beetle is of minor concern but the severity reflects the population of the pest in the orchard; however, the adult root weevil will occasionally girdle the fruit petiole, a direct injury.

Pearleaf blister mite damage on a Bradford pear leaf
Penn State Department of Plant Pathology & Environmental Microbiology Archives , Penn State University, Bugwood.org

Peach silver/plum rust mite (now considered to be one species by taxonomists), **apple rust mite**, all from the genus *Aculus* and **pearleaf rust mite** (*Eriophyes pyri*), are too small to be seen with the naked eye. Diagnosis in the field can be made by the form of the leaf damage (blister) and plant species.

SanJose scale on apple
Phil Sloderbeck, Kansas State University, Bugwood.org

San Jose scale (*Diaspidiotus perniciosus*) can attack all of the common tree fruit species and many ornamental trees and shrubs. This pest will feed on the twigs, branches, fruit, and foliage. If uncontrolled, San Jose scale can kill a tree and/or make the fruit unmarketable. Monitoring for this pest and IPM plans for it should start as soon as you plant your orchard to keep ahead of the potential damage this pest can cause.

Twospotted spider mites
Frank Peairs, Colorado State University, Bugwood.org

Several spider mites are pests of tree fruits but in Wyoming, the **twospotted** (*Tetranychus urticae*) and the **McDaniel spider mite** (*Tetranychus mcdanieli*) are the most common. All of the spider mites feed on plants with short, piercing beaks and suck the cell contents out leaving behind white marks initially, which then turn bronze colored as the damage ages. The strands of silk on the foliage produced by aggregations of feeding mites is also diagnostic. Best pest management for orchards strives to control spider mites and other arthropod pests with a minimum of harm to the many predators of the spider mites. This can be done by using selective insecticides and miticides and correctly timing pesticides applications to avoid spider mite flare ups.

Prionus californicus
David Gent, USDA Agricultural Research Service, Bugwood.org

Root boring larvae from the beetle family Prionidae can be serious pests of fruit trees. The larvae can spend anywhere from three to five years feeding on the roots before emerging as nocturnal adults for reproduction only. In Utah, *Prionus californicus* species is recognized as a serious pest of stone fruits growing in sandy soils. Prionid beetle species pheromone mating scents can be used to bait bucket traps to capture adults and disrupt mating of these pests in orchards. Control of the larvae once in the roots is not possible at this time.

Adult Western flower thrip greatly magnified
David Cappaert, Bugwood.org

Western flower thrips (*Frankliniella occidentalis*) are very small insects. The adult thrips are less than 1.5 mm in length; however, these small pests can severely damage a fruit tree flower's reproductive parts, which impacts fruit set. Thrips feeding activity can also scar the skin of developing fruit causing cosmetic damage that decreases its market value.

Several **grasshopper** species in the genus *Melaonplus*, such as this two-stripped adult (below), can damage fruit trees and fruit when they invade orchards in the summer when their normal food plants have been exhausted. Monitoring and treatment of grasshopper populations in nymph (immature grasshoppers) source habitats, outside of the orchard, is the best way to keep these mobile pests from invading and feeding on trees.

Two-stripped grasshopper
Whitney Cranshaw, Colorado State University, Bugwood.org

See grasshopper management under the Integrated Pest Management section for additional information, page 47.

ADDITIONAL TREE FRUIT PESTS OF POSSIBLE CONCERN TO A WYOMING ORCHARDIST

Roundheaded apple tree borer adult
Dawn Dailey O'Brien, Cornell University, Bugwood.org

Roundheaded apple tree borer (*Saperda candida*) adults appear in the spring. The adults deposit eggs on the tree bark. Insecticide treatment of the bark to kill the newly hatched larvae before they tunnel under the bark can be done. This apple pest is more common in the eastern U.S. orchards, but it should be watched for in Wyoming.

Western tentiform leafminer larva exposed for view.
Whitney Cranshaw, Colorado State University, Bugwood.org

Western tentiform leafminer (*Phyllonorycter elmaella*) "mine" the tissue between the upper and lower leaf surface. This insect will feed on many species of fruit trees but is usually found at sub-economic damage levels. The economic thresholds for treatment in apple orchards depends on the date, the number of mines per leaf, and observed level of parasitism of the leafminers. (As well as the level of acceptance of insect damage to consumable fruit.)

Western tent caterpillars in their "tent".
A. Steven Munson, USDA Forest Service, Bugwood.org

Western tent caterpillar (*Malacosoma californicum*) are native moths with a broad plant host range that can reach very high populations sporadically. The silken "tent" shelters, which the caterpillars work together to form on tree branches as a daytime resting place, are easily seen. Physical removal or application of products labeled for leaf feeding caterpillars provide effective control. They only have one generation per year, and many insect predators attack the moths and their eggs.

Plum curculio and its damage
Art Cushman, USDA Systematics Entomology Laboratory, Bugwood.org

Plum curculio (*Conotrachelus nenuphar*), is an injurious pest of apples, cherries, nectarines, peaches, and plums in the eastern U.S. Utah has a campaign to try and stop the spread of this damaging pest in their state through their Department of Agriculture and Food. Growers should keep an eye out for this pest and report any sightings.

Additional in-depth tree fruit pest management resources

- WSU Orchard Pest Management Online http://treefruit.wsu.edu/crop-protection/opm/
- Pacific Northwest Pest management Handbook for Tree fruit Crops https://pnwhandbooks.org/insect/tree-fruit
- Utah State University Extension Tree Fruit Insect Pests https://bit.ly/usu-tree-fruit-insects

DISEASES AND DISORDERS OF SOME STONE FRUIT (CHERRY, PLUM AND OTHERS)

Infectious diseases

Diseases of sour cherry include **cherry leaf spot** caused by the fungus *Coccomyces hiemalis*. Symptoms include small red-purple spots on the leaves that turn brown and may coalesce (merge) over larger areas of the leaf. The tree or shrub will shed affected leaves with increased lesion numbers. This disease overwinters in infected leaves on the ground, and disease development is promoted by warm temperatures and humid conditions. Manage by removing and disposing the infected leaves from the previous season. Cherry leaf spot can be managed with foliar fungicides if applied at early stages of disease.

Black knot is another fungal disease caused by *Apiosporina morbosa* that can infect cherry, plum, chokecherry, and less commonly apricot and peach. Symptoms include unique elongated swellings (galls or knots) on the newer shoots of the tree and occasionally on trunks. Knots can reach up to 12 inches long, initially olive green in color with a corky texture, then turning black and becoming hard and brittle. These galls release spores in the spring when wet. Leaves and shoots affected with knots of susceptible trees can wilt and die. Less susceptible trees can tolerate the galls. Manage by pruning out the galls during the winter with cuts at least 4 inches below the gall. Infected material should be burned, buried, or disposed of.

Brown rot (*Monlinia* species) is a potentially serious fungal disease of Prunus species. Disease can affect blossoms, twigs, and fruit. Symptoms include blossoms that brown, die, and remain attached to the tree, which contrasts with freeze injury in which blossoms fall to ground. The pathogen will infect small twigs resulting in the formation of small twig cankers that often have drops of sticky ooze. Infected, developing fruit will initially have small, firm, brown spots that grow to encompass large portions of the fruit. Infected fruit will dry up and remain attached to the tree. Under periods of high humidity, masses of tan-to-grey spores are apparent on fruit and stem cankers. Disease initiates in the spring as spores from previously infected stem cankers and shriveled fruit on the ground or tree infect blossoms under wet, cool conditions (45 to 70 F) with three to six hours of leaf wetness.

Secondary spore production and spread occurs from cankers and infected fruit causing the disease to spread the entire summer under proper conditions.

Proper sanitation is required for management. Remove infected and overripe fruit and dispose. Prune out diseased twig cankers. Avoid damaging fruit at harvest since the fungus requires injury to infect, thereby reducing post-harvest infections. Fungicide can be used when warranted to protect blossoms and developing fruit.

Powdery mildew can also affect Prunus fruits reducing tree vigor, flower bud production, and fruit quality much like powdery mildew on apple/pear. The powdery mildew fungus that affects cherry and plum is *Podosphaera clandestine*. Powdery mildews are very diverse as a group with many different host-specific strains. A powdery mildew affecting a sour cherry/plum will not infect apple/pear tree and vice versa. Disease development, symptoms, and management are similar to powdery mildew on apple/pear, page 256.

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