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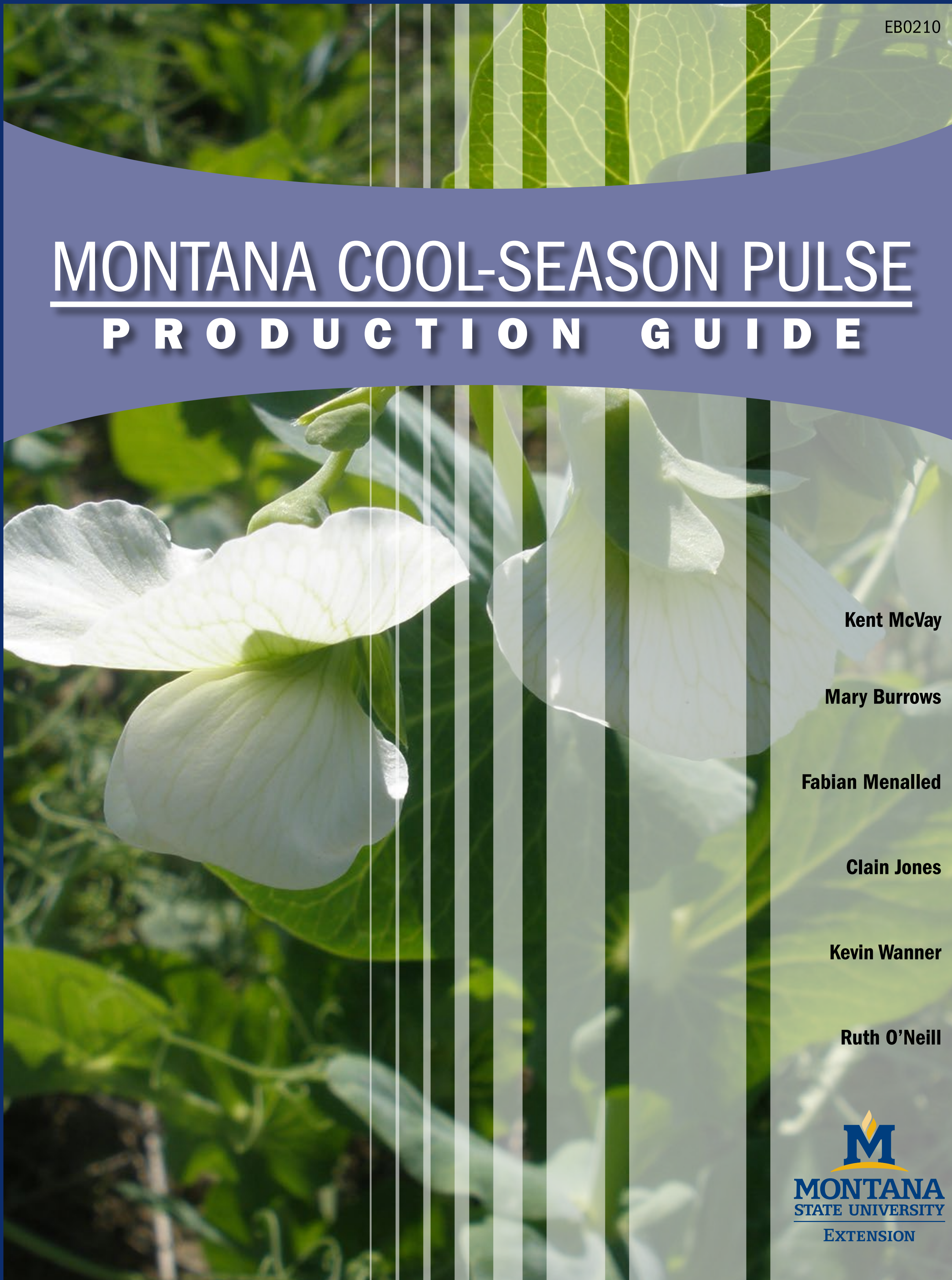

MONTANA COOL-SEASON PULSE PRODUCTION GUIDE

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MONTANA STATE UNIVERSITY
EXTENSION

Preface

This publication provides current knowledge on best management practices for production of dry pea, lentil, and chickpea for producers in the state of Montana. The authors have included basic information needed for successful production of these pulse crops as well as links to more detailed or current information on the Web. When viewing this document online you can simply click on these links to take you to those websites. All links referred to within the text are listed in the back of this publication. Hard copies of many of the references in this publication are available through Montana State University Extension Publications, and through your local county Extension office.

Editor

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Pulse Crop Overview

Dry pea, lentil, and chickpea are crops known as pulses. A pulse is an annual legume grown for human or animal consumption. Most define pulses as those grown solely for the dry seed, which excludes crops like green beans or fresh peas. Including a pulse crop in your dryland rotation can bring significant financial and agronomic benefits. The traditional wheat-fallow system of crop production common in Montana lacks diversity, does not efficiently manage precipitation, and leads to declines in soil organic matter (OM) and soil productivity. Growing a pulse crop in rotation with wheat can help bring some balance to soil in terms of health, biological activity, and overall potential productivity.

Pulse crops can be planted and harvested with the same equipment used for small grain production. Because lentil and chickpea produce seed very close to the ground, additional equipment such as a roller (to press rocks down after planting) and a flex head for the combine are recommended.

Recent trends show nearly equal proportions of lentil and dry pea production in the state with just a small percentage of chickpea produced (Figure 1). As of 2012, pulse crops represent more than one-half million acres of the seven million acres in dryland production in Montana. The increase in dry pea and lentil acreage appears to be sustained growth as compared to the short-term run of chickpea from 1998-2003. In the 1990s pulse acreage was primarily located in the intermountain region near Kalispell. But today the northeast and Triangle regions of Montana are the dominant locations for pulse production (Figure 2). The reasons for sustained growth are many, but they include a concerted effort by the Montana Agricultural Experiment Station (MAES) to evaluate these crops across the region as well as a substantial increase in the number of buyers. According to the Montana State Department of Agriculture[1], by 2012 there were 25 different delivery points for peas, and 23 receiving stations for lentils within the borders of the state.

Lentil (Lens *culinaris*)***:*** The name lentil refers to the shape of the seed which appears like a lens at maturity. Seeds vary in size and color due to genetic variability. The United States Department of Agriculture/Federal Grain Inspection Service (USDA/FGIS) recognizes only one class of lentil, but they distinguish special grades of size, either large or small, based on passage through a 15/64-inch round-hole sieve. Although color is not necessarily a grade by USDA/FGIS, it is a characteristic important to buyers. Typically buyers will categorize different varieties into browns, greens, and reds; named for the color of the seed coat, not the color of the cotyledon.

Adding lentils to your diet can bring lots of flavor and protein to numerous dishes. In the U.S. brown lentils are probably most common, and the type most likely to be found in the grocery store. They range from light

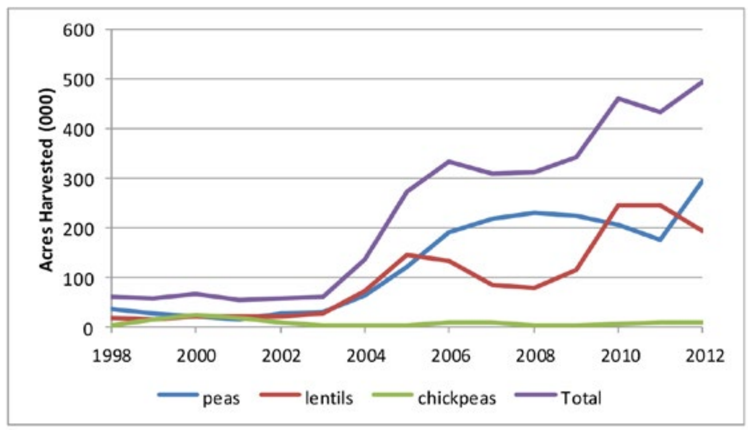


Figure 1. Trend in Montana pulse acreage since 1998 (USDA-NASS).

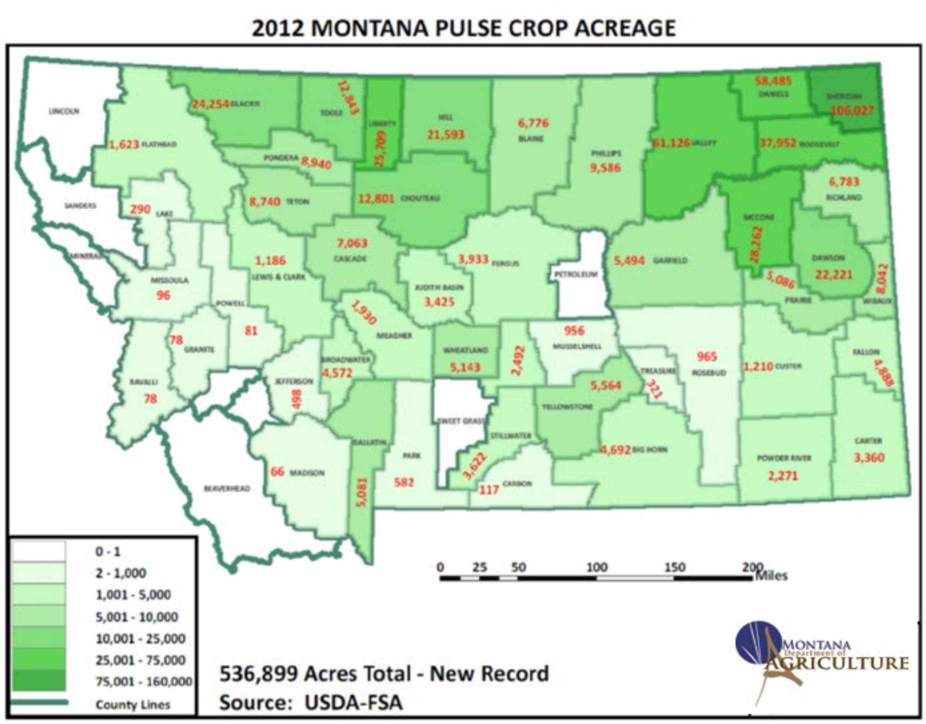


Figure 2. Distribution of pulse acres in Montana in 2012.

brown to dark black. This type cooks in about 20-30 minutes and holds shape very well. Green lentils can be pale or mottled green-brown (like Pardina). Green lentils have a more robust, somewhat peppery flavor, and take a bit longer to cook. They keep a firm texture even after cooking, which makes them an excellent choice for salads and other side dishes. Red lentils can range in color from gold to orange to bright red. Reds are the sweetest and have a nutty flavor. Cooking times are around 30 minutes. Red lentils tend to get mushy once cooked, making them a good choice for Indian soups.

Varietal differences lead to different markets, so when managing grain at harvest it's important to keep each variety segregated. If different colors or different varieties are mixed, the value of the product is diminished, thus affecting the price offered**. Current recommendations are to communicate with your buyer prior to planting the crop.** Lentil crops are grown with and without contracts but it's important to know up front what options will be available come harvest time.

Dry pea (Pisum *sativum* L.)***:*** Dry pea has been grown in Montana for many years, and is very well adapted to the region. The variety arvense, or Austrian winter pea, is typically planted in the fall to establish the plant and is grown only for livestock feed. It then lies dormant through winter and begins growing again in spring. In Montana, typically all above-ground plant material grown in the fall desiccates over winter and regrowth is initiated from crown or sub-crown buds. Winter regrowth has been best when significant warm, dry spells occur in early spring, and worst in dense cereal stubble with prolonged cool, wet growing conditions in April. Seeds of this variety are usually mottled brown and are included in the Mottled Dry Pea class by USDA/FGIS. Spring planted pea is typically either yellow smooth or green smooth, each is in a separate class by USDA/FGIS. In Montana, yellow types tend to outyield green types by about 10 percent, but yield varies strongly among varieties in both market classes.

Pea is very versatile and can be harvested as forage or as grain, or can be terminated by tillage or herbicide and used as cover crop to scavenge residual nutrients and fix atmospheric nitrogen (N) for a following crop. The relatively high percent N content of the forage, typically two to four percent, can contribute a significant amount of N to a following crop. For example, a two-ton forage yield of pea at three percent N provides 120 lb. N per acre. This N is in organic form, but pulse residue has low carbon to N ratios and decomposes rapidly, mineralizing this N into forms available to a following crop. This will be discussed further in the fertility section.

Yellow and green smooth pea are quite nutritious. Protein of the grain can range from 17-28 percent. It contains high levels of carbohydrates making pea excellent livestock feed. Pea has lower amounts of trypsin inhibitors than soybean and can be directly fed to livestock. Dry pea is often cracked or ground as it is added to feed rations to increase digestibility.

Dry pea is also sold for human consumption. The largest market is Asia but demand in the U.S. has steadily grown for the past several years. As recommended for lentil, communicate with your buyer before growing pea. It's important to know your market.

Chickpea (Cicer *arietinum* L.)***:*** Chickpea is grown as a food crop in many countries. Major producers include India, Pakistan, Turkey, Iran, and Mexico. According to the Food and Agricultural Organization of the United Nations (FAO), world-wide chickpea is the most important pulse crop followed by pea and then dry bean. Most people in the U.S. are familiar with the cream-colored kabuli types found on salad bars. Also known as garbanzo bean, chickpea can be processed and served as hummus, a traditional dish in the Middle East, and increasing rapidly in popularity in the U.S. The smaller dark-seeded types of chickpea are known as desi, which are usually ground into flour (dahl) for use in soups or other dishes. Chickpea is typically contract-grown and brings a good price.

Cultural practices

Inoculation: Pulse crops are legumes. Legumes fix N from the atmosphere through Rhizobia bacteria that grow in association with plant roots. The same Rhizobia species is effective for pea and lentil, but a different species is necessary for chickpea. Once bacteria are introduced to the soil, a certain population remains viable for years. Because of plant disease risk, Montana State University recommends limiting the frequency of pulse crops to no more than once in three years on any particular field. Because of this long break, it's a good practice and cheap insurance to inoculate the seed with the proper rhizobium at each planting. These crops need a significant amount of N to produce seed, and if the bacteria is not present, or does not infect plant roots, the plants are at risk of N deficiency (See Box 1). Inoculant formulation can have an impact on the establishment of nodules on plants. Field trials in west-central Alberta found granular soil applied inoculant produced greater yields than liquid or peat powder seed-applied, especially at low applied N rates (0 and 18 lb. N/acre, vs 36 and 71 lb. N/acre) (Clayton et al., 2004).

Box 1. Nitrogen is nitrogen.

When bacteria invade the roots of legumes, they set up shop to fix atmospheric N gas (N_2). This mutually beneficial, or symbiotic relationship, helps both organisms. The bacteria receive energy from the plant, and in exchange the plant receives 'free' N. What happens if the two don't get together? No nodules develop on the plant roots, and the plant is left to scavenge the soil for mineral N. The N can come from the mineralization of soil-OM, or from inorganic forms like fertilizer-N. The plant will complete its life cycle regardless from where the N is supplied. The bottom line is a shortage of N leads to poor plant growth and low yields.

As a point of reference, over the course of a season, a 2000 lb. lentil crop will assimilate at least 80 lb. N/acre. This N can come from the atmosphere through its association with bacteria, or it can come from fertilizer or other sources. It pays to inoculate your soil!

Cropping Systems: Pulse crops are a good choice for diversifying your rotation. These legumes will get their N indirectly from the atmosphere. This reduces overall input and cost of fertilizer. In addition, pulse crop residue breaks down quickly, providing some N credit to a following crop. This credit is approximately 10–20 lb. N/acre depending on yield, but can be substantially higher if the pulse crop is managed as a cover crop. As a cover crop, N credit given is a function of total tonnage produced (download Oregon State calculator)[2].

Fields that have been managed primarily for small grains may have herbicide residues that can prevent successful rotation to pulse crops. Lentil is especially sensitive to background levels of herbicides which use acetolactate synthase (ALS) as found in products such as Finesse, or Glean. For example, the labeled plant-back restriction for lentil following Glean is 36 months, and 24 months for dry pea, but in Montana environments this period may be longer. Before pulse crops can be included in rotations with cereal grains, herbicide management in the small grains phase has to be modified. Post-applied products such as Banvel, or Ally Extra for broadleaf weed control can be successfully substituted for the soil-active herbicides which reduces the plant-back restriction. See the discussion in the weed section for more herbicide choices.

The legacy of decades of small grain breeding work conducted at state universities, by USDA scientists, and by private seed companies has provided many choices when it comes to plant disease management for cereal grains. Pulse crop breeding, by comparison, is still in its infancy. The diseases that damage or kill pulses are typically fungal or bacterial organisms that complete their life cycles on residual crop residue. Most diseases are specific to the host plant, so to prevent reoccurrence or a buildup of disease organisms, the pulse crop residue must be eliminated. In years past tillage was recommended, but no-till systems with extended rotations between pulse crops is just as effective. A more detailed discussion of disease management can be found later in this guide.

In Montana the majority of pulse crop production is under rainfed, or dryland conditions. But irrigated production of pulses is possible. For the past two years dry pea and lentil have been grown under dryland and irrigated production at the Southern Agricultural Research Center. Significant yield increases were seen where irrigation was practiced (Table 1). Disease issues were not a problem in these two years but the potential for disease would be higher under irrigation, requiring more scouting and greater management.

Variety selection: Choosing a variety that excels in your region is as important for pulse crops as it is for any crop. Uniform statewide variety trials for dry pea, lentil, and chickpea have been conducted in Montana for several years. Results are available through Extension Publications[3], and online for all locations at the Southern Agricultural Research Center[4]. It's important to remember when analyzing variety performance data that results from any one year may not mean much. To gain certainty of performance superiority, compare results from sites that are representative of your location. Results from several different years, or results from different locations averaged across one or several years, should be given preference. Unfortunately not all varieties available to you are evaluated in these trials. If you choose to grow a variety that has not been tested, heed the advice of your contractor, or rely on the experience of your neighbors.

Table 1. Impact of irrigation management on yield (lb/acre) potential of dry pea and lentil production in south central Montana (Huntley) from 2011-12.

Crop	2011		2012	
	Dryland	Irrigated	Dryland	Irrigated
Green Pea	1888	4213	1482	2989
Yellow Pea	2182	4486	1630	3338
Lentil	659	1270	534	1744

Pulse crops are true varieties, not hybrids. Keeping seed for your next crop can be a good idea where and when legal to do so. The Montana State Grain Laboratory[5] can test seed lots for presence of disease.

Lentil: Most varieties grown in Montana are spring types, though some winter varieties are available. Most well-drained soils provide good locations for lentil production. Lentil will develop roots in the top two feet of soil. Shallow soils are fine, while deeper soils are also a good choice and will retain a reservoir of moisture for a following crop that may root deeper. Lentil can be successfully no-till drilled on 6- or 7-inch row spacing, placing the seed approximately one to two inches below the surface. Seeding early (similar to spring wheat) is important to encourage more vegetative growth, and taller stature as to set seed higher on the plant. Planting into standing wheat or barley stubble encourages taller plants, and provides some protection from lodging at harvest. Lentil is quite frost tolerant, able to withstand temperatures as low as 21° F. Upon germination, the cotyledons open and the shoot emerges. The cotyledons remain below the soil surface (hypogeal germination) as the first node. A second or 'axillary' node then develops and the third node will usually establish at the soil surface (without leaves). If the shoot is damaged, re-growth can occur from the crown or from axillary (i.e. below ground) nodes. The first leaf usually develops at the fourth node (but is called the first vegetative node). After that new leaves are produced on successive nodes approximately every four to five days. The total number of leaves developing from nodes varies from nine to 15.

Lentil plants are short, growing only to heights of 12-16 inches. Land rolling after planting is recommended to push rocks down so they can be avoided at harvest. This is especially true in rocky or rough fields. It's best to roll soil prior to seedling emergence, but lentil can be rolled any time after planting until the five-node (vegetative) stage. Rolling the same direction as planted and on warmer days rather than cold mornings reduces the risk of stem breakage.

Seed size can vary widely from extra-large green Riveland types with diameters close to eight mm (~1/4 inch), while extra-small reds like Crimson or CDC Impact can have diameters of only three mm. Seeding rates should be adjusted to target a final plant population of 11-15 plants per square foot. Typically that equates to seeding rates of 40-80 lb./acre (See Box 2 for calculations). Be cautioned that higher seed rates can provide a favorable environment for diseases.

Lentil has an indeterminate growth habit, which means they continue to grow vegetatively after setting flowers. Late summer rains can trigger mostly ripe plants to produce new vegetative growth. This growth characteristic can make harvest more challenging, sometimes requiring chemical desiccation to terminate growth to improve seed quality and uniformity for harvest. See the weeds section for some harvest aid recommendations. Forage types, like Indian head, do not store well for long periods.

Clearfield lentil: Varieties in this category have been selected for their tolerance to the herbicide imazamox (Beyond). This tolerance provides an excellent way to help control certain broadleaf weeds such as shepherd's-purse, field pennycress, kochia, and mustards, which are typically hard to control in lentil. In addition grassy weeds such as downy brome, Japanese brome, Persian darnel, jointed goatgrass, wild oats, and volunteer wheat can be controlled using imazamox chemistry. Some of the limitations of using Clearfield is the requirement by BASF that you sign a Clearfield Lentil Stewardship Grower Agreement, which among other things restricts the use of this system to no more than twice in four years on any particular field. This is a policy used to help prevent development of resistant weed biotypes. Since a typical Montana crop rotation already restricts lentil to no more than once in three years, this is not difficult unless you are growing other Clearfield crops. Another limitation is that seed cannot be kept for future planting, but must be purchased as certified seed.

Even with these limitations and restrictions, if weed control in a field going to lentil is suspect, Clearfield lentil may be a good choice. In the U.S. Clearfield lentil is marketed through Pulse USA[6] located in Bismarck, North Dakota. Varieties currently available include CDC Impala CL and CDC Impress CL, which have performed well in the statewide pulse variety trials.

Box 2. Determining Seeding Rates

To determine the proper seeding rate you need the following:

1. seeds per pound
2. purity
3. germination

Target Populations

	Plants/ft^2
Chickpea	4–6
Pea	8–10
Lentil	11-15

XYZ SEED COMPANY
Lentils, variety CDC Redberry
LOT: abc tested 9/2012
SEED WEIGHT: 10,250/lb.

PURE: 97% GERMINATION: 95%
INERT: 3% OTHER:

$$\frac{lb\ seed}{acre} = \frac{12\ plants}{ft^2} \times \frac{1\ lb}{10{,}250\ seeds} \times \frac{100}{95} \times \frac{100}{97} \times \frac{43560\ ft^2}{acre}$$

Spring Pea: Pea require more moisture to germinate than small grains because of their relatively large seed size. This makes them a good candidate for no-till establishment where previous crop residue helps to maintain higher surface moisture. If the soil is conventionally tilled, it should be worked just enough to be clod free. Overworked soil can crust, which can result in poor emergence of the seed. Pea should be planted in well drained soils from one to three inches below the surface and always into moisture. Narrower row spacing (six inches) helps with early season competition against weeds, but pea can be successfully raised in rows as wide as 12 inches. A population of eight to 10 plants per square foot is needed for successful grain production (see Box 1 for calculations), which means for pea, seeding rates of 150-200 lb./acre are common.

Early planting dates improve yield potential by helping the plants reach maturity prior to the hot days of mid-July. Pea is fairly resistant to spring frosts and can re-grow from buds at or below the soil surface if frost damage occurs. Plant pea just prior to your time for planting spring wheat, especially if the seed is treated for disease control. Handle pea seed with care to minimize cracking. Split seeds will not germinate.

The semi-leafless pea varieties that are commonly grown can be straight-combined. They have shorter vine lengths and plants tend to knit together as one mass as they ripen. The lower pods mature first on each plant. Pea is physiologically mature once the majority of pods have turned yellow or tan and can be harvested once moisture content drops to 16-18 percent. Harvesting in early mornings or late evenings when humidity levels are higher helps reduce shattering and seed coat cracking. Pea is easy to thresh, requiring low cylinder speeds and open concave settings to limit splitting and damage to the grain. Reel speeds should be reduced to match ground speed so that vines are not batted but are gently moved into the machine. Use the manufacturer's recommended settings for your combine and **adjust settings throughout the day as conditions change,** as pea is quite susceptible to shatter. Lifter guards and pickup reels improve harvest efficiency, as will the use of a flex head or draper head which will reduce combine maintenance costs and operator stress.

Pea can be swathed prior to harvest if the field is weedy or uneven maturing is a problem, but swathed pea is highly susceptible to wind damage. Delayed harvest, or lengthy times in windrows can lead to greater shattering and bleaching of seeds, which can decrease the value or marketability of pea. Bleaching is much more of a problem for green than for yellow types. When moving harvested grain, augers should be run at slow speeds, or use belt conveyors to minimize damage to the grain.

Chickpea: The seeds of the large kabuli type can be twice the size of most field pea. Seeds should be placed into moist soil to ensure getting a good stand. Seeds should be planted into well-drained soil at two to three inches. Chickpea is considered a cool season crop, but tolerates delayed seeding as compared to pea or lentil. Target a final plant population of four to six plants per square foot (see Box 2) on 6- or 7- inch rows. Like lentil and pea, following germination the cotyledons remain below the soil surface, with scale nodes developed at or near the soil surface. The first true leaves usually appear on the third node.

There are two leaf forms for chickpea regardless of type. The most common leaves are pinnate or compound (i.e. fern-like), approximately two inches long with nine to 15 leaflets per leaf. Many kabuli varieties (but not all) have a unifoliolate leaf type (Figure 3). On average plants produce a new node every three to four days, and flowering begins usually at the 13- or 14-node stage. Kabuli types have white flowers while desi flowers are pink to purple. Single flowers form on short stems located at the base of the leaf. They generally self-pollinate before opening. In general plants mature in 100–130 days, reaching a height of eight to 24 inches. Mature pods will contain from one to two seeds.

Chickpea develops a deeper and more extensive root system than either pea or lentil, and can extract moisture from soil depths similar to that of wheat. The soil profile following chickpea will be as dry or drier than that following wheat because chickpea tends to mature

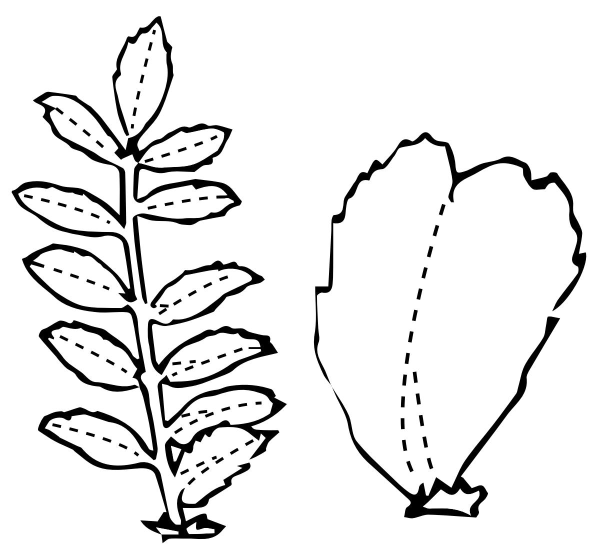


Figure 3. Chickpea leaf-types include fern-like (left) and unifoliate (right).

later than wheat. Lodging is not normally a problem. Seeds are set higher on the plant than on lentil or pea, but rolling is still recommended if rocks are a concern. Chickpea matures about two weeks later than pea or lentil (if planted the same day), usually similar to spring wheat. Drought conditions will hasten maturity, while late season rains will cause plants to green back up. Chemical desiccation may be necessary to facilitate harvest (See Weeds Section for recommendations). Direct-cut harvesting is preferred. For desi types set the combine similar to that for dry pea. For kabuli types, use the dry bean setting. A bean concave set at a wide spacing may be necessary to reduce damage to the large seed. It's important to plant disease-free seed and use seed treatments. Large kabuli types are very susceptible to ascochyta and should be sprayed with a fungicide at flower initiation or whenever disease is observed. In most years plan on applying a fungicide.

Soil Fertility for Annual Legumes

General Principles: The key to optimizing yield and quality of annual legumes is to select the right fertilizer source, rate, placement, and timing for your operation (4R Concept). These are usually interrelated; for example, the right rate, placement and timing are very dependent on the source. There are some general principles that can help get it 'right', which not only can increase your bottom line but help protect our soil, water, and air resources.

Rate: As with other crops, annual legume fertilizer application rates should be based on a soil test (see Interpretation of Soil Test Reports[7]). In general, soil tests from samples taken in the spring rather than fall better reflect the nutrients available to the crop in a growing season because of overwinter changes in levels of nutrients, especially N. However, since legumes can fix their own N, and availability of phosphorus (P) and potassium (K) are less susceptible to overwinter change, fall samples are acceptable to determine fertilizer rates for legumes.

The fertilizer rate guidelines presented in this bulletin are based on a "sufficiency" fertilization rate which is the minimum required to optimize net revenue in the current year. If, instead, the fertilization goal is to "maintain" soil nutrient levels, then crop nutrient removal rates can be used to estimate the amount of nutrients needed to replace those removed by the harvest (Table 2). The maintenance strategy does not require soil testing but will generally require higher application rates than the sufficiency approach when soil tests are moderate to high.

A third strategy, recommended only for non-mobile nutrients (discussed in Timing and Placement) and when fertilizer costs are relatively low, is the "build" strategy. Building up soil nutrient levels quickly should increase the chance that nutrients will not limit crop growth and minimize fertilizer needs when fertilizer costs are high. One strategy for building nutrient supplies quickly is to add the sufficiency rate to the maintenance rate to determine a total rate.

Tissue Testing: If nutrient levels are below critical tissue nutrient concentrations (Table 3) or plant nutrient deficiency symptoms are observed, in-season fertilizer is warranted if applied before potential yield has been reduced. The critical tissue nutrient concentration is the level at which 90 percent of maximum yield is obtained. Because tissue concentrations change with plant maturity, it is important to sample the correct tissue at the correct time. Sampling times are selected based on when nutrient deficiencies begin to appear. Early detection allows for correction of a potential nutrient deficiency within the growing season. Plant and soil samples taken from an affected area can be compared to samples from a healthy area to help identify a limiting nutrient.

Plant nutrient deficiency symptoms can also be used to identify nutrient deficiencies. It is better to rely on soil test recommendations, nutrient removal rates, or early season critical tissue concentrations, if available, because once nutrient deficiency symptoms appear, yield potential has likely already been reduced. Deficiency

Table 2. Estimated pounds of nutrient removed per bushel of chickpea, lentil, or pea seed harvested in Montana or per ton of field pea hay.

Unit	N	P_2O_5	K_2O	S
Seed (lb./bu)[1.]	2.18	0.67	0.87	0.15
Hay (lb./ton)[2.]	46	11	32	NA

1. *Fertilizer Guidelines for Montana Crops*[11]
2. USDA Nutrient content of crops.

Table 3. Leaf nutrient concentration at which 90 percent of maximum yields were obtained.

	Plant tissue concentration		
Crop	S[1.] (%)	Zn[2.] (ppm)	Cu[3.] (ppm)
Chickpea	0.18	17	2.6
Lentil	0.29	25	4.6
Faba bean	0.038	18	2.8

1. Huang et al. 1992. Sampling 2nd to 4th mature leaf at 7th leaf stage, 4 weeks after seeding.
2. Brennan et al. 2001. Sampling newest growth 46 days after seeding.
3. Brennan and Bolland 2003. Sampling newest growth 62 days after seeding.

and toxicity symptoms are illustrated in Plant Nutrient Functions and Deficiency and Toxicity Symptoms[8]. Be cautious of pseudo-deficiencies, such as disease or herbicide damage that may appear similar to nutrient deficiency symptoms.

Source: The nutrient source, for example granular vs. liquid, or monoammonium phosphate (MAP, 11-52-0) vs. diammonium phosphate (DAP, 18-46-0), often does not substantially affect nutrient availability, but should be selected based on cost per pound of available nutrient, ease of application, and potential germination issues if applied with the seed. Some nutrient sources are slow to dissolve into plant available forms. For example, phosphate rock and elemental-sulfur (S) generally do not provide enough phosphate and sulfate, respectively, within the season. However, they can be used to bank soil P and S levels. Organic amendments such as manure can be an excellent source of many nutrients. Manure is especially high in P. Such sources contain variable nutrient amounts and should be tested for nutrient content to calculate application rates.

Timing and Placement: Nutrient mobility in soil largely determines fertilizer timing and placement. Nitrogen fertilizer and sulfate forms of fertilizer are very mobile in the soil so they should be applied close to the time when needed by the crop (see Nutrient Uptake Timing by Crops: to assist with fertilizing decisions[9]). They can also be applied as 'rescue' treatments, i.e. top-dressed, to be taken up by roots. Potassium (K) is relatively immobile and P is very immobile so both are best applied in the root zone at the time of seeding or earlier. Potassium may be top-dressed very early in the growing season, while top-dressed P is most likely ineffective.

Of the micronutrients necessary for N-fixation, iron (Fe), copper (Cu), manganese (Mn) and zinc (Zn) are very immobile and likely unavailable to the plants if broadcast. Foliar applications may help if plants are deficient; primarily because plants need so little that plenty may enter through the leaf. If mobile micronutrients such as chloride (Cl) and boron (B) are deficient, the crop may benefit from top-dressing these nutrients. Be cautious when using micronutrients as crops need very little.

Legume seedlings are very sensitive to salt, and proper fertilizer placement is critical to avoid injury. Avoid placing N, especially urea or urea-ammonium nitrate (28 or 32 solution), directly with the seed. Phosphorus and K can be placed with the seed in limited amounts (see specific nutrients). Potential for seedling injury from fertilizer tends to be higher in dry or coarse-textured sandy soils.

Specific Nutrients

Nitrogen: Legumes must be properly inoculated in order to develop active nodules for N-fixation. Low temperatures, drought or excess moisture, or more than 25-35 lb. total available N/acre (nitrate plus ammonium N) can inhibit nodulation and N-fixation (Saskatchewan Pulse Growers Pea Production Manual[10]). If nodules are lacking or inactive (inactive nodules are white, whereas active nodules are red inside) three to five weeks after emergence, then check with an agronomist to determine whether an immediate fertilizer N top-dress is justified.

A small amount of top-dressed N (10 to 20 lb. N/acre) can help young plants initiate N-fixation and gain vigor, especially in soils low in N (less than 15-20 lb. N/acre; Miller et al., 2005). In unfavorable growing conditions (e.g. dry seed bed), a similar small amount of starter N can be placed away from the seed to boost seedling growth before nodules become fully functional. If MAP is used to supply P (discussed later) it will supply a portion of the starter N suggested for soils low in N. Although higher N may appear to benefit the crop in early growth, high N may produce excessive vegetative growth resulting in reduced pod set, seed production, N fixation, and delayed maturity. Starter N may not always increase yields. Of 58 field trials conducted with field pea over four years in Alberta, 24 percent increased pea seed yield in response to 18-54 lb. N/acre starter N, 72 percent showed no yield response, and nine percent showed decreased yields. Yield changes were modest in the study, averaging just nine percent (McKenzie et al., 2001).

Phosphorus: Phosphorus promotes extensive root growth, vigorous seedlings, early and uniform maturity, and increased tolerance to stress. Adequate P is necessary for good nodulation and N-fixation. Base fertilizer P rates on soil tests (Table 4) or removal rates (Table 2). Annual legume P rate guidelines are approximately 70 percent of wheat P guidelines (Fertilizer Guidelines for Montana Crops[11]). This is because

Table 4. Phosphorus fertilizer guidelines for chickpea, lentil and pea in Montana based on soil analysis.

Olsen P Soil Test Level (ppm)	P_2O_5 (lb/acre)
0	35
4	30
8	25
12	20
16	15

If soil test is above 16 ppm then consider using removal rate (Table 2).
Source: *Fertilizer Guidelines for Montana Crops*[11]

effective rooting depths are shallow for annual legumes (2-3 ft) as compared to wheat (3-5 ft) and available P is highly concentrated in surface soils so legume roots are in a P-rich zone. Additionally, annual legumes lower the soil pH in the root zone which dissolves calcium phosphate minerals, whereas wheat raises the pH in the root zone, decreasing P availability. Note that one Montana study found the increase in P availability following legumes was temporary and did not increase P availability for the subsequent crop (Rick et al., 2011).

Low amounts of P can be seed-placed to encourage vigorous seedlings that compete well with weeds. Safe rates of seed-placed P depend on the P source, soil, and moisture conditions. While the Saskatchewan Ministry of Agriculture suggest MAP should not exceed 20 lb. P_2O_5/acre (Farm Facts: Guidelines for safe rates of fertilizer place with the seed[12]), others have found up to 26 lb. P_2O_5/acre triple superphosphate (TSP) can be seed-placed without toxic effects to seedlings (Karamanos et al., 2003; McKenzie et al., 2001). Seed and seedlings are more likely damaged by MAP than TSP. Diammonium phosphate is much more toxic to seedlings than MAP and requires caution when seed-placed. Safe rates of seed placed P tend to be higher in heavy clay soils, soils with high soil-OM, and with seeding/fertilizer equipment with wide openers which disperse the seed and fertilizer granule in the seed bed. The safe rate is lower in coarser and drier soils.

If soil tests suggest more P is needed than can be safely seed-placed, additional P can be sub-surface side-banded or broadcast and incorporated prior to planting. Pea seed yield was higher when TSP was side-banded one inch below and to the side of the seed rather than seed placed, and the yield response was higher in loam than clay loam soils (Figure 4). Since P can be banked in the soil to reduce risk, consider applying more P with the alternate crop the year prior to the pulse crop.

The addition of P is more likely to increase N-fixation and seed yield when initial soil N and P levels are low. Studies over four years at nine locations in west-central Alberta found 40 lb. P_2O_5/acre to be the optimal rate to increase pea yield with an Olsen P soil test less than nine ppm (Figure 4). There was no yield response when Olsen P levels were above nine ppm (Karamanos et al., 2003). Parallel studies found optimal pea seed yields at 26 lb. P_2O_5/acre on soils with Olsen P levels below 13 ppm and minimal response when Olsen P levels were above 13 ppm (McKenzie et al., 2001).

Potassium and Sulfur: Use soil test results (Table 5) or crop removal rates (Table 2) to determine K_2O application rates. Potassium fertilizer is best broadcast and incorporated, or banded at planting. Low amounts of K may be seed placed. Nitrogen plus K_2O should not exceed 15 lb./acre when placed with the seed. For example, if 50 lb./acre of 11-52-0 is applied as starter, that provides 5.5 lb. N/acre (50 x 0.11). In this case limit an additional K_2O to 9.5 lb./acre (15–5.5 = 9.5) if applied with the seed.

The S need must be based on prior crop performance, S removal rates (Table 2) or plant tissue concentrations (Table 3) because the soil test for sulfate-sulfur (SO_4-S) is not a reliable indicator of plant available S. If the prior crop indicates the field may be S deficient, then 15-20 lb. S/acre as sulfate can be applied at planting (Mahler and Murray, 1996). If legume tissue concentrations indicate low S, then use Table 2 to calculate S rate. For example, a 40 bu/acre pea crop removes about 6 lb. S/acre. This amount can be applied as ammonium sulfate for an in-season rescue treatment. As with P fertilization, soil S levels can be banked by using elemental S, which

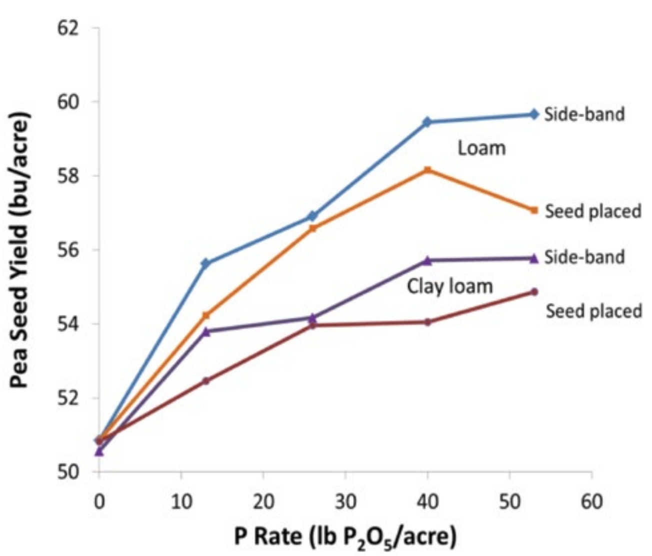


Figure 4. The increase in pea seed yield is lower when TSP is seed-placed than side-banded (one inch below and one inch to the side of the seed) and varies with soil type (Karamanos et al., 2003).

Table 5. Potassium fertilizer guidelines for chickpea, lentil and pea in Montana based on soil analysis.

K Soil Test Level (ppm)	K_2O (lb/acre)
0	45
50	40
100	35
150	30
200	25
250	20

If soil test is above 250 ppm then consider using removal rate (Table 2).
Source: *Fertilizer Guidelines for Montana Crops*[11]

slowly converts to plant available sulfate. In a central Saskatchewan study, 71 lb. S/acre applied as elemental S during the canola portion of a canola, barley, pea rotation provided sufficient S for optimal pea seed yield three years after the initial application (Wen et al., 2003). In contrast, the fields that received sulfate-based S fertilizer did not have sufficient S for the pea yield by the third year, likely because sulfate was removed by crops or leached prior to the year pea was grown.

Micronutrients: The micronutrients Fe, Mn, Zn, Cl, and B have occasionally been found deficient in Montana soils. Because little research has been done on annual legume requirements for micronutrients, suggestions for micronutrient fertilization are presented under the general guidelines at the beginning of this soil fertility section.

Weed Management

Weed management in pulses is of particular importance as these crops are generally considered to be poor competitors due to their slow establishment and limited vegetative growth. Yield losses from competition with weeds can be significant in pulse crops and planning an effective weed management program is a key factor to profitable production.

Growers considering incorporating lentil, dry pea, or chickpea into their rotation should develop an Integrated Weed Management (IWM) plan that considers the entire crop lifecycle from pre-planting to post-harvest. They should also consider the crops utilized prior to seeding pulses as soil residual herbicides can severely damage lentil, dry pea, or chickpea. When developing and implementing an IWM program, producers should take advantage of cultural, physical, and chemical practices to reduce the spread and impact of weeds invading crop fields.

Cultural practices that decrease weed pressure in pulse crops include seedbed preparation, variety selection, proper sowing and crop establishment, insect and disease management, nutrition management, and irrigation scheduling. However, while cultural practices are at the backbone of an IWM plan, they alone may not be enough to secure adequate weed control.

To maximize the effectiveness of any weed management practice and to avoid yield reductions, it is important to target the proper crop growth stage. For example, research conducted at the University of Saskatchewan, Canada, showed that weed control in lentil should start by the five- to six-node stage, and lentil fields should continue weed-free until the 10- to 11-node stage (Fedoruk et al., 2011). While the environmental conditions under which this study took place differ from the ones we regularly experience in Montana, these results illustrate the importance of appropriate timing when developing an IWM program.

Mechanical weed control practices, such as harrowing or rotary hoeing, represent a viable alternative for organic producers, farmers interested in reducing herbicide use, or those facing problems with herbicide resistant weeds. Producers should be aware that mechanical weed control practices need to be applied with caution due to the sensitivity of pulse crops shoots and roots to damage. As a general rule, if harrowing or hoeing is planned, it is recommended to increase seeding rates as mechanical damage may reduce stands. Also, producers should minimize the reliance on tillage due to the increased risk of soil erosion.

Crop rotation is one of the most powerful tools to manage pest problems, including weeds. It is very important to carefully consider the crop rotation history prior to growing pulse crops as they are very sensitive to many of the herbicides commonly used in small-grain production. For example, the high persistence sulfonlylurea (SU) herbicides frequently used in small grain crops such as Ally (metsulfuron), Glean (chlorsulfuron), and Finesse (chlorsulfuron), among others, have often damaged subsequent annual legumes. Producers should be aware that due to the high persistence of these products, it might be necessary to wait up to four years before seeding some pulses, depending on crop, product, and application rate. Moreover, weather conditions and soil properties including pH, moisture, temperature, texture, and soil-OM play a fundamental role in determining herbicide persistence in the soil profile and potential crop injury. In many cases a field bioassay should be conducted prior to seeding a pulse crop to check for existence of residual herbicides. Producers should be aware that bioassays do not forecast sub-lethal yield loss, which is likely the most common type of yield loss experienced and unless bioassays are conducted in field conditions and plants are grown to maturity, results of bioassays could be misleading. Producers interested in learning more about crop rotation restrictions for several herbicides commonly used in small grain crops in Montana should consult Integrated Weed Management in Lentils[13].

To minimize the risk of crop damage due to soil residual herbicides, producers should keep records of the products and rates used in their fields. Producers should also be aware that rotational intervals may vary with herbicide rates and environmental conditions. More information on approaches to reduce the risk of crop injury due to herbicides can be found in Getting the Most from Soil-Applied Herbicides[14].

Chemical weed control can help pulse crop producers manage weeds. However, research and experience has shown that herbicides are most effective when used as part of an IWM program. For example, the applicability and success of herbicides in lentil fields depends on the cropping system, land preparation methods, soil conditions, and weather conditions. Research has shown that if plants are stressed due to environmental or biological conditions, Sencor (metribuzin) applied at recommended rates can provide effective weed control in lentil, but can cause crop damage in stressful conditions such as cold weather, low fertility, disease, or insect pressure. Although Pursuit (imazethapyr) can be used to manage broadleaf weeds in lentil, cold and wet conditions occurring within a week of application can damage the crop.

While information on commonly used herbicides used to manage weeds in pulse crops is provided below, ***producers should carefully read and follow product labels prior to using any herbicide***. Also, while tank-mix combinations of herbicides can be used to control a broader spectrum of weeds, producers should refer to product labels of the tank-mix partners for specific restrictions. Common chemical and trade names are used in this publication for clarity. Inclusion of a common chemical or trade name does not imply endorsement of that particular product or brand of herbicide, and exclusion does not imply non-approval.

Recommendations by Crop

Lentil: Weed management in lentil is essential because they do not compete well and are highly sensitive to soil-residual herbicides, particularly those from the SU-herbicide family.

- ***Dimethenamid-p (Outlook and other trade names)***. 0.56 to 0.98 lb. ai/acre (10-21 fl. oz/acre). Apply pre-plant surface or pre-emergence (PRE) to lentil. Good to excellent control of several annual grasses. Fair to good control of certain annual broadleaf weeds such as pigweed, waterhemp, or black nightshade. Adjust rate for soil type and OM. Consult your seed dealer for restrictions on specific varieties to avoid potential injury due to sensitivity. Emerged weeds are not controlled. May occasionally result in temporary spotting or browning of crop leaves. Lentil may be harvested 70 days after application. Refer to label for tank-mix options.
- ***Ethalfluralin (Sonalan)***. 0.55 to 0.75 lb. ai/acre (1.5-2 pt/acre). Should be fall-applied prior to snow cover into stubble. Incorporate once using minimum soil disturbance with a rotary hoe or harrow. Refer to label for use directions and rotational crop restrictions.
- ***Imazamox (Beyond)***. 0.031 to 0.048 lb. ae/acre (4-6 fl. oz/acre Beyond SG). Apply post-emergence (POST) **only to Clearfield lentil varieties** (2- to 6-leaf stage of lentil) to control small, actively growing annual grass and broadleaf weeds including jointed goatgrass, downy brome, Persian darnel, and Japanese brome. **Non-Clearfield varieties will be seriously injured**. Follow label for stewardship and ALS-resistance management programs.
- ***Imazethapyr (Pursuit).*** 0.5 fl. oz ai/acre (2 oz/acre). Should be applied as shallow pre-plant incorporated (PPI) or PRE for small-seeded broadleaf weed control. No control of ALS-resistant weeds including kochia. Refer to label for use directions and other restrictions. **Certain varieties of lentil may be sensitive to injury especially under environmental stress**.
- ***Metribuzin (Sencor and other trade names).*** 0.25 to 0.38 lb. ai/acre (0.33-0.5 lb. DF or 0.5-0.75 pt 4F). Can be applied as PRE or POST with good control of small-seeded annual broadleaf weeds and suppression of lambsquarter, henbit, chickweed, and mustard. Adjust rates according to soil type. **Crop injury may result under stress conditions caused by cold weather, low fertility, disease or insect damage, or if application is followed by heavy rain.** Do not use on clay knobs or poorly covered subsoils. Do not use on coarse soils or soils with less than 1.5 percent OM. Check label for harvest and graze intervals.
- ***Pendimethalin (Prowl, Prowl H_2O, Pendimax, and other trade names).*** 0.72 to 1.5 lb. ai/acre (1.8-3.6 pt/acre Prowl 3.3 EC or 1.5-3 pt/acre Prowl H20). Follow directions for the specific product used. PPI or PRE. Excellent control of several annual grasses and fair control of small-seeded annual broadleaf weeds such as pigweed and lambsquarter. Poor or no control of mustard, nightshade, smartweed, or large-seeded annual broadleaf weeds. One inch rainfall or mechanical incorporation required prior to planting. Use lower rate on coarse soils and higher rate on fine-textured soils.

- ***Quizalofop P-ethyl (Assure II).*** 0.04 to 0.08 lb. ai/acre (6-12 fl. oz/acre Assure II). Apply POST to manage annual and perennial grasses. Apply with crop oil concentrate (COC) or nonionic surfactant (NIS). Application intervals should be greater than seven days apart to allow re-growth. Do not apply within 60 days of harvest. Consult label for crop rotation restrictions.
- ***Sethoxydim (Poast)****.* 0.19 to 0.47 lb. ai/acre (1-2.5 pt/acre Poast 1.5L, do not exceed 4.0 pt/acre per season). POST*:* Annual grasses (2-4 inches). Requires COC additive. Apply to actively growing grasses. Do not graze or hay vines for livestock feed. Allow 50 days from application before harvest. Control is erratic on grasses stressed by drought, extreme temperatures, and other factors.
- ***S-metolachlor (Dual Magnum and other trade names).*** 0.95 to 1.91 lb. ai/acre (1-2 pt/acre Dual magnum). Apply PPI or PRE. For annual grass and some broadleaf weeds control**. Does not control emerged weeds.** Incorporation improves control. Refer to label for specific rate information regarding soil texture and OM. Use low rates on coarse soils with less than three percent soil-OM and higher rates on fine soils with over three percent soil-OM. Check label restrictions before cutting for hay.
- ***Triallate (Far-Go).*** 1.5 lb. ai/acre (1.25 qt/acre of Far-Go 4L.) PPI or PRE. Mostly used to manage wild oat. Apply prior to wild oat germination. A two-pass incorporation is recommended. Do not rotate to crops other than winter wheat, spring wheat, durum wheat, triticale, barley, pea, lentil, or sugar beet for 12 months after a Far-Go application.

Dry Pea: Pea is a poor competitor with weeds in the early seedling stage. Small weeds can be controlled by harrowing before crop emergence and when pea is three to seven inches tall. Apply broadleaf herbicides to small weeds and small pea to reduce risk of pea injury. Be aware that crop injury due to herbicide applications can occur when plants are under heat or drought stress.

Several herbicides listed above including quizalofop (Assure II), Dual Magnum and generic S-metolachlor products, ethalfluralin (Sonalan), triallate (Far-Go), sethoxydim (Poast), pendimethalin products (Prowl, Prowl H_2O), and Treflan and generic trifluralin can be used to manage weeds in dry pea. ***Producers should carefully review product labels as rates may vary from those listed above***. Other herbicides include:

- ***Bentazon (Basagran).*** 0.5 to 1 lb. ai/acre (1-2 pt/acre). Apply POST to dry pea with at least three pairs of leaves or four nodes. Can be applied as sequential POST applications at 0.25 to 1 lb. ai/acre. Provides control of some broadleaf weeds. It is a contact herbicide and needs good coverage and should be applied when weeds are small. Best results under hot and sunny conditions. Add oil adjuvant at 1-2 pt/acre. Allow a 30-day pre-harvest interval. Do not apply on lentil.
- ***Imazamox (Raptor).*** 0.031 lb. ai/acre (4 fl. oz/acre Raptor). A POST product with foliar and root uptake action. Controls several grasses and annual broadleaf weeds including foxtail, velvetleaf, cocklebur, sunflower, non-ALS resistant kochia, and black nightshade. Less residual activity than for Pursuit; therefore Raptor has potential where rotation restrictions must be minimized. Apply with nonionic surfactant and observe precautions on the label to minimize crop injury. Do not apply Raptor to succulent pea, chickpea (garbanzo beans), or lentil.
- ***Imazethapyr (Pursuit).*** 0.047 lb. ai/acre (3 fl. oz/acre of Pursuit). A PPI or PRE herbicide which has provided very good to excellent control of several annual broadleaves including non-ALS resistant kochia, redroot pigweed, mustard, velvetleaf, and black nightshade. Velvetleaf is controlled most effectively with PPI treatments. **Observe all precautions on the label to minimize crop injury**. Harvest intervals vary across pea varieties. Consult label restrictions regarding planting subsequent crops.

- ***Metolachlor and sulfentrazone*** **(BroadAxe).** 0.99 to 1.6 lb. ai and 1.76 to 2.8 fl. oz ai/acre (20-32 fl. oz/acre). Controls annual grass and small-seeded broadleaf weeds. Can be applied as shallow PPI or PRE. PRE requires rainfall for activation of the herbicide. Herbicide rates should be adjusted for soil type and soil-OM content.
- ***Saflufenacil (Sharpen).*** 0.022 to 0.045 lb. ai/acre (1-2 fl. oz/acre Sharpen). Apply early PPI, *or* PRE, to control small-seeded broadleaf weeds such as kochia, pigweed, common lambsquarter, and nightshade. PRE applications require precipitation for herbicide activation. Methylated seed oil (MSO) or COC are required for control of emerged weeds. An early PRE application of Sharpen can be made for burndown control of emerged broadleaf weeds. Sequential applications must be at least 30 days apart. Do not apply when pea has reached ground crack stage, or after emergence, because severe crop injury will occur. Legume forage may be fed or grazed 65 or more days after application.
- ***Sulfentrazone (Spartan).*** 0.07 to 0.25 lb. ai/acre (2.25-8 fl. oz/acre Spartan 4F). An early PPI, or PRE soil-applied herbicide with root and shoot activity. Apply in spring before crop emergence. Annual broadleaf weed control including pigweed, normal and ALS resistant kochia, and black nightshade. Fair to good control of wild buckwheat and common lambsquarter is possible. Rates should be adjusted based on soil texture, soil-OM, and pH as high risk of crop injury exists. Lower rate recommended for coarse soil with low soil-OM with pH > 7.0. High rates can be used in heavy soils, especially if applied long before planting. Carefully read and follow label to minimize risk of crop injury. Requires precipitation for activation.

Chickpea: The short height and open canopy of chickpea plants makes them one of the weakest competitors against weeds among pulse crops. Consequently, it is very important to minimize weed problems before the crop is planted. **The field's herbicide history is important to avoid crop injury.** Avoid planting chickpea in fields with a history of weed problems, especially perennials such as quackgrass and Canada thistle. Rotary hoeing and/or field cultivating can help manage weeds but extensive damage to chickpea plants can reduce yield and increase disease pressure.

Several herbicides listed above can be used to manage weeds in chickpea fields. Producers should carefully review product labels as rates may vary depending on the crop and environmental condition.

Weed Management at Harvest

Some herbicides can be used as pre-harvest aids for crops. Advantages of a pre-harvest herbicide application include facilitating direct combining of standing crops, managing in-crop weed escapes, reducing dockage, and controlling perennial weeds in subsequent crops. Prior to using a crop desiccant, pulse growers must consider management goals, the market restrictions, weeds present, and the crop seed maturity stage as these variables will affect the herbicide choice. There are two common choices for an in-crop, pre-harvest herbicide: Glyphosate and paraquat. A pre-harvest application of glyphosate provides adequate weed control including winter annual and perennial weeds, but the crop will be slow to dry down. Glyphosate should not be applied to pulse crops grown for seed because it can cause poor germination and low vigor of subsequent seedlings. Paraquat is a true desiccant herbicide that should be used when the main goal is to desiccate the crop.

Generic glyphosate (Roundup and other trade names): Up to 2.25 lb. ae/acre. Check label for rates as glyphosate is available in several different formulations. BURNDOWN: Weeds should be actively growing. Avoid tillage for one day after treating annual weeds and for three to seven days for perennials. Some products contain adequate surfactant; others require NIS and ammonium sulfate (AMS) additive. Use caution to avoid droplet drift to non-target crops. SPOT TREATMENT: Use a two percent solution on perennial weeds. Crop will be killed in treated areas. Allow a seven-day and 14-day pre-harvest interval for broadcast and spot treatment, respectively. PRE-HARVEST AND HARVEST AID: For pea, less than 30 percent seed moisture. Refer to specific glyphosate product label for rates and precautions.

Paraquat (Gramoxone Inteon, Gramoxone Max, Firestorm, Parazone 3SL, and other trade names): 0.37 to 0.5 lb. ai/acre (1.5-2 pt/acre Gramoxone). Follow specific label directions for product used. HARVEST AID: Desiccant, apply when at least 80 percent of pods are yellowing and mostly ripe. Follow handling precautions as Paraquat is toxic when ingested. Do not allow to drift from target site. Restricted use pesticide.

Pulse Diseases

Overview: Pulse crops, like every crop, have numerous disease issues: some can be very detrimental, and others are not as destructive. The 'disease triangle' of the pathogen, susceptible host, and a favorable environment is necessary in order for the disease to manifest and affect the plant (Figure 5). The key to preventing devastating crop losses due to plant disease is to practice an integrated pest management strategy, starting with the selection of high-quality seed of an adapted variety. Use the best management strategies for the crop including crop rotation, appropriate seeding and harvesting dates, good volunteer control between crops, and frequent monitoring of the crop to avoid and mitigate plant disease issues.

Have any disease accurately identified by you, another agriculture professional, or a diagnostic laboratory to ensure that any control measure you implement will be effective and appropriate. For example, a brown spot on a lentil leaf may be ascochyta blight, stemphyllium blight, or anthracnose – management recommendations for each of these diseases is different, and a professional should have the most up-to-date, specific recommendations. If the disease is not accurately identified, you may not treat it with the best method, or you may waste money in treatment for a disease that was not going to alter yield or seed quality. Remember to take a good sample when asking another professional for advice: dig up a large clump of affected plants with a shovel so you don't destroy the root system, avoiding dead plants. Dig up a 'healthy' group of plants for comparison. Wrap the root system with soil still attached in plastic and tie the plastic bag closed around the stem base. Wrap the foliage loosely in plastic and either mail or bring for testing right away, before the plant material deteriorates. Provide relevant information including variety, any pesticide or nutrient applications, the pattern of the symptoms in the field, and photos if you have them. Additional guidelines for sample submission are available from the Schutter Diagnostic Laboratory[15].

Figure 5. The disease triangle.

A new bulletin, Diseases of Cool Season Legumes[16] is available from Montana State University Extension Publications. A more comprehensive treatment of crop disease issues can be found in the Compendium of Pea Diseases and Pests and the Compendium of Chickpea and Lentil Diseases and Pests, both available from the American Phytophathological Society[17]. Here, we will cover some basic principles of plant disease management and use specific diseases as examples.

Seed, seedling, and root rots caused by fungi: Soil-borne fungal diseases are common in all soils regardless of cropping history. The species of fungi causing root rots generally have a wide host range, and can infect both dicots (pulse crops, alfalfa) and monocots (cereals, corn) (see Figure 6). There are some specialized species such as *Fusarium redolens*, which prefers pea over wheat, but root rots rarely occur as a single species. Most often there is a combination of fungi and abiotic factors which predisposes a plant to infection causing damping off and root rots. Pythium, Fusarium, Rhizoctonia, Aphanomyces, and Phytophthora are the complex of fungi usually involved. Abiotic factors such as watersoaked soils, cool soil temperatures for extended periods after planting, drought, and soil compaction, coupled with the lack of a fungicide seed treatment can predispose plants to these fungal diseases. All pulse crop seed should be treated with a fungicide seed treatment such as metalaxyl or mefanoxam which has activity against Pythium, since Pythium is very common in our soils. In addition, a fungicide should be applied to control Fusarium and Rhizoctonia. Plant the healthiest (high germination rate, no seed discoloration), most highly adapted varieties for your area, at the optimal time for emergence and growth. Do not plant pulse crops following other legumes (including cool season pulses, soybean, alfalfa) – a three to five year rotation is optimal to avoid both soil-

Figure 6. Root rot on lentil (left) vs. healthy roots (right).

Figure 7. Aschochyta blight symptoms on pea (left), lentil (middle) and chickpea (right).

borne and residue-borne foliar diseases. Avoid areas with herbicide carryover, which can damage developing seedlings. Soil-borne diseases become important in pulse fields after these crops have been grown several times or in tight rotations. Legumes used as green manures also add pathogen inoculum to the soil and crop residue in the field and should be considered when planning crop sequences.

White mold is a particularly devastating disease that attacks all dicotyledonous (broadleaf) crops including pulses, beans, and oilseeds, and also many weed species. Highly susceptible crops include borage, canola, crambe, sunflower, dry bean, lentil, chickpea (kabuli is more affected than desi) and soybean. Field pea is less susceptible, particularly semi-leafless types. White mold is caused by the fungus *Sclerotinia sclerotiorum*. The fungus survives as a mass of mycelia covered by a dark 'rind' that is resistant to environmental degradation. When temperatures and moisture are favorable, inverted cup mushrooms called apothecia develop that then release spores that infect senescent flowers directly. The fungus can grow directly from sclerotia into stems, leaves, and flowers that are in contact with the soil. The fungus fills the stem with sclerotia, which then survive in and on the soil surface.

The disease can be prevented by not introducing sclerotia into the field via dirty or infected seed. Resistant varieties are available for some crops. Rotation with cereal crops, control of weeds, irrigation management, and the use of foliar protectant fungicides can help reduce the incidence of white mold. Timing and penetration of the canopy are crucial when choosing a foliar fungicide. The optimal time to spray is at first flowering. Applications at early pod are not effective since the primary infection window has passed. Adequate coverage can be facilitated by using a spray volume of 15-20 gallons per acre, keeping ground speeds below 10 miles per hour, maintaining nozzle pressure at 40 psi, using a flat fan nozzle to produce medium sized droplets (200-350 microns), and setting the boom at the correct height above the canopy.

Foliar fungal diseases: There are a number of foliar diseases of pulse crops that can be extremely detrimental. Pulse growers should be familiar with the most common disease symptoms and scout their crop regularly in order to implement appropriate management early. Most foliar diseases of pulse crops are carried on the crop residue, but many are also seed-borne. For this reason, it is important to accurately identify any disease issues before carrying seed over to the next crop year, have rotations of three to five years between pulse crops to allow breakdown of crop residue harboring the pathogen, and have seed tested for seed-borne diseases such as Ascochyta blight before planting. Seed testing services are available from numerous labs including the Montana State Seed Lab[18]. Contact information for several seed and plant testing laboratories is provided in the back of this publication.

Ascochyta blight is often the most concerning leaf and stem disease, and can cause significant damage. Different species of the pathogen cause disease on pulse crops, and cause disease exclusively on the crop to which they are specialized. In chickpea, Ascochyta blight is caused by the pathogen *Ascochyta rabiei*. On lentil, *Ascochyta fabae* f. sp. *lentis* causes disease, and on pea, three species: *Mycosphaerella pinoids*, *Phoma pinodella*, and *Ascochyta pisi*, cause the disease. Lesions on susceptible chickpea varieties cause a distinct 'target' pattern of dark fungal reproductive structures called pycnidia and tan diseased tissue (Figure 7). These

Figure 8. Bacterial blight (left) and Aschochyta blight (right).

lesions spread to cause stem breakage and infect pods, leading to seed infection. Lesions on pea and lentil tend to be less distinctive, but under ideal conditions form distinctive tan to brown lesions with a target shaped pattern. The symptoms vary with the pathogen, plant hosts, resistance reactions of the plant, weather conditions, and timing of infection.

Anthracnose, caused by *Colletotrichum truncatum*, is an important disease of lentil, and lesions are easily confused with those of Ascochyta blight. Anthracnose is considered the most important disease of lentil in Canada, where good resistance to Ascochyta is available in lentil varieties. Once this disease enters a field on seed or through wind-borne inoculum, it is persistent until the microsclerotia and infested debris are degraded, at least three years. Fungicides should be applied for control at canopy closure or the first symptoms of disease. The disease can progress rapidly and cause defoliation and indented lesions on the stem which cause breakage and lead to the development of dead spots in the field.

Stemphylium blight of chickpea and lentil is caused by the pathogen *Stemphlium botryosum*, and is an emerging disease of lentil in Canada. Leaf spots begin as small, water-soaked, black to brown spots that expand and cause defoliation of the plant. This disease attacks late in the growing season and fungicides have not been effective.

Gray mold (Botrytis) is caused by *Botrytis cinerea* in chickpea and lentil. It is considered of minor importance in most years, but can be very serious when it occurs. Symptoms include water-soaked lesions which progress to gray/brown lesions and are often covered with a gray fuzzy 'mold.' Flowers commonly drop and cause significant yield loss. The fungus survives on infected seed and in infested soil and plant debris as environmentally resistant sclerotia and chlamydospores. The pathogen has a very broad host range of over 100 plant species, so crop rotation and weed control are critical management tools. In addition the use of resistant varieties, proper irrigation management, and plowing to bury residue can be used to manage disease. Seed treatment fungicides including thiabendazole (Mertect) can reduce seed-borne inoculum.

Fungicide resistance: Fungicide seed treatments can be effective at limiting seed-borne pathogens. However, with increased, often prophylactic (applications where no disease symptoms have been identified) fungicide use, fungicide resistance is more likely to occur. When resistance to fungicides develops, the resistant population spreads very rapidly. Fungicide resistance often travels to new areas with pathogen populations in seed. The potential for fungicide resistance to develop in response to strobilurin (Group 11, Quinone outer Inhibitors, QoI) is particularly high since these fungicides target a single site. Resistance to strobilurin fungicides (pyraclostrobin [Headline], azoxystrobin [Quadris]) has already developed for Ascochyta rabiei in chickpea in North Dakota and Montana (Wise et al., 2008; Wise et al., 2009). It is very important to rotate chemical classes of fungicides if using fungicides more than once per season. Once resistance develops to one type of strobilurin fungicide, the plant pathogen is subsequently resistant to all strobilurins and those products are lost for disease management for at least several generations of the fungus with no fungicide selection pressure (Fernandez-Ortuno, et al., 2010; Vincelli, P., 2007). A list of current seed treatment and foliar fungicides approved for use on pulse crops can be found online at the NDSU Fungicide Guide[19].

More information on specific diseases, variety resistance, and fungicide efficacy can be found from your local county Extension agent and agricultural professionals.

Table 6. Insect Pest Scouting Calendar for Pulse Crops

Seedling to 1st leaf stage (May)	2nd leaf stage to flowering (June)	Flowering to Pod Development (July)	Pod Development to Harvest (August)
Cutworms	Aphids	Aphids	Grasshoppers
Grasshoppers	Cutworms	Grasshoppers	Lygus bugs
Pea leaf weevil	Grasshoppers	Lygus bugs	
Wireworms	Lygus bugs	Pea Aphids	
Source: Janet J. Knodel, Extension Entomologist, NDSU.			

Bacterial diseases: Bacterial diseases occur sporadically in Montana. They are generally associated with hail events, and seed transmission of the pathogen. The most commonly occurring bacterial disease is bacterial blight of pea, caused by *Pseudomonas syringae* pv. *pisi*. Symptoms are easily confused with Ascochyta blight, but fungicides do not control bacterial diseases, so accurate identification of this disease is very important.

Symptoms of bacterial blight and Ascochyta blight appear similar (Figure 8). Accurate identification is critical because of management considerations. Note that bacterial blight lesions are angular and limited by the veins, whereas ascochyta blight lesions are circular and not limited by the veins. Hailstone marks infected by bacterial blight are often circular but lack concentric rings common to fungal structures. Bacterial blight lesions will generally dry up if there is no additional rain to disperse the disease. But if conditions are favorable, bacterial blight can spread rapidly through the canopy.

Viral diseases: Diseases caused by viruses are not common in Montana but will likely become so as pulse acreage increases. Viruses are most often a problem in years where there are high aphid populations. Symptoms include yellowing of the foliage, rolling of leaves, chlorotic windows on leaves, stunting, lack of pod fill, and resetting, all depending on the specific virus and plant variety. For recommendations on management, the virus species must be accurately identified.

Insects

Significant economic damage to pulse crops in Montana and North Dakota due to insects is not common. This may in part be explained by the recent introduction of pulse crop acreage across the region and the lag time it takes for some insect pests to follow the crop expansion. However, there are several insects that have periodically caused economic damage to pulse crops and one insect that is expanding its range eastward, so it is important to know how to identify these insects and to scout fields regularly (Table 6). General resources include the High Plains IPM guide[20] that provides insecticide recommendations, and a webpage developed by the North Central IPM Center Pulse Working Group[21].

Grasshoppers: There are as many as 100 different species of grasshoppers that occur in Montana but a limited number cause economic damage. Species in the genus *Melanoplus* commonly damage crops in Montana, including the migratory (*Melanoplus sanguinipes*), two-striped (*M. bivittatus*), differential (*M. differentialis*) and the red-legged (*M. femurrubrum*) grasshoppers (Figure 9). Populations tend to increase, sometimes to outbreak levels, during hot and dry periods of drought that favor grasshopper development. Cool, wet weather slows grasshopper development and favors the build-up of natural grasshopper diseases which limits the population. Pulse crops are not a favored host for feeding but grasshoppers will move into crops from surrounding grassy areas, especially when grasses dry out late in the season. Each species has food preferences, but at high populations they can eat most any type of plant. Defoliation is often visible first on the crop margins.

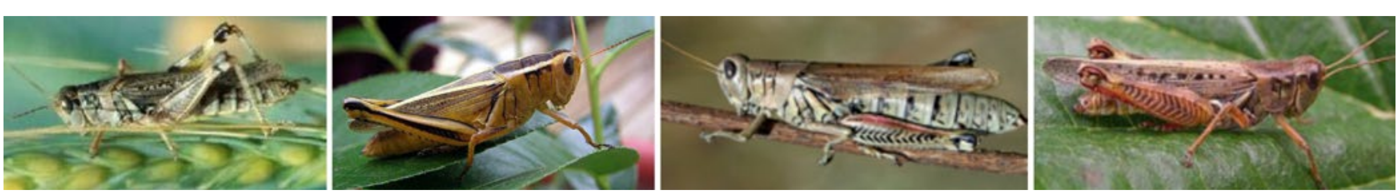


Figure 9. Four grasshoppers of economic importance in Montana. From left: Adult migratory, two striped, differential, and red-legged grasshoppers.

Figure 10. Adult army cutworm moth, adult pale western cutworm moth, adult dingy cutworm moth, Pheromone trap used to monitor adult moths, Larval caterpillar resting just below the soil surface.

Most grasshoppers overwinter as eggs that can hatch during May, June or July depending on the species and weather conditions. Juvenile nymphs develop through five instar stages while feeding for 30-40 days before becoming adults that can live and feed for another 40-60 days. The nymphs resemble the adults but without fully formed wings; only adult grasshoppers can fly. The Grasshoppers[22] website maintained by USDA/ARS, in Sidney, Mont., has comprehensive information about grasshopper biology and management. Included at this site are annual hazard maps summarizing current grasshopper populations.

Scout pulse crops for feeding injury from nymphs in the seedling stage, and for adults in the early bud stage through pod development. Grasshopper treatment thresholds are based on the number of grasshoppers per square yard. Four 180°sweeps with a 15-inch sweep net equals one square yard. Alternatively the square foot method can be used: visually count the number of grasshoppers in a one square foot area. Randomly repeat 18 times while walking through the field and divide the total number of grasshoppers by two to give the number per square yard. Thresholds for treatment are listed in Table 7. A "threatening" rating indicates a need to treat with an insecticide. Research has found that grasshoppers can damage lentil crops by feeding on the flowers. **The threshold for lentils during flowering stage is only two grasshoppers per square yard within the crop**. If grasshoppers are entering the crop from surrounding grassy areas, spraying a 150-foot border around the crop with an insecticide may be adequate for control.

Cutworms: Cutworms are the larval caterpillar stage of moths. There are three main species that damage crops in Montana: the army cutworm (AC; *Euxoa auxiliary*), the pale western cutworm (PWC; *Agrotis orthogonia*), and the dingy cutworm (DC; *Feltia jaculifera*) (Figure 10). The AC and DC feed above ground on leaves and shoots, defoliating the plant, while the PWC chews through the stem at ground level, cutting new shoots as they emerge. All three can cause stand thinning during crop emergence. DC was particularly damaging to pea crops in the eastern Montana, western Dakota region during the late 1990s.

From late July to October the adult moths fly and mate, and the females lay eggs on or just below the soil surface. AC and DC eggs hatch in fall and the larvae begin feeding. They then overwinter in the soil as immature caterpillars, and are present very early during crop emergence where they can injure seedling pea plants. PWC eggs typically hatch in the spring. Larvae feed at night but may be found feeding above ground on overcast days. When scouting look for poor plant stands. During the day larvae retreat to the soil and can be found by scraping the soil, especially near the base of intact plants that are close to damaged areas. Cutworms many times will work their way down a row, resulting in stand gaps.

Thresholds for control have not been established for pulse crops. In small grains, 4-5 AC and/or 2-3 PWC per square foot exceed damage thresholds and insecticide

Table 7. Economic thresholds for grasshopper control on pulse crops.

Rating	Nymphs per square yard		Adults per square yard	
	Margin	Field	Margin	Field
Light	25-35	15-23	10-20	3-7
Threatening*	50-75	30-45	21-40	8-14
Severe	100-150	60-90	41-80	15-28
Very Severe	200+	120	80+	28+

Source: North Central IPM Center, Pulse Working Group[21]
*Threatening indicates a need to treat with an insecticide.

treatment is recommended. Thresholds have not been established for DC, but their feeding behavior is similar to AC. Cutworm damage is controlled by foliar applications of insecticide.

Pheromone traps can be used to monitor adult moths during August and September. Montana State University Extension Entomology along with collaborating county agents and producers monitor adult AC and PWC moths across Montana each year to help evaluate annual risk. This Cutworm Risk Monitoring[23] system provides advance warning of region-wide population changes and impending outbreaks.

Lygus bug: The genus *Lygus* includes over 40 species of plant-feeding insects collectively referred to as lygus bugs, many are significant agricultural pests. The adult and immature stages (Figure 11) feed on plant juices with their straw-like mouthparts. Feeding is often concentrated on the reproductive terminals of plants, including the shoots, buds, flowers, developing pods, and seeds. Developing flowers often wilt and eventually abort, pods can be distorted, and developing seeds may shrivel or suffer cosmetic damage. "Chalk spot" (Figure 12), or the appearance of a chalky white spot on the dried seed can be caused by lygus bug feeding. However, this symptom can also be caused when pea is harvested at too high a moisture content.

The adults are one-quarter inch long, with a flat, oval-shaped body that can be combinations of green, yellow or brown depending on species, often with a distinctive lightly colored triangle or V-mark between the wings (Figure 11). The juvenile stages are bright green and often can be confused with aphids because of their small size. Juvenile lygus bugs move more rapidly than aphids when disturbed and later stages have distinct black markings on the abdomen.

Figure 11. Lygus bug (above). Juvenile instar stages to adult, viewed from left to right. Figure 12. Chalk spot on lentil seed (left).

Lygus bugs overwinter as adults in protected areas under plant litter, inside a host plant, or in adjacent areas, and then fly into favored host crops in the spring. After mating, females lay their eggs on host plant tissue. There are generally three generations per summer in Montana, with the last two generations taking as little as two weeks to develop from egg to adult. Lygus bugs may move in from nearby alfalfa or canola fields, especially after alfalfa hay is cut. Chalk spot damage has been reported for lentil in the Pacific Northwest production areas but has not been seen as a significant problem in Montana and has not been confirmed in pea crops. Populations can be monitored during blooming and pod set using a sweep net. Insecticide treatment is recommended when seven to 10 adults are collected per 25, 180° sweeps averaged from at least five randomly selected locations in a field. Take sweeps during the warm sunny part of the day.

Pea Leaf Weevil: The pea leaf weevil is a significant pest of field pea and dry bean crops throughout Europe, Asia and Africa. It was introduced to the Pacific Northwest in the 1930s and has quickly spread throughout North America. It has been found in the pea producing areas of Washington, Idaho and Montana. Its movement eastward is tracking the increased pulse crop acreage found in Alberta, Saskatchewan, Montana and North Dakota.

The adult insects are small, brown, and gray. Weevils range in length from one-eighth inch to less than one-quarter inch with longitudinal stripes (Figure 13). The adults enter pea fields early in the spring after overwintering in surrounding sheltered areas such as roadsides, shelterbelts and alfalfa fields. They feed on the emerging pea plants, leaving a distinctive scalloped appearance to leaves (Figure 13). At lower populations the pea crop typically recovers from this damage, but at high populations defoliation can be severe and growing shoots may be destroyed. After feeding, the mated females lay eggs in the soil, and the larvae burrow into and feed on the N-fixing root nodules. At high populations 90 percent

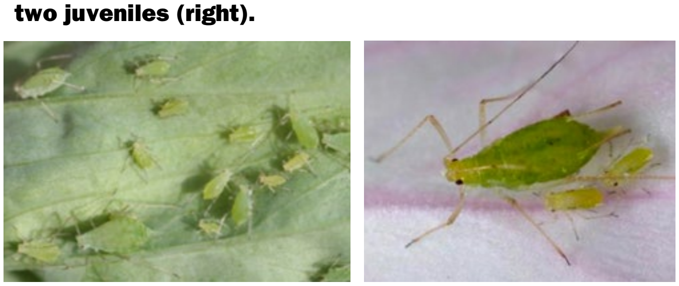
Figure 13. Adult pea leaf weevil (left) and typical feeding damage on pea leaf (right).

of the nodules can be destroyed, reducing grain yields and N inputs into the soil. Larvae feed for 30-60 days within the nodules before maturing to the pupa stage that lasts for 15-19 days, after which the new adults emerge from the soil. This next generation of adult weevils feed on a variety of legume plants during the summer before flying and dispersing to overwintering sites.

Pea fields should be scouted for the distinctive signs of adult feeding evident on the leaves soon after crop emergence. Because weevils migrate into pea fields from surrounding overwintering grounds, feeding damage by the adults often appears first on field edges. At the two- to four-leaf stage, treatment may be warranted when 25 percent of plants have signs of feeding injury. If notching is only occasional, or the insects are hard to find on a warm sunny day, or new leaves are not damaged, treatment may not be necessary. By the six-leaf stage the plants become more tolerant and some defoliation can be tolerated. It should be noted that the degree of yield loss from larval feeding has not been well quantified and may depend on soil N levels. Insecticidal sprays can be applied to control adult weevils in the spring, but timing is critical and results may be variable since population reductions only occur when the females are killed prior to laying eggs. Recent research has demonstrated that insecticidal seed treatments can be effective at controlling both the adults and larvae and their damage to pea plants (Cárcamo et al., 2012). However, monitoring tools and thresholds for adult migration into the fields have not yet been established and the decision to treat seed can only be based on past field history.

Pea aphids: Pea aphids, *Acyrthosiphon pisum*, are commonly found infesting pulse crops and can cause economic damage. They are small, pear-shaped insects one-eighth to one-quarter inch in length, pale to dark green in color with long, spindly legs (Figure 14). Aphids feed on plant sap using straw-like mouth parts, concentrating on lower leaf surfaces, buds, stems, and developing pods. Feeding damage can weaken and stunt infested plants causing yield loss at higher populations.

Figure 14. Juvenile and adult aphids feeding on the underside of a leaf (left). Close up of an adult aphid and two juveniles (right).



Pea aphids can indirectly damage pulse crops by vectoring viral diseases.

Pea aphids overwinter as eggs in alfalfa, clover, vetch or on dead stems and debris, hatching when new spring growth is available. The first generation hatching in the spring are all female insects. The immature stages resemble miniature versions of the adult form, molting four to five times over 10-14 days before becoming mature adults. The adult females give live birth asexually to about one dozen offspring each day, and populations can explode quickly when conditions are favorable. Most pea aphids are wingless. However, some females throughout the growing season are winged, aiding in dispersal. Males, which appear in the late summer, are also winged. During the fall, adults mate, producing fertilized eggs for overwintering.

Pulse crops are particularly susceptible to yield loss in the flowering and early pod stage, especially if plants are heat stressed. Pea aphids should be scouted when 50-75 percent of the crop is flowering by scouting several locations in the field. An average of nine to 12 aphids per sweep is considered the threshold for treatment. Alternatively, the number of aphids on the tips of five 8-inch plants can be counted at each site. An average of two to three aphids per plant tip is considered the threshold for treatment. If the economic threshold is exceeded, a single application of insecticide when 50 percent of plants have produced some young pods will protect the crop against yield loss and be cost-effective. However, the threshold for economic damage may depend on value of the crop as well as environmental conditions such as heat stress. Do not confuse pea aphids with lygus bugs that have a similar appearance but are more robust and move rapidly.

Aphid populations often are kept in check by beneficial insects such as parasitoid wasps and predators such as lady bird beetles and lacewings. If natural enemies are present during scouting, the field should be resampled in two days. If the aphid population is decreasing, treatment may not be needed. In some cases insecticide application can make aphid infestations worse by eliminating the beneficial insects.

Wireworms: Wireworms (Elateridae family) are the larval stage of click beetles (Figure 15), as many as 20-30 different species can damage a variety of crops in Montana and the region. Wireworms live in the soil and feed on seeds, the roots and stem of developing seedlings, decaying plant material and in some cases other small soil dwelling animals. The first generation of organochlorine and organophosphate insecticides, released in the 1950s and applied as seed treatments, controlled wireworms and prevented crop damage. Organochlorine insecticides were removed from the U.S. market because of their increased appearance in drinking and recreational water and because of human health concerns. The newer neonicotinoid class of insecticides currently used as seed treatments do not suppress larval populations in the soil and crop damage from wireworms is becoming more common. Crop damage appears as thin patchy stands early in the growing season. Pulse crops are not as susceptible to damage as wheat and barley crops, but do suffer economic damage when populations are high.

The adult beetles do not cause damage. They are active during May and June when they mate and females lay eggs in the soil. Depending on the species, the larval stage can require as many as five years to complete development to the adult beetle stage. This means wireworms can cause damage in a given field for years and field history is an important predictor of future damage. Larvae move deep in the soil to survive winter, returning to the surface in spring to feed on seeds and developing seedlings. As soil surface temperatures increase and moisture decreases in the summer, the wireworms again move to deeper locations in the soil. When larvae are mature they form pupal chambers three to four inches below the soil surface. The immature adults remain in the pupal chamber for the winter, emerging the following spring. Wireworms occur in dryland cropping systems but continuously cropped irrigated fields are more at risk of developing high populations.

Thin patchy areas during stand development should be scouted for wireworms. Simply digging plants in the affected areas will reveal wireworms feeding on the roots. At this stage no treatments are recommended, however, confirming the presence of wireworms is important for management decisions in the next cropping season. Early in the spring, bait stations can be used to monitor larval populations before the field is planted (Figure 16). An average of one to two larvae per bait station is considered the threshold for treatment. Current insecticidal seed treatments will provide crop protection but do not kill larvae in the soil, and higher rates are required in heavily infested fields. Because wireworms feed on many things and live for several years, crop rotation has not been effective at eliminating populations in the soil. Cultural practices that can help include increasing seeding density by 10 percent and planting infested fields last to reduce the amount of time that vulnerable seeds and small seedlings are exposed to wireworms.

Figure 15. Wireworms, adult (upper left), juveniles (upper right), and patchy stand due to wireworm feeding damage (bottom).

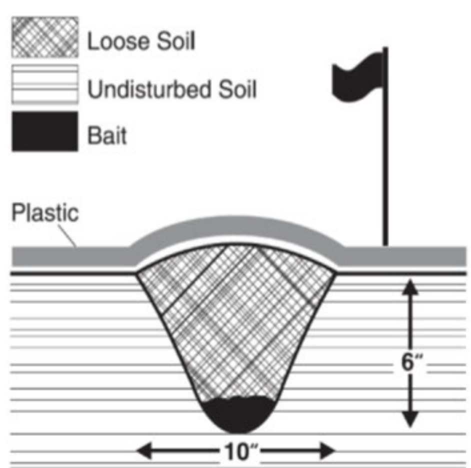


Figure 16. Wireworm bait station

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Endnotes

Web links

1. agr.mt.gov
2. http://smallfarms.oregonstate.edu/calculator
3. www.msuextension.org/store/
4. www.sarc.montana.edu
5. http://agr.mt.gov/agr/Programs/Commodities/GrainLab
6. www.pulseusa.com
7. http://msuextension.org/publications/AgandNaturalResources/MT200702AG.pdf
8. http://msuextension.org/publications/AgandNaturalResources/4449/4449_9.pdf
9. http://msuextension.org/publications/AgandNaturalResources/EB0191.pdf
10. http://spg.bekinetic.ca/publications/publications/Pea_Production_Manual/
11. http://msuextension.org/publications/AgandNaturalResources/EB0161.pdf
12. http://www.agriculture.gov.sk.ca/Default.aspx?DN=e42316e3-15ea-4249-ac0e-369212b23131
13. http://msuextension.org/publications/AgandNaturalResources/MT201009AG.pdf
14. http://msuextension.org/publications/AgandNaturalResources/MT200405AG.pdf
15. http://diagnostics.montana.edu/
16. http://msuextension.org/publications/AgandNaturalResources/EB0207.pdf
17. http://www.apsnet.org/Pages/default.aspx
18. http://plantsciences.montana.edu/seedlab/
19. http://www.ag.ndsu.edu/extplantpath/publications-newsletters/fungicides
20. http://wiki.bugwood.org/HPIPM:Main_Page
21. http://www.ndsu.edu/pubweb/pulse-info/index.html
22. http://www.sidney.ars.usda.gov/grasshopper/
23. http://cutworm.org/

Testing for Seed-borne Pathogens of Pulse Crops

Contact each vendor for details on services, prices, sampling, and shipping methods.

Montana State Seed Testing Laboratory
Department of Plant Sciences/Plant Pathology
Room 40 Marsh Lab
PO Box 173145
Bozeman, MT 58717-3145
406-994-2141

North Dakota State Seed Department
PO Box 5257
Fargo, ND 58105-5257
701-231-5400

SGS Seed Services, Inc.
Laura Carlson, Sarah Dammen
236 32nd Avenue
Brookings, SD 57006
605-692-7611

Discovery Seed Labs, Ltd.
450 Melville Street
Saskatoon, SK
S7J 4M2 Canada
306-249-4484

20/20 Seed Labs Inc.
3618 – 6th Avenue North
Lethbridge, AB
T1H 5C4 Canada
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