Pest Management Strategic Plan for Pulse Crops (Chickpeas, Lentils, and Dry Peas) in the United States

Summary of a workshop held on
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*NOTE: Trade names for various products are used throughout this document as an aid for the reader in identifying these products. The use of trade names does not imply endorsement by the work group or any of the organizations represented.*
Previous PMSPs

Two Pest Management Strategic Plans have been written for pulse crops. They were released in 2003 and in 2007.

The 2003 PMSP

In 2002, the pulse industries in both the United States and Canada expressed interest in positioning themselves to approach the North American Free Trade Agreement (NAFTA) Technical Working Group for the purpose of harmonizing crop protection materials and maximum residue levels (MRLs) and establishing a NAFTA label. A work group consisting of U.S. and Canadian growers, commodity groups, pest control advisors, regulators, and university specialists, along with representatives from the U.S. Department of Agriculture (USDA), the Western Region Pest Management Center, Agriculture and Agri-Food Canada and the Canadian Pest Management Regulatory Agency (PMRA) met for two days in Saskatoon, Saskatchewan, Canada in June of 2002. The purpose of the meeting was to identify the needs of pulse growers in the two countries with reference to possible research, regulatory, and education actions regarding pesticides. The result of this exercise was publication of the Pest Management Strategic Plan for Pulse Crops (Chickpeas, Lentils, and Dry Peas) in the United States and Canada, on June 20, 2003.

Outcomes relating to the critical needs defined in the 2003 PMSP were discussed in the 2007 PMSP, which is available by contacting the Western Integrated Pest Management Center, http://westernipm.org.

The 2007 PMSP

At the time of the meeting that led to the 2007 pulse PMSP, the U.S. Environmental Protection Agency (EPA) had completed the risk assessments required under the Food Quality Protection Act of 1996 (FQPA) and was continuing its pesticide reregistration process. Several pesticide registrations had been cancelled, while other pesticides had been relabeled with greater restriction on their uses. The Endangered Species Act (ESA) was impacting the availability and restricting the use of certain pesticides. No-spray “buffer zones” were being established for certain pesticides, and the practical impacts of these were not yet fully understood. All of these issues led to a meeting of U.S. pulse industry stakeholders in February of 2006. This second PMSP did not include Canada.

A work group consisting of growers, commodity groups, pest control advisors, regulators, USDA-Agriculture Research Service personnel, and university specialists met for one-and-a-half days in Spokane, Washington. Through this meeting and subsequent correspondence between work group members, the needs of pulse growers were identified regarding possible research, education, and regulatory actions impacting pest management. The result of this exercise was a list of critical needs, general conclusions, and tables listing the timing of operations and the efficacies of various management tools for specific pests. Outcomes of the critical needs defined in 2007 follow. The complete 2007 PMSP is available by contacting the Western IPM Center, http://westernipm.org.
OUTCOMES

The following list summarizes those needs determined by the 2006 work group to be the most critical to pulse-crop pest management at that time. Overall top priorities – those pertaining to all pulses – are listed first, followed by the top priorities for each of the three pulse crops under examination. Outcomes to date follow each bulleted priority.

Research

- Research and/or develop broadleaf weed controls, especially post-emergent, targeting kochia, nightshades, Mayweed chamomile, prickly lettuce, and sowthistle.

Many new controls have been registered (see Regulatory, below). These weeds are still problems, as are common lambsquarters and wild buckwheat. Broadleaf weed control in pulses remains a critical issue. Narrowleaf hawksbeard and other winter annuals are emerging as important weed species to control. Looking ahead, controls for grass weeds other than Group I and II types will become more important, particularly if resistance continues to build.

- Develop varieties with resistance to diseases.

‘CDC Frontier,’ ‘CDC Alma,’ and ‘CDC Orion’ chickpeas have good Ascochyta blight resistance and other varieties also have improved resistance. ‘Hampton’ dry pea exhibits resistance to *Pea enation mosaic virus* and *Bean leafroll virus*. ‘Hampton’ and other commercial varieties now have some resistance to root rots (*Aphanomyces* spp.), yet these diseases are still a major problem in most pulses. Root diseases have become and will continue to be more of an issue. Resistant varieties will need to be developed.

- Continuing and additional research on biology of pathogens and insects.

Sanford Eigenbrod of the University of Idaho received a grant and did some very helpful foundational work on aphids, but more work is needed. We have come a long way from the 80% crop losses due to aphids from the 1980s, but aphids are still problematic, as are the diseases associated with them (i.e., *Pea enation mosaic virus* and *Bean leafroll virus*).

- Further investigate transgenic breeding for pest management.

Today’s market is very limited for genetically modified pulses (GMOs). We know how to do this but have not proceeded due to market considerations during the past decade.

- Research disease management through crop rotation.

More research and active trials needed. Lack of long-term funding for these types of projects has been a main barrier to implementation. Educational outreach to growers of recommendations developed thus far is still lacking.

- Find an alternative to systemic insecticide dimethoate.

In practical terms, there really is no alternative with comparable efficacy and cost. Flonicamid (Beleaf) has promise in that it kills Lygus and aphids while being soft on pollinators and other beneficial and non-target species, but its expense makes its use prohibitive in most pulse-growing situations. Knowledgeable growers are motivated to find an alternative to dimethoate,
but the 30 days of control achieved with this organophosphate (OP) is very cost effective; other tools are more expensive and only last approximately 14 days.

- **Develop an effective aphid management program and associated tools (such as seed treatments that persist in systemic manner).**

Systemics are available, but they are neonicotinyls, which are problematic. Development is proceeding. Bifenthrin (Capture) has some early season efficacy against pea leaf weevil and offers some suppression of pea aphid, but does not work as well as dimethoate. Similarly, lambda-cyhalothrin (Warrior), pymetrozine (Fulfill), esfenvalerate (Asana), methomyl (Lannate), and imidacloprid (Provado) are available, but none are cost effective. Other emerging pests that might be helped by systemic seed treatments include seed corn maggot, which is now impacting chickpeas in the Palouse region of the Pacific Northwest and cutworm (in all pulses, but more in peas and lentils). These pests are only problematic in some years (depending on conditions, primarily soil moisture); pest pressures may increase with climate change and increasing pulse crop acreage in the West.

- **Improve crop quality and breeding for competitiveness and desirable characteristics such as bleach resistance.**

Bleach resistance is important in green peas, which are grown primarily in the PNW (where the climate lowers the risk of bleach occurring), but increasingly are being grown in the Northern Plains as well. Preplant, preemergence weed controls currently applied provide only ~30 days of protection, whereas the crop canopy isn’t really formed for 45 days. Few controls are available for that 15-day gap. Basagran can be sprayed over the top of peas, but not chickpeas or lentils. Many plant growth and crop management factors fall under the descriptions of “competitiveness” and “desirable characteristics.” Definition of crop quality is evolving, and can include size, appearance/color, protein content, winter hardiness, and more.

**Regulatory**

- **Register 2,4-DB, linuron, clethodim, prometryn, thiabendazole, prothioconazole, and other triazole fungicides.**

Efforts toward 2,4-DB registration were dropped, as it kills lentils and wasn’t tough enough on weeds. Linuron received a Section 18 emergency registration, followed by a full registration for all pulse crops. Clethodim (Select) is now registered. Prometryn was deemed ineffective and therefore not pursued. Thiabendazole (LSP seed treatment) became a long-running Section 18 and is now fully registered for all pulse crops. The DMI (FRAC 3) fungicides prothioconazole (Proline) and difenoconazole (Quadris) are registered. Other fungicides have also been registered. Novaluron is in the IR-4 pipeline for dry peas. Pyridate (Tough), which was discontinued in chickpeas in 2004, may be reregistered; this product was formerly chickpea-specific, but will have overall implications for pulse crops. A new class of fungicides, the SDHI group (FRAC 7), has received registrations on pulses. Endura (boscalid), Vertisan (penthiopyrad), Priaxor (a premix of the QoI fungicide pyraclostrobin and the SDHI fluxapyroxad), Aprovia Top (a premix of the DMI fungicide difenoconazole and the SDHI benzovindiflupyr), and ProPulse (a premix of the DMI fungicide prothioconazole and the SDHI fluopyram) are now registered for foliar use on chickpeas, lentils, and peas. The SDHI fungicides sedaxane, penflufen, and fluxapyroxad have been registered for use as seed treatments on chickpeas, lentils, and peas. The triazole carboxamide fungicide ethaboxam (Intego Solo, FRAC
22) has been registered for use as a seed treatment on chickpeas, lentils, and fresh-market peas but not dry peas. Registration of the fluazinam (Omega, FRAC 29) on lentils and peas is anticipated; efficacy of fluazinam against key diseases has been demonstrated, and residue analyses for fluazinam have been funded by the USDA IR-4 program and are in progress. Fluazinam exhibits multi-site activity and has a mode of action that is distinct from other fungicides currently registered for use on lentils and peas.

- **Standardize crop groupings and crop zones.**

The last CODEX session (held in China, May 2015) approved crop grouping for pulses. Working on worldwide crop zones.

- **Ensure that pesticide labels for legume crops list winter legumes on the label.**

While this was stated as a critical need in 2004, there is no need to separate out fall-planted legumes from spring-planted legumes for labeling purposes. All of the products that can be used on spring-planted legumes can also be used on fall-planted legumes.

- **Work with registrants and EPA to expedite pesticide registrations and label reviews and decisions.**

Progress has been made. The process for (including ways of expediting) registrations has changed over the ensuing decade. Registration is more complex than ever, as we address MRLs and other international concerns. Today’s system takes 20 months regardless of interventions to expedite, but industry leaders have a greater understanding of the process, which helps. Concentrating on conditional registration Section 3s rather than just Section 18s has become the norm, which also helps avoid unnecessary work and gaps in registrations for important tools.

- **Defend the dimethoate registration at the 0.5 lb rate.**

Shortly after the meeting that produced the previous PMSP, this use was retained on lentils for control of Lygus and aphid. The pulse industry still needs to defend any use of dimethoate, due to widespread concerns about its toxicity to non-target species. Moving to nighttime spraying (when pollinators aren’t flying) might be a concession viewed favorably by detractors. Spraying in some but not all years might become the best option but the bottom line is that, at this time, this tool is still critical.

- **Work with NRCS to establish crop residue requirements for Conservation Stewardship Program and other Farm Bill programs.**

These concerns have shifted. CSP is no longer an issue. Farm Bill programs have changed. Studies have shown that biomass increases are associated with increased yield.

**Education**

- **Communicate economic benefits of growing and consuming pulse crops (system approach/crop rotation, moisture, organic matter, and disease management).**

Progress has been made, still need funding to improve. See discussion of the International Year of Pulses in the Introduction section.
• Develop an electronic one-stop website for pulses. Site would optimally include:
  forecasting, weather, markets, pesticides, plant-back issues, global information, seeding,
production practices, MRLs, and resistance ratings.

“WikiPulsia” is under development—a cloud-based, participant-driven site.

• Offer programs on pesticide modes of action and resistance management.

The pulse industry has a limited number of products registered and therefore limited modes of
action available to do any specific job. Grass weeds, for example, have only one mode of action.
Pythium root rot has products representing two modes of action (the FRAC 4 phenyl-amide
fungicides metalaxyl and mefenoxam and the FRAC 22 thiazole carboxamide fungicide
ethaboxam) on chickpeas and lentils, and one mode of action (FRAC 4 phenyl-amide fungicides)
on dry peas. Resistance to QoI (FRAC 11) fungicides has developed in the causal agents of
Ascochyta blight in chickpeas and field peas. Where strains resistant to the QoI fungicides occur,
chlorothalonil (FRAC M), DMI (FRAC 3), and SDHI (FRAC 7) fungicides are the only
chemistries available for managing Ascochyta blight, and the DMI fungicide prothioconazole is
utilized disproportionately since chlorothalonil and SDHI fungicides are less effective than
prothioconazole. The anticipated registration of fluazinam (FRAC 29) on field peas and lentils
will provide another mode of action for Ascochyta blight management in those crops, but
fluazinam is generally also less effective against Ascochyta blight than the DMI fungicide
prothioconazole (Proline). In many cases, the only way to change modes of action when
managing weeds is to rotate to another crop where other controls are used. New growers need to
be educated when they rotate from another crop with respect to herbicide carryover (i.e., if you
use a product in wheat with an 11-month plant-back, you can’t plant fall pulses). There is
widespread resistance to QoI fungicides in Didymella rabiei (formerly A. rabiei) of chickpea in
North Dakota and Montana. Metalaxyl-resistance in Pythium spp. is a big issue in Washington
state. Ethaboxam (Intego Solo), which has a new mode of action (FRAC 29) that would be useful
in managing metalaxyl-resistant Pythium spp., is currently being considered for a Section 18 on
dry peas.

• Educate funding sources on need for long-term research projects.

This work continues. In a crop where rotations are a critical part of the whole-farm approach,
multi-year projects are necessary. The Pulse Crop Health Initiative is part of this plan.

• Develop and offer programs on disease and insect management.

Disease identification workshops have been offered to pulse growers in Washington state at
events sponsored by the USA Dry Pea and Lentil Council and in Montana and North Dakota at
events sponsored by the Northern Pulse Growers Association and Extension. Additional outreach
is still very much needed – in disease and pest identification as well as treatment. WikiPulsia will
be part of this. Ideally, a working group will result from the 2017 PMSP process that will
continue to assist in this.

• Educate consumers on pulse crops and acceptance of GMOs.

Much progress has been made in the past decade about pulse crop awareness. GMO acceptance
is still in the future; while the concept has a bad reputation in the most prosperous nations, the
advantages will outweigh the negatives in developing nations over time. Herbicide tolerance in
lentils has been developed and released in CDC (Canadian) varieties. These varieties are tolerant to different classes of herbicides to assist growers with weed control. They are not considered GMO.

**Chickpea-specific Research**

- Research whether current plant-back restrictions are strictly necessary, especially in the case of chickpeas (e.g., planting after simazine).

No longer an issue, see below.

- Research atrazine and simazine efficacy and applicability in chickpeas.

No longer available.

- Research imazamox and prometryn in chickpeas.

Imazamox still of interest; prometryn found ineffective.

- **Develop biological-based control for Pythium (damping off) in chickpea.**

There are still no effective biologically based controls for management of Pythium spp. in chickpea.

  - **Investigate new chemistries for weed control such as Harmony GT, Express, Spartan, linuron, diuron, and prometryn.**

Spartan and linuron are now labeled; diuron and prometryn were not pursued due to lack of efficacy.

- **Develop methods to stop growth of chickpeas in the fall (such as a growth regulator or swathing).**

Glyphosate and gramoxone are labeled as pre-harvest aids. Still investigating this.

- **Develop cost-effective grasshopper control tactics in chickpeas.**

This cyclical pest is still an issue.

- **Develop cutworm controls in chickpea, where there are no registrations.**

Still lacking in research.

- **Develop solution to rabbit problems.**
Elk and deer are the vertebrate pests of note. Need grower input on vertebrates.

- Develop additional determinate chickpea varieties.

Indeterminate varieties are yielding better, so this may or may not still be of concern.

- Develop method of protecting chickpea pods from Ascochyta blight.

This disease is controlled in the Palouse (Pacific Northwest) via production practices, resistant varieties, and a climate that does not favor its development. Ascochyta blight may become more of an issue in the Northern Plains, but is presently controlled. In Montana, Ascochyta blight seems to occur late in the season, likely ruling out most fungicides due to PHIs. Resistance of *Ascochyta rabiei* to QoI fungicides is widespread in Montana and North Dakota. Chlorothalonil (FRAC M) and SDHI (FRAC 7) fungicides are generally less effective against Ascochyta blight than the DMI fungicide prothioconazole, and prothioconazole is relied upon heavily for Ascochyta blight management in chickpeas in the Northern Plains. Research on the efficacy of tank-mixing chlorothalonil and prothioconazole, a cost-effective strategy for improving fungicide resistance management, is in progress.

**Chickpea-specific Regulatory**

- Add Ascochyta blight to the chickpea section of the azoxystrobin (Dynasty) label.

Now available.

- Expedite registrations for cutworm control in chickpea.

Some products are now available but additional registrations are still important.

**Lentil-specific Research**

- Are currently mandated rotational timings (pea-pea 2 year, lentil-lentil 2 year) necessary? (Crop insurance issue.)

Yes, studies in Canada have shown that this rotation is necessary due to Aphanomyces root rot and other root diseases.

- Develop taller lentil varieties.

Still need more competitive varieties.

- Continue varietal research for higher crop residue (greater biomass) in lentils (to reduce erosion).
Both are still goals, but emphasis has shifted.

- **Research the elimination of chalky spot on peas and lentils, including investigation and development of resistant varieties.**

Chalky spot on lentils comes primarily from Lygus feeding, so controlling Lygus is critical. Lygus presence at any level is now known as a threshold event triggering spraying. Seeking use of the controls used for Lygus such as flonicamid (Beleaf) might help, although those controls might be too expensive.

**Lentil-specific Regulatory**

- **Pursue 2,4-DB registration for lentils.**

Dropped; too harmful for lentils.

**Dry Pea-specific Research**

- **Develop a more competitive upright pea plant.**

Remains a priority; new varieties over the past decade address this.

- **Investigate effects of Lygus damage to dry peas.**

Chalky spot in dry peas appears to come from hail rather than Lygus, but this remains to be verified.

- **Develop methods to separate pea-weevil-infested peas from those not infested.**

This has become even more important as pea weevil moves into Montana’s vast acreage. This is a game-changer. Additional research is required. “Sweating,” or holding for 30 days to allow adult pests to leave the harvested peas, is part of the process but not the whole solution.

- **Develop weevil-resistant pea varieties.**

This would be wonderful, and a cross between a *Pisum fulvum* (with its weevil-resistant pod) and pea was in the works with Australia but was discovered to contain an allergen, so this particular variety was not pursued. There is potential here. Experimental success also occurred with a transgenic bean-gene cross for amylase inhibitor that conferred immunity to the weevil. This also has potential. In addition to developing resistant varieties, efforts are underway toward obtaining a USDA-APHIS permit to introduce egg parasitoid *Uscana senex* from Brazil or Chile. This parasitoid will attack the eggs of pea weevil and destroy them.
• Research elimination of chalky spot on peas and lentils, including investigation and development of resistant varieties.

Still need to determine whether hail or Lygus is the culprit.
Introduction

Edible seeds of legumes are known as pulses. They include peas, beans, lentils, and chickpeas. The term “pulse” comes from the Latin word “puls,” which means a thick soup. Pea, lentil, and chickpea species are part of the larger plant family known as the Fabaceae or legume family. The Fabaceae family includes about 600 genera and 13,000 species, making it the third largest family within the plant kingdom. This family includes cultivated species such as alfalfa, soybeans, and many edible beans. For the purposes of this document, the term “pulse crops” will represent chickpeas, lentils, and dry peas. No other pulse crops will be included in the discussions.

Pulses are considered environmentally friendly because of their reduced dependence on fossil fuels. Instead of requiring fertilizer applications, they are able to obtain much of their nitrogen requirement from the atmosphere by forming a symbiotic relationship with *Rhizobium* or *Mesorhizobium* bacteria in the soil. Pulse crops’ low crop residues and low carbon-to-nitrogen ratios eliminate the need for burning and make rotating to the next crop using reduced tillage very easy.

Pulse crops have a hypogeal type of germination meaning that the seed leaves (cotyledons) remain below ground. Soybeans and dry beans have an epigeal type of germination, which means the seed leaves emerge from the soil. Hypogeal germination makes pulse crops more frost-tolerant than soybeans or dry beans. Additionally, pulse crops are more tolerant of post-plant, preemergence, or early postemergence tillage operations such as harrowing, culti-packing, or rotary hoeing (each of which disturbs the soil) than are soybeans or dry beans. Later (mid-season to late-season) mechanical operations are less practical because of the crops’ low growth habit and pod set.

Pulse crops are an important food source in developing nations and, increasingly, a popular food in the U.S. and other developed nations as their nutritive qualities – high fiber, low fat, high protein, low glycemic index – are recognized and appreciated. The United Nations declared 2016 as the International Year of Pulses (IYP 2016, [http://ipy2016.org](http://ipy2016.org)), to highlight the importance of pulse crops and the role they play in providing worldwide nutrition and food security. This made 2016 an especially appropriate year for pulse growers and other stakeholders to step forward and revisit the Pest Management Strategic Plan for the expanding and changing U.S. pulse industry.

Pulse growers in the United States recognize the importance of developing long-term strategies to address pest management needs. These strategies include identifying critical pesticide uses; retaining critical uses; researching pest management methods with emphasis on economically viable solutions; and understanding the impacts of pesticide cumulative risk. This document is designed to review and evaluate these strategies.
Work Group

A work group consisting of growers, breeders, pest control advisors, merchandisers, regulators, USDA-ARS personnel, and university specialists met for one-and-a-half days in Bozeman, Montana on November 9-10, 2016. The purpose of the meeting was to identify the current needs of pulse growers in terms of research, education, and regulatory actions regarding pesticides and other pest management tools. The result of this exercise was a list of critical needs, general conclusions, and tables listing the timing of operations and the efficacies of various controls for specific pests. These materials have been compiled and reviewed by work group members and are presented in this Pest Management Strategic Plan, the third such document in the evolving U.S. pulse crop industry. This document and its appendices are intended to serve as a comprehensive foundation for the continuing transition to more sustainable pest management in pulse crops in the United States.

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Critical Needs Summary by Crop

The following list summarizes those needs determined by the work group to be the most critical to pulse crop pest management in 2016. Chickpea critical needs are listed first, followed by those for lentil, then dry pea.

CHICKPEAS

Research
- Develop Ascochyta blight-resistant varieties.
- Identify new chemistries for fungicide resistance management with a particular focus on metalaxyl-resistant *Pythium* spp.
- Identify chemistries with alternate modes of action with efficacy against Ascochyta blight of chickpeas.
- Expand insecticide options.
- Continue evaluating currently registered insecticide products.
- Review economic thresholds for insects and develop thresholds for insect pests that do not have thresholds.
- Increase biological control and pheromone-based monitoring/trapping research.
- Expand herbicide options for broadleaf and grass weed management through continued evaluation of currently available products and by breeding for tolerance to herbicides.
- Expand management options for priority weed species.
- Prioritize and optimize cultural management inputs including seeding rate, row spacing, planting date, and crop rotation for improved crop competitiveness with weeds.
- Focus on systems-based weed management strategies grounded in sound agroecological practices.
- Develop insect, disease, and weed pest-forecasting models and decision-support tools.

Regulatory
- Understand pathogen movement in seed as related to phytosanitary trade barriers.
- Register fluazinam (Omega) for management of Ascochyta blight on chickpeas.
- Register diflubenzuron (Dimilin) for grasshopper control.
- Register pyridate (Tough).
- Register tribenuron (Express).
- Obtain USDA-APHIS permit to import *Uscana senex* from Brazil or Chile for control of pea weevil.

Education
- Identification and sustainable management of diseases: variety resistance list, crop rotation lists or tables, flip cards for varieties, forecasting.
- Increase grower awareness of IPM practices in weed and insect management.
- Increase grower awareness of pollinators and pollinator safety.
- Herbicide resistance management and residue carryover education.
- Weed management IPM.
LENTILS

Research
- Identify root rot pathogens.
- Develop improved management strategies for Fusarium and Aphanomyces root rots.
- Develop rigorous fungicide-usage recommendations for management of white mold, including application timing, methods, and technology (spray pattern, droplet size, pressure, water volume); understand relative efficacy of applications made shortly before vs. shortly after canopy closure.
- Identify viruses and determine resistant varieties.
- Expand insecticide options.
- Continue evaluating currently registered insecticide products.
- Review economic thresholds for insects and develop thresholds for insect pests that do not have thresholds.
- Increase biological control and pheromone-based monitoring/trapping research.
- Expand herbicide options for broadleaf and grass weed management through continued evaluation of currently available products and by breeding for tolerance to herbicides.
- Expand management options for priority weed species.
- Prioritize and optimize cultural management inputs including seeding rate, row spacing, planting date, and crop rotation for improved crop competitiveness with weeds.
- Focus on systems-based weed management strategies grounded in sound agroecological practices.
- Develop insect, disease (white mold), and weed pest-forecasting models and decision-support tools.

Regulatory
- Register fluazinam (Omega) for Anthracnose, Ascochyta, and Sclerotinia stem rot control.
- Understand pathogen movement in seed as related to phytosanitary trade barriers.
- Expedite flonicamid (Beleaf) registration for aphid and Lygus control (in the IR-4 pipeline).
- Register diflubenzuron (Dimilin) for grasshopper control.

Education
- Identification and sustainable management of diseases: variety resistance list, crop rotation lists or tables, flip cards for varieties, forecasting.
- Increase grower awareness of IPM practices in insect management.
- Increase grower awareness of pollinators and pollinator safety.
- Herbicide resistance management and residue carryover education.
- Weed management IPM.
DRY PEAS

Research

- Research management of Fusarium species complex (identification, variety resistance, fungicide efficacy).
- Investigate pathogen movement in seed and seed treatments for management.
- Quantify soil and risk for root rot with an emphasis on Aphanomyces.
- Develop improved management strategies for Aphanomyces root rot.
- Identify fungicides with different modes of action for Ascochyta blight management in field peas.
- Develop thresholds for seed-borne *Pseudomonas syringae* pv. *pisi* and other causal agents of bacterial blight in field pea seed (like *Pseudomonas syringae* pv. *syringae*); evaluate the efficacy of seed treatment with streptomycin for management of seed-borne bacterial blight pathogens.
- Develop thresholds for *Pea seed-borne mosaic virus* and improve detection methods to include new strains.
- Expand insecticide options; continue evaluating currently registered insecticides.
- Review economic thresholds for insects and develop thresholds for insect pests that do not have thresholds.
- Increase biological control and pheromone-based monitoring/trapping research.
- Expand herbicide options for broadleaf and grass weed management through continued evaluation of currently available products and by breeding for tolerance to herbicides.
- Prioritize/optimize cultural management inputs including seeding rate, row spacing, planting date, and crop rotation for improved crop competitiveness with weeds.
- Focus on systems-based weed management strategies grounded in sound agroecological practices.
- Develop insect, disease, and weed pest-forecasting models and decision-support tools.

Regulatory

- Understand pathogen movement in seed as related to phytosanitary trade barriers.
- Register ethaboxam (Intego Solo) for Aphanomyces root rot and metalaxyl-resistant *Pythium* spp.
- Register fluazinam (Omega) for Ascochyta blight control.
- Register diflubenzuron (Dimilin) for grasshopper control.
- Register tribenuron (Express).
- Register acifluorfen (pending confirmation of crop tolerance).

Education

- Identification and sustainable management of diseases: variety resistance list, crop rotation lists or tables, flip cards for varieties, forecasting.
- Educate growers on pea leaf weevil and pea weevil biology, ID, and management.
- Increase grower awareness of IPM practices in insect management.
- Increase grower awareness of pollinators and pollinator safety.
- Herbicide resistance management and residue carryover education.
- Weed management IPM.
Pulses and Growing Regions of the U.S.

Pulse crops are grown primarily in the northwestern and northcentral United States. While significant production of pulses (including dry beans, which are not covered in this document) takes place in California, the Southwest, and the Great Lakes regions, this PMSP focuses on the major production regions for chickpeas, lentils, and dry peas. For discussion purposes, we will refer to the primary pulse-growing regions as:

- **Pacific Northwest** – Washington, Oregon, Idaho
- **Northern Plains** – Montana, North Dakota, South Dakota, Minnesota
- **High Plains** – Wyoming, Colorado, Nebraska, Kansas

Chickpeas (*Cicer arietinum*)

Chickpeas are an annual grain legume. They come in two types, “desi” and “kabuli,” based on seed size, color, and the thickness and shape of the seed coat. (See the USA Dry Pea & Lentil Council’s website at [http://usapulses.org](http://usapulses.org) for photos illustrating various types of pulses.)

Desi types are usually smaller, angular seeds with thick seed coats that range in color from light tan and speckled to solid black. Desi chickpeas require a specialized seed-coat-removal process if used for human food. The process, called decortication, requires adjusting the moisture level of the seeds to facilitate the mechanical removal of the thick seed coat. The seeds, which after decortication resemble a small yellow pea, are processed into numerous South Asian ethnic food products.
Kabuli types, also known as “garbanzo beans” in the United States, are larger seeds with paper-thin seed coats that range in color from white to pale cream-color to tan. In North America, most kabuli chickpeas are marketed as canned chickpeas for salads or as hummus. Kabuli chickpeas are also marketed as dry chickpeas and ground flour.

In the United States, chickpeas are grown primarily in the Pacific Northwest and Northern Plains, with some production in California, the High Plains, and Arizona.

Chickpea plants are erect with primary, secondary, and tertiary branching, resembling a small bush. They flower profusely and have an indeterminate growth habit, continuing to flower and set pods as long as conditions are favorable. Pod set occurs on the primary and secondary branches and on the main stem. The individual round pods generally contain one seed in kabuli types and often two seeds in desi types. Chickpeas have deeper taproots than peas and lentils, which gives them an advantage in moisture-deficient areas.

**Lentils (Lens culinaris)**

Lentil plants are herbaceous, with slender stems and branches. Plant height ranges from 12 to 15 inches for most varieties, but can vary from 8 to 30 inches depending on variety and environment. Plants have a slender taproot with fibrous lateral roots. Rooting patterns range from a many-branched, shallow root system to types that are less branched and more deeply rooted. The taproot and lateral roots in surface layers of the soil have nodules that vary in shape from round to elongate. Stems of lentil plants are square and ribbed and usually thin and weak. Branches arise directly from the main stem and may emerge from the cotyledonary node below ground or from nodes above ground. Leaves are relatively small compared to those of other large-seeded food legumes. Pods are oblong, laterally compressed, and approximately ¼ to ¾
inch long and 1/8 to 3/8 inch wide; they usually contain one or two lens-shaped seeds. Seed diameter of varieties commonly grown in the United States ranges from around 1/8 inch to a little over ¼ inch and colors range from light green or greenish red to gray, tan, brown, or black. Purple and black mottling and speckling of seeds are common in some varieties.

In the United States, lentils are grown primarily in the Pacific Northwest and Northern Plains. Several market classes of lentils are grown in these regions, based on seed size, cotyledon color, and seed coat coloration.

Lentil varieties grown in North America are divided into class according to size and color. Some example classes and varieties are listed below (not an exhaustive list).

<table>
<thead>
<tr>
<th>Type or Style</th>
<th>Size</th>
<th>Color, Characteristic</th>
<th>Cotyledon Color</th>
<th>Example Varieties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pardina</td>
<td>3 to 4 mm</td>
<td>Small, Brown (Mottled)</td>
<td>Yellow</td>
<td>Pardina, Morena</td>
</tr>
<tr>
<td>Eston</td>
<td>3 to 4 mm</td>
<td>Small, Green (Mottled)</td>
<td>Yellow</td>
<td>CDC Eston, CDC Viceroy</td>
</tr>
<tr>
<td>Specialty</td>
<td>3 to 4 mm</td>
<td>Small, Black;  Small, French Green</td>
<td>Black or Yellow</td>
<td>Beluga, Caviar, IndianHead, DePuis</td>
</tr>
<tr>
<td>Regular</td>
<td>4 to 5 mm</td>
<td>Medium, Brown (Mottled)</td>
<td>Yellow</td>
<td>Brewer, Merritt</td>
</tr>
<tr>
<td>Richlea</td>
<td>4 to 5 mm</td>
<td>Medium, Green (Clear Seeded)</td>
<td>Yellow</td>
<td>CDC Richlea, CDC Viceroy, Avondale</td>
</tr>
<tr>
<td>Laird</td>
<td>6 to 7 mm</td>
<td>Large</td>
<td>Yellow</td>
<td>CDC Laird, Mason, Pennell, CDC Greenstar, CDC Greenland</td>
</tr>
<tr>
<td>Red Chief</td>
<td>4 to 5 mm</td>
<td>Medium, Red</td>
<td>Red</td>
<td>Red Chief</td>
</tr>
<tr>
<td>Crimson</td>
<td>3 to 4 mm</td>
<td>Small, Red</td>
<td>Red</td>
<td>CDC Red Robin, Crimson, CDC Redberry, CDC Maxim, CDC Red Cliff</td>
</tr>
</tbody>
</table>
Dry Peas (*Pisum sativum* and *P. sativum* spp. *arvense*)

Dry peas are a cool-season annual crop produced primarily in the Northern Plains, High Plains, and Pacific Northwest, with scattered production in northern California, Nevada, Arizona, New England, and a few other states. Also known as “field peas,” they differ from succulent peas in that dry peas are marketed as dry, shelled products for either human food or livestock feed, whereas succulent peas are marketed as fresh or canned vegetables. There are two main types of dry peas. One type has normal leaves and vine length of 3 to 6 feet. The second type is semi-leafless (with modified leaflets) with shorter vine lengths of 2 to 4 feet.

Dry peas emerge and perform well in a variety of seedbeds, including direct seeding into grain residue. Dry peas are typically grown following cereal crops. As with the other pulse crops discussed here, most dry peas are spring-planted; optimal planting dates range from mid-March to mid-May when soil temperatures are above 40°F. In most years, delayed planting lowers quality and seed yield. Dry peas are adapted to grow during the cool season when evapotranspiration is minimal. Growers in the Pacific Northwest and parts of the northern plains rely on stored soil moisture for a large part of their growth cycle.

Fall-planted peas – peas planted in the fall with a tolerance to winter temperatures – of the green and yellow market classes have been released for both feed markets and, more recently, for food markets. Fall-planted peas also show promise as a cover crop in all regions of North America. Austrian winter peas are raised for forage and specialty feeding applications. Fall-planted peas provide producers with significantly improved yields, possible adaptability to drought or summer season heat due to earlier bloom dates, earlier harvest potential, and longer-term nitrogen.
fixation for better soil health. Fall-planted pea acres are expected to expand across current growing regions and to provide additional pulse acres in summer fallow/winter wheat rotations.

Depending on the variety, dry peas start flowering after a specific number of nodes are reached and flowering continues until moisture or nitrogen deficiency brings it to an end. Dry pea varieties have either a determinate or indeterminate flowering habit. Determinate varieties mature in 80 to 90 days, indeterminate varieties in 90 to 100 days. Dry pea harvest begins in late July (for spring-planted peas), when pods are dry and seed moisture is 8% to 18%, depending upon the growing region. They are combined directly in the field. A timely harvest is important to avoid post-maturity disease, seed bleaching, and seed shatter.
Organic Production

The demand for organically produced pulse crops has grown substantially since the release of the previous PMSP. In the intervening years, the U.S. organic standard has been developed and organic production insurance has become available, both of which have paved the way for an increase in this market segment.

Organic production of peas, lentils, or chickpeas for seed harvest begins with careful selection of fields for production based on presence of weeds, diseases, and insects. Pulses, especially peas, are also used in organic production systems as cover crops and forage crops as well as for grain and seed, but pest management requirements are generally less critical for cover and forage uses than with pulses grown for seed. The pest management problems of organically produced crops mirror those of conventional production. Efforts to develop disease- and insect-resistant varieties for conventional production have been, and will continue to be, key to the success of organic production. A non-GMO inoculant is applied when planting into soils that do not have a history of pea, lentil, or chickpea production.

Disease Management

Fields that do not have a history of recent pulse production are selected to reduce the incidence of pulse diseases. In addition, varieties that are resistant to the most prevalent diseases are selected wherever possible. Disease-free seed with high vigor is critical to chickpea production. Burial or destruction of pulse crop residue and long rotational intervals between pulse crops may be used as part of a disease-reduction strategy.

Insect Management

To avoid planting into high populations of wireworm, potential production fields may be bioassayed for wireworms before planting. Non-crop border habitat and refuge areas may be maintained to enhance populations of aphid natural enemies. Supplemental releases of aphid predators or parasitoids may be necessary in peas, and Lygus parasitoids may be present in lentils. In peas, planting is sometimes delayed until after conventional crops in the area have emerged to reduce pea leaf weevil infestation. To combat pea seed weevil, border and refuge areas may be seeded to a trap crop of Austrian Winter Pea or another purple-flowered pea variety a week or two before seeding the organic pea crop.

Weed Management

Since available pulse varieties are generally poor competitors, fields with historically high populations of weeds are avoided. Unless planted in rows, fields are seeded and then cross-seeded at a combined rate of 180-200 lbs. per acre. Planting is often delayed to allow additional clean cultivation before planting. Post-emergence harrowing, especially with a rotary hoe, may also be used. Rotary hoeing may be done more than once and can be quite effective in managing small weed seedlings during the first three weeks following planting. Depending on variety and growth habit, harrowing is only practical for a short time after crop emergence because it can damage the crop.
Crop Stages in Brief

This section summarizes the general activities and production considerations in pulse crops at each crop stage. Activities and considerations specific to management of weeds, diseases, insects, nematodes, and vertebrate pests are discussed in the section devoted to that pest under Pulse Pests and Management Options, following this section.

Pre-Plant
Pulses are often grown in rotation with other crops. As rotation partners, pulses offer several agronomic and economic advantages. Cereal crop yields often increase when planted after legumes because cereal pest cycles have been disrupted. Legume crops enable use of different herbicides than the cereal crops to clean up grassy weeds. Legumes conserve soil moisture and limit soil erosion by offering an option other than summer fallow. Finally, pulses increase the nitrogen content of the soil.

Field history and crop rotation are important pest management considerations in pulse production, particularly with respect to weeds. The decision to grow pulses in a given field is typically made one to three years in advance to allow for proper site preparation, rotation partner selection, and plant-back considerations. Weed control is critical in pulses because they are slow to establish, produce limited vegetative growth, and do not compete strongly with weeds. A carefully considered crop rotation scheme, which may include chemical fallow, can help decrease weed populations. Grass weeds are easier than broadleaf weeds to manage in pulses, therefore pulse growers tend to avoid fields with a history of broadleaf perennial weed problems.

Many herbicides used in small-grain production may persist in the soil, resulting in pulse crop injury and yield loss. Rotational intervals depend in part upon how long herbicides remain in the soil. Factors that affect herbicide persistence include soil pH, moisture, temperature, texture, and organic matter. In areas with a dry climate and short growing season, herbicides generally degrade slower than in warmer, moister areas. Sulfonylurea herbicides persist longer in higher pH soils. When soil pH exceeds 7.5 to 7.9, sulfonylurea residues may remain in the soil much longer than described on the label. Under such conditions, a field bioassay is required the year before seeding pulses.

Pulses are best grown following a cereal rather than a crop that can harbor pulse diseases such as botrytis, powdery mildew, aphanomyces root rot, and fusarium root rot caused by species specific to pulses. Pulse crops are susceptible to diseases that can overwinter in the soil and in stubble. These considerations are important in management of weeds and diseases and in minimizing residual herbicide injury to the crop.

Planting
Variety selection at planting is critical to the success of the crop. It is imperative that varieties with general adaptation to the region be identified as well as varieties that best counter the stresses in a given field. End uses and markets need to be considered as some varieties fit very specific market niches. As new varieties are developed, testing programs to assure their performance in each region will be needed.
Lentils, dry peas, and desi chickpeas are cool-season crops that can be seeded early into cool soils (40°F); kabuli chickpeas require warmer soils (46-50°F). The rate at which the soil warms affects early crop vigor, which in turn affects the plants’ tolerance of weeds and diseases.

Pulse crops can be planted under conventional, minimum-till, or no-till production systems. Direct seeding techniques and low-till and no-till techniques can be very effective for pulse production. Extended rotations are especially important in direct seeding systems to reduce the spread of disease from intact residues on the soil surface and to allow for a slower breakdown of residual herbicides. Pulse crops generally follow winter wheat or spring barley. Cereal stubble that is plowed or chiseled in the fall is cultivated for weed control and herbicide incorporation, then harrowed and rolled. (Pulse beds are also rolled after planting, which is discussed in the “Preemergence” section below.) Growers try to avoid excessive tillage in the spring to prevent drying out the seedbed.

Most pulse seeds can emerge from deep seeding depths due to their large size. However, deep seeding is not required, provided that the seed is accurately placed in firm, moist soil. Seeding depth is also determined by herbicide incorporation depth. In direct-seeding systems, the seed is placed at a shallower depth than systems utilizing pre-tilled soils, as soil moisture is usually much higher in untilled soils.

Direct seeding and low-till and no-till methods have distinct advantages. Mulch from surface residue changes surface ecology. The soil aeration changes, which in turn facilitates water pass-through and favors certain organisms. The resulting improved soil tends to promote plant health, and healthy plants are better able to resist pest pressure. There are, however, a few drawbacks to direct seeding and low-till/no-till techniques. Pulse crops grown under these systems have a greater reliance on non-selective herbicides such as glyphosate (Roundup Ultra). Low-till and no-till systems limit the ability to incorporate pesticides, which is required with some herbicides. Also, the untilled residues remaining on the soil surface from the previous crop may tie up residual herbicides, rendering them ineffective.

**Preemergence**

After planting, pulse crop beds are rolled to smooth the soil surface. This field operation improves the harvesting of low-hanging pulse pods by reducing harvest losses and breakage of sickle section and guards, and improves harvest rate. Rolling is done anytime from immediately after seeding up to the 5- to 7-node stage in lentils and up to the 5-leaf stage in peas. Chickpea beds are rolled prior to emergence only.

**Emergence to Harvest**

Pulse crops have a low growth habit and low pod set. This affects the practicality of mid- to late-season mechanical weed control and often necessitates specialized attachments for combine headers to allow mechanical harvest. Some lentils and dry peas are swathed or desiccated prior to harvest due to uneven maturity or weed infestation, an operation that also requires specialized combine attachments. Chickpeas may be swathed prior to harvest, but this is less common. Fields are inspected prior to harvest for variety characteristics and certifiability of seed.
Harvest
Harvest of pulse crops takes place once the crop has matured and dried out to a certain moisture level. Harvest date depends upon crop and region (see Activity Tables, Appendix A). Drying usually occurs naturally, but desiccant herbicides may be used in years with warm, wet springs and cool, wet summers that promote luxuriant plant growth. Under such conditions the crop will continue to flower and set pods and weeds will continue to grow as long as moisture is available. If growers wait for natural dry down to occur under such high-moisture conditions, they risk pod shattering, sprouting, seed coat slough, and seed bleaching. Sometimes application of desiccants is limited to “green spots” within a field.

In years when weeds are less threatening, dry peas and lentils are mechanically swathed or direct combined. Timely harvest of dry peas and lentils is critical to avoid post-maturity disease.

Post-Harvest, Shipping and Storage
Even though peas and chickpeas produce a limited amount of crop residue, they develop one of the best seedbeds for subsequent crops with direct-seed cropping systems. The high nitrogen to carbon ratio of pulses provides a nitrogen benefit to non-legume crops in the system and reduces the need for nitrogen fertilizer application.

Following removal of the crop, typical operations include: sampling for certified seed, applying perennial weed controls, heavy harrowing to manage residue (in some regions), fertilization for the next season’s crop, and pre-plant chemical application and incorporation for the next crop.

After the crop leaves the field, it is stored (warehoused) and monitored. Seed moisture must be carefully controlled (typically in the range of 12 to 14%) to prevent storage molds, spoilage, heat damage, insect damage, and unintentional germination. Moisture is tested several times during the first few weeks of storage to maintain proper levels and to prevent seed sweating. If moisture levels are too high, bin aeration may be employed. Aeration cools and dries the seed to forestall storage problems. It is important to make sure the fan size is appropriate to the bin size and the crop. Grain dryers are sometimes used on chickpea, but they must be used with extreme caution because they may cause mechanical and thermal damage to the crop.
## Crop Stages and Pest Occurrence – Spring-Planted Pulses

<table>
<thead>
<tr>
<th>Phenological Stage</th>
<th>Pest Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Plant</td>
<td>4-6 mo. before planting</td>
</tr>
<tr>
<td>Planting</td>
<td>March-June depending on crop and region</td>
</tr>
<tr>
<td>Pre-Emergence</td>
<td>April-May-June</td>
</tr>
<tr>
<td>Pre-Bloom</td>
<td>Approx. May-June</td>
</tr>
<tr>
<td>Bloom to Pre-Harvest</td>
<td>Approx. July-August</td>
</tr>
<tr>
<td>Harvest</td>
<td>August-September</td>
</tr>
<tr>
<td>Post-Harvest, Shipping and Storage</td>
<td></td>
</tr>
</tbody>
</table>

### Alternaria blight (Alternaria spp.)
- Pre-Bloom

### Anthracnose (Colletotrichum truncatum species complex)
- X

### Ascochyta blight (Didymella and Pevronella spp.)
- X

### Bacterial blight (Pseudomonas syringae, Xanthomonas campestris)
- X

### Botrytis gray mold (Botrytis spp.)
- X

### Fusarium and verticillium wilt (Fusarium oxysporum and Verticillium spp.)
- X

### Common molds (Penicillium and Aspergillus spp.)
- X

### Powdery mildew (Erysiphe spp.)
- X

### Root rots / damping off (Aphanomyces euteiches, Fusarium spp., Rhizoctonia solani, Pythium spp.)
- X

### Seed-borne diseases (Ascochyta, Botrytis)
- X

### Seed rots (Fusarium, Pythium, Rhizoctonia)
- X

### Septoria blight (Septoria spp.)
- X

### Stemphylium blight (Stemphylium botryosum, S. sarcinforme)
- X

### Virus diseases
- X

### White mold (Sclerotinia spp.)
- X

### Aphids
- X

### Armyworm
- X

### Cutworms
- X

### Grasshoppers
- X

### Lygus bugs
- X

### Pea leaf weevil
- X

### Pea weevil
- X

### Seed corn maggots
- X

### Wireworm
- X

### Weeds
- X

### Birds
- X

### Rodents
- X

### Deer, elk, pronghorn
- X
## Crop Stages and Pest Occurrence – Fall-Planted Pulses

<table>
<thead>
<tr>
<th>Pre-Plant</th>
<th>Planting</th>
<th>Pre-Emergence</th>
<th>Pre-Bloom</th>
<th>Bloom to Pre-Harvest</th>
<th>Harvest</th>
<th>Post-Harvest, Shipping, and Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-4 mo. before planting</td>
<td>August-October, depending upon crop and region</td>
<td>August-October</td>
<td>Approx. February-May</td>
<td>Approx. April-June</td>
<td>June-July-August</td>
<td></td>
</tr>
</tbody>
</table>

### Pest Occurrence

- **Alternaria blight** (*Alternaria spp.*)
- **Anthracnose** (*Colletotrichum truncatum* species complex)
- **Ascochyta blight** (*Didymella* and *Peyronella* spp.)
- **Bacterial blight** (*Pseudomonas syringae*, *Xanthomonas campestris*)
- **Botrytis gray mold** (*Botrytis spp.*)
- **Fusarium and verticillium wilt** (*Fusarium oxysporium* and *Verticillium* spp.)
- **Common molds** (*Penicillium* and *Aspergillus* spp.)
- **Powdery mildew** (*Erysiphe spp.*)
- **Root rots / damping off** (*Aphanomyces euteiches*, *Fusarium* spp., *Rhizoctonia solani*, *Pythium* spp.)
- **Seed-borne diseases** (*Ascochyta*, *Botrytis*)
- **Seed rots** (*Fusarium*, *Pythium*, *Rhizoctonia*)
- **Septoria blight** (*Septoria* spp.)
- **Stemphylium blight** (*Stemphylium botryosum*, *S. sarciniforme*)
- **Virus diseases**
- **White mold** (*Sclerotinia* spp.)
- **Aphids**
- **Armyworm**
- **Cutworms**
- **Grasshoppers**
- **Lygus bugs**
- **Pea leaf weevil**
- **Pea weevil**
- **Seed corn maggots**
- **Wireworm**
- **Weeds**
- **Birds**
- **Rodents**
- **Deer, elk, pronghorn**

### Crop Stages

- **Pre-Plant**
- **Planting**
- **Pre-Emergence**
- **Pre-Bloom**
- **Bloom to Pre-Harvest**
- **Harvest**
- **Post-Harvest, Shipping, and Storage**
Pulse Pests and Management Options

DISEASES
Chickpeas, lentils, and dry peas are infected by a number of fungal, bacterial, and viral pathogens that can cause seed, pod, seedling, and root diseases. These diseases may result in reduced germination, stand, yield, and quality. In this section, we will discuss diseases common to pulse crops in the United States. Diseases are listed in alphabetical order, along with the chemical, biological, and cultural methods available to manage each.

Disease management begins with field selection and an appropriate rotation scheme. Rotating pulse planting with cereals helps reduce the level of seed-, soil-, and residue-borne pathogens. However, rotation with non-host crops will not eliminate seed and root rot disease since these pathogens remain viable in the soil for several years and can infect other crops. Growers in the High Plains and Northern Plains typically plant the same type of pulse crop only once every four years to allow residues to decompose and pathogen numbers to fall off. In the Pacific Northwest, growers tend to replant the same crop sooner, typically every two or three years.

Cultivar selection is the next line of defense. Pulse growers select vigorous cultivars that are best suited to their climatic region and have the highest level of disease resistance available.

Planting pathogen-free seeds helps prevent introduction of pathogens into fields where they are absent and helps forestall increases in inoculum levels in fields where pathogens are present.

Residue-management practices such as straw chopping, burial, or burning are utilized in some instances to aid in disease management.

A typical integrated pest management program for diseases in pulses includes use of chemical controls along with cultural practices. Chemical controls for diseases in pulse crops fall under two categories: seed treatments and foliar treatments. Registered chemical controls are listed for each disease, in alphabetical order by active ingredient(s), followed by one or more common trade names in parenthesis to aid in identification. Where available, the group code assigned by the Fungicide Resistance Action Committee (FRAC, http://www.frac.info) is provided. FRAC codes are based on modes of action. Generally speaking, repeated use of fungicides with the same FRAC code has the potential to promote resistance and is avoided by growers.

Information in this section is derived in part from the Montana State University publication Diseases of Cool Season Legumes (Pulse Crops: Dry Pea, Lentil and Chickpea) and from tables developed by the North Central Integrated Pest Management Center Pulse Crop Working Group.

Alternaria Blight
This foliar disease is caused by Alternaria spp., a fungal pathogen with a very wide host range. Temperatures of 75 to 82°F and relative humidity >85% favor the disease, which results in lesions on plant tissue and can cause leaflet drop. Research is ongoing to determine the pathogenicity of Alternaria spp. found associated with pulse crop seed and what environmental factors favor disease development. High levels of Alternaria blight are commonly associated with pea seed.
Alternaria blight is highly prevalent in Northern Plains, but its overall crop impact is unknown. It is uncommon in the Pacific Northwest and considered a minor pest in that region. Prevalence in High Plains is unknown.

**Chemical Controls:** Seed treatments can protect seedlings for up to 40 days after planting and foliar sprays are also available. Controls listed are registered on all three pulses unless otherwise noted. There are no known controls approved for use in organic systems.

**Seed Treatments**
- Azoxystrobin (Dynasty, FRAC 11), a quinone outside inhibitor available for lentils and chickpeas.
- Captan (Captan 4L, FRAC M4), a phthalimide available on dry pea.
- Fludioxonil (Maxim 4FS, FRAC 12), a phenylpyrrole.
- Ipconazole (Rancona 3.8 FS, FRAC 3), a triazole treatment.
- Ipconazole + metalaxyl (Rancona Summit, FRAC 3 and 4).
- Prothioconazole + penflufen + metalaxyl (EverGol Energy, FRAC 3, 7, and 4).
- Thiram (42-S Thiram, FRAC M3), a dithiocarbamate treatment.
- Trifloxystrobin + metalaxyl (Trilex 2000, FRAC 11 and 4).
- Toclofos-methyl (Rizolex), an aromatic hydrocarbon (FRAC 14, proposed).

**Foliar Treatments**
- Azoxystrobin (Quadris Flowable, FRAC M3), a quinone outside inhibitor.
- Azoxystrobin + chlorothalonil (Quadris Opti, FRAC 11 and M).
- Azoxystrobin + difenoconazole (Quadris Top, FRAC 11 and 3).
- Azoxystrobin + propiconazole (Quilt, FRAC 11 and 3).
- Difenoconazole + benzonidiflupyr (Aprovia Top, FRAC 3 and 7).
- Fluxapyroxad + pyraclostrobin (Priaxor, FRAC 7 and 11).
- Penthiopyrad (Vertisan, FRAC 7), a succinate dehydrogenase inhibitor.
- Picoxystrobin (Aproach, FRAC 11), a quinone outside inhibitor.
- Pyraclostrobin (Headline SC, FRAC 11), a quinone outside inhibitor.

**Biological Controls:** None.

**Cultural Controls:** Use of clean seed, decreased planting density, and reduced irrigation can help manage this disease.

**Critical Needs for Alternaria Blight Management in Pulses:**

**Research:**
- Discern availability of resistant cultivars.
- Determine relative aggressiveness of the pathogens.
- Identify species.
- Research and understand host range.
- Study disease cycle.
- Ascertain environmental conditions that favor this disease.
PESTS & MANAGEMENT OPTIONS: DISEASES

- Develop disease models.
- Determine an economic threshold.
- Develop efficacy data for chemical, biological, and cultural controls.
- Identify the significance of seed-borne Alternaria blight and compare and understand seed vs. foliar Alternaria blight.

**Regulatory:** None.

**Education:** Create and distribute a table with control information including crops to grow in rotation.

**Anthracnose**
This foliar disease is caused by *Colletotrichum destructivum* species complex in lentil and chickpea. Anthracnose is an important disease of lentils in some production regions but is not considered a disease of economic importance in field peas. The disease causes leaf lesions, girdling of stems, lodging, premature plant mortality, and seed shriveling and discoloration. *Colletotrichum* spp. are favored by temperatures of 68 to 75°F and 24 hours of leaf wetness. Where it occurs, Anthracnose can be a very serious disease. It can be severe in the Northern and High Plains, but is a relatively minor pest in the Pacific Northwest.

**Chemical Controls:** The following foliar fungicides are registered. They are applied at canopy closure or first sign of the disease. Multiple applications may be needed.
- Azoxytrobin (Quadris Flowable, FRAC 11), a quinone outside inhibitor.
- Azoxytrobin + chlorothalonil (Quadris Opti, FRAC 11 and M).
- Azoxytrobin + propiconazole (Quilt, FRAC 11 and 3).
- Difenoconazole + benzovindiflupyr (Aprovia Top, FRAC 3 and 7).
- Fluxapyroxad + pyraclostrobin (Priaxor, FRAC 7 and 11).
- Penthiopyrad (Vertisan, FRAC 7).
- Picoxytrobin (Aproach, FRAC 11).
- Pyraclostrobin (Headline SC, FRAC 11), a quinone outside inhibitor.
- Thiophanate-methyl (Topsin 4.5FL, FRAC 1), a methyl benzimidazole carbamate.

**Biological Controls:** None.

**Cultural Controls:** Use of clean seed helps limit introduction of this disease, as do crop rotation (choice of rotation partners and length of rotations), use of resistant varieties, and tillage to reduce residue.

**Critical Needs for Anthracnose Management in Pulses:**

**Research:**
- Discern species diversity and aggressiveness within the *C. destructivum* complex.
- Rigorously assess seed-to-seedling transmissibility of pathogen and develop seed thresholds.
• Conduct fungicide efficacy trials.
• Develop resistant varieties.
• Develop disease models.
• Study epidemiology and develop degree-day models.
• Lack of regional epidemiologist limits research capacity.

Regulatory: Fluazinam (Omega) in IR-4 pipeline.

Education: Symptom discernment.

Aphanomyces Root Rot
Caused by the oomycete pathogen *Aphanomyces euteiches*, this is one of the four major root rots in pulse crops. Infection can occur before or after the plant emerges, including in older, established plants if the soil remains cool and moist. Symptoms include stunted, yellow plants with caramel-colored, infected roots. Highly prevalent in the PNW, emerging in the Northern Plains, and status has not been determined in the High Plains.

Chemical Controls: None.

Biological Controls: None.

Cultural Controls: Crop rotation can be useful in managing Aphanomyces root rot if a low level of the pathogen is present. Lentil, pea, and alfalfa are the most important hosts within the pulse-growing regions; faba, dry edible bean, and snap bean are also hosts that may play a minor role. Rotation with chickpea can help, because it is a poor host. Cultural options are limited or non-existent once pathogen levels build to a destructive level. The pathogen’s oospores can survive in the soil up to 20 years.

Critical Needs for Aphanomyces Root Rot Management in Pulses:

Research:
• Ethaboxam (Intego Solo) is a thiazolecarboxamide (FRAC U5) seed treatment available in lentils and chickpeas, but its efficacy against *Aphanomyces spp.* is unknown and needs to be investigated.
• Anecdotal evidence from Canada indicates that faba bean is a good rotation partner for limiting this disease, but this needs to be investigated, as conflicting observation indicates that this crop is a host.
• Determine whether length of rotation has an impact in limiting the disease.
• Discern resistant varieties via marker-assisted selection.
• Develop a detection method such as a quantitative soil bioassay.
• Discern diversity of the pathogen.
• Develop disease model.
• Test the compounds, including biologicals and herbicides, including dinitroanilines, used in potato late blight (or other oomycete diseases) to determine efficacy.
• Investigate cover crops such as oats and mustards as rotation partners or green manures.
- Identify the rotational interval out of lentils and field peas that is needed to maintain profitable lentil and field pea production in regions where Aphanomyces root rot is a concern.
- Quantify the relationship between crop residue levels and Aphanomyces root rot.

**Regulatory:** None.

**Education:**
- Diagnosis and management.
- Extend results of research to growers and other stakeholders.

**Ascochyta Blight**
This foliar disease is caused by several *Didymella* and *Peyronellaea* species that are host-specific. Former genus names include Ascochyta, Mycosphaerella, and Phoma (see table below for current taxonomy). Ascochyta blight is present and considered a major disease in all three growing regions. It is more damaging in cool, wet years. All pulse crops are susceptible, with chickpea incurring the most damage. Pardina lentil varieties are also relatively susceptible. In chickpea, the causal fungus is *D. rabiei*. The causal pathogen in lentil is *D. lentis*. Dry pea can be infected by *P. pinodes*, *P. pinodella*, and *D. pisi*, with *P. pinodes* being the most damaging pathogen. *D. pisi* is predominant in Montana but *P. pinodes* and *P. pinodella* have been identified in northeastern Montana.

<table>
<thead>
<tr>
<th>Host plant</th>
<th>Causal fungal species current name</th>
<th>Synonyms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chickpea</td>
<td><em>Didymella rabiei</em></td>
<td>Ascochyta rabiei</td>
</tr>
<tr>
<td>Lentil</td>
<td><em>Didymella lentis</em></td>
<td>Ascochyta lentis</td>
</tr>
<tr>
<td>Pea</td>
<td><em>Didymella pisi</em></td>
<td>Ascochyta pisi</td>
</tr>
<tr>
<td></td>
<td><em>Peyronellaea pinodes</em></td>
<td>Ascochyta pinodes, Mycosphaerella pinodes (sexual stage)</td>
</tr>
<tr>
<td></td>
<td><em>Peyronellaea pinodella</em></td>
<td>Ascochyta pinodella, Phoma pinodella</td>
</tr>
</tbody>
</table>

Ascochyta blight produces lesions that, under severe infection, can coalesce and lead to defoliation, stem breakage, and lodging.

These blights present even greater issues in organic production because no organically approved seed or foliar treatments are available.

**Chemical Controls:** The following seed and foliar treatments are available in all three pulses unless otherwise noted. Foliar treatment depends on crop, variety, time of infection, percent of plants infected, and amount of tissue impacted. If used, foliar fungicides are applied at bloom initiation or canopy closure, or when the first symptoms are seen. Additional applications may be necessary, and growers attempt to rotate FRAC Codes to manage resistance.
**Seed Treatments**

While registered, efficacy of these treatments is questionable.

- Fludioxonil + mefenoxam (Apron MAXX RTA, FRAC 12 and 4).
- Fluxapyroxad (Systiva XS, FRAC 7), a succinate dehydrogenase inhibitor, registered for suppression only.
- Ipconazole + metalaxyl (Rancona Summit, FRAC 3 and 4).
- Prothioconazole + penflufen + metalaxyl (EverGol Energy, FRAC 3, 7, and 4), registered for suppression only.
- Pyraclostrobin (Stamina, FRAC 11), a quinone outside inhibitor, registered for suppression only. Not recommended on chickpea.
- Pyraclostrobin + fluxapyroxad + metalaxyl (Obvious, FRAC 11, 7, and 4) has demonstrated efficacy against some of the causal pathogens, but its effectiveness may be reduced in areas with fungal populations that are resistant to strobilurin fungicides.
- Sedaxane + mefenoxam + fludioxonil (Vibrance Maxx, FRAC 7, 4, and 12).
- Thiabendazole (Mertect 340-F, FRAC 1), a benzimidazole carbamate treatment.
- Fludioxonil + mefenoxam (Apron Maxx RTA, FRAC 12 and 4) has recently received approval for use in some growing regions.

**Foliar Treatments**

- Azoxystrobin (Quadris Flowable, FRAC 11), a quinone outside inhibitor, exhibits efficacy against Ascochyta blight where fungicide resistant strains are not present. There is a known risk of resistance in chickpea in the Northern Plains and a few fungicide-resistant dry pea isolates have been found.
- Azoxystrobin + chlorothalonil (Quadris Opti, FRAC 11 and M) is available in chickpea.
- Azoxystrobin + difenoconazole (Quadris Top, FRAC 11 and 3).
- Azoxystrobin + propiconazole (Quilt, FRAC 11 and 3) is available in chickpea.
- Boscalid (Endura, FRAC 7), a succinate dehydrogenase inhibitor.
- Chlorothalonil (Bravo WeatherStik and others, FRAC M), a multi-site inhibitor available for use in chickpea and lentil.
- Difenoconazole + benzovindiflupyr (Aprovia Top, FRAC 3 and 7).
- Fluopyram + prothioconazole (ProPulse, FRAC 7 and 3), available in lentils and chickpeas.
- Fluxapyroxad + pyraclostrobin (Priaxor, FRAC 7 and 11).
- Penthiopyrad (Vertisan, FRAC 7), a succinate dehydrogenase inhibitor.
- Picoxystrobin (Aproach, FRAC 11), a quinone outside inhibitor. Like azoxystrobin, it exhibits efficacy against Ascochyta blight where fungicide resistant strains are not present.
- Prothioconazole (Proline, FRAC 3), a demethylation inhibitor.
- Pyraclostrobin (Headline SC, FRAC 11), a quinone outside inhibitor. Like azoxystrobin and picoxystrobin, it exhibits efficacy against Ascochyta blight where fungicide resistant strains are not present.

**Biological Controls:** None.
**Cultural Controls:** As Ascochyta blight is primarily a residue-borne disease, a rotation of two, three or more years between the same legume crop can allow for residue decomposition and help manage the proliferation of the disease. Tillage can also hasten residue decomposition. Growers in the Pacific Northwest delay planting of chickpeas in the spring to avoid Ascochyta blight.

The disease can also be seed-borne. Laboratory analysis of seed can detect the pathogen. Chickpea growers seek zero percent of the fungus in seed; pea and lentil growers can tolerate a low rate (<5%).

Dry pea and lentil cultivars vary in their tolerance to Ascochyta blight. Some chickpea and lentil cultivars with partial resistance to Ascochyta blight are available and breeding efforts are underway to identify improved resistance.

**Critical Needs for Ascochyta Blight Management in Pulses:**

**Research:**
- Develop disease modeling; expand on existing Pacific Northwest efforts in chickpea to include other regions.
- Rigorously evaluate the capability of long-distance atmospheric movement of ascospores produced on overwintered chickpea and field pea residues.
- Discern susceptibility among varieties.
- Conduct fungicide efficacy trials.
- Determine economic thresholds.
- Discern pathogen species diversity and aggressiveness.
- Investigate intercropping (such as flax and chickpea) for disease management.
- Develop and validate rapid detection methods.
- Study fungicide resistance and develop management strategies.
- Develop seed and foliar treatments compatible with organic systems.

**Regulatory:** Obtain expanded registration of fluazinam (Omega) on chickpeas, field peas, and lentils.

**Education:**
- Make modeling tools available to growers.
- Disseminate fungicide resistance information.
- Educate growers on variety susceptibility.

**Bacterial Blight**
This foliar disease is caused by *Pseudomonas syringae pv. pisi* (and likely other pathogens such as *Pseudomonas syringae pv. syringae*) in pea and *Xanthomonas campestris pv. cassiae* in chickpea. It is very widespread in pea and also occurs frequently in chickpea and lentil and is increasing in importance. It typically only occurs following hail or other mechanical damage. Plants often recover but recovery varies depending on variety and on the timing and severity of the infection.
Bacterial blight occurs routinely in the Northern Plains, where it is a very common early-season disease. This disease can result in complete crop loss in some years. If it occurs early enough and the crop dries out, it can recover, but does not always. The disease is less common in the Pacific Northwest, primarily due to lack of severe hailstorms and lower humidity than the other regions.

Little is known in current organic systems, but bacterial blight is likely to become a major pest as acreage increases. Planting later, when environmental conditions are less favorable, can help discourage disease establishment.

**Chemical Controls:** Copper is used by some growers, but there are no efficacy data. Seed treatment of 1% hypochlorite is available.

**Biological Controls:** None.

**Cultural Controls:** Use of clean seed and crop rotation aids in management of bacterial blight. Tillage can hasten stubble degradation. Some resistance has been noted in green pea to some strains of bacterial blight, but sources of resistance have not been identified in dry pea.

**Critical Needs for Bacterial Blight Management in Pulses:**

**Research:**
- Explore cultivar susceptibility and resistance.
- Identify products that manage foliar infections.
- Develop thresholds for acceptable levels of seed-borne *Pseudomonas syringae* pv. *pisi* and other causal pathogens in field peas.
- Assess the efficacy of seed treatment with streptomycin sulfate for management of seed-to-seedling transmission of *P. syringae* pv. *pisi* and other implicated pathogens in field peas.
- Research relationship between bacterial blight and late-season fungal diseases and physical damage.
- Determine whether other bacterial pathogens are associated with bacterial blight-like symptoms.

**Regulatory:** If field trials demonstrate efficacy against seed-to-seedling transmission of *P. syringae* pv. *pisi* and/or *Pseudomonas syringae* pv. *syringae* or other pathogens in field peas, obtain registration of streptomycin sulfate on field peas.

**Education:** Educate growers on discriminating between Ascochyta blight and bacterial blight.
Damping Off
Damping off is a term used to describe collapse and death of young pulse seedlings. It can be caused by several different pathogens including *Pythium, Fusarium, Rhizoctonia*, and *Aphanomyces* spp., many of which are usually favored by excessive soil moisture. Poor emergence is often the first sign of damping off. The infection event can occur before or after emergence, however. Severe infection can lead to plant death. Damping off occurs in all pulses and in all growing regions. Organic growers utilize the cultural controls listed below to help manage damping off.

**Chemical Controls:** Seed treatments are available to manage the causal pathogens.
- Ethaboxam (IntegoSolo, FRAC U5), registered for use on lentils, chickpeas, and fresh-market peas but not dry peas, has efficacy against *Pythium* spp. and possibly *Aphanomyces euteiches*.
- Fludioxonil + mefenoxam (Apron MAXX RTA, FRAC 12 and 4), a mixed-mode-of-action treatment with efficacy on *Fusarium, Pythium*, and *Rhizoctonia* spp. that also provides some suppression of *Sclerotinia* spp.
- Ipconazole + metalaxyl (Rancona Summit, FRAC 3 and 4), a mixed-mode-of-action treatment with efficacy on the four listed causal pathogens.
- Prothioconazole + penflufen + metalaxyl (EverGol Energy, FRAC 3, 7, and 4), a mixed-mode-of-action treatment with efficacy on the four listed causal pathogens.
- Pyraclostrobin + fluxapyroxad + metalaxyl (Obvious, FRAC 11, 7, and 4), a mixed-mode-of-action treatment with efficacy on the four listed causal pathogens.
- Sedaxane + mefenoxam + fludioxonil (Vibrance Maxx, FRAC 7, 4, and 12), a mixed-mode-of-action treatment with efficacy on the four listed causal pathogens.

**Biological Controls:** *Bacillus* and *Trichodema* products are registered biocontrols but their efficacy is questionable under cool soil temperatures commonly associated with pulse crops.

**Cultural Controls:** Selection of high quality seed aids in management of damping off. Water management, increased seeding rate, shallow planting depth, avoiding soil compaction, selection of planting date (delaying for optimal temperature), and noting electrical conductivity (EC) values of seed – an indicator of seed vigor – can aid in management.

**Critical Needs for Damping Off Management in Pulses:**

**Research:** Refer to individual causal pathogens.

**Regulatory:** Expedite ethaboxam (Intego) full registration for dry pea.

**Education:** Establish importance of pulse seed EC levels associated with plant vigor and avoidance of damping off.
Fusarium Root Rot
Fusarium root rot is a major and ubiquitous problem across all growing regions. Caused by a number of different *Fusarium* species, this is one of the four major root rots in pulse crops. Favoring cool, wet springs followed by drought, fluctuating water conditions, and high soil nitrogen levels, the symptoms include reddish-brown to brown or black roots and lack of secondary roots.

Chemical Controls: The following seed treatments are registered for management of Fusarium root rot.
- Fludioxonil + mefenoxam (Apron MAXX RTA, FRAC 12 and 4).
- Fluxapyroxad (Systiva XS, FRAC 7), a succinate dehydrogenase inhibitor.
- Ipconazole (Rancona 3.8 FS, FRAC 3), a triazole treatment.
- Ipconazole + metalaxyl (Rancona Summit, FRAC 3 and 4).
- Prothioconazole + penflufen + metalaxyl (EverGol Energy, FRAC 3, 7, and 4).
- Pyraclostrobin + fluxapyroxad + metalaxyl (Obvious, FRAC 11, 7, and 4).
- Sedaxane + mefenoxam + fludioxonil (Vibrance Maxx, FRAC 7, 4, and 12).
- Trifloxystrobin (Trilex Flowable, FRAC 11), a quinone outside inhibitor.
- Trifloxystrobin + metalaxyl (Trilex 2000, FRAC 11 and 4).
- Toclofos-methyl (Rizolex, FRAC 14, proposed), an aromatic hydrocarbon.
- Thiabendazole (Mertect 340-F, FRAC 1), a benzimidazole carbamate treatment.

Biological Controls: None.

Cultural Controls: As with the other root rot pathogens, *Fusarium* spp. are very common in soil and have a broad host range, so crop rotation is of little use in managing Fusarium root rot. Some *Fusarium* spp. are more damaging than others, however. (For example, *F. graminearum*, which causes root and crown rot in wheat, does not infect pea very well. *F. redolens*, which is decimating to peas, can be found on wheat at low levels causing root rot, but is not a major pathogen of wheat.) Understanding the species present can assist in rotation decisions.

Critical Needs for Fusarium Root Rot Management in Pulses:

Research:
- Discern variety resistance.
- Research species diversity and aggressiveness.
- Efficacy data are lacking for both chemical seed treatments and biological controls.
- Investigate crop rotation role in disease management. Host diversity makes this pathogen difficult to address with rotation.
- Research agronomic practices including seeding density to reduce crop stress.

Regulatory: None.

Education: Identification and management.
**Fusarium Wilt**

Fusarium wilt is a vascular disease caused by *F. oxysporum*, with subspecies being specific to each crop: *F. oxysporum* f. sp. *pisi* on pea, *F. oxysporum* f. sp. *lentis* on lentil, and *F. oxysporum* f. sp. *ciceris* on chickpea.

Relatively warm soil temperatures (74 to 82°F) are optimal for expression of Fusarium wilt symptoms. It is a major issue in peas in the Pacific Northwest; its prevalence in pulses in the Northern Plains and High Plains and in Pacific Northwest lentils and chickpeas has yet to be determined.

**Chemical Controls:** None.

**Biological Controls:** None.

**Cultural Controls:** Since *F. oxysporum* persists for a long time in the soil and can increase in a field each time a susceptible crop is planted, a minimum of four years between crops can help to curtail progress of this disease, but this is impractical for most growers.

Planting resistant cultivars has been successful in managing this pathogen. Most dry pea cultivars are resistant to Race 1 and some cultivars have both Race 1 and Race 2 resistance.

**Critical Needs for Fusarium Wilt Management in Pulses:**

**Research:**
- Identify races on all pulses and characterize the distribution of these races across major production areas.
- Seed treatments should be investigated.
- Chickpea and lentil varieties with resistance should be developed, and varieties resistant to more races should be developed for dry peas.

**Regulatory:** None.

**Education:** Identification and management.

**Gray Mold**

This foliar disease is caused by the fungal pathogen *Botrytis cinerea*. The disease impacts chickpea and lentil, and while it is considered of minor importance on U.S. pulses, it can have serious impacts when flower and pod infection occur. The pathogen can also cause a seedling soft-rot of dry pea and chickpea. It is more prevalent in the Northern Plains than in the Pacific Northwest.

Symptoms begin as water-soaked lesions on stems, branches, leaves, flowers, and pods, which progress to gray/brown lesions that may be fuzzy. Gray mold is favored by temperatures of 68 to 75°F and relative humidity >95%.
Chemical Controls:

Seed Treatments
- Ipconazole (Rancona 3.8 FS, FRAC Code 3), a triazole treatment.
- Ipconazole + metalaxyl (Rancona Summit, FRAC 3 and 4).
- Prothioconazole + penflufen + metalaxyl (EverGol Energy, FRAC 3, 7, and 4).
- Pyraclostrobin + fluxapyroxad + metalaxyl (Obvious, FRAC 11, 7, and 4).
- Sedaxane + mefenoxam + fludioxonil (Vibrance Maxx, FRAC 7, 4, and 12).

Foliar Treatments
- *Bacillus subtilis* strain QST 713 (Serenade ASO, Serenade Opti, FRAC 44), a microbial.
- Boscalid (Endura, FRAC 7), a succinate dehydrogenase inhibitor.
- Cypredinil + fludioxonil (Switch, FRAC 9 and 12).
- Fluazinam (Omega, FRAC 29), is available in chickpeas.
- Penthiopyrad (Vertisan, FRAC 7), a succinate dehydrogenase inhibitor.
- Thiophanate-methyl (Topsin 4.5FL, FRAC 1), a methyl benzimidazole carbamate, available for use on chickpea.

Biological Controls: None.

Cultural Controls: Practices used to manage white mold can be useful in gray mold management. Practices that increase airflow through the canopy discourage gray mold development, including use of erect cultivars, wide seed and row spacing, and orienting rows in the direction of the prevailing wind. Crop rotation with non-hosts such as cereal crops and corn, reducing irrigation, and deep plowing also help manage the disease.

Critical Needs for Gray Mold Management in Pulses:

Research:
- Identify resistant varieties.
- Conduct fungicide efficacy trials for chemical and biological controls.

Regulatory: None.

Education: Identification and management practices.

Powdery Mildew
This foliar infection is caused by a variety of pathogens including *Erysiphe pisi*, *E. trifolii*, and *E. baeumleri*. These pathogens can reside on infected trash, leguminous weeds, or volunteer plants from previous crops. Infected plants are covered with a white powdery mass of spores that can be rubbed off of the leaf. Disease develops at moderate to warm temperatures (70 to 85°F) and is favored by overnight dew, not rain. Powdery mildew can cause the crop to mature unevenly and can create problems at harvest. Desiccants cannot penetrate the fungus and are thus not used.
Early infections with powdery mildew can cause significant yield loss, making this disease a major problem when and where it occurs. It occurs sporadically in spring-planted pulses in the Northern Plains, but generally occurs late enough in the season that it is not economical to control. Many varieties susceptible to powdery mildew grown in the Northern Plains can be difficult to grow elsewhere due to higher humidity and rainfall, which promote disease.

Fall-planted peas experience greater problems with powdery mildew; it is virtually ubiquitous and can delay maturity and present a fire hazard at harvest.

**Chemical Controls:** These foliar fungicides are available in all three pulses unless otherwise noted and can be effective against powdery mildew if applied early in disease development.

- Azoxystrobin (Quadris FL and others, FRAC 11).
- Azoxystrobin + difenconazole (Quadris Top, FRAC 11 and 3).
- *Bacillus subtilis* strain QST 713 (Serenade ASO, FRAC 44), a microbial.
- Fluxapyroxad + pyraclostrobin (Priaxor, FRAC 7 and 11).
- Penthiopyrad (Vertisan, FRAC 7), a succinate dehydrogenase inhibitor.
- Picoxystrobin (Aproach, FRAC 11), a quinone outside inhibitor.
- Pyraclostrobin (Headline SC, FRAC 11), a quinone outside inhibitor.
- Sulfur (Kumulus DF), available for use in dry pea.

**Biological Controls:** None.

**Cultural Controls:** Resistant varieties in dry pea.

**Critical Needs for Powdery Mildew Management in Pulses:**

**Research:**
- Study population genetics for identification and management.
- Assess comparative efficacy of registered fungicides.
- Develop varieties with resistance to new race of pathogen found in wild pea.
- Develop disease forecast models.

**Regulatory:** None.

**Education:**
- Increase exposure to existing diagnostic information such as pulse website.
- Utilize modeling as it becomes available.
- Educate growers on identification and management.

**Pythium Root Rot**
Caused by the oomycete (water mold) *Pythium* spp., this is one of the four major root rots in pulse crops. It is difficult to diagnose but is generally characterized by poor root system development in which the roots turn brown. It can be a major problem in cool, wet springs and can occur throughout the pulse-growing regions of the United States. Metalaxyl-resistant strains of Pythium are known to occur in the Pacific Northwest.
**Chemical Controls:**
The following seed treatments have efficacy against *Pythium* spp. and are available in all three pulses unless otherwise noted.

- Ethaboxam (Intego Solo) is a thiazolecarboxamide (FRAC U5) available in lentils and chickpeas.
- Fludioxonil + mefenoxam (Apron MAXX RTA, FRAC 12 and 4).
- Ipconazole + metalaxyl (Rancona Summit, FRAC 3 and 4).
- Mefenoxam (Apron XL, FRAC 4) is a phenylamide treatment.
- Metalaxyl (Allegiance FL, FRAC 4) is a phenylamide treatment.
- Prothioconazole + penflufen + metalaxyl (EverGol Energy, FRAC 3, 7, and 4).
- Pyraclostrobin + fluxapyroxad + metalaxyl (Obvious, FRAC 11, 7, and 4).
- Sedaxane + mefenoxam + fludioxonil (Vibrance Maxx, FRAC 7, 4, and 12).
- Trifloxystrobin + metalaxyl (Trilex 2000, FRAC 11 and 4).

**Biological Controls:** While products with *Bacillus* spp., *Beauveria bassiana*, and *Trichoderma* spp. are available, their efficacy is questionable.

**Cultural Controls:** *Pythium* spp. are very common in soil and have a broad host range, so crop rotation is of little use in managing Pythium root rot.

**Critical Needs for Pythium Root Rot Management in Pulses:**

**Research:**
- Management for metalaxyl-resistant strains; understand mechanism of resistance.
- Monitor for metalaxyl resistance in the Pacific Northwest and other regions.

**Regulatory:** Obtain a Section 18 registration for ethaboxam (Intego Solo) for dry peas.

**Education:** Identification and management.

**Rhizoctonia Root Rot**
Caused primarily by the fungal pathogen *Rhizoctonia solani*, this is one of the four major root rots of pulse crops. The first sign of Rhizoctonia root rot is poor or declining stands. Root development suffers and roots tend to be brown to black in color. This root rot is very common where volunteer grain and weeds were sprayed with herbicide, particularly glyphosate, within days of planting. The fungus grows quickly in the dying plants and reaches a high population, which then attacks new seedlings. This is called the “green bridge.”

This root rot is present in all pulses and all growing regions. It is not a major problem in the Northern Plains at this writing.

**Chemical Controls:** The following seed treatments have efficacy against *Rhizoctonia* spp. and play a key role in managing this root rot. Unless noted otherwise, the treatment is available in all three pulses.
• Azoxystrobin (Dynasty, FRAC 11), a quinone outside inhibitor, available for lentils and chickpeas.
• Fludioxonil + mefenoxam (Apron MAXX RTA, FRAC 12 and 4), a mixed-mode-of-action treatment available in all three pulses with efficacy on Fusarium, Pythium, and Rhizoctonia spp. that also provides some suppression of Sclerotinia spp.
• Fluxapyroxad (Systiva XS, FRAC 7), a succinate dehydrogenase inhibitor.
• Ipconazole (Rancona 3.8 FS, FRAC 3), a triazole treatment.
• Ipconazole + metalaxyl (Rancona Summit, FRAC 3 and 4).
• Penflufen (Evergol Prime, FRAC 7), a succinate dehydrogenase inhibitor.
• Prothioconazole + penflufen + metalaxyl (EverGol Energy, FRAC 3, 7, and 4).
• Pyraclostrobin + fluxapyroxad + metalaxyl (Obvious, FRAC 11, 7, and 4).
• Sedaxane (Vibrance, FRAC 7), a succinate dehydrogenase inhibitor.
• Sedaxane + mefenoxam + fludioxonil (Vibrance Maxx, FRAC 7, 4, and 12).
• Trifloxystrobin (Trilex Flowable), a quinone outside inhibitor (FRAC 11).
• Trifloxystrobin + metalaxyl (Trilex 2000, FRAC 11 and 4).
• Toclofos-methyl (Rizolex, FRAC 14, proposed), an aromatic hydrocarbon.

**Biological Controls:** None.

**Cultural Controls:** Some growers address the “green bridge” phenomenon by delaying seeding two to three weeks after herbicide application if direct seeding or by seeding two to three weeks after tillage, which allows the tissue of treated plants to decompose.

**Critical Needs for Rhizoctonia Root Rot Management in Pulses:**

**Research:**
- Research green bridge phenomena.
- Variety resistance.
- Species diversity (population genetics) and pathogenicity analysis.
- Determine crop rotation impacts.

**Regulatory:** None.

**Education:** Identification and management.

**Septoria Blight**
This foliar disease of pea is caused by Septoria spp. It is easily confused with Ascochyta blight due to the small black spots that form in the lesions. Lesions are often yellowed and sunken, and can be circular or irregular in shape. A key to diagnosing Septoria blight is the pycnidia do not occur in concentric lesions, as they do with Ascochyta blight. Septoria blight is considered a minor disease in U.S. pulse production.

**Chemical Controls:**
• Azoxystrobin (Quadris Flowable, FRAC 11), a quinone outside inhibitor. There is a known risk of resistance in chickpea in the Northern Plains and a few fungicide-resistant dry pea isolates have been found.
• Azoxystrobin + chlorothalonil (Quadris Opti, FRAC 11 and M 05), available in chickpea.
• Azoxystrobin + difenoconazole (Quadris Top, FRAC 11 and 3).
• Azoxystrobin + propiconazole (Quilt, FRAC 11 and 3), available in chickpea.
• Boscalid (Endura, FRAC 7), a succinate dehydrogenase inhibitor.
• Chlorothalonil (Bravo WeatherStik, FRAC M 05), a multi-site inhibitor available for use in chickpea and lentil.
• Difenoconazole + benzovindiflupyr (Aprovia Top, FRAC 3 and 7).
• Fluopyram + prothioconazole (ProPulse, FRAC 7 and 3), available in lentils and chickpeas.
• Fluxapyroxad + pyraclostrobin (Priaxor, FRAC 7 and 11).
• Metconazole (Quash, FRAC 3), a demethylation inhibitor.
• Pentylopyrad (Vertisan, FRAC 7), a succinate dehydrogenase inhibitor.
• Picoxystrobin (Aproach, FRAC 11), a quinone outside inhibitor.
• Prothioconazole (Proline, FRAC 3), a demethylation inhibitor.
• Pyraclostrobin (Headline SC, FRAC 11), a quinone outside inhibitor.
• Sulfur (Kumulus DF).

Biological Controls: None.

Cultural Controls: The tactics that aid in management of Ascochyta blight also discourage Septoria blight: residue management, crop rotation, use of disease-free seed, and use of resistant cultivars.

Critical Needs for Septoria Blight Management in Pulses:

Research: Monitoring for presence and damage.

Regulatory: None.

Education: Identification and management.

Stemphylium Blight
This foliar disease of chickpea and lentil is caused by the fungal pathogen Stemphylium botryosum on chickpea and lentil, and Stemphylium sarciniforme on chickpea. It is present in Canada and in the Northern Plains and is considered to be a disease of emerging importance.

The pathogen prefers warm (~77°F), moist (85% relative humidity and eight hours of leaf wetness) conditions for disease development. Infected seed has a much lower germination rate.

Chemical Controls: Azoxystrobin (Quadris Flowable, FRAC 11) is registered for use.

Biological Controls: None.
**Cultural Controls:** As the pathogen can be transmitted by residue, soil, seed, wind, and stubble, equipment and personnel sanitation practices help reduce its spread.

**Critical Needs for Stemphylium Blight Management in Pulses:**

**Research:**
- Learn to better identify this disease.
- Monitor for presence and damage.
- Quantify the impact of the disease on seed yield and quality.
- Develop lentil varieties with improved resistance, especially red lentils.
- Assess fungicide efficacy.

**Regulatory:** None.

**Education:** Identification and management.

**Verticillium Wilt**
This vascular disease is caused by *Verticillium dahliae* and *V. albo-atrum*. It is considered of economic importance on chickpea, but *V. dahliae* can also infect lentil and pea. Verticillium wilt is favored by moist conditions and can progress very rapidly, defoliating plants and decreasing yields. Warm, dry weather can halt the progression of the disease. The Verticillium wilt pathogens are present in pulse-growing regions, but the disease is not causing economic symptoms at this time and treatments are not being used. There are no critical needs with respect to Verticillium wilt at this writing, but growers and researchers are monitoring for its presence and impact.

**Chemical Controls:** Not being used.

**Biological Controls:** Not being used.

**Cultural Controls:** Crop rotation with non-hosts like cereals assists in managing this disease. As the pathogens can also survive in the soil and on stubble, sanitation practices help to discourage the spread of Verticillium wilt.

**Viral Diseases**
A number of viruses can infect pulse crops. The symptoms of infection can be subtle and easily confused with other disorders, including nutritional deficiency. A common vector for many of these diseases is the pea aphid (*Acyrthosiphon pisum*); occurrence and severity of viral diseases tend to be greater when aphid populations are high. Among viruses vectored by the pea aphid are *Pea enation mosaic virus* (PEMV), *Bean leafroll virus* (BLRV), *Bean yellow mosaic virus* (BYMV), *Pea streak virus* (PSV), and *Pea seedborne mosaic virus* (PSbMV).
Pea enation mosaic virus is one of the most important and destructive viruses of lentil worldwide. Symptoms may be confused with growth regulator herbicide damage. The cowpea aphid (Aphis craccivora), green peach aphid (Myzus persicae), potato aphid (Macrosiphum euphorbiae), and foxglove aphid (Aulacorthum solani) also vector PEMV. PEMV is seedborne. It is not known whether the virus is seed transmissible.

Bean leafroll virus (also known as Pea leafroll virus) is a luteovirus, which means the aphid must feed for an extended time to acquire and transmit the virus to new plants, so insecticides to control aphids should be effective against this disease. The pea aphid is the principal vector. Other aphids can also transmit the virus. This virus is not seedborne.

Bean yellow mosaic virus is a potyvirus that is transmitted non-persistently by more than 50 aphid species, including the pea aphid. The virus has a wide host range (>200 species) that includes chickpea, field peas, lentils, vetch, lucerne hay, and faba beans. BYMV may cause mottling, bright mosaic, or vein clearing of leaves of infected plants, although the leaves may remain asymptomatic. The virus is seedborne. Planting clean seed can help prevent the spread of BYMV.

Pea streak virus causes severe pod damage and seedling abortion. Many pods may not fill and the surface of the pods contain many small pitted brown streaks or marks. The pods often may have a purplish discoloration. Pea aphid is the principal vector. This virus is not seedborne.

Pea seedborne mosaic virus has the potential to be an important pathogen of pea. The virus is seedborne and seed transmissible, and can also be transmitted by alate aphids that visit, but may not colonize, the pea crop such as Myzus persicae. PSbMV can also be transmitted mechanically, by plants rubbing against each other, and cause stunted clusters of plants in the field. The primary mechanism for eliminating PSbMV is planting clean seed.

Other viruses that have been identified in legume crops include Alfalfa mosaic virus and Cucumber mosaic virus.

Viral diseases are more common in the Pacific Northwest than in the Northern Plains or High Plains.

Chemical Controls: Controlling aphid vectors is the first line of defense in managing viral diseases. See the Insect section of this document for more information.

Biological Controls: None known.

Cultural Controls: Alfalfa is a very good host of the pea aphid, so growers exercise caution when planting near alfalfa.

Critical Needs for Management of Virus Diseases in Pulses:

Research:
- Explore and develop resistant varieties.
• Study and compare vector competency among aphid species and biotypes.
• Study vector lifecycle and population genetics.
• Determine role of alternate hosts including weeds and cultivated legumes like clovers and vetch.
• Study impacts of cropping systems and rotations and their effects on vectors.
• Identify seed-borne and seed-transmitted viruses.
• Look into deep sequencing to identify viruses.
• Develop and validate quick, in-field virus identification methods for growers.
• Conduct commercial insecticide efficacy trials including optimal timing.
• Investigate role of trap crops.
• Refine existing prediction models for infection and spread of viruses.
• Determine seed thresholds for Pea seedborne mosaic virus.
• Determine resistance levels or develop varieties with resistance to Pea seedborne mosaic virus.

Regulatory: None.

Education:
• Identification and management of vectors and virus diseases.
• Disseminate emerging research results.

White Mold
This foliar disease is caused by the fungal pathogens Sclerotinia sclerotiorum, S. trifoliorum, and S. minor, which have very broad host ranges. The fungus can colonize pulse flowers or other parts of the plant such as dying leaves in the lower canopy after canopy closure and plant parts such as stems in contact with the soil. White mold can kill tissue and fill the stem with white hyphae and sclerotia, which then survive in the soil for many years. White mold is more common in fall-planted pulses (dry peas and lentils) than in spring pulses. It also occurs in chickpea, but is less common. Favored by cold, wet conditions after canopy closure, this disease is common in the Northern and High Plains and is also seen in low-lying areas in the Pacific Northwest.

Chemical Controls: The following foliar treatments are registered for white mold control in pulses. The registration, unless stated otherwise, covers all three crops.
• Bacillus subtilis strain QST 713 (Serenade ASO, Serenade Opti, FRAC 44), a microbial.
• Boscalid (Endura, FRAC 7), a succinate dehydrogenase inhibitor.
• Cyprodinil + fludioxonil (Switch, FRAC 9 and 12), available for use in chickpea.
• Fluazinam (Omega, FRAC 29), available in chickpeas.
• Fluopyram + prothioconazole (ProPulse, FRAC 7 and 3).
• Metconazole (Quash, FRAC 3) is a demethylation inhibitor, registered for suppression of white mold (Sclerotinia spp.)
• Penthiopyrad (Vertisan, FRAC 7), a succinate dehydrogenase inhibitor.
• Picoxystrobin (Aproach, FRAC 11), a quinone outside inhibitor.
• Prothioconazole (Proline, FRAC 3), a demethylation inhibitor.
Thiophanate-methyl (Topsin 4.5FL, FRAC 1), a methyl benzimidazole carbamate, is available for use on chickpea.

**Biological Controls:** *Coniothyrium minitans* (Contans) can be applied to soil for parasitization of sclerotia.

**Cultural Controls:** Clean seed and crop rotations with cereals can help manage this disease. Airflow discourages this disease, so seed and row spacing and use of upright, determinate varieties can help. Avoiding over-fertilization with nitrogen to deter excessive vine growth is important, to forestall vine collapse and creation of areas of high humidity in the canopy.

**Critical Needs for White Mold Management in Pulses:**

**Research:**
- Identify genes associated with resistance and develop and promote resistant varieties.
- Understand mechanism and effects of seed-borne infestation.
- Investigate biological control agents.
- Study plant architecture and spacing as means of disease avoidance.
- Develop forecasting and modeling methods.
- Develop fungicide-usage recommendations: fungicide application timing; fungicide efficacy when products are applied shortly before canopy closure; fungicide efficacy when products are applied after canopy closure; and fungicide application methods needed to optimize fungicide performance, including nozzle spray pattern, droplet size, application pressure, and water volume.

**Regulatory:** Obtain registration of fluazinam (Omega) on field peas, lentils, and chickpeas.

**Education:**
- Identification and management.
- Use of forecasting and modeling tools available.
- Understanding role of crop rotation.
Critical Needs for Management of Diseases in Pulse Crops:

Research
- Develop Ascochyta blight-resistant chickpea varieties.
- Identify new chemistries for fungicide resistance management in chickpeas with a particular focus on metalaxyl-resistant Pythium spp.
- Identify root rots in lentils.
- Identify viruses and determine resistant pea and lentil varieties.
- Research management of Fusarium species complex (identification, variety resistance, fungicide efficacy, cultural practices including crop rotation) in dry peas and lentils.
- Quantify soil and risk for root rot in dry peas with an emphasis on Aphanomyces root rot.
- Develop disease forecasting models such as one for white mold in lentils.
- Develop fungicide usage recommendations for white mold in lentils.
- Identify and determine white mold resistance genes and develop and promote white mold-resistant varieties.
- Identify fungicides with alternate modes of action with efficacy against Ascochyta blight of chickpea.

Regulatory
- Understand pathogen movement in seed as related to phytosanitary trade barriers in all pulses.
- Register fluazinam (Omega) for Anthracnose, Ascochyta, and Sclerotinia stem rot control on lentils, and Ascochyta blight control on chickpeas and field peas (in IR-4 pipeline).
- Register ethaboxam (Intego Solo) for Aphanomyces root rot and metalaxyl-resistant Pythium root rot (in IR-4 pipeline) on dry peas.

Education
- Identification and sustainable management of diseases:
  - variety resistance list
  - crop rotation lists and tables
  - flip cards for varieties
  - use of forecasting tools
INSECTS
Presented in alphabetical order. Under Chemical Controls, Insecticide Resistance Action Committee (IRAC) codes indicating mode of action are provided where known.

Aphids
Aphids create serious problems in pulse crops. The pea aphid \textit{(Acyrthosiphon pisum)} is a small, light green insect that attacks all three pulses, causing direct damage by feeding on the plants. They feed by sucking plant juices, which can deplete plant vigor and result in plant death. Perhaps more importantly, pea aphid causes indirect damage by vectoring several important viruses that result in stunted, less productive (or non-productive) plants (see Viral Diseases in the previous section). Other aphids known to vector viral diseases include the cowpea aphid \textit{(Aphis craccivora)}, green peach aphid \textit{(Myzus persicae)}, potato aphid \textit{( Macrosiphum euphorbiae)}, and foxglove aphid \textit{(Aulacorthum solani)}. The cowpea aphid, though present in fields, is not considered a serious direct pest because it arrives in the field after the seeds are formed.

Aphids have historically been most problematic in the Pacific Northwest, where they move to pea and lentil fields in May to June. Aphids are increasingly moving into the Northern and High Plains and are becoming problematic there as well.

The University of Idaho has an Aphid Tracker website with information on pea aphid thresholds and management at \url{http://www.cals.uidaho.edu/aphidtracker/trackerindex.asp}.

Chemical Controls: Controlling aphids with systemic aphicides is partially successful in reducing the field spread of viruses. Overwintering aphids feed on infected host crops and can spread virus to pulses before insecticides are applied for aphid control, but aphicides are useful in stopping the spread of secondary infection to pulses.

- Beta-cyfluthrin (Baythroid XL*, IRAC 3), a pyrethroid, provides suppression only.
- Beta-cyfluthrin + imidacloprid (Leverage 360*, IRAC 3 and 4).
- Bifenthrin (Brigade 2EC*, Capture LFR*, others*, IRAC 3), a pyrethroid.
- Bifenthrin + imidacloprid (Brigadier*, Skyraider*, Swagger*, IRAC 3 and 4).
- Bifenthrin + zeta-cypermethrin (Hero*, IRAC 3).
- Chlorantraniliprole + lambda-cyhalothrin (Besiege*, Voliam Xpress*, IRAC 28 and 3).
- Chlorpyrifos + bifenthrin (Match-Up*, IRAC 1 and 3).
- Cyfluthrin (Tombstone*, IRAC 3), a pyrethroid, provides suppression only.
- Dimethoate (Cygon, Digon, Dimethoate 4EC, 4E, and 400, IRAC 1), an organophosphate, is applied to 100% of Washington crops and 70 to 90% of Montana crops at the bloom stage. Although other insecticides are registered for and applied for control of pea aphid, dimethoate is still a critical tool because of its low cost and superior efficacy. Dimethoate is under rigorous regulatory scrutiny because of its impacts on pollinators. Pulse-crop growers could consider spraying dimethoate at dusk, the way seed-crop producers do, to limit its potential impact on bees and also as a show of good faith that they are doing everything they can to minimize pollinator impacts. Another benefit of using dimethoate is that the application made for pea aphid control is typically sufficient for Lygus bug control as well.
- Esfenvalerate (Adjourn*, Asana LX*, IRAC 3), a pyrethroid.
• Flupyradifurone (Sivanto Prime, IRAC 4D), a nicotinic acetylcholine receptor (nAChR) agonist.
• Gamma-cyhalothrin (Declare*, IRAC 3), a pyrethroid.
• Imidacloprid (IRAC 4), a neonicotinyl, is available in many formulations, some of which (e.g., Gaucho, Admire Pro, Malice 2F) control only early season aphids, while others (e.g., Pasada 1.6F, Sherpa, Malice 75WSP) provide control at all life stages.
• Lambda-cyhalothrin (Grizzly Z*, Warrior II*, others*, IRAC 3), a pyrethroid.
• Malathion (various trade names, IRAC 1), an organophosphate.
• Spirotetramat (Movento, IRAC 23), a ketoenol.
• Thiamethoxam (Cruiser 5FS, Cruiser Maxx, IRAC 4), a neonicotinyl, controls early season aphids.
• Zeta-cypermethrin (Mustang Maxx, Respect, IRAC 3), a pyrethroid.
(*Restricted use pesticide.)

Biological Controls: Beauveria bassania (Mycotrol O), a biological control, is available and is listed by the Organic Materials Review Institute (OMRI) for organic use.

Natural predators and parasitoids are usually not present in sufficient numbers to reduce aphid populations below economically damaging levels. Commercially available predators and parasitoids are not economically viable.

Cultural Controls: Scouting is employed before pesticides are applied.

Early seeding has been known to reduce damage in the Northern Plains.

Alternate pea aphid hosts include alfalfa, clover, and some leguminous weeds, therefore growers exercise caution when planting near these hosts.

Aphid-resistant varieties would be used if available, but they are not currently available for commercial release.

Critical Needs for Aphid Management in Pulses:

Research:
• Investigate Coccinellidae (lady beetles) and green lacewings (Chrysopidae) conservation and augmentive biocontrol on a commercial scale against pea aphid.
• Study intercropping impacts.
• Identify aphid biotypes and determine their vector competency for key viruses.
• Identify other aphid species that serve as vectors.
• Investigate development and maintenance of beneficial arthropod habitats.
• Determine optimal pollinator-safe insecticides and application practices.
• Screen insecticides for efficacy.
• Validate thresholds established in Canada for use in the Northern Plains.

Regulatory:
• Expedite flonicamid (Beleaf) registration (in IR-4 pipeline).

Education:
• Identification and management.
• Pollinator-safe practices.
• IPM practices.

Armyworms
Armyworms are caterpillars, or the larvae of moths. Species that may be present in pulses include the western yellowstriped armyworm (*Spodoptera praefica*). See also army cutworm (*Euxoa auxiliaris*), discussed in the Cutworms subsection.

A relatively minor problem in terms of crop damage in pea and lentil, armyworms can be a contaminant in dry peas at harvest. Short PHI products may be used before harvest or the worms may be cleaned from the harvested crop.

Armyworms are more likely to result in economic damage in chickpea, and more controls are registered for this pulse.

Armyworms are a common pest in the Pacific Northwest and are also problematic in Montana pulses, but are not typically controlled in the rest of the Northern Plains or High Plains.

Chemical Controls:
• Beta-cyfluthrin (Baythroid XL*, IRAC 3), a pyrethroid, controls first and second instars.
• Beta-cyfluthrin + imidacloprid (Leverage 360*, IRAC 3 and 4).
• Bifenthrin (Brigade 2EC*, Capture LFR*, others*, IRAC 3), a pyrethroid.
• Bifenthrin + imidacloprid (Brigadier*, Skyraider*, Swagger*, IRAC 3 and 4).
• Bifenthrin + zeta-cypermethrin (Hero*, IRAC 3).
• Chlorantraniliprole (Coragen, IRAC 28), an anthranilic diamide, is available in chickpea.
• Chlorantraniliprole + lambda-cyhalothrin (Besiege*, Voliam Xpress*, IRAC 28 and 3).
• Chlorpyrifos + bifenthrin (Match-Up*, IRAC 1 and 2).
• Carbaryl (Sevin), a carbamate (IRAC 1).
• Cyfluthrin (Tombstone*, IRAC 3), a pyrethroid, controls first and second instars.
• Gamma-cyhalothrin (Declare*, IRAC 3), a pyrethroid.
• Lambda-cyhalothrin (Grizzly Z*, LambdaStar*, Warrior II*, IRAC 3), a pyrethroid.
• Methoxyfenozide (Intrepid 2F, IRAC 18), a diacylhydrazine, is available in chickpea.
• Methomyl (Lannate LV*, IRAC 1), an N-methyl carbamate, is registered for use in chickpea.
• Spinetoram (Radiant SC, IRAC 5), a spinosyn, controls first and second instars.
• Spinosad (Success, IRAC 5), a spinosyn, is registered in chickpea. Controls first and second instars. Some formulations are OMRI-listed for organic production.
• Zeta-cypermethrin (Mustang Maxx*, Respect*, IRAC 3), a pyrethroid.

(*Restricted use pesticide.)
**Biological Controls:** *Bacillus thuringiensis* is available for use in chickpea and provides some suppression. Some formulations are OMRI-listed for organic production. *Beauveria bassiana* and *Metarhizium brunneum* (*anisopliae*) are also available.

**Cultural Controls:** None.

**Critical Needs for Armyworm Management in Pulses:**

**Research:**
- Develop scouting and monitoring protocols.
- Expand emerging knowledge regarding pheromone-based monitoring to predict population levels.

**Regulatory:** None.

**Education:** Educate growers how to identify army cutworm vs. armyworm and adjust management practices accordingly.

**Cutworms**
Cutworms are caterpillars, or the larvae of moths. Species that may be present in pulses include the variegated cutworm (*Pedroma saucia*), dingy cutworm (*Feltia jaculifera*), red-backed cutworm (*Euxoa ochrogaster*), pale western cutworm (*Agrotis orthogonia*), and army cutworm (*E. auxiliaris*). Cutworms occasionally cause damage to pulse crops. They overwinter as eggs or young larvae. In spring, the larvae feed on newly emerged shoots, often cutting them off below the soil surface. Pulse crops can recover from cutworm damage if cool, moist growing conditions occur. Recovered plants are generally set back 4 to 7 days by the damage.

Cutworms are a major problem in the Northern Plains, but the damage is cyclical. They are a pest of emerging importance in the Pacific Northwest.

**Chemical Controls:**
- Beta-cyfluthrin (Baythroid XL*, IRAC 3), a pyrethroid.
- Beta-cyfluthrin + imidacloprid (Leverage 360*, IRAC 3 and 4).
- Bifenthrin (Brigade 2EC*, Capture LFR*, others*, IRAC 3), a pyrethroid.
- Bifenthrin + imidacloprid (Brigadier*, Skyraider*, Swagger*, IRAC 3 and 4).
- Bifenthrin + zeta-cypermethrin (Hero*, IRAC 3).
- Chlorantraniliprole + lambda-cyhalothrin (Besiege*, Voliam Xpress*, IRAC 28 and 3).
- Chlorpyrifos + bifenthrin (Match-Up*, IRAC 1 and 3).
- Carbaryl (Sevin, IRAC 1), a carbamate.
- Cyfluthrin (Tombstone*, IRAC 3), a pyrethroid.
- Esfenvalerate (Adjourn*, Asana XL*, IRAC 3), a pyrethroid.
- Gamma-cyhalothrin (Declare*, IRAC 3), a pyrethroid.
- Lambda-cyhalothrin (Grizzly Z*, LambdaStar*, Warrior II*, IRAC 3), a pyrethroid.
- Methomyl (Lannate LV*, IRAC 1), an N-methyl carbamate, registered for use in chickpea.
• Spinosad (Success, IRAC 5), a spinosyn. Some formulations are OMRI-listed for organic production.
• Zeta-cypermethrin (Mustang Maxx*, Respect*, IRAC 3), a pyrethroid. (*Restricted use pesticide.)

**Biological Controls:** Entomopathogenic (predatory) nematodes such as *Heterorhabditis indica*, *Steinernema kraussei*, *Steinernema feltiae*, *Steinernema riobrave*, and *S. carpocapsae* are available.

**Cultural Controls:** Weed management assists in cutworm management as the adults seek broadleaf weeds in which to lay their eggs.

**Critical Needs for Cutworm Management in Pulses:**

**Research:**
• Efficacy studies needed on chemical options.
• Efficacy studies needed on entomopathogenic (predatory) nematodes.
• Habitat management including soil health and other preferences for predatory nematodes.
• Investigate availability, use, and efficacy of parasitoids for cutworms.

**Regulatory:** None.

**Education:**
• Educate growers on species diversity and timing of pest activity and management.
• Explain monitoring methods as they are developed.
• Identification and discernment of armyworm vs. army cutworm and other caterpillars.

**Grasshoppers**
Grasshoppers (*Caelifera* spp.) are a sporadic pest in pulse production. They have many hosts and do not strongly prefer pulse crops, but when present can be problematic. As few as two grasshoppers per square yard can cause serious yield losses in lentils. Grasshoppers chew through young seedlings even if they do not eat the plant. Because they tend to gravitate toward other hosts, grasshopper damage is often seen on pulse seedlings bordering ditches and roads. Dry, drought-type conditions exacerbate grasshopper populations. Grasshoppers are present in all pulse-growing regions.

**Chemical Controls:**
• Beta-cyfluthrin (Baythroid XL*, IRAC 3), a pyrethroid.
• Beta-cyfluthrin + imidacloprid (Leverage 360*, IRAC 3 and 4).
• Bifenthrin (Brigade 2EC*, Capture LFR*, others*, IRAC 3), a pyrethroid.
• Bifenthrin + imidacloprid (Brigadier*, Skyraider*, Swagger*, IRAC 3 and 4).
• Bifenthrin + zeta-cypermethrin (Hero*, IRAC 3).
• Chlorantraniliprole + lambda-cyhalothrin (Besiege*, Voliam Xpress*, IRAC 28 and 3).
• Chlorpyrifos + bifenthrin (Match-Up*, IRAC 1 and 3).
• Carbaryl (Sevin, IRAC 1), a carbamate, is slower acting than other modes of action (e.g., pyrethroids), as it must be ingested.
• Cyfluthrin (Tombstone*, IRAC 3), a pyrethroid.
• Esfenvlerate (Adjourn*, Asana XL*, IRAC 3), a pyrethroid.
• Dimethoate (Dimethoate 400 & 4E, IRAC 1), an organophosphate.
• Gamma-cyhalothrin (Declare*, IRAC 3), a pyrethroid.
• Lambda-cyhalothrin (Grizzly Z*, LambdaStar*, Warrior II*, IRAC 3), a pyrethroid.
• Malathion (various trade names, IRAC 1), an organophosphate, is attractive if grasshoppers are a problem near harvest, as it has a 1-day PHI.
• Zeta-cypermethrin (Mustang Maxx*, Respect*, IRAC 3), a pyrethroid.
(* Restricted use pesticide.)

Biological Controls: Several predators and parasites attack grasshoppers or their eggs. However, none of these are viable as a control agent in the event of a grasshopper outbreak. Disease agents including the microsporidia *Nosema locustae* have some efficacy.

Cultural Controls: In areas where grasshoppers are a problem, the previous year's egg count may play a role in field selection. This is useful when potential pulse fields border rangeland, Conservation Reserve Program land, and pastures.

Clean summer fallowing can be used to starve young grasshoppers as they emerge and trap strips (areas of green growth) are used to concentrate the population before an insecticide is applied.

Critical Needs for Grasshopper Management in Pulses:

Research: Biological controls appear promising.

Regulatory:
• Add pulses to diflubenzuron (Dimilin) label; it acts as a chitin inhibitor with activity against juveniles.
• Add pulses to neem-based extracts (Aza-direct) label.

Education: Grower awareness of grasshopper damage on pulses.

Lygus Bugs
Lygus bug (*Lygus* spp.) is a major insect pest of dry peas in the Northern Plains and lentils in all growing regions. Hosts for these pests include weeds such as mustards and lambsquarters and crops such as alfalfa and clover. Lygus bugs pierce tender leaves, stems, buds, petioles, and developing seeds. They produce depressed, pale lesions on the seed known as “chalky spot syndrome.”

Chemical Controls:
• Beta-cyfluthrin (Baythroid XL*, IRAC 3), a pyrethroid.
• Bifenthrin (Brigade 2EC*, others*, IRAC 3), a pyrethroid.
• Bifenthrin + imidacloprid (Brigadier*, Skyraider*, Swagger*, IRAC 3 and 4).
• Bifenthrin + zeta-cypermethrin (Hero*, IRAC 3).
• Chlorantraniliprole + lambda-cyhalothrin (Besiege*, Voliam Xpress*, IRAC 28 and 3).
• Chlorpyrifos + bifenthrin (Match-Up*, IRAC 1 and 3).
• Carbaryl (Sevin, IRAC 1), a carbamate.
• Cyfluthrin (Tombstone*, IRAC 3), a pyrethroid.
• Dimethoate (Dimethoate 400, 4E, 4EC, IRAC 1), an organophosphate.
• Gamma-cyhalothrin (Declare*, IRAC 3), a pyrethroid.
• Lambda-cyhalothrin (Grizzly Z*, Warrior II*, others*, IRAC 3), a pyrethroid.
• Methomyl (Lannate LV*, IRAC 1), an N-methyl carbamate. (Not recommended by Northern Plains university specialists.)
• Zeta-cypermethrin (Mustang Maxx, Respect, IRAC 3), a pyrethroid. (* Restricted use pesticide.)

**Biological Controls:** Minute pirate bugs, damsel bugs (nabids), and big-eyed bugs are important Lygus predators. Lygus parasitoids are also present in the region, however university research indicates parasitism levels are very low.

**Cultural Controls:** As Lygus are often controlled in the course of aphid control, scouting is employed only when no aphid control is used. Economic thresholds have been established for Lygus bugs in lentils. When lentils are in bloom and pod formation has begun, sweep nets are used to determine presence and quantity of adult Lygus bugs, though the low (6-inch tall) growth habit of lentils makes this method more difficult than in other crops. Any presence of Lygus bugs just before or during bloom justifies treatment according to the lentil industry. Keeping weeds controlled helps discourage Lygus populations.

**Critical Needs for Lygus Bug Management in Pulses:**

**Research:**
• Further study impacts of weed control on Lygus populations.
• Understand Lygus movement between different crops.
• Research trap crops as a Lygus management tactic.
• Conduct insecticide efficacy studies.
• Develop threshold information.
• Identify which Lygus species are present and causing crop damage; understand life cycles and regional differences.
• Areawide IPM development.

**Regulatory:** Expedite flonicamid (Beleaf) registration (in IR-4 pipeline).

**Education:**
• Educate growers on species identification and control thresholds.
• Promote IPM strategies and pollinator safety.

**Pea Leaf Weevil**
The pea leaf weevil (*Sitona lineatus*, not to be confused with pea weevil *Bruchus pisorum*, covered in the next subsection) adult is a very serious pest in dry peas, causing economic loss in all production areas every year. Most of the damage occurs in the spring on peas in the seedling stage. Early adults feed on seedlings, scalloping leaf edges and damaging terminal buds. Severe foraging may cause heavy leaf damage, destruction of the terminal buds, and ultimate destruction of the plant. The larvae, however, cause the most serious damage to the plants. Once the larvae hatch, they begin feeding on the *Rhizobium* or nitrogen-fixing nodules of the pea roots, resulting in partial or complete inhibition of nitrogen fixation by the plant. This damage results in poor plant growth and low seed yields, and may make the peas more susceptible to drought stress.

Pea leaf weevil (PLW) infests wild and cultivated legumes, also causing economic damage to field pea and faba beans. Chickpeas are not preferred, but may become infested when near a host crop. Lentils are not considered a host for pea leaf weevil.

Weather and soil conditions during the growing season have a strong influence on the damage caused by PLW. Cool, wet spring weather slows dry pea development and extends the time that peas remain in the seedling stage, which makes them more susceptible to PLW. Some of the recently developed pea varieties are slower to mature, therefore at risk for greater PLW damage. Damage by the PLW can be localized or cover large areas. Severely infested dry pea fields may suffer up to 100% crop loss.

**Chemical Controls:** Both preventive (seed treatment) and sprayed insecticides may be used to aid in the management of pea weevil. Insecticidal seed treatments protect the root nodules from larval feeding; use of treated seed is based on the history of weevil damage in the field. Foliar sprays are targeted toward the adult weevil, specifically the female weevils before they lay eggs, to prevent yield loss caused by the larvae. The economic threshold for spraying is reached when ¼ to 1/3 of the plants exhibit feeding notches on the clam leaves (the most recently emerging leaves that are still folded together) or leaf pairs. Growers examine a row of 10-20 seedlings at several locations, including the interior of the field, to establish an average number of plants with feeding damage.

**Larval control with insecticide seed treatments:**
- Imidacloprid (Gaucho 600, Enhance AW, IRAC 4), a neonicotinyl.
- Thiamethoxam (Cruiser 5FS, Cruiser Maxx, IRAC 4), a neonicotinyl.

**Adult control with foliar application:**
- Alpha-cypermethrin (Fastac CS, Fastac EC, IRAC 3), a pyrethroid.
- Beta cyfluthrin (Baythroid XL, IRAC 3), a pyrethroid.
- Bifenthrin (Brigade 2EC*, Capture LFR*, others*, IRAC 3), a pyrethroid.
- Bifenthrin + zeta-cypermethrin (Hero*, IRAC 3).
- Carbaryl (Sevin, IRAC 1), a carbamate.
- Chlorpyrifos + bifenthrin (Match-Up*, IRAC 1 and 3).
- Cyfluthrin (Tombstone*, IRAC 3), a pyrethroid.
- Lambda-cyhalothrin (Warrior and generics*, IRAC 3), a pyrethroid.
- Malathion (IRAC 1), an organophosphate.
Phosmet (Imidan, IRAC 1), an organophosphate, is considered an essential insecticide for pea leaf weevil control in Pacific Northwest only. Applications of phosmet are often combined with dimethoate (Cygon) for aphid control.

Zeta-cypermethrin (Mustang Maxx, Respect, IRAC 3), a pyrethroid. (*Restricted use pesticide.)

**Biological Controls:** Natural predators are usually not present in sufficient numbers to reduce pea leaf weevil below economically damaging levels. Native ground or carabid beetles are known to eat pea leaf weevil eggs. Further research is needed on biological control.

**Cultural Controls:** Certain best management practices can aid in pea leaf weevil management. These include seeding crops early; use of inoculants and adequate fertilizer to maximize yields; rotating to a non-host crop; and planting trap crops along field borders.

**Critical Needs for Pea Leaf Weevil Management in Pulses:**

**Research:**
- Research new pesticides (foliar for adults and seed treatment for larvae) as alternatives to OPs and carbamates.
- Study crop rotation’s role in pea weevil management.
- Research role of beneficial insects and predatory organisms, including understanding tactics and habitat management to conserve them.
- Understand intercropping as part of IPM.
- Develop degree-day modeling.
- Develop pheromone-based monitoring method.
- Research potential of biological control.

**Regulatory:**
- Address devastating organophosphate and carbamate losses.

**Education:**
- General IPM including scouting and identification.
- Use of pheromones in an IPM program.

**Pea Weevil**
The pea weevil (*Bruchus pisorum*, not to be confused with pea leaf weevil *Sitona lineatus*, covered in the previous subsection) is found throughout the entire U.S. dry pea production region. It is considered a serious pest of dry peas in the Pacific Northwest, where it causes significant damage and economic loss nearly every year. It is a minor pest in the Northern and High Plains. Adult pea weevils overwinter in fencerow areas, in timbered areas adjacent to fields, and on roadside vegetation. Female weevils lay eggs within the pea pods during the early bloom stage, then the larvae remain within the peas, eating the pea seed from the inside and emerging after harvest. Larvae are the damaging life stage. Despite its name, this pest is not a true weevil but a plant-feeding beetle.
Damage from pea weevil is most often discovered when the product reaches the elevator. Infestation causes economic losses due to the outright loss of seed contents and also due to diminished germination and market value of damaged seed. Pea weevil excrement also contains the toxic alkaloid (cantharidin), which poses a health hazard to humans and animals.

**Chemical Controls:** If scouting reveals that the economic threshold has been reached, insecticides are applied to prevent the females from laying eggs. Sampling is done via sweep net, with two weevils in 25 sweeps considered the treatment threshold. Once eggs are laid on the pea pods, all treatments are ineffective.

- Carbaryl (Sevin 4F, Sevin XLR Plus, IRAC 1), a carbamate.
- Cyfluthrin (Renounce 20WP*, Tombstone*, Tombstone Helios*, IRAC 3), a pyrethroid.
- Malathion (IRAC 1), an organophosphate.
- Phosmet (Imidan, IRAC 1), an organophosphate, is considered an essential insecticide for both pea weevil and pea leaf weevil control. Applications of phosmet are often combined with dimethoate (Cygon, others, IRAC 1) for aphid control. (*Restricted use pesticide.)

**Biological Controls:** Natural predators are usually not present in sufficient numbers to reduce pea weevil populations below economically damaging levels. However, an egg parasitoid of pea weevil, *Uscana senex*, has been commercially reared and successfully used in Chile and Brazil to control this pest. The rates of parasitism obtained range between 49-82%.

**Cultural Controls:** Control measures that may discourage pea weevil damage include planting early maturing varieties, harvesting early, and destroying crop residues.

**Critical Needs for Pea Weevil Management in Pulses:**

**Research:**
- Study and refine the “sweating” process (variables including temperature, timing, etc.) that self-cleans peas, including whether or not the 30-day window is sufficient.
- Identify pheromone for pea weevil monitoring.
- Investigate storage temperature’s effect on the pest.
- Research conservation, augmentation, and efficacy of natural enemies.
- Investigate varietal resistance to this pest.

**Regulatory:** The egg parasitoid *Uscana senex* is known in Brazil and Chile; USDA-APHIS permits to be sought for attempting release in Northern Plains.

**Education:** General IPM including scouting and identification.

**Seed Corn Maggot**
The seed corn maggot (*Delia platura*) feeds on germinating seeds and seedling dry pea, chickpea, and lentil plants and can thin or destroy stands. It is a minor pest in the Pacific Northwest and is a sporadic, minor pest in the other regions.
Chemical Controls:
- Bifenthrin (Capture LFR*, IRAC 3), a pyrethroid, is registered in dry pea and chickpea.
- Chlorpyrifos* (various trade names, IRAC 1), an organophosphate.
- Imidacloprid (Gaucho 600, Enhance AW, IRAC 4), a neonicotinyl.**
- Thiamethoxam (Cruiser 5FS, Cruiser Maxx, IRAC 4), a neonicotinyl.**
(*Restricted use pesticide.)
(**These two neonicotinoids applied as seed treatments will control seed corn maggot and wireworms.)

Biological Controls: None. Since much of this species’ life cycle is takes place underground, it does not appear to have many natural enemies. While instances of predation by spiders, ants, and birds upon adults and of fungal diseases infecting larvae have been reported, none of these predators or pathogens is considered significant in controlling populations.

Cultural Controls: Preventative measures for seed corn maggots include late planting, shallow planting, higher seeding rates, a well-prepared seedbed, and turning cover crops early (which renders field less attractive to egg laying by flies). No-till fields are less likely to have seed corn maggot problems because the germinating seeds alone are not sufficient to attract large populations of egg-laying females. Attractiveness of an area for egg laying can also be reduced by removing nearby food sources such as flowering weeds and sweet-smelling substances from surrounding areas. However, flowering weed removal also impacts the availability of nectar for beneficial insects. Growers avoid plowing green matter under because high organic matter favors the adult flies.

Critical Needs for Seed Corn Maggot Management in Pulses:

Research:
- Assess presence and population levels.
- Understand role of green manures, cover crops, etc. in management.
- Develop attractants or baits as part of an attract-and-kill strategy.

Regulatory: None.

Education: Identification and understanding of pest presence, life cycle, and damage.

Wireworms
Wireworms, the gregarious and soil-dwelling larvae of click beetles (Elateridae), are a major pest of wheat and also cause damage to pulse crops. Larvae are yellowish, slender, shiny, and have hard bodies with three pairs of legs and biting-chewing mouthparts. Larvae may pass through 8 to 14 instars depending on genera and soil conditions.

Several species of wireworm may be present in pulses. Limonius californicus, L. infuscatus, L. canus and Hypnoidus bicolor are known in the Northern Plains. Wireworm larvae feed on germinating seeds and dry pea and lentil seedlings and can thin or destroy stands. The wireworm larvae typically take several years to develop. They cause little damage the first year but feed
heavily thereafter, cutting off and damaging roots. As wireworm growth, development, and movement in soil are highly dependent upon soil moisture and temperature, their density and injury to lentils are directly related to soil moisture. Wireworm populations are generally low in years of average or below-average precipitation, and high and damaging in years of above-average precipitation. The two peak periods of activity are from April to May and September to October.

**Chemical Controls:**
There is no easy or perfect way to estimate wireworm infestations. The following methods are among those used:
1. **Soil Sampling:** Growers excavate 20 well-spaced, 1-square-foot-by-4-to-6-inch-deep soil samples for every 40 acres being planted. The presence of 3 or more wireworms per square foot (1 per square foot in North Dakota) signals that control measures are needed.
2. **Solar Baiting:** Approximately 2 to 3 weeks before the fall freeze, growers dig 10 to 12 holes (each 4 to 6 inches deep) distributed across each 40 acres of field. They place one cup wheat and one cup shelled corn in each hole, cover with soil, then cover with an 18-inch square of clear plastic. The bait pits are dug up to assess wireworm presence.
3. **Stocking Traps:** Similar to the solar baiting approach, these are made with disposable nylon foot socks filled with germinated grain. The traps are buried for a week or two and larvae are subsequently counted, with 2-4 wireworms per trap (~180 cc of seed) constituting a threshold.
4. **Simple Observation:** Some growers simply treat if wireworms are observed during disk or seeding.

If treatment is deemed necessary, the following are options.
- Bifenthrin (Capture LFR*, Ethos XB*, IRAC 3), a pyrethroid, is registered in dry pea and chickpea.
- Imidacloprid (Gaucho 600, Enhance AW, IRAC 4), a neonicotinyl.
- Thiamethoxam (Cruiser 5FS, Cruiser Maxx, IRAC 4), a neonicotinyl.
- Zeta-cypermethrin (Mustang Maxx, Respect, IRAC 3), a pyrethroid, applied at plant or in-furrow.

(*Restricted use pesticide.)

**Biological Controls:** Trials conducted by Montana State University Western Triangle Ag Research Centers indicated that the three fungi *Metarhizium brunneum* F52, *Beauveria bassiana* GHA, and *Metarhizium robertsii* DWR 346, when applied as granules in furrow or as soil drenches, were more effective in controlling wireworms than when used as seed-coating treatments for wireworm control, and provided an efficacy comparable or superior to imidacloprid.

**Cultural Controls:** While some growers have experimented with trap crops, trials conducted at Western Triangle Ag Research Centers have indicated that wireworms are significantly more attracted to peas and lentils than other plants such as canola, corn, durum, and barley.

**Critical Needs for Wireworm Management in Pulses:**

**Research:**
• Further investigate validity of leaving weeds in the field as a management strategy.
• Continue research on predatory nematodes.
• Continue research on beneficial fungi.
• Need replacements for neonicotinyl seed treatments; need treatments that actually kill, not just repel (repellants leave the population in the soil).
• Assess impact of soil health on wireworm populations.
• Research resistance management.
• Investigate whether the toxins in neonicotinoid seed treatments are systemically translocated to the pollen and nectar, thereby impacting pollinator safety.

Regulatory: None.

Education: None.
Critical Needs for Management of Insects in Pulse Crops:

Research
- Expand insecticide options.
- Continue evaluating currently registered insecticide products.
- Review economic thresholds for insects and develop thresholds for insect pests that do not have established thresholds.
- Increase biological control research.
- Develop forecasting models.
- Develop pheromone-based monitoring methods.

Regulatory
- Register diflubenzuron (Dimilin) for grasshopper control.
- Expedite flonicamid (Beleaf) registration for aphid and Lygus control (in IR-4 pipeline).

Education
- Increase grower awareness of IPM practices in insect management.
- Increase grower awareness of pollinators and pollinator safety.
- Educate growers on biology, identification, and management of insect pests of pulse crops.
WEEDS

The majority of pulse growers in the United States do not use tillage to control weeds. Most growers use some form of minimum till or no-till to conserve soil moisture and reduce erosion. However, some growers may use conventional tillage to control weeds mechanically, which also allows incorporation of certain herbicides.

In no-till systems, weed control begins with fall, preplant, or preemergence herbicides. Winter annual and perennial weeds are best controlled in the fall. A non-selective herbicide such as glyphosate is typically applied alone or with other herbicides in the fall and spring to control emerged weeds or for residual weed control.

In conventional tillage, fall or spring pre-seeding tillage is used to control weeds and to activate some soil-incorporated herbicides. Spring tillage controls early-emerging summer annual weeds. Shallow tillage avoids bringing weed seeds up near the soil surface where they are likely to germinate. Excessive tillage dries the seedbed, making shallow seeding less effective, and also leads to soil erosion.

Weeds are managed with stale seedbed techniques such as delaying seeding, allowing weeds to emerge, and then destroying them with either tillage or a non-selective herbicide. However, some weeds may be favored by delayed seeding. Delayed seeding may also diminish yield potential and quality, so this disadvantage must be weighed against any weed-control advantage.

No single herbicide will control all broadleaf weeds in pulse crops. Perennial broadleaf weeds like field bindweed and Canada thistle must be controlled in the previous crop (for example wheat), through fall herbicide applications, and then spring burndown. Annual broadleaf weeds such as kochia and Russian thistle can be difficult to control in pulse crops. Growers rely on soil-applied herbicides to control annual weeds preplant or preemergence. However, these herbicides typically do not control all annual weeds. Thus, there is a need for postemergence herbicides in pulse crops. This can be troublesome because postemergence herbicide options are limited and expensive in dry pea and almost non-existent in lentil and chickpea. Where postemergence herbicides are labeled, it is critical to spray weeds when they are small (1-3 inches).

Besides reducing yields through competition, weeds present other problems in pulse production. Some weeds can contribute exudates at harvest that stain pulses, reducing quality. Weeds also interfere with harvesting. Kochia can grow to the size of small Christmas trees and can plug a combine when in sufficient size and quantity. Wild buckwheat can wrap around the crop and pull it to the ground. Wild buckwheat can also wrap around the header and make threshing difficult. Pre-harvest desiccants such as paraquat are available to dry down weeds prior to harvest, but desiccation effectiveness can vary with specific weeds, weed size, and environmental conditions.
Specific Problem Weeds
The most problematic weed pests in each region are listed below.

Pacific Northwest
Perennials: Canada thistle, field bindweed, quackgrass
Annual Grasses: wild oat, Italian ryegrass, downy brome, jointed goatgrass, volunteer cereals
Annual Broadleaves: brassicas (esp. mustard, pennycress), prickly lettuce, dog fennel (mayweed chamomile), nightshades, kochia, common lambsquarters, pigweeds, wild buckwheat, Russian thistle

Northern Plains
Perennials: Canada thistle, field bindweed, quackgrass, perennial sowthistle, dandelion, foxtail barley (perennial grass)
Annual Grasses: wild oat, downy brome, Japanese brome, jointed goatgrass, Persian darnel, volunteer cereals, foxtail (green, yellow and giant)
Annual Broadleaves: brassicas (esp. wild mustard, pennycress, shepherdspurse), prickly lettuce, nightshades, kochia, common lambsquarters, redroot pigweed, Galium spp., Russian thistle, horseweed/marestail, volunteer canola, narrowleaf hawksbeard, vetch, common mallow, wild buckwheat, wild sunflower, common ragweed, marshelder, waterhemp, biennial wormwood, false chamomile

High Plains
Perennials: Canada thistle, field bindweed, quackgrass, perennial sowthistle, dandelion, foxtail barley (perennial grass)
Annual Grasses: wild oat, downy brome, volunteer cereals, foxtail (green, yellow, and giant), Persian darnel
Annual Broadleaves: brassicas (esp. mustard, pennycress), prickly lettuce, nightshades, kochia, common lambsquarters, pigweeds, Galium spp., buckwheat, horseweed/marestail, volunteer soybean, wild buckwheat

Cultural Practices
Selecting appropriate fields and being mindful of rotation is the first step in weed management. Many growers find that extending rotations so that the legume crop is grown only once every three to four years helps keep weed populations more manageable.

Choice of field, seed, herbicides, and use of clean equipment are essential weed-control practices for all pulse growers. Use of clean, weed-free seed helps avoid introducing new weed species into fields. Growers increasingly utilize certified seed, which is weed-free and also results in greater vigor. Selection of herbicide-resistant varieties when available, such as Clearfield lentil, is useful for postemergence weed management.

Optimal seeding rate, timing, spacing, and depth help ensure a vigorous crop and enhance the crop’s ability to compete with weeds. The use of drills with an appropriate amount of soil disturbance also aids in managing weeds. Rotary hoeing, harrowing, and rolling are mechanical controls that may aid in weed management.
Weeds that emerge with or before the crop have a greater impact on the crop than those that emerge later. Some growers manipulate the timing of their pulse crop seeding to take advantage of known weed emergence and enhance the crop’s ability to compete. Early seeding may allow the crop to get a head start before weeds emerge. This is especially true with respect to weeds such as green foxtail that require warm soil for germination and in low-till and no-till systems where there is little or no general soil surface disturbance to encourage early weed germination. Conversely, delayed seeding, when combined with tillage prior to seeding or crop emergence, may be employed to eliminate early and more competitive weeds and to activate soil-incorporated herbicides. Delayed seeding can be risky, however, as it can reduce both quality and yield. Non-selective preemergent herbicides create the same advantage as preemergent tillage by clearing the field as the small crop seedlings emerge.

The way in which fertilizer is used – timing, quantity, type, placement – will affect weed growth as well as the crop. It is important that the pulse crop establish quickly and at an adequate density to compete successfully with emerging weeds. Starter fertilizer is often banded at or near the seed planting to assist in early vigor.

Knowledgeable growers repeatedly inspect their pulse fields during the growing season to identify weeds and monitor herbicide effectiveness. They observe, mark, and map weed patches for future control. Field histories are important in predicting weed populations in a given field. The weeds in a pulse crop are generally similar to those experienced in previous years in the same field in cereal crops.

Mechanical weed control is generally impractical once pulse crops have fully emerged due to the crop being grown in narrow rows that preclude in-crop cultivation. In-crop row cultivation is also avoided due to its contribution to erosion in some regions. Some producers, especially those producing organic pulses, cultivate for weed control after crop emergence.

While cultural weed management practices confer many benefits, employment of cultural practices alone cannot achieve an economic level of control. Most weeds are addressed through integrated weed management, combining cultural practices with the judicious use of herbicides.

**Chemical Controls**

Controls and application timing for each pulse crop are listed first, followed by a list of controls in alphabetical order (by active ingredient, followed by one or more common trade names in parentheses) with comments specific to each crop and region where pertinent. See also Appendix B, Efficacy Tables for Herbicides, for additional specific information.

**Dry pea:**

- **Preplant or Preemergence:** carfentrazone, dimethenamid, ethalfluralin, imazethapyr, metolachlor, metribuzin, pendimethalin, saflufenacil, sulfentrazone, triallate, trifluralin

- **Postemergence:** bentazon, clethodim, imazamox, imazethapyr, MCPA (Pacific Northwest only), MCPB, metribuzin, quizalofop, sethoxydim

- **Preharvest:** flumioxazin, glyphosate, paraquat, saflufenacil
Pests & Management Options: Weeds

Lentil:
- **Preplant or Preemergence:** carfentrazone, dimethenamid, ethalfluralin, imazethapyr, metolachlor, metribuzin, pendimethalin, saflufenacil, triallate, trifluralin
- **Postemergence:** clethodim, quizalofop, sethoxydim. Imazamox in Clearfield variety only
- **Preharvest:** flumioxazin, glyphosate, paraquat

Chickpea:
- **Preplant or Preemergence:** carfentrazone, dimethenamid, ethalfluralin, imazethapyr, metolachlor, metribuzin, pendimethalin, saflufenacil, sulfentrazone, triallate, trifluralin
- **Postemergence:** clethodim, quizalofop, sethoxydim
- **Preharvest:** flumioxazin, glyphosate, paraquat, saflufenacil

Registered controls:
- Bentazon (Basagran) is applied postemergence to control or suppress annual broadleaf weeds. Bentazon is labeled for dry pea, but not lentil or chickpea. Bentazon is most effective in warm temperatures (~70°F to 85°F) when applied to small (<4”), actively growing weeds. Bentazon can be tank mixed with imazamox or graminicides (grass weed controls) for postemergence weed control.
- Carfentrazone (Aim) is applied preplant or preemergence. Carfentrazone is a non-residual, foliar-contact herbicide that suppresses or controls very small broadleaf weeds. It is also registered as a desiccant, but is not effective by itself.
- Clethodim (Select) is used for annual and perennial grass control. Resistance to clethodim has been slower to develop than resistance to quizalofop.
- Dimethenamid (Outlook) is applied preplant or preemergence for residual control of annual grasses and broadleaf weeds in chickpea and lentil. Is not used extensively due to the weed spectrum controlled and price. Primarily controls or suppresses pigweed, lambquarters, and annual grasses.
- Ethalfluralin (Sonalan) is typically applied in no-till systems in the fall just prior to freeze-up for residual control of annual grass and broadleaf weeds. In conventional tillage, it is usually applied in the spring with two incorporations. Ethalfluralin does not control mustard species. Winter wheat cannot be planted following spring-applied ethalfluralin, but can be planted following a previous fall application.
- Glyphosate (Roundup) is applied in the fall, preplant, or preemergence for control of annual and perennial weeds. In the fall, glyphosate is typically applied for control of perennial and winter annual weeds. It is also used as a harvest aid.
- Imazamox (Raptor, Beyond) is registered for postemergence use in dry pea or Clearfield lentil only. Imazamox controls annual grasses and some broadleaf weeds. In dry pea, imazamox must be tank mixed with bentazon to reduce crop injury. Imazamox requires an 18-month rotation restriction to barley, non-Clearfield canola, flax, potato, safflower, and sugarbeet.
• Imazethapyr (Pursuit) can be applied preplant or preemergence in dry pea, lentil, or chickpea. Imazethapyr can also be applied postemergence in dry pea. It is used primarily to control certain broadleaf weeds. It can be soil-applied at 2 fl oz in North Dakota and 3 fl oz in other states. Postemergence applications in dry pea are limited to 2 fl oz.
• MCPA. Some MCPA sodium salt and MCPA amine labels allow postemergence applications on dry pea (Pacific Northwest only) for annual broadleaf weed control. MCPA can cause some dry pea injury and controls a narrow weed spectrum.
• MCPB (Thistrol) is labeled for use only in dry pea for postemergence control or suppression of Canada thistle and some broadleaf weeds.
• Metribuzin (various) can be applied preemergence or postemergence in dry pea, lentil, or chickpea for suppression of annual broadleaf weeds. Metribuzin can be applied preemergence in the Pacific Northwest only, but all risk is assumed by the grower. Metribuzin requires a seeding depth of at least two inches. The label warns of potential crop injury in cool, wet conditions and sandy soils.
• Parquat (Gramoxone) is registered for use as a desiccant in dry pea, lentil, and chickpea. It is applied when the crop is mature and at least 80% of the pods are yellowing and mostly ripe with no more than 30% of the leaves still green in color.
• Pendimethalin (Prowl) is available for use in all pulses for a narrow spectrum of broadleaf and grassy weeds. Pendimethalin requires 0.5-1.0 inch of rainfall for adequate soil activation. In the Northern Plains, pendimethalin can be applied preplant in the spring or can be applied in the fall, increasing the likelihood of winter moisture aiding incorporation. Winter wheat cannot be planted following spring-applied pendimethalin, but can be planted following a previous fall application.
• Pronamide (Kerb) is labeled for preplant application on winter peas only in the Pacific Northwest. It is not used much because of cost and carryover potential.
• Quizalofop (Assure II) is applied postemergence to all pulse crops to control annual and perennial grasses. Some biotypes are resistant to quizalofop.
• S-metolachlor (Dual Magnum, Dual II Magnum) can be used in dry pea, lentil, and chickpea. It can be applied in the fall, preplant, or preemergence. The weed spectrum controlled by metolachlor does not provide a great deal of benefit in the Northern Plains. In addition, there is a 4.5-month rotation restriction before planting wheat and barley. Thus, metolachlor is not used often in winter wheat growing regions because of the plant-back restrictions. This is not a problem for fall-planted winter peas.
• Saflufenacil (Kixor) can be applied preplant or preharvest.
• Sethoxydim (Poast) is applied postemergence to all pulse crops to control or suppress annual and perennial grasses.
• Sulfentrazone (Spartan) can be used for broadleaf weed control in dry pea and chickpea, but not lentil. It is a key herbicide for kochia, Russian thistle, pigweed, and wild buckwheat in the Northern Plains. Higher rates are needed for some weeds such as wild buckwheat and biennial wormwood. Sulfentrazone requires at least 0.5 inch of rain for proper activation. Crop injury is much more likely in high pH, low organic matter, sandy soils. Dry peas are more sensitive to sulfentrazone than chickpea.
• Triallate (Far-Go, Avadex) is a soil-applied herbicide that can be lost to volatilization if not incorporated one to two times. Triallate has a narrow weed spectrum and primarily controls only wild oat and annual ryegrass. Triallate provides suppression of brome species.
• Trifluralin (Treflan) is used very infrequently now. It is applied in no-till systems in the fall just prior to freeze-up for residual control of annual grass and broadleaf weeds. In conventional tillage, it is usually applied in the spring with two incorporations. Trifluralin does not control mustard species.

Herbicide resistance is a serious concern for pulse growers. Many herbicide-resistant weeds such as wild oat, green foxtail, kochia, horseweed, and others have been found in all the pulse-growing areas. Repeated use of a given product or products with similar chemistries or modes of action contributes to resistance development. An international survey of herbicide-resistant weeds is available on-line at [http://www.weedscience.org](http://www.weedscience.org). This database tracks hundreds of resistant biotypes and thousands of regions and can be searched geographically, by weed, or by herbicide mode of action.
Critical Needs for Management of Weeds in Pulse Crops:

Research
- Expand herbicide options for broadleaf and grass weed management through continued evaluation of currently available products and by breeding for tolerance to herbicides.
- Expand management options for priority weed species.
- Prioritize and optimize cultural management inputs including seeding rate, row spacing, planting date, and crop rotation for improved crop competitiveness with weeds.
- Focus on systems-based weed management strategies grounded in sound agroecological practices.
- Develop forecasting models.

Regulatory
- Expedite registration and Codex/CPR harmonization for bentazon (Basgran).
- Expedite registration for tribenuron (Express) for control of narrowleaf hawksbeard.
- Register pyridate (Tough).
- Register acifluorfen (pending confirmation of crop tolerance).

Education
- Herbicide resistance management education.
- Herbicide residue carryover education.
- Weed management IPM.
NEMATODES

The impact of nematodes on pulse crop production is not well understood and the presence and differentiation of species within pulse plantings has not been thoroughly quantified. Surveys in North Dakota conducted between 2014 to 2016 may be the most comprehensive to date. These surveys found stunt and pin nematodes to be the most prevalent, and also confirmed the presence of lesion, dagger, spiral, lance, stubby-root, and root-knot nematodes. (Yan et al. 2015, Upadhaya et al. 2017). Note that these surveys do not necessarily reflect nematode populations in other pulse-growing states or regions. Cyst nematodes (specifically, pea cyst nematodes), for example, have been reported in Washington State.

Direct nematode damage in pulses has not been quantified. It is likely that nematodes’ primary negative impact on pulse production is the opportunity their feeding creates for infection by disease pathogens or infestation by root-feeding insects.

Nematodes move slowly in soil but farm equipment carrying infested soil can spread nematodes to new fields quickly.

Based on work group consensus, the species believed to potentially be of concern are discussed below, in alphabetical order.

**Cyst Nematode** (*Heterodera* spp.)
Cyst nematodes of concern in pulse production include *Heterodera ciceri* and *H. rosii* in chickpea, *H. ciceri* in lentil, and *H. goettingiana* in pea.

At low population densities, field symptoms are not visible. At high population densities, field symptoms occur as patches of stunted and yellow plants. Lemon-shaped cysts are the diagnostic signs. Cysts (adult female bodies) can be found embedded in the roots; they are white when young but turn brown when old. A cyst usually contains 100-300 eggs, which hatch to juveniles that then infect plant roots. Under optimal conditions for nematode development, yield losses have been assessed at 20-50%.

**Chemical Controls:** None.

**Biological Controls:** None.

**Cultural Controls:** Crop rotation is an effective means to control cyst nematodes because they have a narrow host range. Generally, a 3- to 5-year rotation out of host plants is needed to reduce nematode densities to low or non-detectable levels. Fallowing can reduce nematode population densities. Delay of planting date helps minimize nematode invasion and reproduction. Soil solarization is effective in reducing nematode population levels but is not cost-effective in pulse crops.
Critical Needs for Cyst Nematode Management in Pulse Crops:

Research:
- Survey cyst nematodes.
- Evaluate improved means of detection and identification of cyst nematode species.
- Identify and develop resistant cultivars.

Regulatory:
- *Heterodera goettingiana* has limited distribution in the United States and is listed as an exotic nematode plant pest by APHIS. *H. ciceri* is on the list of nematodes that are not known to occur in the United States and also listed as an exotic nematode plant pest.

Education:
- Increase nematode disease awareness and symptom identification in IPM outreach.

Reniform Nematode (*Rotylenchulus reniformis*)
Reniform nematode is one of the major nematode pests of chickpea worldwide. Its presence has not been detected in pulses in the Northern Plains, High Plains, and the Pacific Northwest.

Chemical Controls: Telone (1,3-dichloropropene) and Vydate (oxamyl) could be used to control reniform nematode if it were present, although this might not be practical.

Biological Controls: The fungus *Paecilomyces lilacinus* combined with oil cakes has been shown to reduce the damage caused by these nematodes.

Cultural Controls: Reniform nematodes have a vast host range but crop rotation with cereals such as corn, sorghum, and wheat can reduce their numbers. Soil solarization with polyethylene and soil amendments such as animal manure and oilseed cakes can be used to decrease population densities but this may not be economical for pulse crops.

Critical Needs for Reniform Nematode Management in Pulse Crops:

Research:
- Survey and detection of the possible presence of the nematode in the major pulse crop producing regions.

Regulatory:
- The United States currently restricts possible importation of reniform nematodes mainly to protect the cotton industry.

Education:
- Increase nematode disease awareness and symptom identification as part of general IPM outreach.
**Root-knot Nematode** (*Meloidogyne* spp.)
The root-knot nematodes of potential concern in pulse production include *Meloidogyne arenaria*, *M. artiellia*, *M. incognita*, and *M. javanica*. These nematodes have six life stages including eggs, first and second juveniles within the egg, free second-stage juveniles in soil, three stages of juveniles (J2, J3, and J4) in plant tissue, and sedentary adult females in plant tissue or adult males moving freely in soil or stuck in egg sacs.

Root-knot nematodes are the most economically important plant-parasitic nematodes and some species have a wide host range. Infected plants lack vigor. The primary symptoms include galls or knots, stunted plants, and reduced roots. Infected plants cannot properly absorb water and nutrients. Yield losses of up to 80% have been reported. Lighter soil (sandy and sandy loam) tends to enhance the crop damage from root-knot nematodes.

**Chemical Controls:** Chemical pesticides such as Telone (1,3-Dichloropropene), Vapam (metam sodium), Vydate (oxamyl), and Movento (spirotetramat) can be used to control root-knot nematodes.

**Biological Controls:** A few fungi (e.g., *Trichoderma viride*, *T. harzianum*, *Paecilomyces lilacinus*, *Bacillus subtilis*) and bacteria (*Pasteuria penetrans*) are potential biocontrol agents for root-knot nematode species.

**Cultural Controls:** Crop rotation with poor hosts or non-hosts can reduce the nematode population. However, since some root-knot nematode species have a wide host range, effective crop rotation is difficult. Other economically feasible cultural practices include use of cover or trap crops, organic amendments free of nematodes, proper fertilization, and use of resistant or tolerant cultivars.

**Critical Needs for Root-knot Nematode Management in Pulse Crops:**

**Research:**
- Detection, identification, and quantification of root-knot nematode species.
- Identification of resistant or tolerant cultivars and development of new resistant cultivars.

**Regulatory:** *Meloidogyne artiellia* is on the list of nematodes that are not known to occur in the United States and listed an exotic nematode plant pest by APHIS.

**Education:** Increase nematode disease awareness and symptom identification as part of general IPM outreach.
**Root Lesion Nematode (Pratylenchus spp.)**
Several species of root lesion nematodes have been reported to infect roots of pea, chickpea, and lentil including *Pratylenchus penetrans*, *P. neglectus*, and *P. thornei*. Both *P. neglectus* and *P. thornei* are widespread in dryland wheat fields in the Pacific Northwest, where they damage crops in rotation with wheat. The root lesion nematode is one of the most common plant-parasitic nematodes and has a wide host range.

Root lesion nematodes are migratory endoparasites. The vermiform stages of root lesion nematodes completely enter root tissue and move inside the root to extract cellular contents, which results in dark lesions on invaded roots. These nematodes remain mobile and may move into and out of roots and may deposit eggs in soil as well as within root tissue. Yield losses of 20-75% have been reported depending upon the nematode species and population density.

The field symptoms caused by root lesion nematodes are not diagnostic, as they are similar to other biotic and abiotic issues. Fields impacted by root lesion nematodes appear generally unthrifty and may exhibit areas of yellowing and wilting. Symptoms expressed in the foliage are easily confused with common problems such as poor soil depth, soil texture, soil pH, mineral nutrition, or water availability. The symptoms also have many of the same characteristics as diseases such as Fusarium crown rot, Pythium root rot, and Rhizoctonia root rot.

**Chemical Controls:** Soil fumigation (with methyl bromide, methyl isothiocyanate, or chloropicrin) can be effective for managing nematodes but this practice is not economically feasible for pulse crops. Root lesion nematodes can theoretically be controlled by the use of nematicides such as Vapam (metam sodium) and Vydate (oxamyl).

**Biological Controls:** None.

**Cultural Controls:** Crop rotation is limited because *P. neglectus* is polyphagous, with a broad range of hosts such as legumes, cereals, biofuel crops, and many genera of broadleaf and grass weeds. Soil amendments including white mustard, rapeseed and ryegrass have been used to manage root lesion nematodes. Using resistant or tolerant cultivars is the most efficient and cost-effective means for protecting crops against root lesion nematodes. Cultivars of pea, chickpea, and lentil exhibit varying degrees of resistance, but this has not been thoroughly investigated.

**Critical Needs for Root Lesion Nematode Management in Pulse Crops:**

**Research:**
- Surveys of root lesion nematodes.
- Detection and identification of root lesion nematode species.
- Evaluation of the reproduction ability and the effect of root lesion nematodes on plant growth parameters and yield.
- Identification and development of resistant cultivars.

**Regulatory:** None.

**Education:** Increase root lesion nematode disease awareness as part of general IPM outreach.
Stem and Bulb Nematode (*Ditylenchus* spp.)
The stem and bulb nematode, *Ditylenchus dipsaci*, is distributed mainly in temperate climates of the world and has been associated with lentil, chickpea, and pea crops. A related species, *D. weischeri*, has been known to reproduce on two pea cultivars, but generally speaking pea and other annual pulse crops including chickpea and lentil are non-hosts. *D. dipsaci*, however, is a serious parasitic nematode of many plant species and a quarantine nematode in many countries. Typical symptoms of *D. dipsaci* damage include swelling and distortion of stems, leaves, and flowers, shortened internodes, proliferation of axillary buds, and stunting and necrosis of stems. This nematode is able to reduce seed vigor and cause blackening on infected seed pods.

**Chemical Controls:** Seed treatment, fumigants, and nematicides have been found effective to some extent in suppressing this nematode but are not an economically feasible means of controlling this nematode for large areas.

**Biological Controls:** None.

**Cultural Controls:** Crop rotation is restricted because of the broad host range of this nematode. Current management practices to control this nematode include sanitation in fields, proper weed control, avoiding adjacent or rotational host crops, hot-water treatment of infected seed, using certified nematode-free seed, and use of tolerant or resistant cultivars.

**Critical Needs for Stem and Bulb Nematode Management in Pulse Crops:**

**Research:**
- Monitor the occurrence, abundance, and distribution of the nematode when its activity is suspected.
- Identify species of stem and bulb nematodes.

**Regulatory:** *Ditylenchus dipsaci* is a quarantine nematode in many countries.

**Education:** Nematode awareness and symptom identification as part of general IPM outreach.
Critical Needs for Management of Nematodes in Pulse Crops:

Research

- Monitor across growing regions when nematode activity is suspected.
- Conduct nematode surveys in other regions as warranted.
- Research root-knot and root lesion nematodes as a proactive measure.

Regulatory: None.

Education: Include nematode damage awareness and symptom identification as part of general IPM outreach.
VERTEBRATES

While pulse crops might appear to be less susceptible than other crops to damage by vertebrates, a variety of birds and mammals can have negative impacts on pulse-crop production. At planting, birds such as geese and pheasants and rodents including ground squirrels and voles may eat surface and sub-surface seeds. After crop emergence, rabbits and other foliage-eating vertebrates can pose problems in pulse crops, especially chickpeas. Elk, pronghorn antelope, and deer present a problem in some areas; elk have been known to wipe out entire research trial plots. Growers who swath or windrow crops may experience damage by ducks and geese feeding on crops. Growers within two miles of lakes and similar staging areas are likely to suffer more damage from waterfowl than other growers. Growers have even reported problems with theft of crop by humans who resell at farmer’s markets.

Significant and specific information regarding widespread damage by vertebrates is lacking in pulse crops. It is unclear whether this lack of information is due to vertebrate avoidance, lack of producer awareness, under-reporting, or a combination of issues including the possibility of reasons not considered. Thus, pulse growers’ needs with respect to vertebrate pests focus on identification and assessment of damage.

Critical Needs for Management of Vertebrates in Pulse Crops:

Research
- Discern whether pulse crops are less vulnerable to damage by vertebrate pests than other crops, as opposed to the damage simply being less noticeable.
- Identify the environmental and habitat characteristics of areas that are more susceptible to vertebrate damage, such as water proximity that influences waterfowl prevalence.
- Develop a simple decision model to signal the need for control of vertebrate pests.
- Refine damage assessment to ensure accurate identification of the pest.
- Investigate diversionary tactics. For instance, would leaving some narrow rows of standing grain in a swathed field reduce damage by waterfowl to the pulse crop?
- Survey growers to understand issues such as hunting. Do producers believe present hunting activity for ungulates is sufficient to meet control needs?

Regulatory: Address hunting regulations if deemed appropriate by growers.

Education
- Develop a risk calendar to show producers when each vertebrate species is likely to damage crops.
- Encourage farmers to reduce waterfowl hunting on harvested fields to reduce moving birds to swathed fields.
- Provide tips for accurately identifying the vertebrate pest causing the damage. For example, turkeys may be blamed for damage because they are noticed in fields where damage has occurred even though research has shown that turkeys, at most, cause minimal damage.
For More Information

The pest management practices, critical needs, tables, and general conclusions presented here are the result of a cooperative effort by the work group listed at the front of the document. For additional information on the production of chickpeas, lentils, and dry peas in the United States contact:

U.S.A. Dry Pea & Lentil Council
2780 W. Pullman Road
Moscow, ID 83843-4024
USA
Phone: 208-882-3023
Fax: 208-882-6406
http://www.pea-lentil.com

References


Fungicide Resistance Action Committee website, http://frac.info

Insecticide Resistance Action Committee website, http://irac-online.org


APPENDICES

A – Activity Tables
B – Efficacy Tables for Herbicides
C – Efficacy Tables for Fungicides
D – Efficacy Tables for Insecticides
### Activity Table for Chickpeas
(P=Pacific Northwest, N=Northern Plains)

#### Cultural Activities

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Note: Information based on grower and pest control advisor experience.

#### Pest Management Activities and Crop Monitoring Profile

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Note: Information based on grower and pest control advisor experience.
* For weed control and herbicide incorporation.
# Activity Table for Lentils
*(P=Pacific Northwest, N=Northern Plains)*

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Note: Information based on grower and pest control advisor experience. Includes both fall and spring lentils.

## Pest Management Activities and Crop Monitoring Profile

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<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
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</tr>
</tbody>
</table>

Note: Information based on grower and pest control advisor experience.

* For weed control and herbicide incorporation.
Activity Table for Dry Peas
(P=Pacific Northwest, N=Northern Plains, H=High Plains, F=Fall-planted)

Cultural Activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>JAN</th>
<th>FEB</th>
<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
<th>NOV</th>
<th>DEC</th>
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<tbody>
<tr>
<td>Sample Soil</td>
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<td></td>
<td></td>
<td></td>
<td>F</td>
<td>F</td>
<td>N,H</td>
<td>N,H</td>
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<td>Fertilize</td>
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<td>N,H</td>
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<td>F</td>
<td>N,H</td>
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</tr>
<tr>
<td>Irrigate*</td>
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<td>F</td>
<td>F</td>
<td>F</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Test Petioles†</td>
<td>F</td>
<td>F</td>
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<td>Swath</td>
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<td>P</td>
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</table>

Note: Information based on grower and pest control advisor experience. Includes fall and spring dry peas.
* Fields are pre-irrigated if necessary to increase soil moisture levels, then planted, rolled, and irrigated again.
† This activity is rare. Based on test, if nitrogen is needed, it is applied by fertigation.

Pest Management Activities and Crop Monitoring Profile

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<th>Activity</th>
<th>JAN</th>
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<th>MAR</th>
<th>APR</th>
<th>MAY</th>
<th>JUN</th>
<th>JUL</th>
<th>AUG</th>
<th>SEP</th>
<th>OCT</th>
<th>NOV</th>
<th>DEC</th>
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<td>P,N</td>
<td>H</td>
<td>H</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
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<td>P,H,F</td>
<td>P,N</td>
<td>H,F</td>
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</tr>
<tr>
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<td>P,N</td>
<td>H,F</td>
<td></td>
<td>P</td>
<td>P</td>
<td>P</td>
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</tr>
<tr>
<td>Apply Fungicide</td>
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<td>F</td>
<td>F</td>
<td>P,F</td>
<td>H,F</td>
<td>P,N</td>
<td>H</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apply Spot Herbicide</td>
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<td>F</td>
<td>F</td>
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<td></td>
</tr>
<tr>
<td>Rogue Weeds</td>
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<td>F</td>
<td>F</td>
<td>F</td>
<td></td>
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<td>P,H</td>
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<tr>
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<td>P,F</td>
<td>P,N</td>
<td>H,F</td>
<td>P,N</td>
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</table>

Note: Information based on grower and pest control advisor experience.
* For weed control and herbicide incorporation.
# EFFICACY TABLES FOR HERBICIDES

## Part 1: Perennials

See also Parts 2, 3A, and 3B for additional weed types.

Efficacy key: E = Excellent (greater than 90% control), G = Good (80-90% control), F = Fair (65-80% control), P = Poor (less than 65% control), N = no or little activity against this weed.

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>(Pea, lentil, chickpea)</th>
<th>Canada thistle</th>
<th>Dandelion</th>
<th>Field bindweed</th>
<th>Foxtail barley</th>
<th>Quackgrass</th>
<th>Sowthistle (perennial)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentazon (Basagran)</td>
<td>P</td>
<td>F-G</td>
<td>P</td>
<td>P</td>
<td>N</td>
<td>N</td>
<td>P</td>
<td>Apply to small weeds POST</td>
</tr>
<tr>
<td>Carfentrazone (Aim)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Apply to small weeds PP or PRE</td>
</tr>
<tr>
<td>Clethodim (Select)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Grass control POST</td>
</tr>
<tr>
<td>Dimethenamid (Outlook)</td>
<td>LC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Some annual grasses, broadleaves.</td>
</tr>
<tr>
<td>Ethalfuralin (Sonalan)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Some annual grasses, broadleaves.</td>
</tr>
<tr>
<td>Glyphosate (Roundup Ultra)</td>
<td>PLC</td>
<td>G-E</td>
<td>G-E</td>
<td>G-E</td>
<td>G-E</td>
<td>G-E</td>
<td>G-E</td>
<td>Fall, PP, PRE</td>
</tr>
<tr>
<td>Imazamox (Raptor, Beyond)</td>
<td>P, CL</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>-</td>
<td>F</td>
<td>N-P</td>
<td>Use POST in dry pea and Clearfield lentil</td>
</tr>
<tr>
<td>Imazethapyr (Pursuit)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Plant-back restrictions.</td>
</tr>
<tr>
<td>MCPA sodium salt</td>
<td>P</td>
<td>P-F</td>
<td>P-F</td>
<td>P</td>
<td>N</td>
<td>N</td>
<td>P-F</td>
<td>May cause crop injury.</td>
</tr>
<tr>
<td>MCPB (Thistrol)</td>
<td>P</td>
<td>P-F</td>
<td>P-F</td>
<td>P</td>
<td>N</td>
<td>N</td>
<td>P-F</td>
<td>Spot treatment for thistle suppression.</td>
</tr>
<tr>
<td>Metribuzin (Sencor)</td>
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<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Soil-applied</td>
</tr>
<tr>
<td>Paraquat (Gramoxone)</td>
<td>PLC</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td>Pre-harvest desiccant</td>
</tr>
<tr>
<td>Pendimethalin (Prowl)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
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</tr>
<tr>
<td>Quizalofop (Assure II)</td>
<td>PLC</td>
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<td>N</td>
<td>N</td>
<td>G-E</td>
<td>G-E</td>
<td>N</td>
<td>Grass control POST</td>
</tr>
<tr>
<td>S-metolachlor (Dual Magnum)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Plant-back restrictions on wheat</td>
</tr>
<tr>
<td>Sethoxydim (Poast)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>G</td>
<td>G</td>
<td>N</td>
<td>Grass control POST</td>
</tr>
<tr>
<td>Sulfentrazone (Spartan)</td>
<td>PC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Increased activity in high pH, low OM, sandy soils</td>
</tr>
<tr>
<td>Triallate (Far-Go, Avadex BW)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<tr>
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<td>N</td>
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</table>
## EFFICACY TABLES FOR HERBICIDES

### Part 2: Annual Grasses

See also Parts 1, 3A, and 3B for additional weed types.

Efficacy key: 
E = Excellent (greater than 90% control), 
G = Good (80-90% control), 
F = Fair (65-80% control), 
P = Poor (less than 65% control), 
N = no or little activity against this weed.

<table>
<thead>
<tr>
<th>Herbicide Name</th>
<th>Type</th>
<th>(Pre Emergent, Pre Emergent)</th>
<th>Downy brome</th>
<th>Green foxtail</th>
<th>Yellow foxtail</th>
<th>Italian ryegrass</th>
<th>Japanese bromegrass</th>
<th>Jointed goatgrass</th>
<th>Persian darnel</th>
<th>Volunteer cereals</th>
<th>Wild oat</th>
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<tbody>
<tr>
<td>Bentazon (Basagran)</td>
<td>P</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Apply to small weeds POST</td>
<td></td>
</tr>
<tr>
<td>Carfentrazone (Aim)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Apply to small weeds PP or PRE</td>
<td></td>
</tr>
<tr>
<td>Clethodim (Select)</td>
<td>PLC</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>G-E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>Grass control POST</td>
<td></td>
</tr>
<tr>
<td>Dimethenamid (Outlook)</td>
<td>LC</td>
<td>P-G</td>
<td>G-E</td>
<td>G-E</td>
<td>F-G</td>
<td>P</td>
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<td></td>
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<td>Some annual grasses, broadleaves.</td>
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<tr>
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<td>E</td>
<td>E</td>
<td>N-P</td>
<td>P</td>
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<td>E</td>
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<td>E</td>
<td>E</td>
<td>Fall, PP, PRE</td>
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</tr>
<tr>
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<td>G-E</td>
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<td>G-E</td>
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<td>Use POST in dry pea and Clearfield lentil</td>
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<tr>
<td>Imazethapyr (Pursuit)</td>
<td>PLC</td>
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<td>G</td>
<td>F-G</td>
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<td>MCPA sodium salt</td>
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<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<td>N</td>
<td>N</td>
<td>N</td>
<td>May cause crop injury.</td>
<td></td>
</tr>
<tr>
<td>MCPB (Thistrol)</td>
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<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
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<td>N</td>
<td>N</td>
<td>Spot treatment for thistle suppression.</td>
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</tr>
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<td>PLC</td>
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<td>F</td>
<td>F</td>
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<td></td>
<td>P</td>
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<td></td>
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<td>Soil-applied</td>
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</tr>
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<td>Parquat (Gramoxone)</td>
<td>PLC</td>
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<td>G</td>
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<td>G</td>
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<td>Pendimethalin (Prowl)</td>
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<td>N-P</td>
<td>P</td>
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<tr>
<td>Quizalofop (Assure II)</td>
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<td>F-G</td>
<td>G-E</td>
<td>G-E</td>
<td>E</td>
<td>G-E</td>
<td>E</td>
<td>E</td>
<td>Grass control POST</td>
<td></td>
</tr>
<tr>
<td>S-metolachlor (Dual Magnum)</td>
<td>PLC</td>
<td>P-F</td>
<td>F-E</td>
<td>F-E</td>
<td></td>
<td></td>
<td>P</td>
<td>P-F</td>
<td></td>
<td></td>
<td>Plant-back restrictions on wheat</td>
<td></td>
</tr>
<tr>
<td>Sethoxydim (Poast)</td>
<td>PLC</td>
<td>P-G</td>
<td>E</td>
<td>E</td>
<td>G</td>
<td>G</td>
<td>G-E</td>
<td>G-E</td>
<td></td>
<td></td>
<td>Grass control POST</td>
<td></td>
</tr>
<tr>
<td>Sulfentrazone (Spartan)</td>
<td>PC</td>
<td>P</td>
<td>P</td>
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<td></td>
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<td>N</td>
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<td>Increased activity in high pH, low OM, sandy soils</td>
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<tr>
<td>Triallate (Far-Go, Avadex)</td>
<td>PLC</td>
<td>P</td>
<td>-</td>
<td>-</td>
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<td>N</td>
<td>F-E</td>
<td></td>
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</tr>
<tr>
<td>Trifluralin (Fintan)</td>
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<td>F-G</td>
<td>E</td>
<td>E</td>
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<td>N-P</td>
<td>P</td>
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</table>
# Efficacy Tables for Herbicides

## Part 3A: Annual Broadleaves A-M

See also Parts 1, 2, and 3B for additional weed types.

Efficacy key: E = Excellent (greater than 90% control), G = Good (80-90% control), F = Fair (65-80% control), P = Poor (less than 65% control), N = no or little activity against this weed.

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>(Pea, lentil, (Chickpea)</th>
<th>Buckwheat, Wild</th>
<th>Hawsheard, NL</th>
<th>Horseweed</th>
<th>Kochia</th>
<th>Lambsquarters</th>
<th>Lettuce, Prickly</th>
<th>Marsholder</th>
<th>Mustard, Wild</th>
<th>Mustard, Win ann</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentazon (Basagran)</td>
<td>P</td>
<td>P-G</td>
<td>P-F</td>
<td>P-E</td>
<td>F-E</td>
<td>G</td>
<td>G-E</td>
<td>E</td>
<td>E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carfentrazone (Aim)</td>
<td>PLC</td>
<td>P</td>
<td>P</td>
<td>N</td>
<td>F-E</td>
<td>F-G</td>
<td>P</td>
<td>P</td>
<td>P</td>
<td></td>
<td>Apply to small weeds POST</td>
</tr>
<tr>
<td>Clethodim (Select)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Grass control POST</td>
</tr>
<tr>
<td>Dimethenamid (Outlook)</td>
<td>LC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>F-G</td>
<td>-</td>
<td>N</td>
<td>P</td>
<td>F</td>
<td>Some annual grasses, broadleaves.</td>
</tr>
<tr>
<td>Ethalfluralin (Sonalan)</td>
<td>PLC</td>
<td>P</td>
<td>P</td>
<td>N</td>
<td>P</td>
<td>F-G</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>P</td>
<td>Some annual grasses, broadleaves.</td>
</tr>
<tr>
<td>Glyphosate (Roundup)</td>
<td>PLC</td>
<td>P-G</td>
<td>F-G</td>
<td>G-E</td>
<td>F-E</td>
<td>P-E</td>
<td>P-G</td>
<td>G-E</td>
<td>E</td>
<td>G-E</td>
<td>Fall, PP, PRE</td>
</tr>
<tr>
<td>Imazamox (Raptor, Beyond)</td>
<td>P, CL</td>
<td>P</td>
<td>F-G</td>
<td>N</td>
<td>E</td>
<td>P-F</td>
<td>G</td>
<td>G-E</td>
<td>E</td>
<td>E</td>
<td>Use POST in dry pea and Clearfield lentil</td>
</tr>
<tr>
<td>Imazethapyr (Pursuit)</td>
<td>PLC</td>
<td>P</td>
<td>N</td>
<td>E</td>
<td>P</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>Plant-back restrictions.</td>
</tr>
<tr>
<td>MCPB (Thistrol)</td>
<td>P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Spot treatment for thistle suppression.</td>
</tr>
<tr>
<td>Metribuzin (Sencor)</td>
<td>PLC</td>
<td>F-G</td>
<td>F</td>
<td>F-G</td>
<td>F-P</td>
<td>G-E</td>
<td>E</td>
<td>G-E</td>
<td>G-E</td>
<td></td>
<td>Soil-applied</td>
</tr>
<tr>
<td>Paraquat (Gramoxone)</td>
<td>PLC</td>
<td>F</td>
<td>F-G</td>
<td>F-G</td>
<td>G-E</td>
<td>E</td>
<td>F-G</td>
<td>G</td>
<td>E</td>
<td></td>
<td>Pre-harvest desiccant</td>
</tr>
<tr>
<td>Pendimethalin (Prowl)</td>
<td>PLC</td>
<td>P</td>
<td>P</td>
<td>N</td>
<td>P</td>
<td>F-G</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>P</td>
<td>Some annual grasses, broadleaves.</td>
</tr>
<tr>
<td>Quizalofop (Assure II)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Grass control POST</td>
</tr>
<tr>
<td>S-metolachlor (Dual Magnum)</td>
<td>PLC</td>
<td>N-P</td>
<td>N</td>
<td>N-P</td>
<td>P-F</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Plant-back restrictions on wheat</td>
</tr>
<tr>
<td>Sethoxydim (Poast)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Grass control POST</td>
</tr>
<tr>
<td>Sulfentrazone (Spartan)</td>
<td>PC</td>
<td>P-F</td>
<td>P</td>
<td>F</td>
<td>F-E</td>
<td>G-E</td>
<td>P</td>
<td>P</td>
<td>G</td>
<td>P</td>
<td>Increased activity in high pH, low OM, sandy soils</td>
</tr>
<tr>
<td>Triallate (Far-Go, Avadex BW)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Must be incorporated twice.</td>
</tr>
<tr>
<td>Trifluralin (Treflan)</td>
<td>PLC</td>
<td>P</td>
<td>P66</td>
<td>N</td>
<td>P</td>
<td>F-G</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>P</td>
<td>Must be incorporated twice.</td>
</tr>
</tbody>
</table>
## EFFICACY TABLES FOR HERBICIDES

### Part 3B: Annual Broadleaves N-Z

See also Parts 1, 2, and 3A for additional weed types.

Efficacy key: E = Excellent (greater than 90% control), G = Good (80-90% control), F = Fair (65-80% control), P = Poor (less than 65% control), N = no or little activity against this weed.

<table>
<thead>
<tr>
<th>Herbicide</th>
<th>(P)ea, (L)entil, (C)hickpea</th>
<th>Nightshade, E/Black</th>
<th>Nightshade, Hairy</th>
<th>Pigweed, Redroot</th>
<th>Ragweed, Common</th>
<th>Smartweed, Annual</th>
<th>Sunflower</th>
<th>Thistle, Canada</th>
<th>Thistle, Russian</th>
<th>Wornwood, Biennial</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bentazon (Basagran)</td>
<td>P</td>
<td>N</td>
<td>F-G</td>
<td>F-E</td>
<td>P-F</td>
<td>E</td>
<td>E</td>
<td>E-G</td>
<td>G</td>
<td>G-E</td>
<td>Apply to small weeds POST</td>
</tr>
<tr>
<td>Carfentrazone (Aim)</td>
<td>PLC</td>
<td>N-P</td>
<td>N-P</td>
<td>G</td>
<td>N</td>
<td>N</td>
<td>P</td>
<td>N</td>
<td>F</td>
<td>-</td>
<td>Apply to small weeds PP or PRE</td>
</tr>
<tr>
<td>Clethodim (Select)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Grass control POST</td>
</tr>
<tr>
<td>Dimethenamid (Outlook)</td>
<td>LC</td>
<td>F-G</td>
<td>F-G</td>
<td>G-E</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>P-F</td>
<td>N</td>
<td>Some annual grasses, broadleaves.</td>
</tr>
<tr>
<td>Ethalfluralin (Sonalan)</td>
<td>PLC</td>
<td>N-P</td>
<td>N-P</td>
<td>E</td>
<td>N</td>
<td>P</td>
<td>N</td>
<td>N</td>
<td>F-G</td>
<td>N</td>
<td>Some annual grasses, broadleaves.</td>
</tr>
<tr>
<td>Glyphosate (Roundup)</td>
<td>PLC</td>
<td>P-G</td>
<td>P-G</td>
<td>E</td>
<td>G-E</td>
<td>G-E</td>
<td>G</td>
<td>F-E</td>
<td>F-E</td>
<td>Fall, PP, PRE</td>
<td></td>
</tr>
<tr>
<td>Imazamox (Raptor)</td>
<td>P, CL</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>N</td>
<td>G-E</td>
<td>E</td>
<td>N-P</td>
<td>G-E</td>
<td>P</td>
<td>Use POST in dry pea and Clearfield lentil</td>
</tr>
<tr>
<td>Imazethapyr (Pursuit)</td>
<td>PLC</td>
<td>E</td>
<td>E</td>
<td>E</td>
<td>N</td>
<td>G</td>
<td>G-E</td>
<td>N</td>
<td>P-E</td>
<td>N</td>
<td>Plant-back restrictions.</td>
</tr>
<tr>
<td>MCPA sodium salt</td>
<td>P</td>
<td>P-F</td>
<td>P-F</td>
<td>P-F</td>
<td>G</td>
<td>F</td>
<td>G</td>
<td>P-F</td>
<td>P</td>
<td>F-G</td>
<td>May cause crop injury.</td>
</tr>
<tr>
<td>MCPB (Thistrol)</td>
<td>P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Spot treatment for thistle suppression.</td>
<td></td>
</tr>
<tr>
<td>Metribuzin (Sencor)</td>
<td>PLC</td>
<td>P</td>
<td>P</td>
<td>G-E</td>
<td>P-F</td>
<td>G</td>
<td>F</td>
<td>N</td>
<td>-</td>
<td>-</td>
<td>Soil-applied</td>
</tr>
<tr>
<td>Paraquat (Gramoxone)</td>
<td>PLC</td>
<td>G-E</td>
<td>G-E</td>
<td>E</td>
<td>G-E</td>
<td>E</td>
<td>E</td>
<td>P</td>
<td>E</td>
<td>-</td>
<td>Pre-harvest desiccant</td>
</tr>
<tr>
<td>Pendimethalin (Prowl)</td>
<td>PLC</td>
<td>N-P</td>
<td>N-P</td>
<td>E</td>
<td>N</td>
<td>P</td>
<td>N</td>
<td>N</td>
<td>F-G</td>
<td>N</td>
<td>Some annual grasses, broadleaves.</td>
</tr>
<tr>
<td>Quizalofop (Assure II)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Grass control POST</td>
</tr>
<tr>
<td>S-metolachlor (Dual Magnum)</td>
<td>PLC</td>
<td>G</td>
<td>F</td>
<td>F-G</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>P</td>
<td>N</td>
<td>Plant-back restrictions on wheat</td>
</tr>
<tr>
<td>Sethoxydim (Poast)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Grass-back restrictions on wheat</td>
</tr>
<tr>
<td>Sulfentrazone (Spartan)</td>
<td>PC</td>
<td>E</td>
<td>F-G</td>
<td>F-E</td>
<td>N</td>
<td>G-E</td>
<td>N</td>
<td>N</td>
<td>G-E</td>
<td>G</td>
<td>Increased activity in high pH, low OM, sandy soils</td>
</tr>
<tr>
<td>Triallate (Far-Go, Avadex BW)</td>
<td>PLC</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>N</td>
<td>Must be incorporated twice.</td>
</tr>
<tr>
<td>Trifluralin (Treflan)</td>
<td>PLC</td>
<td>N-P</td>
<td>N-P</td>
<td>E</td>
<td>N</td>
<td>P</td>
<td>N</td>
<td>N</td>
<td>F-G</td>
<td>N</td>
<td>Must be incorporated twice.</td>
</tr>
</tbody>
</table>
EFFICACY TABLES FOR FUNGICIDES
Part 1: Seed Treatments

Adapted from a table of registered controls drafted by the Northcentral Integrated Pest Management Center Pulse Crop Working Group in February 2016. In most cases, data are lacking to provide efficacy ratings, therefore R (Registered but control level not known) or S (Suppression only) are given. Where efficacy is stated, E = Excellent (greater than 90% control), G = Good (80-90% control), F = Fair (60-80% control), and P = Poor (less than 60% control). These notes apply to this Part 1 table as well as the Part 2 (foliar treatment) table that follows.

<table>
<thead>
<tr>
<th>Class (FRAC Group)</th>
<th>Active ingredient</th>
<th>Product</th>
<th>(Pea, Lentil, Chickpea)</th>
<th>Ascochyta Blight</th>
<th>Pythium</th>
<th>Aphanomyces</th>
<th>Rhizoctonia</th>
<th>Fusarium</th>
<th>Botrytis</th>
<th>Sclerotinia</th>
<th>General fungi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzimidazole Carbamates (1)</td>
<td>Thiabendazole</td>
<td>Mertect 340-F</td>
<td>P,L,C</td>
<td>R</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dithiocarbamates (M3)</td>
<td>Thiram</td>
<td>42-S Thiram</td>
<td>P,L,C</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triazoles (3)</td>
<td>Ipconazole</td>
<td>Rancona 3.8 FS</td>
<td>P,L,C</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phenylamides (4)</td>
<td>Mefenoxam</td>
<td>Apron XL</td>
<td>P,L,C</td>
<td>R</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Metalaxyl</td>
<td>Allegiance FL</td>
<td>P,L,C</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Succinate-dehydrogenase inhibitors (7)</td>
<td></td>
<td>Sedaxane</td>
<td>Vibration</td>
<td>P,L,C</td>
<td>S²</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>Fluxapyroxad</td>
<td>Systiva XS</td>
<td>P,L,C</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>Penflufen</td>
<td>Evergol Prime</td>
<td>P,L,C</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>Quinone outside Inhibitors (11)</td>
<td>Azoxystrobin</td>
<td>Dynasty</td>
<td>L,C</td>
<td>S²</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>Pyraclostrobin</td>
<td>Stamina</td>
<td>P,L,C</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>Trifloxystrobin</td>
<td>Trilex Flowable</td>
<td>P,L,C</td>
<td>R</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>PhenylPyroles (12)</td>
<td>Fludioxonil</td>
<td>Maxim 4FS</td>
<td>P,L,C</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>Aromatic hydrocarbons (14, proposed)</td>
<td>Toclofos-methyl</td>
<td>Rizolex</td>
<td>P,L,C</td>
<td>R</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>Thiazolecarboxamides (U5)</td>
<td>Ethaboxam</td>
<td>Intego Solo</td>
<td>L,C</td>
<td>R</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>Phthalimides (M4)</td>
<td>Captan</td>
<td>Captan 4L</td>
<td>P</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
</tbody>
</table>

1 Registered for protection against fungi; check label for details
2 Check label for details on fungal species. See Ascochyta Blight section for species details and taxonomy updates.
3 Product efficacy may be reduced in areas with fungal populations that are resistant to strobilurin fungicides.
4 Product efficacy may be reduced in areas with Pythium populations that are resistant to metalaxyl fungicides.
5 Section 2ee in Montana. Registration pending in other states.
# Efficacy Tables for Fungicides

## Part 2: Foliar Treatments

See introductory notes on previous table, Part 1.

<table>
<thead>
<tr>
<th>Class (FRAC Group)</th>
<th>Active Ingredient</th>
<th>Product (Pea, Lentil, Chickpea)</th>
<th>Ascochyta blight (Pea, Lentil, Chickpea)</th>
<th>Acacia mearnsii (Acacia)</th>
<th>Anthracnose (Pea, Lentil, Chickpea)</th>
<th>Grey mold (Botrytis) (Pea, Lentil, Chickpea)</th>
<th>Powdery mildew (Pea, Lentil, Chickpea)</th>
<th>Septoria (Pea, Lentil, Chickpea)</th>
<th>Stemphyllium (Pea, Lentil, Chickpea)</th>
<th>White mold (Sclerotinia) (Pea, Lentil, Chickpea)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methyl benzimidazole carbamate (1)</td>
<td>Thiophanate-methyl</td>
<td>Topsin 4.5FL</td>
<td>C</td>
<td>R</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demethylation inhibitors (3)</td>
<td>Prothioconazole</td>
<td>Proline</td>
<td>P</td>
<td>G-E</td>
<td>F</td>
<td>G-E</td>
<td>G</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Metconazole</td>
<td>Quash</td>
<td>P</td>
<td>C</td>
<td>F</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Succinate dehydrogenase inhibitors (7)</td>
<td>Boscald</td>
<td>Endura</td>
<td>P</td>
<td>L</td>
<td>P-F</td>
<td>P</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td></td>
<td>Penthioyparad</td>
<td>Vertisan</td>
<td>P</td>
<td>L</td>
<td>F-G</td>
<td>R</td>
<td>P</td>
<td>R</td>
<td>R</td>
<td>R</td>
</tr>
<tr>
<td>Quinone outside inhibitors (11)</td>
<td>Azoxystrobin</td>
<td>Quadris Flowable</td>
<td>P</td>
<td>L</td>
<td>R³</td>
<td>R</td>
<td>G-E</td>
<td>R</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Picoxystrobin</td>
<td>Aproach</td>
<td>P</td>
<td>C</td>
<td>R³</td>
<td>R</td>
<td>G-E</td>
<td>R</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pyraclostrobin</td>
<td>Headline SC</td>
<td>P</td>
<td>C</td>
<td>R⁵</td>
<td>R</td>
<td>E</td>
<td>R</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>Other (29)</td>
<td>Fluazinam</td>
<td>Omega 500F</td>
<td>C</td>
<td></td>
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1 Good efficacy when good fungicide deposition is achieved to the interior of the canopy; poor to fair efficacy with poor deposition.

2 Where fungicide resistant strains are not present (chickpea, MT and ND med-high risk; in pea, a few fungicide-resistant isolates have been found). Specifically, in field trials conducted in North Dakota, all 3 QoI’s have shown excellent efficacy against QoI-sensitive Ascochyta and no efficacy against QoI-insensitive Ascochyta.

3 Pycloconazole shows some efficacy against powdery mildew, but not enough testing has been conducted to determine whether its efficacy rating should be fair or good.

4 Chlorothalonil has exhibited efficacy against these pathogens, but degree depends upon fungicide deposition within the canopy.

5 Priaxor has shown excellent efficacy against QoI-sensitive Ascochyta and fair to good efficacy against QoI-insensitive Ascochyta.

6 Priaxor has shown efficacy against powdery mildew, but not enough testing has been conducted to assign a level of efficacy.
EFFICACY TABLES FOR INSECTICIDES

Adapted from a table of registered controls drafted by the Northcentral Integrated Pest Management Center Pulse Crop Working Group in February 2016. Table includes the most widely marketed products, and is not intended to be a list of all labeled products. Efficacy ratings: E = Excellent (greater than 90% control), G = Good (80-90% control), F = Fair (60-80% control), P = Poor (less than 60% control), N/A = not used against this weed pest. See last page of this multi-page table for footnote key.

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<th>Active ingredient</th>
<th>Product</th>
<th>Crop</th>
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<th>Grasshoppers</th>
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# APPENDIX D

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## Appendix D

### Table: Insecticide Preparations for Pulse Crops

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<tr>
<th>Class</th>
<th>Active ingredient</th>
<th>Product</th>
<th>Crop</th>
<th>Armyworms</th>
<th>Cutworms</th>
<th>Grasshoppers</th>
<th>Lygus Bugs</th>
<th>Pea Aphid</th>
<th>Seed Corn Maggot</th>
<th>Wireworms</th>
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<tbody>
<tr>
<td>Mixed</td>
<td>Beta-cyfluthrin + imidacloprid</td>
<td>Leverage 360&lt;sup&gt;1&lt;/sup&gt;</td>
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<td></td>
<td>Bifenthrin + imidacloprid</td>
<td>Brigadier&lt;sup&gt;2&lt;/sup&gt;</td>
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<td>Bifenthrin + zeta-cypermethrin</td>
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<td>Chlorantraniliprole + lambda-cyhalothrin</td>
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<td>Chlorpyrifos + bifenthrin</td>
<td>Match-Up&lt;sup&gt;3&lt;/sup&gt;</td>
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<sup>1</sup>P=pea, L=lentil, C=chickpea  
<sup>2</sup>Commercial seed treatment only  
<sup>3</sup>Restricted use pesticide  
<sup>4</sup>Foliar application labeled for control of pea aphid on lentil