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PULSE CROP
Production Field Guide for North Dakota

NDSU | EXTENSION

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Field Pea Production

Introduction

Field pea, or “dry pea,” is marketed as a dry, shelled product for human or livestock food. Field pea differs from fresh or succulent pea, which is marketed as a fresh or canned vegetable.

The major field pea-producing areas include Canada, Europe, Australia and the U.S. Historically, field pea primarily was grown in the Palouse region of Washington and Idaho. In the 1990s, North Dakota, South Dakota and Montana began producing dry pea.

The pea production in North Dakota peaked in 2006 (Figure 1). The majority (more than 70%) of the dry pea produced in the U.S. is exported.

Uses

Field pea is a grain legume commonly consumed throughout the world and is popular in human vegetarian diets.

Field pea has high levels of the amino acids, lysine and tryptophan, which are relatively low in cereal grains. Field pea contains approximately 21% to 25% protein. Peas contain high levels of carbohydrates, are low in fiber and contain 86% to 87% total digestible nutrients, which makes them an excellent livestock feed.

Field pea also contains 5% to 20% less of the trypsin inhibitors than soybean. This allows it to be fed directly to livestock without having to go through the extrusion heating process.

Field pea often is cracked or ground and added to cereal grain rations. Research has shown that field pea is an excellent protein supplement in most livestock rations.

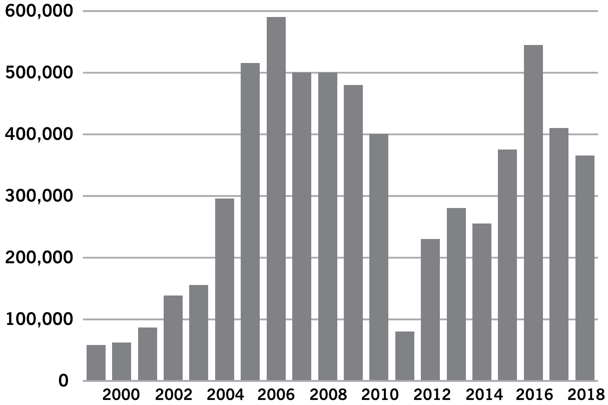

Figure 1. North Dakota Dry Pea Harvested Acreage, 1999 to 2018.

Source: North Dakota Agricultural Statistics Service – U.S. Department of Agriculture.

Use as a Forage or Cover Crop

Field pea often is used in forage crop mixtures with small grain. Field pea forage is approximately 18% to 20% protein. Pea interseeded at 60 to 100 pounds per acre with a small grain such as oat can increase the protein concentration of the mixed forage by 2 to 4 percentage points and increase the relative feed value by 20 points versus oat seeded alone.

Field pea also may be grown as a cover crop to improve or maintain future soil productivity. Opportunities exist to utilize just-harvested pea fields for a volunteer pea cover crop. At harvest, a small percentage of the dry field pea seeds will have dropped to the ground, even when combines are well-adjusted. These seeds may be stimulated to germinate and start growing. This may require a light harrowing of the field to incorporate the seed.

Soil moisture is essential for germination to take place. As the stimulated volunteer plants follow a main crop of field peas, high numbers of *Rhizobium leguminosarum* bacteria inoculum will be in the soil and nodulation is typically excellent.

The growing pea plants will provide a soil cover and protect the soil from erosive forces. This system can make use of the remaining growing season in the fall because field pea is tolerant to minor frost.

The total amount of biomass produced depends upon the pea plant density, the timing of initiation of regrowth, soil moisture, rainfall and the date of a killing frost. However, not enough time is left of the growing season to expect to harvest a second dry pea crop for seed.

The volunteer pea crop can be used for grazing or the biomass can be left on the soil or worked into the soil. Research at Carrington found that fall-produced dry pea biomass reached 1,500 to 3,000 pounds per acre. After grazing, the pea stubble can be left through the winter for reducing soil erosion and capturing snow.

Adaptation

Field pea is an annual cool season grain legume or pulse crop. Field pea has two main types. One type has normal leaves and vine lengths of 3 to 6 feet; the second type is the semi-leafless type that has modified leaflets reduced to tendrils, resulting in shorter vine lengths of 2 to 4 feet. Pea normally has a single stem but can branch from nodes below the first flower.

Most varieties of pea produce white to reddish purple flowers, which are mostly self-pollinated. Each flower will produce a pod containing four to nine seeds. Most pea varieties grown as a cash grain crop have determinate flowering growth habit.

Indeterminate flowering varieties will flower for long periods, and ripening can be prolonged under cool, wet conditions. Indeterminate varieties are later in maturity, ranging from 90 to 100 days. Determinate varieties will flower for a set period and ripen with earlier maturity of 80 to 90 days.

Field pea is sensitive to heat stress at flowering, which can reduce pod and seed set. Indeterminate varieties are more likely to compensate for periods of hot, dry weather and are more adapted to arid regions. Determinate, semi-leafless varieties that have good harvestability are more adapted to the wetter regions.

Pea roots can grow to a depth of 3 to 4 feet; however, more than 75% of the root biomass is within 2 feet of the soil surface. A relatively shallow root system, high water use efficiency and early plant maturity make field pea an excellent rotational crop with small grains, especially in arid areas where soil moisture conservation is critical.

Field pea is well-adapted to cool, semiarid climates. Field pea seed will germinate at a soil temperature of 40 F.

Emergence normally takes 10 to 14 days. Field pea has hypogeal emergence in which the cotyledons remain below the soil surface. Seedlings are tolerant of spring frosts in the low 20s, and if injured by frost, a new shoot will emerge from below the soil surface until approximately seven nodes are above the soil surface.

Flowering usually begins 40 to 50 days after planting. Flower duration is normally two to four weeks, depending on the growth habit and environment during flowering.

Field pea has shown to be well-adapted to the northern growing regions in North Dakota (Figure 2). Field pea yields can be slightly lower or similar to spring wheat on a pound or bushel basis within a specific region.

A six year average of Agassiz field pea yield at the North Central Research Extension Center near Minot was 3,277 pounds, or 55 bushels per acre, compared with Faller hard red spring wheat at 4,241 pounds, or 71 bushels per acre.

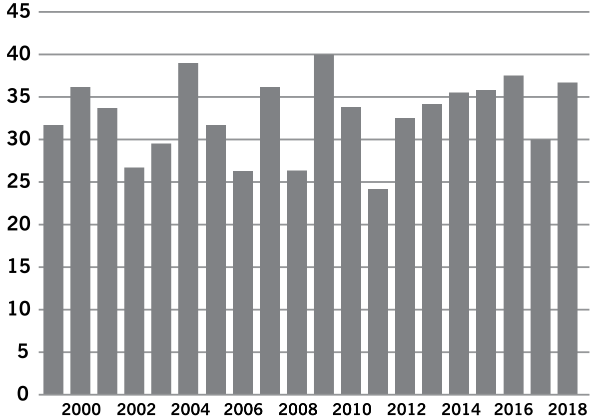

Figure 2. Average North Dakota Dry Pea Yield in Bushels Per Acre (60 pounds per bushel), 1999 to 2018.

Source: North Dakota Agricultural Statistics Service – USDA.

Growth Stages of Field Pea

Table 1. Growth stages of field pea.

Field Pea Growth Stages	Description
Vegetative Growth Stages	
VE	Seedling emergence, epicotyl emerges from the soil
VS	Two small-scale leaves (cataphylls) appear on the stem (do not count this node)
V1	First multifoliolate leaf fully expanded at the first node above VS, no tendril
V2	Second multifoliolate leaf fully expanded, tendril present
V3	Third multifoliolate leaf fully expanded, tendril present
V4	Fouth multifoliolate leaf fully expanded, tendril present
Vn	nth multifoliolate leaf fully expanded, tendril present
Reproductive Growth Stages	
R1	Flower bud present at one or more nodes
R2	First open flower at one or more nodes
R3	Early flat pod present at one or more nodes
R4	Green seeds fill the pod cavity
R5	Leaves start to yellow and lower pods turn yellow to golden brown
R6	Dry seeds fill the pod cavity at one or more nodes
R7	Most pods on the plant are yellow or golden brown

Varieties, Types and Performance

Selecting the appropriate field pea variety should be based on the review of the many differences that exist among varieties and location grown. Factors to consider should include uses, market class, yield potential, harvest ease, vine length, maturity, seed size and disease tolerance.

The first criterion for selecting a variety should be market class. The green and yellow cotyledon types are the primary market classes. All field pea varieties may be considered feed peas, but only selected varieties are acceptable for the green or yellow human edible market.

After market type is determined, growers should review the field pea performance test information from trials conducted across the state while paying particular attention to those trials reflective of their farming area.

Crop harvestability is a very important factor in variety selection and often is noted by harvest ease scores in trial results. Growers prefer a variety that will stand upright at harvest that allows a faster harvest, minimal equipment modification and higher seed quality.

Most varieties that have shorter vines and are semi-leafless will be easier to harvest. Reviewing harvest ease data is important because varieties within this plant type differ greatly in standability.

A wide selection of field pea varieties exists for producers across the region. A good source of information to aid in variety selection is field trial evaluations conducted by the various NDSU Research Extension Centers across the state. These trials include the most promising varieties with information recorded on the important traits necessary for making proper variety selection.

The most recent “North Dakota Dry Pea Variety Trial Results and Selection Guide” (A1469) can be useful for comparing variety data. This publication can be found at **www.ag.ndsu.edu/varietytrials/field-pea** or a hard copy is available from county Extension offices.

Field Selection

Field pea can be grown on a wide range of soil types. Field pea has moisture requirements similar to those of cereal grains. However, peas have lower tolerance to saline and water logged soil conditions than cereal grains. Avoid saline soils (electrical conductivity [EC] greater than 1.5 millimhos/centimeter).

Field pea commonly is grown in rotation following small grains. Field pea will fix the majority of the plants’ required nitrogen (N) if the seed is inoculated properly.

Fields with a history of perennial weed problems such as Canada thistle, dandelion and field bindweed should be avoided. Previous soil-applied herbicides may result in crop rotation restrictions when field pea is planted in the following year(s).

Check field application records, rainfall totals, soil type, pH and tillage to make decisions on planting field pea. Consult the most recent NDSU Extension publication W253, “North Dakota Weed Control Guide,” and herbicide labels for rotational restrictions.

Seeding

Field pea can be grown in a no till or conventional-till cropping system. Avoid excessive tillage in the spring to avoid drying out the seedbed. Pea seed requires considerably higher amounts of moisture for germination than cereal grains.

Field pea are grown in narrow rows (6 to 10 inches). A conventional grain drill or air seeder that is capable of handling large seed without cracking is important.

Field pea should be seeded early, in April to mid-May, so flowering will occur during potentially cooler weather in June and early July. Seeding date studies conducted in North Dakota indicate that field pea yields decrease significantly when seeding is delayed beyond mid-May. Seeding field pea beyond mid-May will result in the crop beginning to flower in mid-July, which increases the risk of heat stress and disease problems, such as powdery mildew, reducing yields.

Maintaining firm seed-to-soil moisture contact is critical. Seeding pea well into moisture is critical, and seeding peas into dry soil should be avoided. A seeding depth of 2 inches is recommended, with a rule of thumb that field pea should be seeded at least 1/2 inch into moisture and never seeded into the interface where soil moisture meets dry soil.

Seeding Rate

The seeding rate will depend on the size of the seed. Field pea varieties will range from 1,600 to 5,000 seeds per pound. Do not plant seed based on bushels per acre. Plant on a pure-live-seed basis to establish a plant density of 300,000 to 350,000 plants per acre or seven to eight plants per square foot.

Always select high-quality, disease free seed. When seeding pea, always adjust for germination and allow for a certain percent of the seed that germinates not becoming an established plant. Planting equipment should be calibrated or modified to allow for seed and inoculant to flow properly without cracking the seed or plugging the opener.

Seed Treatments

For a listing of registered seed treatments and specifics on disease control, consult the most current version of NDSU Extension publication PP622, “North Dakota Field Crop Plant Disease Management Guide.” Consulting the seed treatment label for its effect on rhizobium inoculants is very important.

Soil pH

Field pea can reach maximum yield potential with soil pH from 5.5 to more than 7. Zone sampling fields may indicate areas within fields where soil pH should be increased using a form of finely ground limestone.

The most common local source would be sugarbeet waste lime, available from sugarbeet processors in Sydney, Mont., or the factories in the Red River Valley. South Dakota has four limestone quarries, and Minnesota and Montana have several. Field pea production is concentrated in North Dakota counties that include large acreages of acidic soils along the Missouri River and through Minot, and north through Mohall.

Importance of Symbiotic N-fixing Bacteria

A common requirement for efficient production of field pea is inoculation with specific N-fixing bacteria. Field pea should be inoculated with *Rhizobium leguminosarum*, designated a Class C inoculant by inoculation providers.

Inoculants usually are available as a granulated product, applied similarly to an in-furrow fertilizer application, but at a much lower rate; a liquid product, which is best applied to the seed and mixed; and a powder, which requires a sticking agent and is mixed with the seed similar to what is required for the liquid products.

Inoculants are live bacteria, so they need to be handled and stored correctly. Avoid extreme heat or cold; storing them in a cool, dark environment until needed is best. Seeding experts also recommend you do not pretreat seed and store it for more than one day.

Studies that have examined the value of inoculants to legume grain crops indicate that from 50% to 90% of the N used by the crop during a season comes from N-fixation by the symbiotic N-fixing bacteria. Most studies that have examined N fertilization of field pea, chickpea and lentil found no value, and sometimes a yield reduction, from adding more than 10 pounds of N per acre to these legumes.

Avoid growing these legumes on soils with more than 60 pounds of N per acre residual N to the 2-foot depth because this resulted in lower yield than growing the legumes in soil with lower residual N.

Fertilization

Yield for a field in a given year is most dependent on the environment: rainfall, temperature and other factors. Within the environment, fertilizer rate is important. So the influence of the fertilizer rate is on "relative yield," not "specific yield."

In a lower-yielding environment, caused usually by too much water or not enough, nutrients are not as efficiently taken up; therefore rates relative to final yield are higher. In a high-yielding environment caused by close to ideal soil moisture and seasonal temperature, the efficiency of nutrient uptake is much higher, as is the release of nutrients from the soil and previous residues. Therefore, the rates indicated in Table 2 are not related to yield goal, but they are appropriate for all yield environments.

Nitrogen (N)

Inoculate with *Rhizobium leguminosarum* bacteria. In the rare circumstance that soil residual N is less than 15 pounds per acre to the 2-foot depth, the addition of 15 pounds of N per acre might be helpful for early growth. Usually the N in phosphate fertilizer can provide this easily.

Phosphorus (P)

Although low rates of seed-placed starter sometimes may increase field pea yield when soil test P levels are low, they also consistently reduce field pea stand. A broadcast P application, and even a midrow band P application, will result in greater yield most of the time. Recommended P_2O_5 rates based on soil test values are presented in Table 2.

The use of a fungal “P-enhancement” product containing *Penicillim bilaiae* would be useful only when soil pH is greater than 7 and the soil has significant carbonates. The maximum P released by this amendment would be about 10 pounds of P_2O_5 per acre during the entire season. The products would have no P benefit if the soil pH were equal or less than 7.

Potassium (K)

Field pea is not responsive to soil K except when it is extremely low. A 100 parts per million (ppm) K soil test level is adequate for high field pea production.

Table 2. Phosphorus and potassium recommendations for field pea.

Olsen P, ppm					K soil test, ppm	
0-3	4-7	8-11	12-15	16+	<100	>100
P_2O_5 rate to apply lb/acre					K_2O rate to apply, lb/acre	
40	30	20	10	0	30	0

Sulfur (S)

Field pea has shown yield increases to S in seasons with a wet spring. Sulfate is soluble and can leach in loam or coarser soils due to excessive rainfall/snowmelt.

Sulfur deficiency is most likely on loam and coarser textured soils, but in recent years, S deficiency has been experienced even in high-clay soils with organic matter greater than 5% in very wet spring seasons. A rate of 10 pounds per acre of S as a sulfate would be enough to sustain a high-yielding pea crop.

Elemental S is not an effective S source in North Dakota, so its presence in a composite fertilizer granule should not be considered as a plant food. The S soil test is not diagnostic and should not be conducted or considered in making a decision whether to fertilize with S.

Micronutrients

Micronutrients, including zinc, copper, manganese and iron, have not been shown to be deficient for field pea despite what any soil test might indicate.

Soluble Salts

Field pea and lentil are generally more sensitive to soil salts than chickpea. Avoiding

seriously saline soils (electrical conductivity [EC] greater than 1.5 millimhos/centimeter) would be prudent for pea and lentil. Note soil test salt (EC) levels in areas that struggle to produce grain and plan to seed a more tolerant crop there in the future for greater farm income.

A comprehensive strategy to address salinity issues within fields also would help extend the field choices for successful legume production. For more information, visit the NDSU Soil Health website: **www.ndsu.edu/soilhealth**.

Organic Production

Soil fertility is probably one of the minor management considerations for organic production of field pea, lentil and chickpea. Compost/composted manure would be an excellent source of P, K and other nutrients for production of these pulse crops. The restriction would be to apply these the year prior to pulse production so that too much N is not released during the early pulse growing season.

Lacking access to compost/composted manure, buckwheat grown the year before and used as a green manure prior to seed set can make some P available to the pulse crops. Weed control and control of pests in general will be major considerations for organic pulse production in North Dakota.

Weed Control

Field pea is a poor competitor with weeds, especially during the first month after planting. Relatively slow early season growth and a lack of complete ground cover by the crop canopy allow weeds to be competitive. A well-established stand of seven to eight plants per square foot is critical for field pea to be competitive with weeds.

Perennial and annual weeds that emerge early in the season, including common lambsquarters, kochia, volunteer grain, wild mustard and wild oat, are very competitive with pea. For example, a Canadian trial indicated that two wild mustard plants per square foot reduced pea yield as much as 35%.

Good weed control is also very important in raising high-quality human edible pea. Weeds such as kochia, Russian thistle, nightshade and wild buckwheat can cause harvest problems with fields that are intended to be straight combined. Nightshade berries can stain the pea seed at harvest, causing a reduction in quality.

Cultural methods that should be used as part of an integrated weed management system include crop rotation, field selection, rapid crop establishment at an adequate density and the use of clean seed. Soil-applied plus postemergence-applied herbicides are needed for satisfactory weed control. Postemergence herbicides should be applied to small weeds and pea (less than 2- to 4 inch height) to maximize weed control and minimize crop injury. Preharvest desiccants also are labeled to dry weeds for a more efficient harvest.

Table 3. Field pea herbicides for North Dakota.

Herbicide	Product/a (ai/a)	Weeds	When to Apply	Remarks
Soil-applied Herbicides				
Far-Go (triallate)	**1.25 qt. EC** (1.25 lb.)	Wild oat	PPI.	PPI immediately after application. A two-pass incorporation improves weed control.
Prowl **Prowl H2O/** generics (pendimethalin)	**1.75 to 3.6 pt. EC** **1.5 to 3 pt. ASC** (0.72 to 1.5 lb.)	Grass and some broadleaf weeds Poor wild oat and no wild mustard control	PPI fall or spring.	Apply in fall when soil temperature is less than 45 F to reduce fall herbicide degradation. Adjust rate for soil type. Some pea varieties may be injured.
Treflan/generic trifluralin	**1 to 1.5 pt. EC** **5 to 7.5 lb 10G** (0.5 to 0.75 lb.)			
Sonalan (ethalfluralin)	**1.5 to 2 pt. EC** **5.5 to 7.5 lb. 10G** (0.55 to 0.75 lb.)			
Dual/II/Magnum/ generics (S/metolachlor)	**1 to 2 pt. EC** (0.95 to 1.9 lb.)		Shallow PPI or PRE.	PRE requires precipitation for herbicide activation. Adjust rates for soil type, organic matter and pH. Refer to label for rate structure.
BroadAxe XC **Spartan Elite** (metolachlor and sulfentrazone)	**20 to 32 fl. oz. EC** (0.98 to 1.58 lb. and 1.75 to 2.8 oz.)	Annual grass and small-seeded broadleaf weeds		
Spartan Charge (carfentrazone and sulfentrazone)	**3.75 to 7.75 fl. oz. SE** (0.16 to 0.34 oz. and 1.48 to 3.05 oz.)	Small-seeded broadleaf weeds	Shallow PPI or PRE.	PRE requires precipitation for herbicide activation. Adjust rates for soil type, organic matter and pH. Refer to label for rate structure.

Authority Supreme (sulfentrazone and pyroxasulfone)	**4.3 to 10 fl. oz. SC** (1.12 to 2.6 oz. and 1.12 to 2.6 oz.)		Shallow PPI or PRE.	PRE requires precipitation for herbicide activation. Adjust rates for soil type, organic matter and pH. Refer to label for rate structure.
Pursuit/ generics (imazethapyr)	**2 fl. oz. SL** (0.5 oz.)	Small broadleaf weeds. No control of ALS-resistant weeds.		Shallow PPI improves consistency of weed control. PRE requires precipitation to activate herbicide.
Sharpen (saflufenacil)	**1 to 2 fl. oz. SC** (0.36 to 0.72 oz.)	Small broadleaf weeds, kochia, pigweed, lambsquarters, nightshade and winter annuals.	EPP, shallow PPI or PRE.	PRE requires precipitation to activate herbicide. Provides burn-down control of small emerged broadleaf weeds, including winter-annual species. Refer to label for tank-mix options.
Metribuzin	**0.25 to 0.5 lb. DF** **0.38 to 0.75 pt. 4F** (0.19 to 0.38 lb.)	Suppression of lambsquarters, henbit, mustard and chickweed.	Preplant or PRE.	Contact herbicide requiring small weed size, greater than 20 gallons per acre and full sunlight. Use only registered formulations. Adjust rate for soil type. Refer to label for application and environmental information, and special precautions that may affect weed control and crop safety. Allow a 50 day PHI.
	0.167 to 0.33 lb. DF **0.25 to 0.5 pt. 4F** (0.125 to 0.25 lb.)		Post. Weeds: small.	

POST-applied Pea Herbicides

Herbicide	Product/a (ai/a)	Weeds	When to Apply	Remarks
Basagran 5L / generic bentazon + MSO adjuvant	**0.4 to 1.6 pt. SL/ 0.5 to 2 pt. applied 1 to 4 times.** (0.25 to 1 lb.)	Small broadleaf weeds and suppression of Canada thistle.	POST. At least 3 pairs of leaves or 4 nodes. Broadleaf weeds: small	Nonresidual, contact herbicide requiring greater than 15 gallons per acre and full sunlight. Add oil adjuvant at 1 to 2 pt. per acre. Maximum bentazon amount per season is 2 lb./acre.

POST-applied Pea Herbicides (continued)

Herbicide	Product/a (ai/a)	Weeds	When to Apply	Remarks
Pursuit/ generics (imazethapyr)	**2 fl. oz. SL** (0.5 oz.)	Small annual broadleaf weeds. No control of ALS-resistant weeds.	Small annual broadleaf weeds. No control of ALS-resistant weeds. POST. Pea: at least 3 inches tall but prior to 5 nodes and prior to flowering. Weeds: small. Allow a 60-day PHI.	**User assumes all risk of crop injury.** Add NIS at 1 pt. per 100 gallons or oil adjuvant at 1 to 2 pt. per acre. Oil adjuvant increases weed control and risk of crop injury. Do not apply during adverse weather conditions. Risk of Raptor carryover is less than Pursuit. Bentazon may be applied sequentially to improve weed control. Bentazon antagonizes Raptor and reduces risk of injury to field pea.
Raptor + Basagran 5L / generic bentazon (imazamox)	**4 fl. Oz. SL + .4 to 0.8 pt./A. SL/ 0.5 to 1 pt./A. SL** (0.5 oz.+ 0.25 to 0.5 lb.)	Small annual grass and broadleaf weeds and suppression of Canada thistle.		
Varisto (bentazon and imazamox)	**11 to 21 fl. Oz. SL** (0.34 to 0.66 lb. + 0.26 to 0.5 oz.)			
Thistrol (MCPB)	**2 to 6 pt. SL** (0.5 to 1.5 lb. ae)	Small broadleaf weeds	Post. Pea: Prior to 6 inches tall.	Slight, temporary injury may occur. Do not apply when temperature exceeds 90 F or when peas are stressed. Suppresses Canada thistle.
Assure II **Targa** (quizalofop)	**7 to 12 fl. oz. EC** (0.77 to 1.32 oz.)	Annual grasses and quackgrass	POST PHI: Assure = 60 Clethodim = 21 days and prior to bloom. Poast = 30 days.	Add oil adjuvant at 1 gal./100 gallons water but not less than 1.25 pt. per acre. Refer to label for tank-mix options.
Poast (sethoxydim)	**0.5 to 1.5 pt. EC** (0.1 to 0.3 lb.)	Annual grasses		
Select Max 1EC **Select 2EC** **Shadow 3EC** (clethodim)	**9 to 16 fl. oz. EC** **4 to 8 fl. oz. EC** **2.7 to 5.3 fl. oz. EC** (1 to 2 oz.)			

Preharvest Pea Herbicides

Herbicide	Product/a (ai/a)	Weeds	When to Apply	Remarks
Glyphosate	Up to 2.25 lb. ae	Emerged grass and broadleaf weeds	Harvest aid and prior to harvest. Pea greater than 80% yellow/ brown pods and less than 30% seed moisture. PHI: Glyphosate = 7 days. Aim = 0 days. Paraquat = 7 days Sharpen = 3 days Valor = 5 days	Use only registered formulations. Apply with AMS at 8.5 lb. per 100 gallons. **Do not apply to field pea grown for seed because reduced germination/vigor may occur.**
Aim + MSO adjuvant (carfentrazone)	**1 to 6 oz. SL + 1 qt./A.** (0.256 to 1.5 oz.)	Desiccant		Contact herbicides require greater than 15 gallons per acre and full sunlight. Apply at greater than 10 gallons per acre for ground and greater than 5 gallons per acre for aerial application. Apply Aim, Sharpen and Valor with AMS at 8.5 to 17 lb./100 gallons water or UAN at 2.5 gal./100 gallons water and with glyphosate or paraquat for weed desiccation. Glyphosate improves weed control from Sharpen and Valor but antagonism may occur on biennial and perennial weeds. **Do not apply Sharpen to field pea grown for seed because reduced germination/vigor may occur.**
Paraquat + NIS **RUP**	**1.2 to 2 pt. 2SL** **0.8 to 1.3 pt. 3SL** (0.3 to 0.5 lb.)			
Sharpen + MSO adjuvant (saflufenacil)	**1 to 2 fl. oz. SC +** **1 to 1.5 pt./A** (0.36 to 0.72 oz.)			
Valor SX/ generics **Valor EZ** + (flumioxazin) + MSO adjuvant	**2 to 3 oz. WDG** **2 to 3 fl. oz. SC** **2 pt.** (1.02 to 1.53 oz.)			

For information on registered herbicides and directions for use, consult the “North Dakota Weed Control Guide” (W253) and herbicide labels.

Diseases

Many diseases infect field pea and can affect yield, but this guide will focus only on the most important. A pea disease tool is available; the NDSU Extension publication PP1790, "Pea Disease Diagnostic Series," provides photos of the main pea diseases, symptoms, factors favoring development and facts about the control of the disease.

General Disease Management

Controlling diseases in field pea begins with crop rotation. A preferred crop rotation would have field pea planted with at least four cropping years between plantings. For the most important root rot pathogens, little to no difference occurs between lentil and field pea in susceptibility, and a minimum of a four-year rotation would be needed for either of these crops, especially when soil conditions are relatively wet. A three-year rotation will be adequate to control foliar disease pathogens.

For additional information on fungicides labelled in field pea, consult the NDSU Extension publication PP622, "North Dakota Field Crop Plant Disease Management Guide." Always read and follow label instructions.

Blights

Ascochyta (Mycosphaerella) blight and bacterial blight are economically important diseases of field pea that are confused easily. On leaves, petioles and pods, Ascochyta blight develops as brownish to black flecks, often with a purplish tint (Photo 1). On leaves, it also can cause large, tan, round to oval lesions composed of several concentric rings (Photo 2). On pods, lesions often are sunken and can result in discolored seeds.

On stems, lesions are purplish brown and are centered on nodes; when stem lesions are severe, plants often lodge and sometimes ripen prematurely (Photo 3). Diseased tissue is never translucent, does not readily shatter and is not constrained by veins. Ascochyta is always most severe at the base of the plant and is most prevalent when cool, wet weather occurs during late vegetative growth and bloom.

Ascochyta blight can be managed successfully with fungicides, but fungicides are not effective against bacterial blight. The optimal timing of fungicide applications varies based on conditions but often coincides with full bloom and early pod development. Varieties differ in their susceptibility to Ascochyta, but susceptibility ratings are generally unavailable and no commercial variety carries full resistance to Ascochyta or bacterial blight.

Bacterial blight, which easily is confused with Ascochyta blight, causes lesions on leaves, petioles, stems and pods that appear shiny to greasy when the lesions are fresh. Leaf lesions often are constrained by veins and frequently become translucent or shatter as they age.

Bacterial blight often develops at similar severity in the midcanopy as the lower canopy, and it is most sever after rain storms accompanied by strong winds or after hail storms. Both diseases survive in crop residues and are seed-borne and seed-transmitted.

Root Rots and Wilts

Root rots and wilts are the most damaging diseases to field pea in North Dakota. These include Ascochyta foot rot, Aphanomyces root rot, Fusarium wilt, Pythium seed and root rot, and Rhizoctonia root rot. Management tools include long crop rotations, planting disease-free seed, planting into well-drained soils, selection of varieties with genetic resistance (if available) and application of fungicide seed treatments.

Ascochyta foot rot will form blackish purple lesions on the stem at the base of the plant. Severe infections of ascochyta will result in premature ripening, lodging and reduced yields. Additionally, low levels of discolored and/or shrunken seed may be present. These fungi survive on plant debris, and spores can survive for years on field pea stubble. Spores also can be carried on the seed; therefore, planting disease-free seed is very important.

Aphanomyces root rot is caused by a fungal-like organism (oomycete) and can overwinters in the soil as thick-walled spores (oospores) that can survive for many years. In the presence of pea roots, the oospores will germinate and eventually swimming spores (zoospores) that can infect pea roots will be formed.

Infection may occur at any stage of plant growth. Plants are most at risk when soil is saturated for a long period of time. Symptoms appear as caramel-brown lesions on the roots. The pathogen infects the cortex (outer portion) of the root; therefore, when plants are pulled from the soil, the cortex may slough off, leaving only a small strand of vascular tissue intact.

Fusarium wilt, caused by *Fusarium oxysporum f. sp pisi*, occurs in the pea-growing region in North Dakota. The first symptoms are downward curling and yellowing of leaves. Notably, yellowing frequently only occurs on one side of the plant. Vascular tissue may be yellow-orange in infected plants (Photo 4).

Pythium seed and seeding rot typically occurs very early in the growing season and is favored by cool and wet soils, poor seed vigor and compacted soils. Symptoms include rotted seed with soil that is difficult to remove from the seed coat, rotted root tissue, stunted plants and pinched-off secondary roots.

Rhizoctonia root rot occurs on many crops in our region, including field pea. Symptoms include reddish-brown sunken lesions at the base of the stem, "spear tipping" of roots that appear to have been pinched off, and stunting and yellowing plants.

■ *Powdery Mildew*

Powdery mildew is a disease that can cause economic loss in our region. Powdery mildew is commonly first observed as tufts of discrete white fungal growth on leaf tissue (Photo 5). White growth may cover all green tissue quickly, but it can be wiped off easily with a finger. Initially, underlying tissue remains green, but as the disease develops, underlying tissue takes on a bluish hue (Photo 6).

Powdery mildew develops in dry, warm weather accompanied by nights with dew. The disease overwinters on plant residue of field pea and alternate hosts. Powdery mildew infections usually do not occur until midsummer. Yield loss typically does not happen unless the infection occurs during early to midpod set.

Powdery mildew is most likely to cause severe damage in late-planted field pea. Planting field pea after mid-May means the crop likely will mature during warm, dry weather favorable to disease development. The combination of planting early and the use of resistant varieties will aid in reducing risk with this disease.

Powdery mildew impacts seed yield, seed weight and seed size. Most commercial field pea varieties are susceptible to powdery mildew but resistant varieties are available. Fungicides have efficacy when applied at the first signs of powdery mildew in the lower canopy but are of limited effectiveness once the disease has spread to the mid- and upper canopy.

■ *Sclerotinia Stem Rot (White mold)*

Sclerotinia sclerotiorum can infect many broadleaf weeds and crops, including field pea. Symptoms of the disease include a white, fluffy, fungal growth found on dead or decaying tissue. The fungal growth can develop into hard, black bodies (sclerotia) found inside the stem, which can cause premature ripening of the plant.

Typically, long-vine varieties having normal leaf arrangement are more susceptible to sclerotinia because they tend to lodge after flowering, forming a dense canopy close to the soil surface and increasing the risk of infection.

Generally, semi-leafless pea that has good standability will avoid any serious sclerotinia infections. Infection risk increases if field pea is planted close in rotation with broadleaf crops such as sunflower, dry edible bean, canola or mustard.

Insect Pests

The NDSU Extension publication E1877, “Pulse Crop Insect Diagnostic Series: Field Pea, Lentil And Chickpea,” summarizes integrated pest management for insect pests of pulse crops, including identification, crop damage, monitoring or scouting tips, economic threshold, cultural control, host plant resistance, biological control and chemical control.

Table 4. Insect pest scouting calendar of pulse crops by crop stages.

Seedling to 3rd-node Stage	4th-node Stage to Flowering (R1)	Flowering (R1) to Pod Development (R4)	Pod Development (R4) to Harvest
May	**June**	**July**	**August**
Cutworms Grasshoppers Pea leaf weevils (peas only)	Pea aphids Cutworms Grasshoppers Lygus bugs Pea leaf weevils (peas only)	Pea aphids Grasshoppers Lygus bugs	Grasshoppers Lygus bugs

Cutworms

Lepidoptera: Noctuidae

Life Cycle

Several species of cutworms cause problems to agricultural crops in the northern Great Plains, such as dingy cutworm (Photo 13), army cutworm, red-backed cutworm and pale Western cutworm. Adult cutworms are a moth, and have dark wing colors (brown to gray) with markings and about a 1.5-inch-long wing length.

Cutworms have one generation per year. They overwinter as eggs or young larvae (photo 14), depending on the species. Eggs hatch in April or early May, and young larvae (or caterpillars) feed at night on weeds and volunteer plants before the crop emerges.

Larvae molt six times and grow larger with each instar. A mature cutworm larva is about 1.5 inches long and the size of a pencil in width.

Cutworms are most noticeable from late May through mid-June, except for the army cutworm, which is active in April through May.

After cutworms complete their development in late June, they burrow deeper into the soil and make a small pupal chamber. Adult moths emerge from August through early September. Adults mate and females lay eggs on or just below the surface of loose, dry soil; weedy stubble; or fallow fields, depending on the species.

Damage

Cutworm damage first appears on hilltops, south-facing slopes or in areas of light soil, which warm earlier in the spring. Larvae will cut young pulse plants in the seedling to six- to eight-leaf stages. Cut plants can be found drying up and lying on the soil surface. As damage continues, fields will have areas of bare soil where pulse plants have disappeared. In a severe infestation, the entire field can be destroyed.

Pest Management

Scout fields by looking for freshly damaged (cut-off) plants. Dig down 3 or more inches around the cut-off plant and search for cutworm larvae. When disturbed, cutworms curl up or hide under soil debris.

Pulse crops are more susceptible to cutworm damage than small grains because cut plants do not grow back (grains compensate by tillering). **Two to three cutworms per square yard justifies an insecticide treatment in pulse crops.**

Cutworm larvae feed actively at night, so an evening insecticide application is best. As a cultural control technique, weed-free fields and crusted summer fallow fields are less attractive to egg-laying adults in late summer.

Grasshoppers

Orthoptera: Acrididae

Life Cycle

Grasshoppers (Photo 15) are generalists and feed on a wide range of agricultural crops, such as pulse crops, small grains, flax and sunflowers. Grasshoppers overwinter as eggs, and nymphs start to emerge in late April to early May, with peak egg hatch in mid-June.

Nymphs (young grasshoppers, photo 16) will go through five molts before transforming into adults. The length of time from egg to adult is 40 to 60 days. Adults of crop-damaging species become numerous in mid-July, with egg laying usually beginning in late July and continuing into the fall. Eggs are deposited in a variety of noncrop areas, including ditches, shelter belts and weedy fall fields.

Damage
Adults and nymphs feed on green plant material, creating holes on leaves or pods. Grasshoppers pose the greatest threat from the bud stage through early pod development, especially during droughty conditions.

Lentil is less tolerant of grasshopper feeding than field peas and chickpeas. Grasshoppers will consume flower buds and especially early pods of lentil plants. This can result in yield loss and a delay in maturity due to delayed pod set.

Chickpea stems, leaves and seedpods are covered with small hairlike glandular structures that secret malic and oxalic acids, which deter insect pests. Researchers have observed that some grasshopper species are reluctant to feed on chickpea.

Pest Management
Grasshopper outbreaks usually coincide with several years of low rainfall and drought periods. Cool, wet weather increases the diseases that infect and kill grasshoppers. Scout pulse crops for feeding injury from nymphs in the seedling stage and from adults in the early bud stage through pod development.

For lentils, only two grasshoppers per square yard in the flowering or pod stage can reduce yields enough to warrant insecticide treatment. For field peas and chickpeas, the threatening rating (Table 5) is considered the action threshold for grasshoppers.

Grasshopper thresholds are based on the number of grasshoppers (adults or nymphs) per square yard. Four 180-degree sweeps with a 15-inch sweep net equals 1 square yard. The infestation ratings are listed in Table 5. A "threatening" rating would indicate a need to treat with an insecticide for field peas and chickpeas.

Table 5. Threatening levels of nymphs and adults for field peas and chickpeas.

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

*Action threshold.

Wireworms

Coleoptera: Elateridae

Life Cycle

Wireworm larvae (Photo 17) are hard, smooth, slender, wirelike worms varying from 1 to 2 inches in length when mature. They are yellowish white to coppery, with three pairs of small, thin legs behind the head. The last body segment is forked or notched. Adult wireworms are bullet-shaped, hard-shelled beetles that are brown to black and about an inch long. The common name “click beetle” (Photo 18) is derived from the clicking sound that the insect makes when attempting to right itself after landing on its back.

Wireworms usually take three to four years to develop from the egg to an adult beetle. Most of their life cycle is spent as a larva in the soil. Generations overlap, so larvae of all ages may be in the soil at the same time.

Wireworm larvae and adults overwinter at least 9 to 24 inches deep in the soil. When soil temperatures reach 50 to 55 F during the spring, larvae and adults move nearer the soil surface.

Adult females emerge from the soil, attract males to mate, then burrow back into the soil to lay eggs. Females can re-emerge and move to other sites, where they burrow in and lay more eggs. This behavior results in spotty infestations throughout a field. Some wireworms prefer loose, light and well-drained soils; others prefer low spots in fields where higher moisture and heavier clay soils are present.

Larvae move up and down in the soil profile in response to temperature and moisture. After soil temperatures warm to 50 F, larvae feed within 6 inches of the soil surface. When soil temperatures become too hot (greater than 80 F) or dry, larvae will move deeper into the soil to seek more favorable conditions.

Wireworms inflict most of their damage in the early spring, when they are near the soil surface. During the summer months, the larvae move deeper into the soil.

Later as soils cool, larvae may resume feeding nearer the surface, but the amount of injury varies with the crop.

Wireworms pupate and the adult stage is spent within cells in the soil during the summer or fall of their final year. Adults remain in the soil until the following spring.

Damage

Wireworm infestations are more likely to develop when pulse crops follow grasses, including grain crops or pastures. Wireworms damage crops by feeding on the germinating seed or the young seedling. Damaged plants soon wilt and die, resulting in thin stands. In a heavy infestation, bare spots may appear in the field and reseeding is necessary.

Pest Management

No easy sampling methods are available to estimate wireworm infestations. Two methods are:

- **Soil sampling:** Sample 20 well-spaced 1-square-foot sites to a depth of 4 to 6 inches for every 40 acres being planted. If an average of **one wireworm per square foot is found, insecticide treatment would be justified**.
- **Solar baiting:** Put out bait stations in September two to three weeks before freeze-up or spring before planting. Randomly place 10 to 12 stations per 40 acre in the field. Place 1 cup of wheat and 1 cup of shelled corn into a nylon sock and bury the sock 4 to 6 inches deep. Dig up the sock after 10 to 14 days and look for wireworms in and around the germinating bait bag. **If an average of**

one or more wireworm larvae is found per station, insecticide treatment would be justified.

Several insecticides are approved for use as seed treatments to protect seeds from wireworms and other soil insect pests. Insecticides applied to the seed just before planting time is an inexpensive means of reducing wireworm damage to growing crops.

For maximum benefits, treat the seed shortly before seeding; prolonged storage after treatment may reduce germination. If on-farm treaters are used, be sure they are calibrated properly to apply the recommended dosages.

Soil-applied insecticides also are used to prevent damage to plants from soil insect pests. They are applied as a preventive measure because rescue treatments generally are ineffective. The use of these products should be based on some knowledge of the insect pests being present in the soil, which is determined by field scouting and trapping. Using soil insecticides strictly as insurance against crop damage is discouraged.

Pea Aphid

Hemiptera: Aphididae

Life Cycle

Pea aphid, *Acrythosiphon pisum*, is the most common insect pest found in pulse crops. They are small, about ⅛ inch long and pale to dark green with reddish eyes. Pea aphids have multiple generations per year and overwinter as eggs in alfalfa, clover or vetch. In the spring, nymphs hatch from eggs and appear similar to the wingless adult but smaller.

Nymphs molt four times and mature into adults in 10 to 14 days. Pea aphids can reproduce rapidly when temperatures are around 65 F and relative humidity is near 80%. Infestations can originate from local alfalfa fields or aphids migrate in from the southern states.

Damage

Pea aphids have piercing-sucking mouthparts, which suck the juices from plants. Pea aphids are known to vector viral diseases. For example, pea seed-borne mosaic virus (PSbMV) is an economically damaging viral pathogen of field pea that can cause significant losses in seed yield and quality, especially when infections occur before or during flowering. Consult the NDSU Extension publication PP1704, “Pea Seed-borne Mosaic Virus (PSbMV) in Field Peas and Lentils,” for more information.

Pulse crops are especially susceptible from the flowering to early pod stage and during drought stress. An economic infestation can result in lower yields due to less seed formation and smaller seed size. Protein content and other quality issues do not appear to be affected by aphid feeding.

Aphid populations are usually kept low naturally by heavy rains or beneficial insects (parasitoid wasps) and predators, such as ladybird beetles and lacewings. Early seeding also can reduce damage caused by pea aphids.

Pest Management

Scouting for aphids in pulse crops is conducted using a sweep net or examining the number of aphids per plant when 50% to 75% of the crop is flowering. Take 180-degree sweeps using a 15-inch sweep net or check at least five 8-inch plant tips from five different locations in the field. Population estimates should be calculated by averaging counts taken from five separate areas of the field.

If the economic threshold is exceeded, a single application of insecticide at 50% of plants in young pods stage will protect the crop against yield loss. If an insecticide application is necessary during flowering, spray when bee foraging is minimal, preferably during the evening hours (after 8 p.m.).

Threshold for Chickpea: No recommended economic threshold is available for aphids in chickpea. To prevent virus infection, select varieties bred for virus resistance.

Threshold for Field Pea: Aphid feeding on pea in the flowering and early pod stage can result in lower yields due to less seed formation and smaller seed size. Protein content and other quality issues are not impacted by pea aphid feeding injury. During early reproductive growth stages of field pea, an insecticide treatment is recommended when **an average of five to 19 pea aphids per plant or three to 12 pea aphids per 180-degree sweep with a 15-inch-diameter sweep net**.

Threshold for Lentil: Insecticide treatment for pea aphid control should be considered (1) when an economic threshold of **30 to 40 aphids is collected per 180-degree sweep with a 15-inch-diameter sweep net**, (2) when few natural enemies are present, and (3) when aphid numbers do not decline during a two-day period.

Lygus Bugs

Hemiptera: Miridae

Life Cycle

The tarnished plant bug, *Lygus lineolaris*, is one of the more common species of plant bugs, and is known to feed on more than 385 crops and weed plants. An adult Lygus bug is about ¼ inch in length and pale green, light brown or dark brown, with a distinctive triangular marking on its back.

Lygus bugs overwinter as adults in weedy areas under debris along fencerows, ditches and roadsides. Adults emerge in early spring, lay eggs in the stems, leaves and flowers of host plants, and then die. Immature nymphs hatch from these eggs and look like aphids. Several generations occur each year, with the second generation occurring in mid-July to early August.

As with many other insect pests, warm, dry weather favors the buildup of Lygus populations and increases the potential for early season damage to pulse crops. Immature and adult Lygus bugs feed on developing pods and seeds, and have been linked to "chalk spot" damage. Field peas and lentils are more susceptible to Lygus bug injury than chickpeas.

Damage

Lygus bug has a piercing-sucking mouthpart, which punctures the pods and seed coats, injecting a toxic substance into plant parts, often causing chalk spot. Chalk spot is a pit or craterlike depression in the seed coat with or without a discolored chalky appearance. Damaged seeds are smaller, deteriorate faster in storage, have poor germination and produce abnormal seedlings, as well as lower the grade and marketability.

Do not confuse damage caused by Lygus bug to damage caused by rough harvesting or handling. For example, field pea or lentil harvested at high moisture levels also is susceptible to bruising when harvested or handled roughly, resulting in damage similar to chalk spot.

Pest Management

Monitor for Lygus bugs using a 15-inch sweep net during bloom to pod development (until seeds within the pod have become firm). Make 10 180-degree sweeps at five sampling sites in a field during the warm sunny part of the day (2 to 6 p.m.). Lygus populations can increase suddenly. For example, when an alfalfa (preferred host) field is cut, Lygus bugs will migrate quickly, often in high numbers, into nearby pulse crop fields.

No economic threshold has been determined for North Dakota. However, in the Pacific Northwest, **an insecticide treatment is recommended when 10 Lygus per 25 sweeps are present**. Spray a blooming crop when minimal bee activity is occurring, preferably during the evening hours (after 8 p.m.).

Pea Leaf Weevil

Coleoptera: Curculionidae

Pea leaf weevil, *Sitona lineatus*, is an invasive pest, and an economic insect pest of field peas and faba beans, severely reducing yields. The first pea leaf weevil was discovered near Beach in Golden Valley County, southwestern North Dakota, in the fall of 2016. In the last decade, pea leaf weevils have been moving eastward, threatening the increasing field pea acreage. In North Dakota, NDSU Extension entomologists confirmed pea leaf weevils in the following areas: southwest (Dunn, Golden Valley and Stark counties), north-central (Mountrail and Ward counties) and northwest (Divide County).

If any pulse growers suspect pea leaf weevils in new areas, they should report observations to their local Extension agents or NDSU Extension entomology specialists. Consult the NDSU Extension publication E1879, "Integrated Pest Management of Pea Leaf Weevil in North Dakota," for more information.

Life Cycle

Pea leaf weevil infests cultivated and wild legume species, including field peas, faba beans, alfalfa and dry beans. However, their life cycle is completed only on field peas and faba beans. Pea leaf weevil has one generation per year.

The adult weevil is brown, small about 3/16 inch long with a broad snout (Photo 19), and light lines on its wing covers. Adults overwinter in alfalfa and other perennial legumes, roadside ditches and shelterbelts.

When spring temperatures rise above 63 F, adults fly into spring-seeded fields and feed on leaves, causing a half moon, notchedlike appearance along the leaf margins. Adults mate and females lay eggs singly near the soil surface near developing host plants from May to June. Each female can lay about 3,000 eggs during her lifetime.

After two to three weeks, eggs will hatch into larvae. The C-shaped larva is small, about 1/5 inch long, legless and white with a dark head capsule (Photo 20). Newly hatched larvae burrow into the soil to find and feed on N-fixing root nodules of its host plant. Larvae will develop through five instar stages in four to eight weeks.

Mature larva pupate in the soil. The pupal stage is a nonfeeding developmental stage without plant damage. The new generation of adults emerges during late July and into August. Adults search out pulse or related forage crops and feed on the vegetation before seeking overwintering sites in the late fall.

Damage

Adults feed on the early clam leaves, causing a symmetrical pattern of half-moon leaf notches (Photo 21). Leaf feeding by adults typically does not result in yield loss because the crop usually compensates and recovers.

However, larva feed on the N-fixing bacteria within root nodules, causing significant damage to nodules (Photo 22). Larval feeding injury on the root nodules reduces N-fixing ability of plants and yield.

Pest Management

Scouting should occur when crops have just emerged in the spring, especially when pea leaf weevil populations are high. Look for the half-moon leaf notches on the lowest leaves of the plant along field edges first. To establish an average number of plants with leaf notches, exam 10 seedlings per 10 sampling sites in the field for leaf notches (five sampling sites near the field edge and five sampling sites about 35 yards into the field). Space sampling sites in fields about 25 yards apart.

In general, insecticidal seed treatments are more effective than foliar insecticidal sprays for control of pea leaf weevil. Preventive insecticidal seed treatments, such as active ingredient thiamethoxam (Cruiser), reduce defoliation from adults, egg laying and larval feeding on the root nodules. The use of insecticide seed treatment should be based on regional field history of pea leaf weevil populations and damage levels.

To prevent egg laying, foliar insecticides should be applied at the **economic threshold of 30% of the plants having half-moon-shaped feeding notches on the clam leaves (most recently emerging leaves that are folded together) during seedling through the sixth-node growth stage**.

For insecticides registered in pulse crops, producers should consult the most recent version of E1143, "North Dakota Field Crop Insect Management Guide" (published annually). All label instructions for insecticides should be followed carefully.

Harvest

Harvest management is especially important to obtain high-quality field pea to be marketed as human food or seed. High-quality product is needed to receive a premium price for the crop. If the crop has quality problems, including bleached, split, cracked or earth-tagged seed, the livestock feed market likely will be the only option. Earth-tagged seed has dirt attached that cannot be removed.

The decision to start the harvest process will depend on three factors:

- **Crop maturity (stage of uniformity):** Look for a large majority of plants with tan pods on the bottom, yellow to tan pods in the middle and yellow-green pods on the top.
- **Seed moisture content:** Swath or desiccate field pea when the seed moisture content has reached 25% to 30%. Straight combine field pea when the seed moisture content has reached 18% to 20%.
- **Presence of weed growth:** Do not wait for green weed growth to dry down.

Field pea can be swathed to preserve quality if crop maturity is uneven or heavy weed pressure is present. When swathing pea, the seed needs to be at physiological maturity. At this stage of growth, the majority of pods should have turned from green to yellow.

The crop matures from the bottom pods upward. Swathing normally will result in increased harvest losses, but swather modifications make the procedure easier and will reduce harvest loss.

Vine lifters enable producers to get under the pea vines and lift them over the cutting knife. Many growers use a pickup reel to help in moving plant material off the cutter bar onto the canvas.

Field pea should be swathed in the early morning or late afternoon when the humidity is high and the pods are tough to reduce shattering losses. Combining should not be delayed after swathing because pea swaths are susceptible to movement by wind.

Many short to medium vine and semi-leafless pea cultivars have characteristics that allow straight harvesting, compared with cultivars with indeterminate and prostrate vine growth. For example, semi-leafless pea has a more open canopy, remain erect longer and dry down more rapidly after a rain or heavy dew than the indeterminate long vine type.

Straight combining will eliminate the possibility of windrow damage caused by high winds and reduce losses at the cutter bar. A desiccant may be used to enhance crop drying prior to combining.

Maintaining a low cutter bar height is essential to reduce losses. Floating cutter bars or flex-heads and raking-type pickup reels are available to reduce losses and increase harvest efficiency. To reduce seed shattering, the combine reel should be adjusted to a low speed.

Field pea should be combined with seed moisture of 17% to 20% to reduce splitting and seed coat cracking. Breakage increases at moisture contents below 14% to

16%. At this moisture range, the seeds are firm and no longer penetrable with a thumbnail.

Losses from shattering may be reduced by harvesting field pea before all pods are dry. Field pea does not ripen as uniformly as other crops; therefore, harvesting while green leaves and pods remain may be necessary.

Pea vines must be dry or harvest will be extremely slow and difficult. However, seed that is too dry will be susceptible to seed coat breakage or peeling. Harvest should occur during humid conditions, such as at night or early morning, when pods are wet with dew, to minimize seed shatter.

Correct combine settings and operation are important to maintain seed quality. Reel speed should be slow to minimize seed shatter. Low cylinder speeds, normally 350 to 600 rpm, should be used to minimize seed cracking or splitting. The cylinder speed should be reduced as harvest seed moisture decreases.

Initial concave settings of 0.6 inch clearance at the front and 0.3 inch at the rear, with the chaffer at 0.6 inch and sieve size at 0.4, are suggested. Use high airflow for good separation. Adjust combine settings as crop and weather conditions change.

Handling

The combine and portable augers should be operated at full capacity and low speeds to reduce pea seed damage. Alternative seed-handling equipment such as belt conveyors should be considered for handling the grain intended for seed or the human food market. Minimize the number of times seed is handled.

Field pea has improved handling characteristics at higher moisture levels. In most cases, the breakage increases with a decrease in temperature. At all temperature levels, seed coat breakage increases linearly with decreasing moisture content. In addition, a study found that a delay in harvest affects postharvest breakage to a greater degree than seed moisture content.

Drying

The test weight of field pea is similar to that of wheat, so the amount of water per point of moisture that needs to be removed during drying is similar.

Drying in a high-temperature dryer should be done gradually at temperatures below 115 degrees to limit hardening or cracking of seed destined for food use and below 110 degrees to prevent germination reduction in seed. For feed pea, drying temperatures up to 160 degrees can be used, but seed damage likely will occur. This is similar to the recommended temperatures for drying soybean.

If the seed moisture content must be reduced by 5% or more, drying in a high-temperature dryer should take place in two passes. This permits time for moisture equalization in the seed and minimizes stresses on the seed.

Warm seed should be cooled immediately to near average outdoor temperature after binning. Little information exists on using natural-air or low-temperature drying to dry field pea. The equilibrium moisture content is similar to cereal grains such as wheat and corn, so charts for those crops can be used to estimate expected moisture contents.

Because the test weight of pea is similar to wheat, using information for wheat should provide appropriate design guidance on required airflow rates and expected drying times. The resistance to airflow of pea is not well-documented, but it likely is similar to corn, so select fans for natural-air drying using corn data.

Cleaning

Green weed seeds or foreign material should be cleaned from the crop before storage to reduce the potential for deterioration during storage and enhance market opportunities. In addition, removing foreign material may reduce the moisture content by 1 or 2 percentage points.

Storage

The equilibrium moisture content and allowable storage time of pea is similar to that of wheat, so the recommended storage moisture content and storage characteristics will be similar. The allowable storage time for pea at select moisture contents and temperatures is shown in Table 6. This research showed some differences in allowable storage time between pea and wheat.

Allowable storage time values should be considered estimates. They require using aeration to cool or maintain the temperature of pea, proper monitoring and storage management similar to what is required for other types of grain.

Pea seed may be stored at 14% moisture content as long as the seed temperature is kept below 60 F. It may be stored at 16% moisture if the seed temperature is kept below 50 F. If the temperature of stored pea cannot be maintained below 60 F, then the recommended storage moisture content is 13%.

An aeration system should be used to cool the stored pea as outdoor temperature cool, similar to other grains. The seed should be cooled whenever the average outdoor temperature is 10 to 15 degrees cooler than the seed temperature. Field pea should be cooled to about 30 F for winter storage.

Exposure to sunlight also can cause a degradation in color. Good storage facilities maintain the product by protecting it from direct sunlight.

Table 6. Pea Allowable Storage Time.

Grain Temperature (F)	Grain Moisture Content (% w.b.)				
	12	14	16	18	21
	-------------- Storage time in weeks ---------------				
77	31	16	7	4	2
68	55	28	13	7	4
59	100	50	20	12	6
50	200	95	38	20	21
41	370	175	70	39	20

Production Contract Considerations

Production contracts are becoming common in the pulse industry and are expected to be more important in the future.

Understand What You Are Signing: Reading and understanding contract provisions always is important because they describe the rights and responsibilities of both parties in the agreement. Considerable differences can occur in contract terms among companies, and contract provisions often change through time. Discussing contract provisions with the buyer before signing a contract can prevent misunderstandings and help maintain a strong working relationship.

Production Requirements: Most pulse production contracts specifically require the farmer (seller) to use accepted agronomic production practices and apply only registered crop protection products. Some contracts also include a list of acceptable varieties or require the seed to be purchased from the company (buyer). Because pulse crops are most often used as human food, food safety standards and testing likely will become more stringent in the future. Stricter food safety requirements likely will lead to contracts including more detailed production provisions.

Act-of-God Clause: Some pulse contracts contain an act-of-God clause that releases the farmer (seller) from the terms of the contract due to an act of God such as hail, drought, flood or disease. The farmer (seller) must notify the company (buyer) as soon as possible when a potential production problem occurs to ensure that this contract provision is enacted. Many contracts require the farmer to provide written notice within 10 days of an event. An act-of-God clause does not nullify the contract but covers any shortfall in the contracted amount. The farmer (seller) still is required to deliver the production that is available.

Grading and Quality Standards: The USDA Federal Grain Inspection Service standards are the core standards used to trade pulse crops. However, some domestic and international end users are beginning to request more detailed grading and quality specifications. Grading and quality specifications should be listed clearly in the contract. If they are not, be sure to ask the buyer for a copy of the grading and quality standards that will be used.

Delivery Period: Production contracts typically require delivery at harvest, during a pre-specified delivery period or on a "buyer's-call" basis. Harvest delivery refers to delivery directly from the field to the agreed-upon delivery point during the normal harvest period. Some buyers offer alternative prices for pre-specified delivery windows, such as the first half of October, to better match deliveries with expected shipments. Buyer's-call refers to an open-ended delivery schedule in which the company (buyer) will determine the delivery period and schedule deliveries with the farmer (seller) when needed. Buyer's-call typically requires the farmer to store the contracted production until delivery is requested.

Pricing and Payment: Pulse crop production contracts typically use a fixed base price for the contracted production. Price premiums or discounts can be used to adjust for grade and quality differences, but the specific premium or discount rates are normally not known until the time of delivery. Payment generally is made a short time after all of the contracted production has been delivered. However, delayed payment or deferred payment options are often available.

Markets

Field pea most commonly is used for human food products but also can be a valuable animal feed. Green and yellow field peas often are used in soups and Middle Eastern and Asian cuisine. Pea flour and pea protein also are becoming popular food ingredients for snacks and gluten free foods.

Because field peas primarily are used for human food, crop quality and consistency are important. Price discounts often apply for damaged, broken or discolored seeds.

Tests for restricted-use crop chemicals often are conducted and a buyer may reject the production if amounts are above the maximum residual levels, or MRLs. Approximately 50% of the U.S. production of field pea is exported, with India, the Middle East and Asia being the major export destinations.

Chickpea Production

This section in the publication is intended for growers considering kabuli or desi chickpea as a crop. The text covers basic plant growth habit, crop production, field selection, seedbed preparation, fertilization, inoculation, seeding, weed control, diseases, insects, rotational benefits and harvesting.

Uses

Chickpea (*Cicer arietinum* L.) originated in what is now southeastern Turkey and Syria and was domesticated about 9,000 B.C. It is an annual grain legume or "pulse" crop sold in human food markets.

Chickpea is classified as kabuli or desi type, based primarily on seed color and shape. Kabuli chickpea, sometimes called garbanzo bean, has a white to cream-colored seed coat with a "rams's head" shape and ranges in size from small to large (greater than 100 to less than 50 seeds per ounce). Desi chickpea has a pigmented (tan to black) seed coat and small angular seeds.

Before selecting a cultivar, contact potential buyers to ensure it is accepted in the market you are targeting.

Chickpea is a high-value crop adapted to deep soils in the semiarid northern Great Plains. However, disease risks are high, and Ascochyta blight can cause devastating financial losses for growers. Thus, this crop is recommended only for producers who are willing to scout diligently and actively manage disease pressure throughout the entire growing season.

Price Uncertainty

Producers of alternative crops such as chickpea face price volatility in addition to production uncertainty. Chickpea is a high-risk/high-cost crop with potentially high financial rewards. Price uncertainty is a particular challenge with chickpea because it is a small-acreage crop and acres planted can fluctuate dramatically. Harvested acres in North Dakota from 2010 to 2019 are presented in Figure 3.

Markets

Before planting chickpea, knowing where the crop is going to be sold is essential. Because chickpea is a specialty crop, bringing harvested chickpea to the local elevator may not be possible. Therefore, you need to know where to sell and deliver the crop, as well as what the buyer wants.

Things to ask:

- Does the buyer want a specific variety? If yes, buy certified seed because the buyer may require documentation of the seed source, especially if it is a Plant Variety Protected (PVP) variety.
- What are the quality specifications? In the food-grade market, split seeds, cracked seed coasts, discoloration and greens (immature seeds) can result in steep discounts. Buyers of kabuli types

prefer a light and creamy seed color. For these reasons, food-grade chickpea demands careful harvesting, handling and storage to sell for the highest price.

Chickpeas predominantly are used for human food products but also can be used in animal feed. Chickpeas have a wide variety of food uses, including salads, hummus and cooked in stews or curry. Chickpea flour is used as batter for deep-fried meats and vegetables or an ingredient to make flat breads and desserts. Chickpea dishes are widespread in South Asia, the Middle East and Mexico.

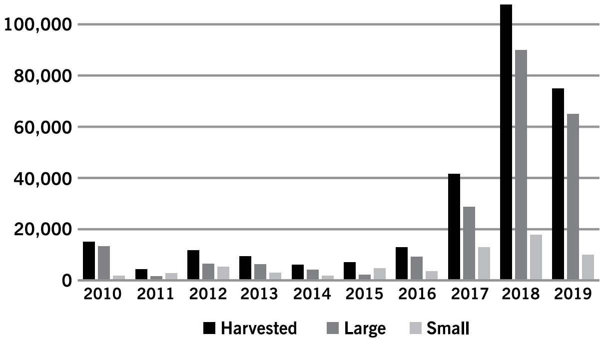

Figure 3. Chickpea harvested acres showing large (kabuli) and small-seeded (desi) chickpea varieties planted from 2010 to 2019 in North Dakota (2019 planting intention is at the beginning of the season).
Source: North Dakota Agricultural Statistics Service.

Because chickpeas predominantly are used for human food, crop quality and consistency are very important. Price premiums are paid for large-sized seeds, but price discounts often apply for damaged, broken or discolored seeds. Tests for restricted-use crop chemicals often are conducted and a buyer may reject the production if amounts are above the maximum residual levels, or MRLs.

Approximately 65% of the U.S. production of chickpea is used domestically. Major export destinations include India, Europe and the Middle East.

Adaptation

Drought Tolerance

Under drought stress conditions, maturity requirements for chickpea are similar to or slightly longer than for spring wheat. However, chickpea has an indeterminate growth habit, which can extend maturity greatly if cool or wet late-summer conditions persist. Chickpea roots deeper than dry pea or lentil and is more drought tolerant because it can tap into stored subsoil moisture, when available.

Photoperiod

Flowering time of chickpea is influenced by photoperiod. Some varieties are highly photoperiod sensitive, while some are not. Some varieties have intermediate response. Fewer degree days are required for flowering in photoperiod-insensitive varieties.

Temperature

Cool growing season temperatures and early fall frost can prevent chickpea from fully maturing. Chickpea tolerance to frost is similar to spring cereal grains. Chickpea tolerates high temperatures during flowering, unlike dry pea.

Growing Season

Chickpea matures later than dry pea or lentil and prefers a longer, warmer growing season. Desi chickpea typically flowers one day to one week earlier than kabuli, depending on the variety. Large-seeded kabuli varieties generally mature one to two weeks later than desi types, which have been bred for earlier maturity. Average maturity will depend on the variety and climatic conditions, and ranges from 100 to 130 days.

If seeding chickpea in early May, plan to harvest by mid-September. Under cool, wet late-summer conditions, maturity can be delayed substantially due to chickpea's indeterminate growth habit, and producers must manage to meet market specifications for green seed content (less than 0.5% to receive U.S. No. 1 grade, USA Dry Pea and Lentil Council).

In a year with abundant fall precipitation, chickpea might never fully mature. Under such conditions, a producer should gauge when the crop has fully mature pods from the bottom of the canopy up to the top 25% of the canopy, and then swath or desiccate.

Varieties

Variety evaluations (Photos 23–26) for North Dakota appear in Table 7.

Chickpea yields range widely in North Dakota. Although some varieties possess some level of Ascochyta tolerance, many varieties have very low levels of tolerance. Even though the desi chickpea market price typically is less than that for large kabuli types, the increased yield potential and lower production costs might result in equal or greater net returns.

Plant Growth Habit

Chickpea has hypogeal emergence in which the cotyledons remain below the soil surface and emerge by elongating epicotyl. This allows the seedling to tolerate late spring frost and have the ability to regrow from the below-ground buds, if the top growth is damaged.

Most chickpea varieties have compound leaves that exhibit a fernlike appearance; however, a few kabuli types have simple leaves. The chickpea plant is erect, with primary and secondary branching resembling a small bush, reaching a height of 8 to 24 inches.

On average, the plant produces a new node every three to four days, and flowers approximately 50 days after plant emergence, at about the 13- or 14-node stage. The plant flowers profusely and has an indeterminate growth habit, continuing to flower and set pods as long as climatic conditions allow.

Table 7. Chickpea seed yield, at various Research Extension Centers in North Dakota, 2016-2018.

Variety	Leaf Type[1]	Days to flower	2016 Hettinger	2016 Minot	2016 Williston	2017 Minot	2017 Carrington	2017 Dickinson	2018 Hettinger	2018 Carrington
		DAP[2]	yield in pounds per acre							
Kabuli										
CDC Frontier	C	50	2,119	1,422	1,872	1,136	2,468	1,150	1,802	2,980
CDC Luna	C	49	2,054	1,014	1,564	1,185	2,196	764	1,589	2,900
CDC Orion	C	45	--	2,315	--	1,187	1,952	--	1,456	3,328
Sawyer	S	49	1,387	965	1,392	1,192	1,608	891	1,439	2,660
Sierra	S	50	879	--	895	1,053	1,487	573	1,066	2,043
Desi										
CDC Anna	C	48	2,136	1,011	1,545	1,146	--	775	1,687	2,645
Mean		48	1,715	1,345	1,454	1,150	1,942	831	1,507	2,759
LSD 0.10		--	268	604	246	87	304	113	208	457

1 C = compound, S = Simple (Photo 23 and 24).
2 DAP = Days after planting.

Kabuli and desi chickpea types can be identified easily by flower color: Kabuli types have white flowers, indicating the absence of pigmentation, while desi types having purple flowers (Photo 25). The pods are oval shaped, borne singly, and contain one or two seeds. Plant height ranges from 10 to 22 inches, while kabuli types often are slightly taller than desi types.

Growth stages for chickpea are divided between vegetative and reproductive phases (Table 8). However, because the plant is indeterminate, new leaves continue to develop after flowering begins.

Cultural Practices – Crop Production

For optimum yield potential and success in chickpea production, give attention to field selection, seeding, inoculation, disease control, weed management, insect pest management, harvesting and crop rotation. Disease management is critical to success.

Crop Rotation

Chickpea, like other annual legumes in a rotation, offers several cropping advantages for the producer. Cereal crop yields often increase when planted after legumes due to the following:

- Cereal pest life cycles are disrupted.
- Alternative herbicides can be used to clean up grassy weeds.
- The soil nitrogen supply is increased.

Table 8. Growth stages of chickpea.

Chickpea Growth Stages	Description
Vegetative Growth Stages	
VE	Seedling emergence
V1	First multifoliolate leaf fully expanded
V2	Second multifoliolate leaf fully expanded
V3	Third multifoliolate leaf fully expanded
V4	Fourth multifoliolate leaf fully expanded
Vn	nth multifoliolate leaf fully expanded
Reproductive Growth Stages	
R1	Early bloom, one open flower
R2	Full bloom, most flowers on the plant open
R3	Early pod, pods visible on lower portions of the plant
R4	Pods have reached their full size but still are flat
R5	Early seed, seed in any single pod fills the pod cavity
R6	Full seed, seeds fill the pod cavity
Physiological Maturity	
R7	Leaves start to yellow and 50% of the pods are yellow
R8	90% of the pods are mature color (gold to brown)

However, chickpea has a moderately deep rooting system (similar to spring wheat), which is effective at extracting subsoil moisture, and because little stubble remains after harvest to trap snow and minimize evaporation, available crop water can be limited following chickpea in dry areas.

Chickpea stubble is not recommended to be planted to winter cereals because seeding disturbance destroys scarce crop residues and soil moisture often is insufficient to allow good germination of the winter wheat crop.

Field Selection

Chickpea can be planted into small-grain stubble. Chickpea should not be planted in a field that was planted to dry pea or lentil last year. Ideally, the field should not have been planted to pulse crops for at least two years to minimize the risk of root rot.

Seed size is a critical marketing factor for large kabuli types, and production in low-rainfall areas after a low-water-use crop such as flax can help ensure adequate water supply late in the growing season when seed size is determined.

Little information is available for chickpea production under irrigation in the northern Great Plains, but experience in southern Alberta and central Montana suggests it is a viable practice, provided Ascochyta blight is managed successfully. At Sidney, Mont., the average chickpea yield under irrigation was approximately 2,100 pounds per acre in 2017.

To select appropriate fields for chickpea, consider previous herbicide use, weed spectrum and pressure, interval since chickpea was last grown, and proximity to current and past chickpea fields. These considerations are critical to managing weeds and diseases and to reduce the potential for residual herbicide injury to the crop. See NDSU Extension publication W253, "North Dakota Weed Control Guide," for more information.

Avoid fields that have a history of perennial weeds, such as Canada thistle and field bindweed. Many herbicides used in small-grain production can carry over and cause chickpea injury and yield loss. The rotational interval for chickpea depends on how long herbicides remain in the soil.

Factors that affect herbicide persistence include pH, moisture and temperature. Because western North Dakota has a dry climate and short growing season, herbicides generally degrade more slowly there than in warmer, wetter areas. Sulfonylurea herbicides (Ally, Ally Extra, Amber, Finesse, Glean, Peak and Rave) persist longer in high-pH soils. In areas with low rainfall and high soil pH (greater than 7.5), sulfonylurea herbicide residues may remain in the soil much longer than described on the label, and a soil bioassay should be conducted before planting chickpea.

For integrated disease management, start by selecting a field that has not had chickpea for at least three years and is at least three miles from previous year's fields. However, even with these precautions, any chickpea field should be considered susceptible to Ascochyta blight during wet periods because long-distance spore transmission appears to occur. Fields that are well-drained are preferred because chickpea can be injured by waterlogged soil relatively quickly, compared with other nonlegume broadleaf or cereal crops.

Seeding

Producer experience suggests that both types of chickpea can be seeded as early as other pulse crops (dry pea and lentil). Chickpea seed should be treated for soil- and seed-borne pathogens (See NDSU Extension publication PP622, "North Dakota Field Crop Plant Disease Management Guide.") Using high-quality seed free of Ascochyta (less than 0.3%) also is essential, and seed treatment is recommended as part of an effective plan for integrated Ascochyta blight management.

Air drills and openers often need minor modifications and adjustments to avoid damaging seeds and facilitate metering of large-seeded kabuli varieties.

Chickpea typically is seeded in narrow row spacings of 6 to 12 inches. The target for established plant densities for kabuli and desi types is four plants per square foot (about 175,000 plants per acre). This usually requires planting four to five chickpea seeds per square foot. Depending on seed size, this often translates into seeding rates of 125 to 150 pounds per acre for large kabuli types and 80 to 100 pounds per acre for desi types.

Processors of kabuli types prefer large seeds and often pay a premium based on size. Breeders consider the ratios of large:medium:small seeds when making their selections because seed size has a genetic component.

However, row spacing, seeding rate and, ultimately, plant population also influence seed size. Producers should be careful not to exceed four established plants per square foot to ensure maximum seed size and enhance the marketability of kabuli-type chickpea.

Seeding depth recommendations are 1 inch below moist soil for small-seeded types and 2 inches below moist soil for large-seeded types. Chickpea can be seeded as deep as 4 inches to utilize available soil moisture for germination.

If the field requires rolling, the operation should be completed immediately after seeding or after the plants are well emerged but before the six-leaf stage of growth. Avoid rolling during plant emergence due to increased risk of injuring plants.

Symbiotic N-fixing Bacteria

A common requirement for efficient production of chickpea is inoculation with specific N-fixing bacteria. Chickpea requires an inoculant with the bacteria Mesorhizobium cicer. This species of rhizobium is unique to chickpea. The rhizobium used for field pea and lentil will not result in a symbiotic relationship and N fixation if used on chickpea.

Inoculants usually are available as a granulated product, applied similarly to an in-furrow fertilizer application, a liquid product, which is best applied to the seed and mixed; and a powder, which requires a sticking agent and is mixed with the seed similar to what is required for the liquid products.

Seed-applied inoculant must be applied to the seed immediately prior to planting. Large populations of introduced rhizobia bacteria must survive in the harsh soil environment for two to three weeks to form nodules effectively on the roots of chickpea seedlings. In dryland cropping regions, peat-based granular inoculant is preferred because it is more reliable in dry seedbed conditions.

In acidic soils, use a granular inoculant instead of a liquid or powder formulation. In acidic conditions, the activity of the rhizobia is reduced, but the use of granular inoculant helps overcome this problem.

Inoculants are live bacteria, so they need to be handled and stored correctly. Avoid extreme heat or cold; storing them in a cool, dark environment until needed is best. Seeding experts also recommend you do not pretreat seed and store it for more than one day.

Studies that have examined the value of inoculants to legume grain crops indicate that from 50% to 90% of the N used by chickpea during a season comes from N-fixation by the symbiotic N-fixing bacteria. Most studies that have examined N fertilization of chickpea found no value, and sometimes a yield reduction, from adding more than 10 pounds of N per acre to chickpea.

Avoid growing chickpea on soils with more than 60 pounds of N per acre residual N to the 2-foot depth because this resulted in lower yield than chickpea grown in soil with lower residual N.

Soil pH

Chickpea can achieve its yield potential on a wide range of soil pH from 5.3 to more than 7. Even at acid pH, yields might be maintained if a granular inoculant was used instead of a liquid or powder formulation. One problem with soil pH is the activity of the symbiotic bacteria, but the use of the granular inoculant solved that problem in a study that specifically looked at this issue.

Fertilization

Yield for a field in a given year is most dependent on the environment: rainfall, temperature and other factors. Within the environment, fertilizer rate is important. In a lower-yielding environment caused usually by too much water or not enough, nutrients are not as efficiently taken up, so rates relative to final yield are higher. In a high-yielding environment caused by close to ideal soil moisture and seasonal temperature, the efficiency of nutrient uptake is much higher, as is the release of nutrients from the soil and previous residues. The rates indicated in Table 9 are not related to yield goal but are appropriate for all yield environments.

Nitrogen (N)

A small amount of starter N increased early vegetative growth in one study and led to a slightly earlier maturity. You have little reason to apply more than 10 pounds of N per acre, usually contained in the P fertilizer source, to chickpea.

Phosphorus (P)

Desi-type chickpea have a lower demand for P, compared with the kabuli types. Kabuli chickpea growers often receive a premium for larger seed size, which is a consequence of greater P rates. Also, a small amount of P (about 10 pounds of P_2O_5 per acre) resulted in greater height of lowest pods due to increased early vegetative growth, which might be of benefit if the field has exposed rocks. Under all but the driest of soil environments, chickpea is relatively tolerant to up to 20 pounds of P_2O_5 per acre.

Potassium (K)

Chickpea has a similar low demand for K as field pea and lentil (Table 9).

Table 9. Phosphorus and potassium recommendations for desi- and kabuli-type chickpea.

	Olsen P, ppm					K soil test, ppm	
	0-3	4-7	8-11	12-15	16+	<100	>100
Chickpea type	P_2O_5 rate to apply pounds per acre					K_2O rate to apply in pounds per acre	
Desi	40	30	20	10	0	30	0
Kabuli	60	40	30	20	10	30	0

Sulfur (S)

Soil testing for soil sulfur is not diagnostic, so it should not be used in any consideration

of S fertilization. In the past 20 years, our soils have become increasingly deficient in sulfur, except for our saline soil areas.

Although chickpea has the ability to support production of its own N nutrition through its relationship with N-fixing bacteria when inoculated, it has no means to support the production of S. Application of 10 pounds of S per acre as ammonium sulfate or another sulfate-containing fertilizer would supply enough S for a growing season, provided a heavy rain did not result in S leaching on sandy-textured soils.

Micronutrients

No evidence indicates any micronutrient deficiency in chickpea in North Dakota.

Soluble Salts

Great variation in salt tolerance occurs among chickpea varieties. Generally, desi types are more tolerant to salts than the kabuli types. However, great variation occurs, even among varieties within type. More screening needs to be conductive to provide better grower guidance.

Determine soil salt (EC) levels, expressed as millimhos/centimeter, in areas that struggle to produce chickpea grain and plan to seed a more salt-tolerant crop there in the future. A comprehensive strategy to address salinity issues within fields helps expand future pulse crop options. For more information on addressing soil salinity, visit the NDSU Soil Health website (**www.ndsu.edu/soilhealth**).

Organic Production

Soil fertility is probably one of the minor management considerations for organic production of chickpea. Compost/composted manure would be a source of P, K and other nutrients for production of chickpea. The restriction would be to apply compost/manure the year prior to chickpea production so that too much N is not released during the early pulse growing season. Lacking access to compost/composted manure, buckwheat grown the year before and used as a green manure prior to seed set can make some P available to the chickpea.

Evidence also indicates that chickpea may have a similar ability to mobilize low-available Ca-held P, as does buckwheat. In a high-pH soil in India, an application of about 150 pounds per acre of finely ground rock phosphate resulted in a chickpea yield increase. Normally, rock phosphate does not release P in alkaline pH, but in this study, P was released under chickpea production.

Weed control and control of pests in general will be major considerations for organic chickpea production in North Dakota.

Diseases

Multiple diseases, including root rots, can affect chickpea. However, Ascochyta blight is easily the most yield-limiting disease of the chickpea, and this disease section will focus exclusively on Ascochyta. We cannot overstate how important *active and engaged* management of Ascochyta blight on chickpea is to produce a successful crop. In a season favorable for disease development, total crop failure can result if Ascochyta blight is not managed appropriately.

Ascochyta Blight is Different

Ascochyta blight is a disease caused by the fungal pathogen *Ascochyta rabiei*. While the disease "Ascochyta blight" also occurs on field pea and lentil, *Ascochyta rabiei* is specific to chickpea. In other words, Ascochyta blight on chickpea is ***different*** from Ascochyta blight on lentil and field pea.

The pathogen is specific to chickpea and does not infect pea or lentil. It also is very aggressive on chickpea, and more importantly, the pathogen in chickpea has developed resistance to QoI fungicides (FRAC 11, also called strobilurins) in our region and is at risk of developing resistance to other classes of fungicides.

Identifying Ascochyta Blight

Scouting for Ascochyta blight is critical; proactive and preventive disease management is necessary because Ascochyta blight cannot be controlled once it reaches epidemic levels. The pathogen can infect all above-ground plant parts any time after chickpea emergence.

Ascochyta blight first appears as small gray specs that quickly turn into brown lesions with dark borders. Small, circular black dots (fungal reproductive structures called pycnidia) will appear in lesions, frequently arranged in concentric rings resembling a bull's-eye (Photo 7).

Ascochyta can affect all above-ground plant parts, including stems (Photo 8), leaves, pods and seeds. The disease often appears first in places close to areas where previous chickpea crops were grown or in areas of higher humidity and longer dew periods, such as along shelterbelts or in low areas.

Disease Cycle

The pathogen causing Ascochyta blight can survive for up to four years in infected residue and seed. If infected seed is planted, the pathogen can grow along with the plant. Even a very low level of infected seed can facilitate an epidemic in a favorable environment.

Ascospores produced on the infected residue (or seed) are dispersed aerially and can travel for miles. Spores that travel through air or from infected seed cause the first infections on leaves, stems or other above-ground tissue. Consequently, a field that never has been planted to chickpea, is not near other chickpea fields and is planted with clean seed still is not immune to Ascochyta blight and must be scouted.

Ascochyta blight develops most rapidly in cool (59 to 77 F) and wet conditions. The small black pycnidia that appear in lesions produce a second spore type (conidia) that are dispersed easily by rain splash and cause new infections within the field. If multiple infection cycles occur, an epidemic can decimate a chickpea crop quickly.

An epidemic can occur particularly fast in a season with frequent rains, heavy dews and high humidity. Hot and dry conditions will slow or stop disease development, but once favorable conditions return, the epidemic will resume.

Managing Ascochyta Blight

Ascochyta blight must be managed with as many strategies as possible. Reliance on fungicides or genetics alone is likely to result in management failure and large economic losses.

No single management strategy can guarantee disease prevention, so use all available strategies to prevent or delay infection. Here are some strategies:

- **Plant clean seed.** This is critical to ensure that high amounts of the pathogen will not be brought into the field at planting. Use seed treatments that are efficacious on Ascochyta.
- **Practice long crop rotations** to help limit the inoculum already present in the field. This is

particularly important in minimum and no-till systems.

- **Select resistant chickpea varieties.** While selecting a variety completely resistant to Ascochyta blight is not possible, some varieties are less susceptible than others.

Fungicides also can be an effective tool to manage Ascochyta blight, but field scouting, application timing, fungicide selection and fungicide rotation are critical for success. See NDSU Extension publication PP622, "North Dakota Field Crop Plant Disease Management Guide," for more information. Multiple fungicide applications likely will be needed to manage the disease in a growing season.

At the time of this printing, QoI fungicides (FRAC 11: also called strobilurns) are ***not effective*** on Ascochyta blight in North Dakota because the pathogen population has developed resistance to them. This includes products such as Headline and Quadris, which are compounds in many premixed products.

However, at the time of this printing, DMI fungicides (FRAC 3: also called triazoles) and SDHI fungicides (FRAC 7) can be used to manage the disease, but the pathogen population could develop resistance to them in the future. Other chemicals, such as chlorothalonil (FRAC M5), are less efficacious but can be useful in fungicide rotation strategies and are unlikely to be rendered ineffective by pathogen resistance development.

When preparing to manage Ascochyta blight with fungicides, consult the most up-to-date information on fungicide timing, efficacy and rotation strategy.

Weed Management

Chickpea is a poor competitor with weeds at all stages of growth. Slow seedling growth, in addition to a relatively sparse optimum plant population of three to four plants per square foot, results in an open crop canopy, which requires season-long weed management. Crop rotation and field selection are cultural methods that should be used as part of an integrated weed management program.

Cultural weed control begins with avoidance. Avoid fields where perennial and annual broadleaf weeds are a major problem, and be sure to control these weeds in the preceding crop. Kochia, Russian thistle, wild mustard and wild buckwheat are the most problematic annual weeds in chickpea and can cause major problems for direct harvesting.

Weeds can be managed with stale seedbed techniques, provided the grower is willing to risk yield loss due to delayed seeding. Stale seedbed techniques include delaying seeding and allowing weeds to emerge, then controlling them with tillage or a nonselective herbicide.

Generally, the first flush is the largest, and the earliest emerging weeds are the most competitive. Stale seedbed techniques are not foolproof because weeds will continue to emerge throughout the growing season, and warm-season annual weeds such as green foxtail (pigeon grass) may be favored by delayed seeding.

As of 2019, no herbicides are registered to be applied postemergence to control broadleaf weeds in chickpea. Group 1 herbicides can be used to control grass weeds.

Controlling emerged weeds with a good burn-down before planting chickpea and using pre-emergent (PRE) herbicides to extend control as long as possible into the growing season are important.

Chickpea is a small, short plant, slow to canopy, and the canopy may not fully close. Without good weed control, yield loss can be substantial.

Several soil-applied herbicides are labeled for managing weeds in chickpea (Table 10). Troublesome broadleaf weeds such as kochia and Russian thistle can be controlled in no-till chickpea with sulfentrazone (Spartan Charge, Spartan Elite and BroadAxe XC) applied in the fall before chickpea is planted or as an early preplant application. NDSU research has shown that spring-applied sulfentrazone provided better season-long control, compared with fall applied.

NDSU research has shown that higher rates of sulfentrazone may be required to control wild buckwheat. Sulfentrazone can be applied from up to 30 days prior to planting to three days after planting.

A burn-down herbicide such as glyphosate may be tank mixed with sulfentrazone if emerged weeds are present. For optimum activity, sulfentrazone needs 0.5 inch of moisture soon after application to become activated in the soil.

Soil factors such as pH, texture and organic matter content affect sulfentrazone activity in soils. Growers should consult the label or a product representative carefully to determine optimum Spartan rates for their fields.

Table 10. Chickpea herbicides for North Dakota.

Herbicide	Product/a (ai/a)	Weeds	When to Apply	Remarks
Soil-applied Herbicides				
Far-Go (triallate)	**1.25 qt. EC** (1.25 lb.)	Wild oat	PPI.	PPI immediately after application. A two-pass incorporation improves weed control.
Prowl **Prowl H2O/** generics (pendimethalin)	**1.75 to 3.6 pt. 3.3EC** **1.5 to 3 pt. 3.8ASC** (0.72 to 1.5 lb.)	Grass and some broadleaf weeds Poor wild oat and no wild mustard control	PPI fall or spring.	Adjust rate for soil type. Apply in fall when soil temperature is less than 45 F to reduce fall herbicide degradation.
Treflan/generic trifluralin	**1 to 1.5 pt. EC** (0.5 to 0.75 lb.)		PPI fall or spring.	Refer to label for additional information.
Sonalan (ethalfluralin)	**1.5 to 2 pt. EC** **5.5 to 7.5 lb. 10G** (0.55 to 0.75 lb.)			Incorporate once using minimum soil disturbance with a rotary hoe or heavy harrow. Refer to label.
Dual/II/Magnum (S/metolachlor)	**1 to 2 pt. EC** (0.95 to 1.9 lb.)		Shallow PPI or PRE.	Shallow PPI improves consistency of weed control. PRE requires precipitation to activate herbicide. Adjust rate for soil type, organic matter and pH. Refer to label for tank-mix options.
Outlook / generic dimethenamid	**16 to 21 fl. oz. EC** (0.75 to 1 lb.)			
BroadAxe XC **Spartan Elite** (s-metolachlor and sulfentrazone)	**20 to 32 fl. oz. EC** (0.98 to 1.58 lb. and 1.75 to 2.8 oz.)	Annual grass and small-seeded broadleaf weeds		
Spartan Charge (carfentrazone and sulfentrazone)	**3.75 to 7.75 fl. oz. SE** (0.16 to 0.34 oz. and 1.48 to 3.05 oz.)	Small-seeded broadleaf weeds		

Authority Supreme (sulfentrazone and pyroxasulfone)	**4.3 to 10 fl. oz. SC** (1.12 to 2.6 oz. and 1.12 to 2.6 oz.)	Annual grass and small-seeded broadleaf weeds	Shallow PPI or PRE.	Shallow PPI improves consistency of weed control. PRE requires precipitation to activate herbicide. Adjust rate for soil type, organic matter and pH. Refer to label for tank-mix options.
Pursuit/generics (imazethapyr)	**2 fl. oz. SL** (0.5 oz.)	Small broadleaf weeds. No control of ALS-resistant weeds.		
Sharpen (saflufenacil)	**1 to 2 fl. oz. SC** (0.36 to 0.72 oz.)	Small broadleaf weeds including winter annual species	Fall, EPP, shallow PPI and PRE.	PRE requires precipitation to activate herbicide. Provides burn-down control of small emerged broadleaf weeds. Refer to label for tank-mix options.

POST-applied Chickpea Grass Herbicides

Herbicide	Product/a (ai/a)	Weeds	When to Apply	Remarks
Assure II **Targa** (quizalofop)	**7 to 12 fl. oz. EC** (0.77 to 1.32 oz.)	Annual grasses and quackgrass	POST PHI: Assure = 60 days. Poast = 50 days. Clethodim = 30 days.	Add oil adjuvant at 1 gallon per 100 gallons water but not less than 1.25 pt. per acre. Refer to label for tank-mix options.
Poast (sethoxydim)	**0.5 to 1.5 pt. EC** (0.1 to 0.3 lb.)	Annual grasses		
Select Max 1EC **Select 2EC** **Shadow 3EC/** generics (clethodim)	**9 to 16 fl. oz. EC** **4 to 8 fl. oz. EC** **2.7 to 5.3 fl. oz. EC** (1 to 2 oz.)	Annual grasses and quackgrass		

Flumioxazin (Valor) can be applied in the fall prior to planting chickpea. Flumioxazin has shown good residual control of several winter annual weeds as well as volunteer canola. Pendimethalin (Prowl) also can be applied fall or spring for broadleaf and grass control, but best results typically are achieved with the fall application.

In conventional tillage systems, trifluralin (Treflan), ethalfluralin (Sonalan) and pendimethalin (Prowl) incorporated preplant will control certain broadleaf weeds, plus foxtail and barnyard grass, but not wild oat or quackgrass. Imazethapyr (Pursuit) can be incorporated preplant or pre-emergence to control certain broadleaf and grass weeds. However, imazethapyr will not control ALS-resistant kochia, and the user assumes all risk of crop injury.

Several soil-applied herbicides are labeled for managing weeds in chickpea (Table 10). Troublesome broadleaf weeds such as kochia and Russian thistle can be controlled in no-till chickpea with sulfentrazone (Spartan Charge, Spartan Elite and BroadAxe XC) applied in the fall before chickpea is planted or as an early preplant application. NDSU research has shown that spring-applied sulfentrazone provided better season-long control, compared with fall applied.

NDSU research has shown that higher rates of sulfentrazone may be required to control wild buckwheat. Sulfentrazone can be applied from up to 30 days prior to planting to three days after planting.

A burn-down herbicide such as glyphosate may be tank mixed with sulfentrazone if emerged weeds are present. For optimum activity, sulfentrazone needs 0.5 inch of moisture soon after application to become activated in the soil.

Soil factors such as pH, texture and organic matter content affect sulfentrazone activity in soils. Growers should consult the label or a product representative carefully to determine optimum Spartan rates for their fields.

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Insect Pests

The NDSU Extension publication E1877, "Pulse Crop Insect Diagnostic Series: Field Pea, Lentil and Chickpea," summarizes integrated pest management for insect pests of pulse crops, including identification, crop damage, monitoring or scouting tips, economic threshold, cultural control, host plant resistance, biological control and chemical control.

Chickpea stems, leaves and seedpods are covered with small hairlike glandular structures that secret malic and oxalic acids, which deter insect pests. Researchers have observed that some grasshopper species are reluctant to feed on chickpea.

Researchers also have noted that chickpea fields infested with mustard will suffer some cabbage looper feeding injury on chickpea plants adjacent to mustard plants. Cutworms and wireworms occasionally damage chickpea stands as well.

For information about insects in chickpea, see the pea insect section.

Insecticides registered for insect pest management in chickpea are listed in the current issue of the NDSU Extension publication E1143, "North Dakota Field Crop Insect Management Guide." Pesticide applicators must read, understand and follower all label directions.

Harvesting

Factors That Affect Ripening

Chickpea has an indeterminate growth habit, which means the growth cycle extends as long as moisture is available. This growth pattern can be problematic in fields with uneven topography, where soil water varies throughout the field, or where seeding problems caused uneven emergence.

Herbicide injury, disease and predation by deer also commonly affect maturity and can result in uneven field ripening, sometimes causing green pods to persist until the first fall frost.

Green pods that are frozen or desiccated will remain green and become an important downgrading factor. Less than 1.0% of green seeds are allowed for the top U.S. commercial grade. Growers should cut around portions of the field with high green seed counts to avoid ruining the whole lot. To maintain a timely harvest for seed quality, some producers have combined different parts of the same kabuli chickpea field on three different dates.

Plants are physiologically mature when seeds begin to change color inside the uppermost pods. Producers have the option to direct combine or swath the crop when the pods are straw yellow.

Most chickpea is sold as a high-quality human food product. While seed size is a major factor in economic returns for the kabuli type, seed color is the single most important factor in determining marketability of the crop. If the seed coats are dark or discolored, the crop will not be accepted by food processors.

Harvesting decisions such as timing and harvesting methods are the major factors determining if you will harvest seeds with the light yellow to cream color demanded by processors. Delayed harvest can result in weathered seed that is not marketable.

Chickpea seed has a thin seed coat that is very susceptible to cracking, which can reduce germination. Combine cylinder speeds should be as low as possible to avoid cracking the seed coat.

Harvest Methods

Chickpea normally has low shattering potential, although pod drop has occurred in some instances when harvesting was delayed. Pod shattering can occur with unusually hot late August and early September temperatures.

The lowest pods typically are 4 inches off the ground, making direct harvesting possible but requiring an experienced combine operator. In some regions, swathing and combining are advantageous due to the fact that delayed harvests can result in darkening of the seed coat.

Most growers desiccate chickpea prior to harvest to facilitate even dry-down. Many varieties are indeterminate and will keep growing as long as they can. In some cases, mature seed is at risk of shattering at the bottom of the plant, while green plant tissue with immature pods persists at the top. Therefore, the decision about when to desiccate needs to balance harvestable yield and quality with the risk of shattering.

Several chemical desiccants are labeled for chickpea in North Dakota (Table 11). If producers prefer desiccation to swathing, they should be aware that a crop intended for seed should not be desiccated with Glyphosate or Sharpen because germination can be affected negatively.

Monitoring seed color is very important to determine proper harvest timing and management. Chickpea can be harvested at 18% moisture but requires that the crop ripen uniformly, which is rare.

Minimizing Seed Damage

Combine speeds, cylinders, sieves and air must be adjusted to prevent seed breakage. Chickpea seeds have a characteristic, protruding beaklike structure that must not be damaged. Seed damage can be minimized by the use of conveyor belts or by keeping augers as full as possible and operating at slower speeds.

Storage

Chickpea can be stored at 15% moisture. Minimizing the number of times chickpea is handled reduces the number of cracked or damaged seeds, which are significant dockage factors.

Table 11. Preharvest herbicides for chickpea in North Dakota.

Herbicide	Product/a (ai/a)	Weeds	When to Apply	Remarks
Glyphosate	Up to 2.25 lb. ae	Emerged grass and broadleaf weeds	Harvest aid and desiccant PHI: 7 days.	Use only registered formulations. Apply with AMS at 8.5 lb. per 100 gallons of water. **Do not apply to crop grown for seed because reduced germination/vigor may occur.** For spot treatment, use a 2% solution for perennial broadleaf weeds at or beyond the bud stage. Crop will be killed in treated areas.
		Perennial weeds	Spot treatment PHI: 14 days.	
Paraquat + NIS **RUP**	**1.2 to 2 pt. 2SL** **0.8 to 1.3 pt. 3SL** (0.3 to 0.5 lb.)	Chickpea and weed desiccant	Prior to harvest greater than 80% yellow/ brown pods and less than 40% green chickpea leaves PHI: Paraquat = 7 days. Sharpen = 2 days.	Contact herbicides require greater than 15 gpa and full sunlight. Apply at greater than 10 gpa for ground and greater than 5 gpa for aerial application. Apply Sharpen with AMS at 8.5 to 17 lb./100 gal. water or UAN at 2.5 gal./100 gal. water and with Glyphosate or Paraquat for weed desiccation. Glyphosate improves weed control from Sharpen and Valor but antagonism may occur on biennial and perennial weeds. Do not graze or hay treated plants. **Do not apply Sharpen to crop grown for seed because reduced germination/vigor may occur.**
Sharpen + MSO adjuvant (saflufenacil)	**1 to 2 fl. oz. SC +** **1 to 1.5 pt./A** (0.36 to 0.72 oz.)			

Lentil Production

The main Lentil (*Lens culinaris* Medik.) production areas in the U.S. are the Palouse region of eastern Washington, northern Idaho, northwestern and northeastern Montana, and western North Dakota.

Lentil production in North Dakota primarily has been confined to the western part of the state because disease is an issue under higher moisture conditions. Lentil is an excellent rotational crop. Production of lentil or other legumes in a diverse cropping system may improve soil health, and provides for an opportunity to control problem weeds such as downy brome, Japanese brome and other grassy annual weeds, as well as the cereal root rots and leaf spotting diseases. Acreage in North Dakota was the highest (255,000) in 2010 (Table 12).

Yield and Markets

During the last 15 years, average lentil yields in North Dakota have ranged from 820 to 1,560 pounds per acre (Table 12). Yield in addition to favorable market prices for lentil during the last 15 years (ranging from $9.10 to $33.10, and average $21.72 per hundredweight) has made lentil in most years an excellent cash crop in North Dakota.

Types and Description of Lentil

Lentil is an annual legume and has a height of 1 to 2.5 feet. Long periods of cool growing conditions result in excessively tall plants and delayed flowering. Many cultivars branch abundantly, depending on plant density, because the crop is capable of compensating for low plant densities in weed-free environments.

Table 12. Number of lentil acres harvested, yield per acre and average price obtained in North Dakota, 2004-2018.

Year	Harvested Acres	Yield in lb. per Acre	Price per Unit $ per cwt
2004	94,000	1,370	14.30
2005	146,000	1,350	10.20
2006	148,000	820	9.72
2007	106,000	1,360	22.80
2008	90,000	920	33.10
2009	163,000	1,560	26.60
2010	255,000	1,540	25.10
2011	77,000	1,070	20.40
2012	158,000	1,220	18.70
2013	126,000	1,400	17.90
2014	66,000	1,320	23.50
2015	162,000	1,310	28.90
2016	294,000	1,320	29.40
2017	250,000	870	23.50
2018	175,000	1,370	15.10

Source: USDA National Agricultural Statistics Service.

Small-seeded cultivars such as CDC Redberry and CDC Red Rider commonly are grown in the Midwest and have red cotyledons. Seed size for the small red cultivars ranges from 33 to 45 grams per 1,000 seeds.

CDC Richlea is a medium-seeded cultivar and has yellow cotyledons with a green seed coat. Large-seeded green cultivars include Pennell. Small-seeded green lentil cultivars such as CDC Viceroy are not grown commonly in the Midwest but have potential in the area.

Lentil flowers may be white, lilac or blue. Flowering in lentil starts from the bottom of the plant and progresses upward toward the top to completion. Flowers are mostly self-pollinated but can be cross-pollinated by small insects. After pollination, lentil forms green pods, each containing one or two seeds.

In general, cool temperatures at planting, warm growing-season temperatures and long days promote early flowering and good seed set. Lentil needs dry conditions during flowering and seed fill. Maturity occurs in about 90 to 100 days, depending on growing conditions.

» Variety Selection

Lentil is composed of different varietal groups and market classes, based on the color of seed and cotyledon. Varietal choice should be made considering yield potential, adaptation and marketability. For variety information on lentil variety performance in North Dakota, see Table 13 and information at **www.ag.ndsu.edu/varietytrials**.

Table 13a. Lentil seed yield (pounds per acre), North Dakota, 2012-2018.

Variety	ND 2012	ND 2013	ND 2014	ND 2015	Hettinger 2015	ND 2016	Carrington 2018	Hettinger 2018	Average
	---------- Yield in pounds per acre ----------								
Green									
CDC LeMay	1,681	2,147	1,839	1,695	3,005	1,233	966	1,334	1,652
CDC Richlea	1,647	2,174	1,945	1,900	2,804	1,699	1,329	1,233	1,814
CDC Viceroy	1,765	2,376	2,097	1,923	2,951	1,622	1,686	1,634	2,007
ND Eagle	--	--	--	--	3,409	1,598	1,667	1,455	--
Pennell	1,658	1,884	1,911	1,467	2,527	1,484	781	1,268	1,633
Red									
CDC Redberry	1,715	2,429	2,006	1,808	3,295	1,874	1,192	1,258	1,912
CDC Red Rider	1,710	2,491	2,027	1,917	2,974	2,386	1,147	1,466	1,972
CDC Rouleau	1,590	2,066	2,366	1,738	3,154	2,576	1,197	1,180	1,926
Mean	1,663	--	--	--	3,015	--	1,246	1,353	1,845
CV %	13	--	--	--	7	--	18.4	18.9	12
LSD 0.10	245	--	--	--	264	--	337	357	177

Table 13b. Clearfield lentil seed yield (pounds per acre), Hettinger 2015-2018.

Variety	Days to Flower	Plant Height	Seeds lb	Test Weight	Grain Yield 2015	Grain Yield 2016	Grain Yield 2018	Average Yield 2-year	Average Yield 3-year
	DAP[1]	inches	seeds	lb/bu	lbs/acre				
Medium Green Type									
CDC Impress CL	54	15	8,655	57.9	--	1,705	1,579	1,642	--
Small Green Type									
CDC Invincible CL	54	13	13,204	58.4	3,624	1,925	1,734	1,830	2,428
French Green Type									
CDC Peridot CL	48	13	11,816	57.9	--	1,483	1,497	1,490	--
Small Red Type									
CDC Maxim CL	48	14	10,787	57.9	4,007	1,601	1,761	1,681	2,456
CDC Impala CL	54	13	14,196	59.2	3,428	1,710	1,846	1,778	2,328
CDC Dazil CL	50	14	12,529	59.2	--	1,623	2,109	1,866	--
CDC Proclaim CL	48	13	11,205	56.9	--	1,741	1,663	1,702	--
Mean	51	14	11,770	58.2	3,518	1,655	1,741	1,713	2,404
C.V. %	2.0	6.6	5.1	1.5	7.6	8.6	14.3	--	--
LSD 10%	1.2	1.1	730	1.1	347	174	305	--	--

[1]Days after planting.

Cultural Considerations

Lentil is primarily a cool-season crop that has excellent potential for dryland production in many areas of North Dakota. The crop is moderately resistant to high temperatures and drought. Lentil does respond to drought stress in the advanced reproductive stage by quickening seed maturation.

Rooting depth is relatively shallow at about 18 to 32 inches, and lentil has relatively high water use efficiency. Precipitation plus stored plant-available soil water in the range of 10 inches is sufficient to produce excellent yields.

When selecting fields for lentil production, producers should consider soil, cropping and herbicide histories, as well as past pest problems. Wet soils inhibit lentil growth; therefore, well-drained clay loam and loamy soils with a pH of 6 to 8 should be selected.

Flat, level fields are easier to harvest, and rolling the crop early in the season can be important to push rocks into the soil. Fields that have been treated with long-term residual herbicides such as atrazine, sulfonylurea herbicides and others should be avoided. Also saline fields should be avoided.

Lentil should be seeded early in the season when the soil temperature reaches at least 40 F. In North Dakota, seeding is suggested from mid-April through mid-May. Lentil can tolerate freezing temperatures, and young plants have been reported to withstand temperatures as low as 25 F.

During germination, lentil cotyledons and growing point remain below the soil surface (hypogeal). This provides better freeze protection than epigeal-germinating crops such as dry bean or soybean because their cotyledons and growing point emerge above the ground.

Should the top portion of the plant be injured by a freeze prior to the fifth node stage, the plant will recover by initiating growth from an underground axillary bud. Beyond the seventh node, the plant is most likely to die.

Lentil can be seeded with available drills used to seed cereal grains in varying row widths at a depth of 1 to 1.5 inches. Because lentil is not a very competitive plant, narrower row spacing is preferred versus wide spacing.

Higher plant populations will provide some competition with the weeds, but growers should select fields relatively free of weeds. Because lentil is a low-growing plant and pods are set close to the soil surface, low-disturbance openers are preferred for seeding.

Plant height can be increased to a limited extent with plant populations near the upper end of the suggested plant population rate. The target plant population for lentil should be 525,000 to 785,000 plants per acre, or 12 to 18 plants per square foot (Figure 4). Seeding rates depend on seed size and germination rate, as well as damage caused by handling and metering seed through the drill. The drill should be calibrated to deliver enough seed to obtain the desired plant stand.

Assuming a seed lot has a 90% germination rate and a 15% loss occurs between damage caused by the drill and seedling failure to establish, a grower should aim to place eight to 12 seeds per foot of row if 6-inch row spacing is used, nine to 15 seeds per foot of row if row spacing is 7.5 inches, 13 to 20 seeds per foot of row if row spacing is 10 inches and 15 to 24 seeds per foot of row if row spacing is 12 inches.

Experienced growers can adjust rates to optimize seeding rates to account for the price of seed and the expected return in yield. High-quality seed (not cracked or chipped) is required. The seed should be handled carefully, and move slowly through augers and drills to minimize damage to the seed.

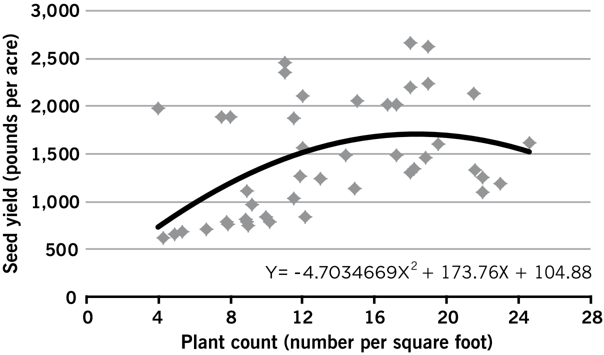


Figure 4. Lentil seed yield in relation to plant density in western North Dakota.

Source: E. Eriksmoen and N. Riveland, NDSU.

Lentil should be planted in a firm, weed-free seedbed. Fields under a no-till cropping system are ideal when seed is placed with low-disturbance opener drills. Rocks may cause issues at lentil harvest. Therefore, rocky fields should be rolled after planting or those fields should not be used to grow lentil.

Development Stages

Knowing the growth stages of lentil is important to properly time various management practices such as rolling, determining potential freeze injury and recovery, and insecticide and herbicide applications. Lentil growth stages and development are categorized as vegetative, reproductive and physiological maturity.

Nodes on the primary stem are used during the vegetative stages to determine development. The first node always is found below the soil surface, and sometimes the second is found below or at the ground surface. A scale or scale leaf will form at these nodes. At the third and fourth nodes, a bifoliolate leaf (two-leaflet compound leaf) will unfold.

Nodulation by nitrogen-fixing bacteria begins at the third- and fourth-node stage. From the fifth node on of the vegetative stages, a multifoliolate leaf will unfold at each node. These multifoliolate compound leaves will be made up of nine to 15 leaflets.

At the fifth node and beyond, rolling the crop to incorporate rocks into the soil surface and freezing temperatures will affect the crop adversely. Just prior to flowering, new leaves develop a short tendril at the leaf tip.

The beginning of the reproductive stage is marked by flowers opening at any node. In early maturing varieties, flowers will open at about the 10th to 11th nodes, while later-maturing varieties will open at the 13th or 14th nodes.

Early bloom is designated as R1 and full bloom when flowers are open on nodes 10 to 13 as R2. At the R4 stage of development, flat pods on nodes 10 to 13 are at full length and mostly flat. At R5, early seed development begins filling the pod. By the time R6 occurs, the seed has filled the pods on nodes 10 to 13.

When leaves are yellowing and 50% of the pods are yellowed, R7, physiological maturity has occurred. At R8, 90% of the pods are golden brown. See the harvest section for proper timing of desiccation and swathing.

Soil pH

Lentil reaches its maximum yield potential with soil pH greater than 7. Zone sampling fields may indicate areas within fields where soil pH should be increased using a form of finely ground limestone. The most common local source would be sugarbeet waste lime.

Lentil production is concentrated in North Dakota counties that include large acreages of acidic soils along the Missouri River and through Minot, and north through Mohall.

Symbiotic N-fixing Bacteria

A common requirement for efficient production of lentil is inoculation with specific N-fixing bacteria. Lentil should be inoculated with *Rhizobium leguminosarum*, designated a Class C inoculant by inoculation providers.

Inoculants usually are available as a granulated product, applied similarly to an in-furrow fertilizer application, but at a much lower rate; a liquid product, which is best applied to the seed and mixed; and a powder, which requires a sticking agent and is mixed with the seed similar to what is required for the liquid products.

Inoculants are live bacteria, so they need to be handled and stored correctly. Avoid extreme heat or cold; storing them in a cool, dark environment until needed is best. Seeding experts also recommend you do not pretreat seed and store it for more than one day.

Studies that have examined the value of inoculants to lentil indicate that from 50% to 90% of the N used by the crop during a season comes from N-fixation by the symbiotic N-fixing bacteria. Most studies that have examined N fertilization of lentil found no value, and sometimes a yield reduction, from adding more than 10 pounds of N per acre.

Avoid growing lentil on soils with more than 60 pounds of N per acre residual N to the 2-foot depth because this resulted in lower yield, compared with soil with lower residual N.

Fertilization

Yield for a field in a given year is most dependent on the environment: rainfall, temperature and other factors. Within the environment, fertilizer rate is important. The influence of the fertilizer rate is on “relative yield,” not “specific yield.”

In a lower-yielding environment, caused usually by too much water or not enough, nutrients are not as efficiently taken up, so rates relative to final yield are higher. In a high-yielding environment caused by close to ideal soil moisture and seasonal temperature, the efficiency of nutrient uptake is much higher, as is the release of nutrients from the soil and previous residues.

Nitrogen (N)

Inoculate with Rhizobium leguminosarum bacteria. Lentil yield has increased with the application of up to 20 pounds of N per acre if residual soil nitrate-N levels are less than 20 pounds of N per acre to 2 feet in depth.

Phosphorus (P)

Although low rates of seed-placed starter have increased lentil yield, when soil test P levels are low, they also consistently reduce lentil stand. A broadcast P application, and even a midrow band P application, will result in greater yield most of the time. Recommended P_2O_5 rates based on soil test values are presented in Table 14.

Potassium (K)

Lentil is not responsive to soil K except when it is extremely low. A 100 ppm K soil test level is adequate for high lentil production (Table 14).

Table 14. Phosphorus and potassium recommendations for lentil.

Olsen P, ppm					K soil test, ppm	
0-3	4-7	8-11	12-15	16+	<100	>100
P_2O_5 rate to apply lb/acre					K_2O rate to apply, lb/acre	
40	30	20	10	0	30	0

Sulfur (S)

Lentil has shown yield increases to S in seasons with a wet spring. Sulfate is soluble and can leach in loam or coarser soils due to excessive rainfall/snowmelt. Sulfur deficiency is most likely on loam and coarser-textured soils, but in recent years, S deficiency has been experienced even in high-clay soils with organic matter greater than 5% in very wet spring seasons. A rate of 10 pounds per acre of S as a sulfate would be enough to sustain a high-yielding lentil crop. Elemental S is not an effective S source in North Dakota, so its presence in a composite fertilizer granule should not be considered as a plant food. The S soil test is not diagnostic; therefore, it should not be conducted or considered in making a decision whether to fertilize with S.

Micronutrients

Micronutrients, including zinc, copper, manganese and iron, have not been shown to be deficient for lentil despite what any soil test might indicate.

Weed Control

Weed competition can reduce vigor and yield of lentil. Lentil seedlings are fairly nonaggressive, and severe weedy fields should be avoided. Moderate weed infestations should be controlled by cultural and chemical methods prior to growing lentil. A limited number of herbicides are labeled for weed control in lentil.

Research at Dickinson, N.D., indicates that in western North Dakota environments, post-plant tillage such as harrowing or using a rotary hoe to control weeds in lentil is a poor substitute for herbicides because weed pressure in following crops can be severe, requiring intense remediation.

Producers should consult the most recent version of the "North Dakota Weed Control Guide" (W-253), which is published annually and is available from the NDSU Distribution Center or www.ag.ndsu.edu/weeds. All label instructions for herbicides should be followed carefully.

Crop Rotations: Managing Weed Resistance and Volunteer Crop Issues

Growers should plan rotations out four or five years into the future to minimize competition from weeds and volunteer crops, and to minimize the occurrence of resistant weeds. Growing the same crops and using the same herbicides too frequently will lead to resistant weeds. Crop and herbicide diversity will lessen the chance of developing resistant weeds significantly.

Weeds resistant to some modes of action during years when lentil is grown will need to be controlled in previous crops using herbicides with effective modes of action and other management techniques. Growers should not confuse herbicide resistance with timing of weed emergence (particularly volunteer grain) that allows weeds to avoid exposure to herbicides due to late emergence.

Because lentil is not a very competitive crop, late flushes of volunteer grain can cause severe management issues. For example, wheat in lentil grain cannot be cleaned out because lentil and wheat kernels are of similar size and density. Wheat kernels in lentil grain can result in severe dockage or even prevent the crop from being sold.

Two applications of one or more post-applied grass herbicides may be required to remove volunteer wheat. Consult the label for proper use and do not exceed the annual limit of the product or the active ingredient found in the product.

Two weeds of particular concern for lentil growers are waterhemp and Palmer amaranth. These weeds are closely related to redroot pigweed, which is more familiar to North Dakota growers . However, waterhemp and Palmer amaranth are far more competitive than redroot pigweed.

These two weeds have an extended germination window and a higher propensity to evolve herbicide resistance. The extended germination window and higher likelihood of herbicide resistance make these weeds very difficult, if not impossible, to control in lentil.

Fields with a history of waterhemp or Palmer amaranth should not be planted into lentil unless populations are managed carefully. Growing lentil in a field with waterhemp or Palmer amaranth can be considered a "no-win" situation for chemical weed control.

Table 15. Weed control in lentil.

Soil-applied Herbicides

Herbicide	Product/a (ai/a)	Weeds	When to Apply	Remarks
Valor (flumioxazin)	**2 or 3 oz.** (1 to 1.5 oz.)	Broadleaf and grass weeds	Fall only	**See label for crop rotation restrictions.**
Sharpen (saflufenacil)	**0.75 fl. oz.** (0.27 oz.)	Annual broadleaves	PP or PRE	Most effective on annual broadleaf weeds when tank mixed with glyphosate. Burn-down only; do not expect residual weed control.
Pursuit (imazethapyr)	**2 fl. oz.** (0.5 oz. ae)	Mustards	PP or PRE	Some growers have seen injury at more than 1 fl. oz.
Far-Go (triallate)	**1.25 qt. EC** (1.25 lb.)	Wild oat	PPI	PPI immediately after application. A two-pass incorporation is recommended.
Prowl **Prowl H20** (pendimethalin)	**1.75 to 3.6 pt. 3.3EC** **1.5 to 3 pt. 3.8ASC** (0.72 to 1.5 lb.)	Grass and some broadleaf weeds	PPI fall or spring	Adjust rate for soil type. Poor wild oat and no wild mustard control. Apply in fall when soil temperature is less than 45 F.
Treflan/ generic trifluralin	**1 to 1.5 pt.** (0.5 to 1 lb.)		PPI fall or spring. See remarks for use in lentil	Lentil: Tolerance is marginal and injury may occur under stress conditions. Refer to label for additional information.
Sonalan (ethalfluralin)	**1.5 to 2 pt.** **5.5 to 7.5 lb. 10G** (0.55 to 0.75 lb.)			Lentil: Fall-apply Sonalan 10G just prior to snow cover into stubble on fields that have been direct-seeded with 30% or less soil disturbance for two to three years. Incorporate once using minimum soil disturbance with a rotary hoe or heavy harrow. Refer to label.

Soil-applied Herbicides (continued)

Herbicide	Product/a (ai/a)	Weeds	When to Apply	Remarks
Dual/generic metolachlor	**1 to 2 pt.** (0.95 to 1.9 lb.)	Grass and some broadleaf weeds	PPI or PRE	S-metolachlor may give greater weed control than generic metolachlor at equal product rates. Shallow PPI improves consistency of weed control.
Outlook/generic dimethenamid	**16 to 21 fl. oz.** (0.75 to 1 lb.)		Shallow PPI, PRE or EPOST to third leaf lentil	Poor wild oat and wild mustard control. Adjust rate for soil type and OM. Shallow incorporation improves consistency of weed control. Refer to label for tank-mix options.
Metribuzin/ generics	**0.33 to 0.5 lb. DF** **0.5 0.75 pt. 4F** (0.25 to 0.38 lb.)	Suppression of lambsquarters, henbit, chickweed and mustard	PRE	Adjust rates for soil type. Refer to label for application and environment information, and special precautions that may affect weed control and crop safety. Allow a 75-day PHI.
	0.167 to 0.33 lb DF **0.25 to 0.5 pt. 4F** (0.125 to 0.25 lb.)		POST Weeds: small	

Refer to current “North Dakota Weed Control Guide” for fall or spring early preplant herbicides.

Post-applied Grass Herbicides

Herbicide	Product/a (ai/a)	Weeds	When to Apply	Remarks
Assure II **Targa** (quizalofop)	**7 to 12 fl. oz.** (0.77 to 1.32 oz.)	Annual grasses and quackgrass	POST: 60-day PHI Grass: Refer to "North Dakota Weed Control Guide"	Apply with COC at 1% v/v.
Poast (sethoxydim)	**1 to 1. 5 pt.** (0.188 to 0.281 lb.)	Annual grasses and quackgrass	POST: 50-day PHI	Apply 1 pt. for annual weedy grasses. Apply 1.5 pt. for volunteer cereals and quackgrass. Apply with COC at 1 qt./A. UAN or AMS may be added to increase activity on hard-to-control grasses.
Select/generic clethodim	**6 to 8 fl. oz.** (1.5 to 2 oz.)	Annual grasses and quackgrass	POST: 30-day PHI	Apply 6 to 8 fl. oz. for annual grasses. May make second application for quackgrass, if needed.
Select Max (clethodim)	**9 to 16 fl. oz.** (1.125 to 2 oz.)	Annual grasses and quackgrass	POST: 30 day PHI	See Select Max label for detailed adjuvant recommendations.

Clearfield Lentil

Beyond (imazamox)	**4 fl. oz.** (0.5 oz.)	Annual grasses and broadleaf weeds	POST	Apply before broadleaf weeds exceed 3 inches and grasses exceed four to five leaves. Will not control ALS-resistant kochia. Wild buckwheat control is better when applied at two-leaf or smaller.

Preharvest Herbicides

Herbicide	Product/a (ai/a)	Weeds	When to Apply	Remarks
Roundup/generic glyphosate	**Up to 2.25 lb. ae**	Emerged grass and broadleaf weeds	Harvest and desiccant	Use only registered formulations. Apply with AMS at 8.5 lb./100 gal. Allow a seven-day PHI for broadcast and 14-day PHI for spot treatment. **Do not apply on crop grown for seed because reduced germination/vigor may occur.** For spot treatment use a 2% solution for perennial broadleaf weeds at or beyond the bud stage. Crop will be killed in treated areas
		Perennial weeds	Spot treatment	
Paraquat **RUP**	1.5 to 2 pt. 2SL 1 to 1.3 pt. 3SL (0.375 to 0.5 lb.)	Lentil and weed desiccant	PHI: Paraquat = 7 days Valor = 5 days	Contact herbicides require thorough coverage. Most active in hot and sunny conditions. Apply paraquat with NIS at 0.25% v/v.
Valor + MSO adjuvant (flumiozazin)	1 to 2 fl. oz. + 1 qt./A (1.53 to 2.3 oz.)			Apply Valor when crop is physiologically mature and a minimum of 80% of pods are yellow to tan and 20% are yellow. Apply with MSO at 1 qt/.A. AMS or UAN may be added to enhance desiccation. Use 15 to 30 gpa spray volume.

Disease

Several important diseases of lentil occur in North Dakota, and management of them is critical for a healthy and profitable crop. We will focus on identification and management of the most common and/or economically important diseases.

Disease Management Overview

The use of an integrated pest management (IPM) system is the most effective way to manage diseases in any given year. Clean seed, crop rotation, selection of a resistant variety (if available) and fungicides are important management tools for most diseases impacting lentil. Combined use of more than one of these strategies often is necessary to achieve satisfactory disease management in lentil.

The use of several management tools also is important for the long-term viability of those tools. Excessive reliance on a single management strategy (for example, foliar fungicides or a specific resistance gene) may be detrimental through time. The development of pathogen resistance to fungicides has been documented on several crops in North Dakota, including chickpea, pea, potato, sunflower and sugarbeet.

Many of the most important pathogens causing disease on lentil in North Dakota are high risk for the development of fungicide resistance. Similarly, exclusive reliance on a single host resistance gene for management of disease will facilitate selection for a pathogen that can overcome that gene. Pathogens have overcome resistance genes on most crops grown in North Dakota.

For more information on fungicide resistance, consult the fungicide resistance action committee (FRAC) available at **www.frac.info**.

For more detailed information on identification of lentil diseases, consult the "Lentil Disease Diagnostic Series," NDSU Extension Publication PP1913, available at **www.ag.ndsu.edu/publications/lentil-disease-diagnostic-series-pp1913**.

For information on labeled fungicides available, consult the most recent edition of the "North Dakota Field Crop Plant Disease Management Guide," available at **www.ag.ndsu.edu/publications/crops**.

Anthracnose

Significance: Anthracnose can cause significant seed yield and quality losses when conditions are favorable.

Cause: Anthracnose of lentil is caused by at least two *Colletotrichum* spp. One of those pathogens, *Colletotrichum truncatum*, has at least two races; therefore, varieties carrying resistance to a single race still may be highly susceptible to anthracnose. Field pea, faba bean and wild vetch also are hosts.

Disease Cycle: Anthracnose overwinters as microscopic fungal resting structures called microsclerotia in crop residue. Microsclerotia can survive for up to three years when residue is buried. However, the viability of microsclerotia declines sharply when residues are left on the surface and a long crop rotation is used, but it is not reduced to zero. Anthracnose can spread to nearby fields by blowing residue and microsclerotia-infested dust.

Infection begins when spores and/or microsclerotia (often blown by dust) come into direct contact with above-ground plant parts (leaves, stem, etc.) under favorable environmental conditions, optimally, 68 to 75 F and 24 hours of surface moisture. Frequently, symptoms are observed first between the eight- and 12-node stage (prior to flowering) and shortly after bloom initiation.

Once infection is established, spores are produced rapidly and splashed to neighboring plants. Under optimal conditions, an epidemic can spread quickly throughout a field. The pathogen can survive on the seed, but seed-borne infection is believed to be of limited importance for establishing disease epidemics.

Symptoms:

- Leaf, stem and pod symptoms usually begin on lower portions of the plant and spread upward. Lesions typically are tan to light brown and may have a darker brown border. As leaf lesions enlarge, premature leaf drop may occur. Numerous small, black microsclerotia form in the lesion centers as pod and stem lesions enlarge (Photo 9).
- Stem lesions often are sunken and girdle the plant as they enlarge, resulting in wilting and chlorosis, and shortly thereafter, plant death. In severe disease outbreaks, patches of plants killed by anthracnose often are observed.
- Anthracnose leaf lesions often are indistinguishable from Ascochyta blight. Laboratory analysis often is required to differentiate the two diseases.

Management:

- **Crop rotation and tillage –** A minimum of a three-year rotation out of lentils are recommended. No-till practices generally will reduce inoculum more quickly than any other tillage practice. However, note that disease pressure is unlikely to be eliminated with tillage and crop rotation alone.
- **Genetic resistance –** Lentil varieties differ in their susceptibility, but little to no information about specific lentil varieties is available.
- **Fungicides –** Fungicides may be a useful management tool. Multiple effective products exist, and rotation of fungicide chemistries among FRAC groups is very important. Consulting the most up to date efficacy and timing recommendations is important. In general, fungicides are best applied (1) when the first foliar lesions are present, (2) before the first stem lesions develop and (3) when the weather is favorable for disease. This timing often, but not always, corresponds with canopy closure. When wet weather persists, a single application may not provide satisfactory disease management.

Ascochyta Blight

Significance: Ascochyta blight is an economically damaging disease of lentil in North Dakota, Montana and the neighboring Prairie Provinces of Canada. Yield losses of 40% to 50% have been reported from Ascochyta blight epidemics, and Ascochyta-associated seed discoloration is common and can result in reduction of grade and quality.

Cause: Ascochyta is caused by the fungal pathogen *Ascochyta lentis*. Although Ascochyta blights also occur on field pea and chickpea, the species of Ascochyta infecting each crop is different. Ascochyta lentis does not infect chickpea or field pea; likewise, the species of Ascochyta that infect field pea and chickpea do not infect lentils.

Disease Cycle: The pathogen survives on seed and infected lentil residue. Both sources of inoculum are important contributors to disease. If infected seed is planted, seedlings may emerge diseased and facilitate secondary infection of nearby plants. A soil temperature of 46 F is optimal for transmission of disease from seed to seedlings.

Infections result in lesions with pycnidia, which produce pathogen spores, and under favorable environmental conditions, will cause epidemics. Infection is favored at temperatures of 50 to 68 F and prolonged leaf wetness (24 to 48 hours). Wind-driven rain is particularly effective at inciting epidemics.

Symptoms:

The pathogen can infect any above-ground plant parts, including, leaves, stems, pods and seed (Photo 10). Lesions usually begin as very small light green to white specks but quickly enlarge and become tan to light brown. Tiny black specks (pycnidia) form in the centers of lesions. Significant infection will cause leaf drop, flower abortion and seed discoloration. Distinguishing Ascochyta blight from Anthracnose is very difficult, and laboratory identification is recommended.

Management:

- **Crop rotation –** A three-year rotation out of lentil is recommended to minimize the transmission of Ascochyta blight from infected lentil residues to a new crop.
- **Clean seed –** The use of clean seed is very important. The pathogen can be transmitted from infected seed to seedlings and can incite an epidemic later in the season. Infected seed suffer from reduced emergence and produce plants with lower vigor and lower grain yield. Infected seed is not always discolored, so seed lots should be submitted for laboratory testing. In regions where cool, moist weather is likely, only seed testing negative for *Ascochyta lentis* should be used. In regions with dry climates, planting some level of infected seed may be tolerable, but it increases the risk of disease outbreaks. Seed lots that exceed 10% incidence of Ascochyta infection should not be used under any condition. The plant diagnostic labs at NDSU and Montana State University offer seed testing services.
- **Genetic resistance –** Lentil varieties differ in susceptibility to Ascochyta blight; no varieties carry complete resistance, but they many exhibit reduced susceptibility to the disease. We recommend that growers inquire about the level of resistance in a variety before selecting it for planting. *Ascochyta lentis* can overcome host resistance rapidly, and cultivars with elevated resistance to Ascochyta blight should be used in conjunction with other disease management practices.

- **Fungicide seed treatment –** Fungicide seed treatment may help manage seed-borne infection. Foliar-applied fungicides may help manage disease, but optimal timing depends on weather, disease pressure and other factors. The Ascochyta blight pathogen is at high risk for the development of fungicide resistance. Fungicide FRAC groups should be rotated, regardless of application method (seed treatment, foliar sprays). Consult the most up to date management recommendations before selecting fungicides.

Botrytis Gray Mold

Significance: Botrytis gray mold can impact all above-ground plant parts, including leaves, flowers, stems, pods and seed. When conditions are favorable for the disease, seed yield and quality losses can be significant. In North America, the disease has been observed in epidemic levels in the U.S. and Canada.

Cause: Botrytis gray mold can be caused by two fungal pathogens, *Botrytis cinerea* and *B. fabae*. In North Dakota, *B. cinerea* is presumed to be the more common. *B. cinerea* has a wide host range that includes many broadleaf crops, including field pea, chickpea, alfalfa and sunflower.

Disease Cycle: The pathogen overwinters on seed and infected crop residue. Disease is initiated by seed-to-seedling transmission or by wind-dispersed fungal spores. When disease begins from infected seed, seedlings often will emerge infected and may die. When disease begins (and progresses) from air-borne spores, infection can take place on any above-ground plant tissue. The disease is favored by high relative humidity (above 95%) and moderate temperatures (59 to 77 F).

Epidemics are more likely after canopy closure, and particularly in dense canopies, which result in favorable microclimates for disease development. Under optimal conditions, the pathogen will reproduce very quickly and can cause a severe epidemic. As the crop senesces, the pathogen will produce resting structures (sclerotia), which can overwinter and incite epidemics in subsequent years.

Symptoms:

- **Seedlings –** Seedling blight is characterized by yellowing and wilting followed by plant death; it is distinguished from other seedling diseases by the prolific gray sporulation of the fungus on the lentil hypocotyl at the soil line. Botrytis seedling blight often spreads plant to plant within a row, resulting in gaps in stand establishment. Botrytis seedling blight can be economically important when infected seed are planted or when lentil is planted into a field with crop residues infested with Botrytis.
- **Mature plants –** When relative humidity is high, abundant gray sporulation can be found on leaves, stems and pods (Photo 11). However, sporulation is often very difficult to find by the late morning or afternoon, especially on dry, windy days. The causal pathogen sometimes also produces small, black sclerotia on diseased tissues. The absence of cottony-white mycelium and the presence of gray sporulation differentiates Botrytis gray mold from Sclerotinia stem rot.

Management:

- **Clean seed and seed treatment –** Infected seed will cause Botrytis seedling blight, and sporulation on plants killed by seedling blight may increase disease pressure in mature stands. Infected seed is not always discolored; if *Botrytis* infection is suspected, seed lots should be submitted for laboratory testing. If clean seed is unavailable, a fungicide seed treatment may be advised. The plant diagnostic labs at NDSU and Montana State University offer seed testing services.

- **Crop rotation –** After an outbreak of Botrytis gray mold, a break of at least three years is recommended before lentils are planted in that field. Avoid planting adjacent to a field that had an outbreak of Botrytis gray mold (on lentil or another crop) the previous year. Severe epidemics can result because spores produced on residues in the adjacent field can be windblown readily into the new lentil crop.

- **Genetic resistance –** Lentil varieties have been reported to differ in their susceptibility to Botrytis gray mold, but no data are available on the relative susceptibility of locally adapted varieties. Varieties with a spreading growth habit and/or a heightened susceptibility to lodging are expected to be most susceptible.

- **Fungicides –** Fungicides are useful tools for the management of Botrytis gray mold on other crops, but data are limited on their efficacy on lentils.

Root Rots

Significance: Root rots occur in lentil and results in stand loss and wilting plants.

Cause: Multiple pathogens, including *Aphanomyces, Fusarium, Pythium* and *Rhizoctonia*, can cause root rots on lentil. Many of these pathogens occur on other crops as well, most notably field pea.

Disease Cycle: The disease cycle for each root rot pathogen is different, and pathogens can cause disease under a variety of environmental conditions. In general, soil-borne pathogens will increase under short/no rotations of the same crop, or rotations to crops susceptible to a similar group or subset of pathogens.

Symptoms:

Root rots may occur on individual plants or clusters of plants in fields. Individual plants often will be stunted, turn yellow and may die. Through time, these same areas may become consistent problem areas in fields, and may enlarge. In general, *Pythium* often occurs early, rots seed and causes root browning; *Aphanomyces*-infected roots may appear caramel colored; *Fusarium*-infected roots may have brown to reddish-brown lesions on the lower stems and roots; *Rhizoctonia*-infected roots may have sunken dark red-brown to brown lesions on the lower stem and roots. For more specific information on symptoms of root rots and other diseases, consult the NDSU Extension Publication PP1913, "Lentil Disease Diagnostic Series," available at **www.ag.ndsu.edu/publications/lentil-disease-diagnostic-series-pp1913**.

Management:
Crop rotation is an important management tool for root rots. Short or no rotation may result in increased pressure from soil-borne pathogens. A four-year rotation, as is recommended for economically limiting foliar diseases (Ascochyta blight, Anthracnose, etc.), also is recommended for root rot management. Nearly all root rotting pathogens affect pea and lentil; therefore, the four-year rotation should exclude peas. Fungicide seed treatments may aid in disease management.

Sclerotinia Stem Rot (White Mold)

Significance: *Sclerotinia sclerotiorum* causes white mold on most broadleaf crops grown in North Dakota, and lentil are very susceptible to Sclerotinia stem rot. The disease is most likely to be a problem in cool and wet environments and when lentil is rotated with other very susceptible crops, including sunflower, dry bean and canola.

Cause: Sclerotinia stem rot is caused by the fungal pathogen *Sclerotinia sclerotiorum*. The pathogen has a very broad host range and infects many broadleaf weeds and broadleaf crops grown in North Dakota, including canola, chickpea, dry edible bean, field pea, soybean and sunflower.

Disease Cycle: *Sclerotinia sclerotiorum* overwinters as a hard, black and large (about the size and color of rat droppings) resting structure called sclerotia. Sclerotia survive on plant residue of susceptible crops or in the soil. During the growing season, sclerotia residing in the top 1 to 1.5 inches of the soil profile may germinate when the soil is at or near its water-holding capacity.

As a rule of thumb, 1 to 2 inches of rain in a week is enough to facilitate germination.

Sclerotia germinate to produce a small mushroomlike structure (about 1/8 to 1/4 inch in diameter) called apothecia. The infection process begins when spores land on dead or senescing tissue, preferably flower petals. Once spores begin to digest the tissue, the pathogen spreads into healthy tissue and will cause lesions, produce white mycelium, and eventually, more sclerotia. Moderate temperatures (approximately 50 to 80 F), ample free surface moisture (long dew periods, fog) and dense canopies promote disease development.

Symptoms:

A bleached or dry bone-colored lesion on stems or branches is the most visually striking symptom. In wet canopies, the pathogen will produce white, fluffy fungal mycelium (mold), hence the common name of the disease, "white mold." Black sclerotia may be found in or on infected tissue.

Management:

- **Crop rotation –** Although crop rotation is important, the long-lived nature of sclerotia and broad host range limit its impact. However, tight rotations of crops highly susceptible to Sclerotinia may build up pathogen inoculum and increase risk to the disease in the future.
- **Tillage –** The impact of tillage on reduction of sclerotia is mixed. This practice is most effective when paired with crop rotation. Sclerotia that are left on or near the surface of the soil after an epidemic (such as in no-till systems) will tend to

germinate in the following year under favorable conditions for the pathogen. This can be beneficial if germination occurs when a nonhost crop (wheat, barley) is grown. However, in drought conditions, they may not germinate at all and simply survive one more season. This is problematic if the cropping system returns to another susceptible broadleaf crop. Conversely, sclerotia that are buried more than 1 to 2 inches in the soil profile likely will not germinate, even if conditions are favorable. However, they survive longer in the soil than on the soil surface, as long as five to seven years. When those sclerotia are brought back up to the soil surface, they may incite an epidemic.

- **Genetic resistance –** Lentil varieties have been reported to differ in susceptibility to Sclerotinia stem rot, and efforts are under way to identify the relative susceptibility of commercially available lentil varieties to Sclerotinia stem rot. Varieties with a spreading growth habit and/or a heightened susceptibility to lodging are expected to be the most susceptible.
- **Fungicides –** Fungicides may be used to manage white mold. Although optimal timing is preventive and often early bloom, other factors such as canopy closure, temperature and moisture should be considered. For best efficacy results, consult the most up to date fungicide recommendations. Importantly, the most efficacious fungicides used for management for foliar diseases (Ascochyta, Anthracnose, etc.) may not be the most effective fungicides for management of white mold.

■ Stemphylium Blight

Significance: Stemphylium blight is a severe disease of lentils in Southeast Asia, where yield losses of up to 80% have occurred). The disease occurs in North Dakota and nearby production regions, but the impact of the disease on lentil yield and quality is largely unknown.

Cause: Stemphylium blight is thought to be caused primarily by the fungal pathogen *Stemphylium botryosum*. The pathogen has a broad host range and also is a saprophyte.

Disease Cycle: The biology of *S. botryosum* on lentil is not well understood; however, researchers assume the fungus survives on infected crop residues, other susceptible hosts or dead plant material as a saprophyte. Although infection can occur at a wide range of temperatures between (41 and 86-plus F), temperatures on the high end of the range are optimal for infection. Prolonged leaf wetness (24 hours or more) is necessary for infection to occur at low temperatures, while only six to 12 hours of wetness is required at higher temperatures. Once infection occurs, lesions are formed and abundant fungal spores are produced on infected leaves. Dispersal of these spores can spread the infection to new plants and create an epidemic. In North Dakota, the disease generally is a problem only when rains occur late in the growing season; lentil appear to be most susceptible to the disease in the last third of the growing season.

Symptoms:

At disease onset, stems are healthy, but leaflets exhibit angular chlortotic to tan lesions that often quickly coalesce to cover the entire leaflet. When relative humidity is high (early mornings and after rainfall events), the pathogen sporulates and diseased leaves take on a gray to black appearance. Shortly after leaves become diseased, leaf drop occurs, leaving the plants defoliated. Often, only terminal leaflets on the tops of the plants remain. Complete defoliation can occur within days of first symptom expression. As the disease progresses further, the stems eventually turn tan and then brown, with the disease progressing from the tip (Photo 12).

Management:

- **Crop rotation –** Data are not available on the influence of crop rotation on Stemphylium blight. However, because the causal pathogen persists well as a saprophyte in the environment, crop rotation is expected to be of limited use for managing this disease.
- **Clean seed –** *Stemphylium* infects lentil seeds, but seed-to-seedling transmission of Stemphylium blight on lentil has not been documented.
- **Genetic resistance –** Lentil varieties differ in their susceptibility to Stemphylium blight; no varieties are completely resistant, but some varieties are less susceptible than others. Limited information on varieties is available.
- **Fungicides –** Whether fungicides protect yield or are economical viable is unclear because the disease rarely develops until late in the growing season in our region.

Insect Pests

The NDSU Extension publication E1877, "Pulse Crop Insect Diagnostic Series: Field Pea, Lentil and Chickpea," summarizes integrated pest management for insect pests of pulse crops, including identification, crop damage, monitoring or scouting tips, economic threshold, cultural control, host plant resistance, biological control and chemical control.

For information about insects in lentil, see the pea insect section.

Insecticides registered for insect pest management in chickpea are listed in the current issue of the NDSU Extension publication E1143, "North Dakota Field Crop Insect Management Guide." Pesticide applicators must read, understand and follower all label directions.

Harvesting Lentil

Lentil requires a growing season of 80 to 100 days, depending on seeding date and stress factors such as high temperatures and moisture stress. Early seeding with higher plant densities will increase plant height and facilitate easier harvesting. Swathing or desiccation is necessary if maturity is uneven, or if green seeds are present.

Lentil is ready to be swathed or desiccated when the lower one-third of the pods are brown to yellow brown and rattle. Pods in the upper canopy of the plant still may be green. Delaying cutting or desiccating will result in large losses due to seed shattering. Swathing the crop when it is slightly damp avoids excessive shatter loss.

As pods begin to dry down, maturity will advance very rapidly with hot, dry conditions. Lentil should be swathed as low to the ground as possible, which dictates slow cutting. Many producers use desiccants and direct harvest lentil. Direct harvest results in reduced shatter losses and less risk of weather losses and delays.

Desiccation followed by direct cutting is extensively used in southwestern North Dakota because swathed windrows move under windy conditions, and rain on windrowed lentil can result in discoloration of the grain.

A flexible ("flex") combine header with automatic height adjustment is ideal for lentil harvest. "Pick-up" reel attachments or "vine lifters" also are useful for lodged crops. Very low cylinder speeds (250 to 500 rpm) should be used to minimize seed splitting.

The beginning setting for the concave should be ¾ inch in the front and about ¼ inch in the back. Adjust to minimize damage to the seed.

Ideal storage moisture content occurs at about 14%; however, the crop should be combined at 16% to 18% moisture and then dried to 14% or less. Lentil should be handled as little as possible after harvest, and when moving is required, it should be done carefully with an elevator or auger. To minimize seed damage, handle seed as little as possible, cushion seed drop by adjusting the height of the drop, and move the grain with an elevator operated at full capacity.

Lentil Drying and Storage

Drying and storing lentil is similar to drying and storing hard red spring wheat. A bushel of lentil seed weighs 60 pounds.

The equilibrium moisture content (EMC) of lentil is similar to corn and wheat at 50% relative humidity and is higher than corn and wheat at higher relative humidities. The recommended storage moisture content and expected allowable storage times for lentil are likely to be similar to corn and wheat, based on having a similar EMC. Recommended storage moisture content for lentil for long-term storage at summer temperatures is less than 14%.

Lentil seed darkens during storage if exposed to light. The storage structure should limit light exposure and the amount of seed exposed on the surface. Darkening of the seed also is affected by temperature and seed moisture content. Darkening of the seed is rapid when stored at warm temperatures and higher moisture contents.

Seed should be cooled using aeration as outdoor temperatures cool to enhance the storage life. Cool the seed to below 60 F as soon as possible and to about 30 F for winter storage. Lentil stored during spring and summer should be kept as cool as possible by covering ducts or fans to limit airflow through the bin that will warm the stored grain.

A loss of germination also is associated with darkening of the seed. Lentil seed from successive years should not be mixed because all the lentil seed may be downgraded by the color changes in the oldest seed.

Table 16. Approximate equilibrium moisture contents for lentil, corn and wheat at selected temperatures and relative humidities.

	Temperature								
Relative	40 F			70 F			85 F		
Humidity	Lentil	Corn	Wheat	Lentil	Corn	Wheat	Lentil	Corn	Wheat
50%	13.5	12.7	13.2	12.0	11.2	12.0	11.7	10.6	11.5
60%	14.6	14.5	14.6	13.7	12.8	13.3	12.5	12.1	12.8
70%	16.8	16.4	16.2	15.5	14.5	14.8	14.5	13.8	14.2
80%	19.9	18.7	18.0	17.5	16.6	16.5	16.9	15.8	15.8

Harvest losses, shatter in the field and seed breakage are higher at lower moisture contents, so harvest frequently occurs at seed moisture contents exceeding the recommended maximum storage moisture content of 14%. Some recommend the seed be threshed at about 16% moisture to obtain a cleaner crop sample and a reduction in shattering losses and seed damage.

Seed breakage susceptibility is related to temperature and moisture content. Moisture content is the primary factor in breakage, with breakage susceptibility increasing below about 15%. Cold seeds are much more susceptible to breakage, even at higher moisture contents. General guidelines are to minimize handling at seed temperatures below zero. Handling damage will be minimized at moderate moisture contents and temperatures.

To maintain the quality of the seed stored in grain bags, ensuring that the lentil seed moisture content is less than 14% moisture and no water enters the bag is essential. High-moisture grain, water condensation under the film or leaks can cause localized mold and widespread spoilage in pulses. Insect activity and mold growth are not prevented even though the bag is sealed. Because light causes darkening of the seed, excluding light from the bag is imperative.

The drying rate or rate of moisture removal from a large seeded lentil variety during high-temperature drying is much slower than wheat. One study indicated a drying time of 3.2 hours for wheat and of eight hours for the large seeded lentil. Therefore, lentil will need to be in the dryer longer than wheat to remove the same amount of moisture. Seed breakage increases with the length of time the seed is being dried in a high-temperature dryer, so limiting seed moisture is desirable.

Research suggests drying air temperatures as high as 160 F may be used for commercial drying, but tiny cracks may develop at this temperature. Test samples of grain dried at different temperatures to determine the maximum allowable drying temperature because safe drying temperature can vary among dryers and with grain condition. Generally, the recommendation is to limit drying air temperature to about 110 F to maintain germination.

Natural air drying of lentil is similar to drying wheat. The weight per bushel, equilibrium moisture content and resistance to airflow are similar. Required airflow rates and expected drying times for natural air drying wheat in August in North Dakota are shown in Table 17.

The Table 18 shows the days required for natural air drying of lentil with unheated ambient air to a final moisture content of 14% in Saskatoon, Sask., based on simulation.

The resistance to airflow of lentil varieties with large seed is a little less than wheat. One publication states it is about 0.75 times that of wheat. The resistance to airflow of small market type lentil is similar to that of wheat. A system designed for wheat should be adequate for lentil.

If harvested lentil has more than a small amount of foreign material, lentil seed should be cleaned before drying to reduce the amount of foreign material that holds moisture and to eliminate finer dockage that interferes with airflow.

Table 17. Fan time with different moisture contents and airflow.

Moisture Content	Airflow Rate (cfm/bu)	Fan Time Hours	Days
18 %	1.00	600	25
17 %	1.00	552	23
	0.75	744	31
16 %	1.00	504	21
	0.75	672	28
15 %	1.00	480	20
	0.75	648	27

Drying during September will take about 30% longer due to the cooler temperatures.

Table 18. Days required for natural air drying of lentil.

Start Date	Moisture Content percent	Airflow Rate 1.0 cfm/bu
	(%)	(Days)
Aug. 15	20	36
Aug. 15	17	26
Sept. 15	20	38
Sept. 15	17	35

Lentil Marketing

Lentil primarily is used for human food products but also can be used in animal feed. Lentil frequently is used in curries, stews, mixed with rice or in salads. Lentil dishes are widespread in India, South Asia and the Mediterranean region. Because lentils are predominantly used for human food, crop quality and consistency are very important.

Price discounts often apply for damaged, broken or discolored seeds. Tests for restricted-use crop chemicals often are conducted, and a buyer may reject the production if amounts are above the maximum residual levels, or MRLs. Approximately 65% of the U.S. production of lentil is exported, with India and Mediterranean countries accounting for the majority of export sales.

NOTES

PHOTO SECTION

1. Early Ascochyta blight lesions on field pea. (S. Markell, NDSU)

2. Ascochyta blight lesions on field pea. (S. Markell, NDSU)

3. Ascochyta blight lesions on leaves and stems of field pea. (S. Markell, NDSU)

4. Pea expressing symptoms of Fusarium wilt, including leaf yellowing and curling on only one side of a plant. (S. Markell, NDSU)

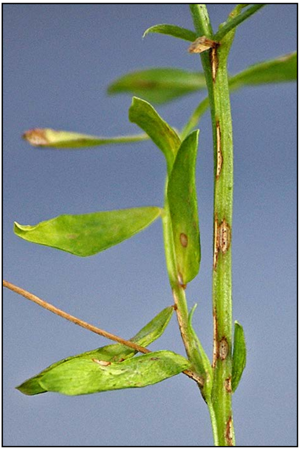
5. Powdery mildew signs include white tufts of fungal growth. (S. Markell, NDSU)

6. Leaf with powdery mildew; white fungal growth often can be wiped off of green tissue. (S. Markell, NDSU)

7. Ascochyta blight lesion on chickpea. (S. Markell, NDSU)

8. Ascochyta blight lesion on chickpea stem. (S. Markell, NDSU)

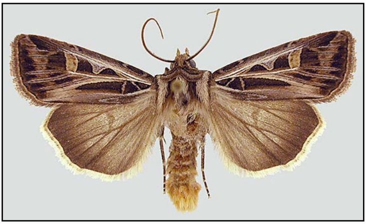
9. Anthracnose lesions on lentil. (M. Wunsch, NDSU)



10. Ascochyta blight lesion on lentil. (M. Wunsch, NDSU)

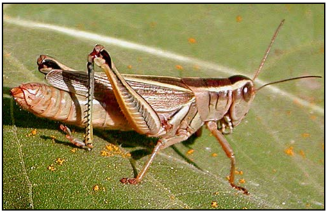
11. Botrytis gray mold lesions on lentil. (M. Wunsch, NDSU)

12. Stemphylium blight lesions on lentil. (M. Wunsch, NDSU)



13. Dingy cutworm adult.
(G. Fauske, NDSU)

14. Dingy cutworm larva.
(J. Gavloski, Manitoba Agriculture, Food and Rural Initiatives)



15. Grasshopper adult.
(J. Knodel, NDSU)

16. Grasshopper nymph.
(G. Fauske, NDSU)

17. Wireworm larva – Elateridae. (M. Boetel, NDSU)

18. Wireworm adult (or click beetle) – Elateridae.
(Eric LaGasa, Washington State Department of Agriculture, www.Bugwood.org)

19. Pea leaf weevil adult.
(M. Dolinski, Canada)

20. Pea leaf weevil larva.
(M. Dolinski, Canada)

21. Leaf feeding notches from pea leaf weevil adult.
(P. Beauzay, NDSU)

22. Pea leaf weevil larva feeding on nitrogen-fixing bacteria within root nodules. (P. Beauzay, NDSU)

23. Chickpea with compound leaf. (C. Keene, NDSU)

24. Chickpea with simple leaf.
(C. Keene, NDSU)

25. Flowering desi chickpea variety with compound leaves.
(T.R. Stefaniak, NDSU)

26. Chickpea variety testing in Minot, N.D. (T.R. Stefaniak, NDSU)

Resources

- NDSU Extension publication A1469, “North Dakota Dry Pea Variety Trial Results and Selection Guide”
- NDSU Extension publication E1143, “North Dakota Field Crop Insect Management Guide”
- NDSU Extension publication E1877, “Pulse Crop Insect Diagnostic Series: Field Pea, Lentil and Chickpea.”
- NDSU Extension publication E1879, “Integrated Pest Management of Pea Leaf Weevil in North Dakota”
- NDSU Extension publication PP622, “North Dakota Field Crop Plant Disease Management Guide”
- NDSU Extension publication PP1362, “Ascochyta Blight of Chickpea”
- NDSU Extension publication PP1704, “Pea Seed-borne Mosaic Virus (PSbMV) in Field Peas and Lentils”
- NDSU Extension publication PP1790, “Pea Disease Diagnostic Series”
- NDSU Extension publication PP1913, “Lentil Disease Diagnostic Series”
- NDSU Extension publication SF725, “Soil Fertility Recommendations for Field Pea, Lentil and Chickpea in North Dakota.”
- NDSU Extension publication W253, “North Dakota Weed Control Guide”

A listing of potential buyers and market opportunities is available from:

Northern Pulse Growers Association
1710 Burnt Boat Drive, Bismarck, ND 58503
Phone: 701-222-0128
Fax: 701-222-6340
Email: info@northernpulse.com
Website: www.northernpulse.com

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For more information on this and other topics, see www.ndsu.edu/extension

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