


2023 Crop Diagnostic Handbook




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Section 1: General Agronomy

Cereals and Annual Grasses Plant Staging

To stage cereal plants, it is important to differentiate between the main stem (largest stem with the most leaves) and the tillers (at the base of leaves on the main stem).

Figure 1.1 (a) Leaf stages of cereals & annual grass weeds

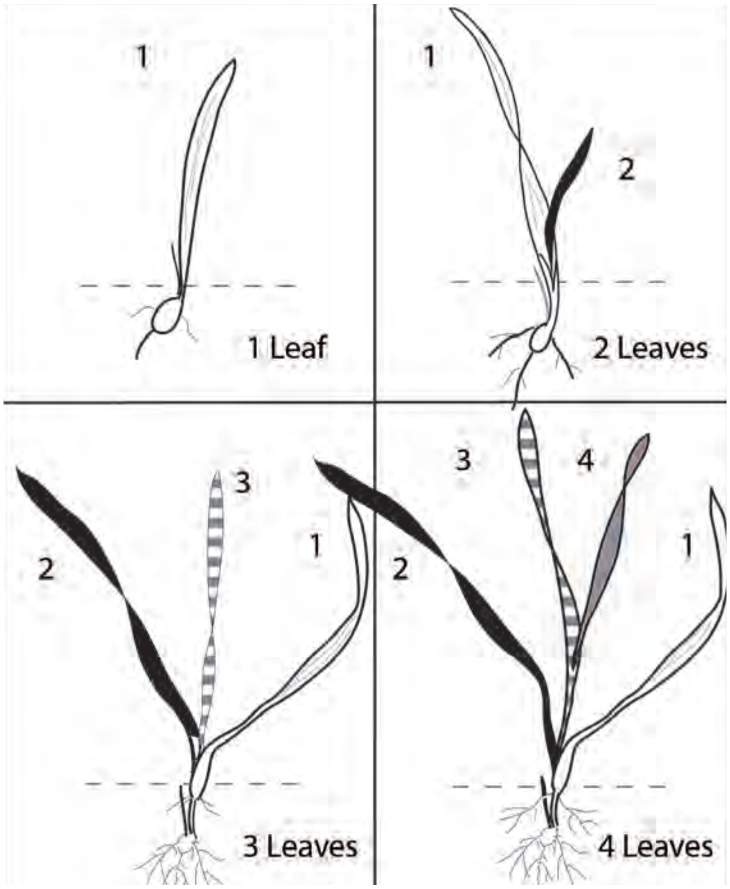
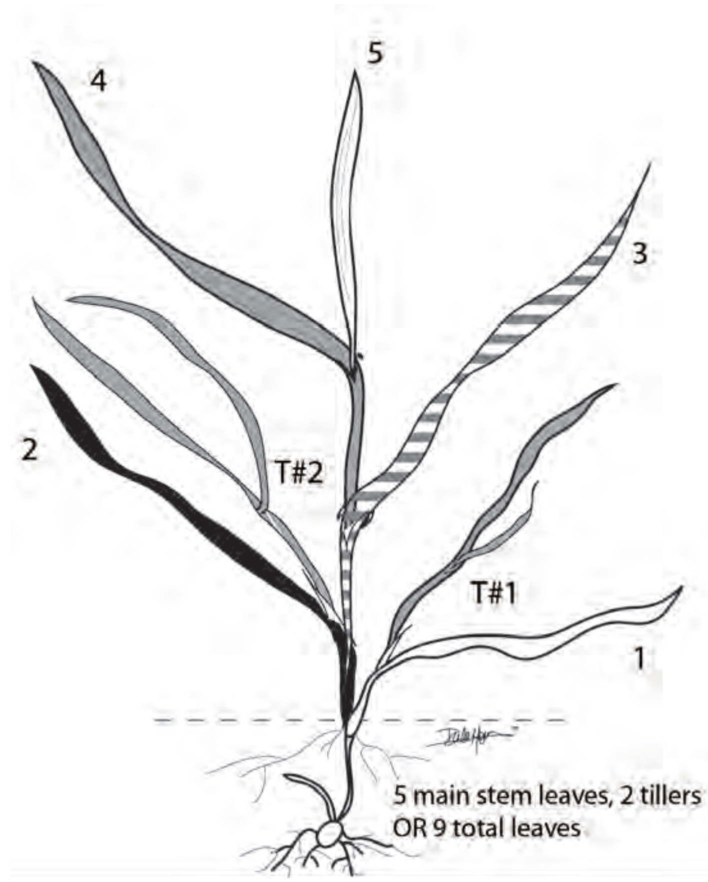


Figure 1.1(b) 5 Main stem leaves, 2 tillers or 9 total leaves



Locate the first leaf

- The first leaf is the lowest leaf with a blunt tip.
- Appears on the opposite side of the plant from the coleoptile and the coleoptilar tiller.

Locate the main shoot

- Position the plant-first leaf points to your left and fan out the leaves and tillers.
- The main shoot is the tallest shoot and has the most leaves.
- Count the leaves on the main shoot or stem. Leaves are counted when they are over one-half the length of the leaf below.

Counting tillers

- Locate the leaf sheath that encloses the base of the tiller.
- Primary tillers arise from each leaf of the main stem.
- Coleoptilar tillers arise from the coleoptilar node at the base of the plant. Coleoptilar tillers appear separate from the other tillers and are not counted when staging.

To check for jointing and stem elongation

- Remove the roots and tillers.
- Split the remaining stem in half and locate the position of the growing point or grain head.
- If three or four nodes are visible, check to see if the last leaf is the flag leaf. Cut the stem below the highest node, unwrap the stem/leaves to expose the developing head.
- If there are no leaves enclosing the head then the last leaf is the flag leaf.

- The flag leaf is the last leaf to emerge before the head emerges.
- The leaf prior to the flag leaf is called the penultimate leaf.

Note: The flag leaf is a major contributor to grain yield. Emergence of the flag leaf (last leaf) is important for application timing of fungicide and plant growth regulators.

Boot stage

- Look for swelling in the stem that moves upward towards the top of the plant.
- The boot stage ends when the awns are present or if no awns then the end of the head emerges.

Note: This stage is when susceptibility to wheat midge starts. As soon as the boot splits, the crop is susceptible. The crop is no longer susceptible half way through flowering.

Heading and flowering

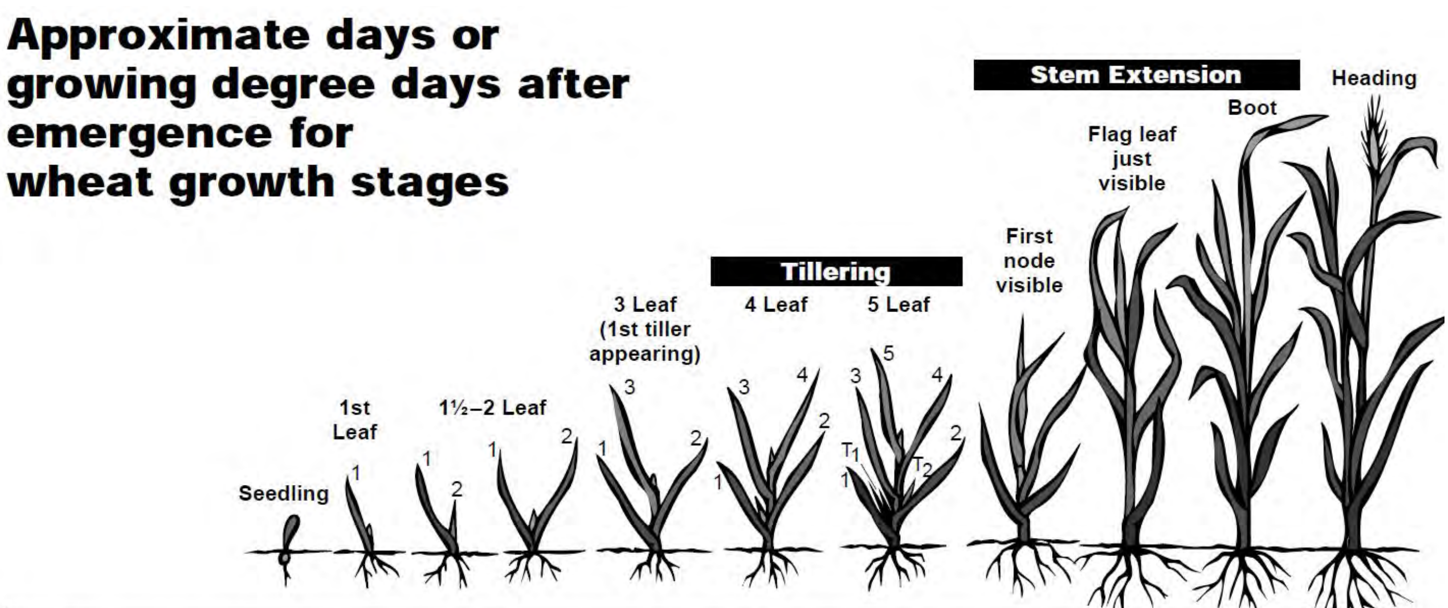
- Head emergence starts when the first spikelet is visible above the flag leaf and ends when the head is fully emerged.
- For closed-flowering cereals (mostly barley varieties), flowering occurs prior to head emergence.
- For open-flowering cereals (most wheat varieties), flowering and pollination occurs one to seven days after heading.
- Visible yellow anthers mark the end of flowering.

Grain development

- During the milk stage (early kernel development), a milky fluid forms that becomes more solid as the stage progresses.
- Kernel formation is completed during the dough development stage. The developing kernel is physiologically mature at the hard dough stage even though it still contains approximately 30 per cent water.

Note: Late dough stage can be determined by making a thumbnail imprint in the kernel that does not disappear.

Figure 1.1 (c) Wheat growth stages



Early Planting (days)	7-8	14-16	20-22	26-28	31-33	34-36	44	53	58
Late Planting (days)	6-7	11-13	16-18	21-23	25-27	28-31	38	45	49
Growing Degree Day* (units)	72	144-215	358	501	644	715	1075	1359	1500

Figure 1.1 (d) Wheat growth stages

Growing Degree Day Units

$GDD = (T_{MAX} + T_{MIN}) / 2 - T_{BASE}$

$$\text{*Growing Degree Day Units} = \frac{\text{(Maximum Day Temperature + Minimum Day Temperature)}}{2} - 32$$

To convert this to Celsius, $GDD^C = 5/9 * GDD^F$

Note: It takes nine Fahrenheit degree-days to make five Celsius degree-days

An alternative way to stage crop development is with Growing Degree Days. With this system, heat value is calculated for each day. When these numbers are added together, it can provide an estimate of the amount of seasonal growth crops have achieved. One degree day is one day when the average temperature is at least one degree above the lower developmental temperature for a crop.

Barley		Stage	GDD C
Emergence	Leaf tip just emerging from above-ground coleoptile.	1.0	109-145
Leaf development	Two leaves unfolded.	1.2	145-184
Tillering	First tiller visible (tillering of cereals may occur as early as stage 1.3, in this case continue with 2.1).	2.1	308-360
Stem elongation	First node detectable.	3.1	489-555
Anthesis	Flowering commences; first anthers of cereals are visible.	6.1	738-936
Seed fill	Seed fill begins. Caryopsis of cereal watery ripe (first grains have reached half of their final size).	7.1	927-1145
Dough stage	Soft dough stage, grain contents soft but dry, fingernail impression does not hold.	8.5	1193-1438
Maturity complete	Grain is fully mature and drydown begins. Ready for harvest when dry.	8.9	1269-1522

Wheat (Hard Red)		Stage	GDD C
Emergence	Leaf tip just emerging from above-ground coleoptile.	1.0	125-160
Leaf development	Two leaves unfolded.	1.2	169-208
Tillering	First tiller visible (tillering of cereals may occur as early as stage 1.3, in this case continue with 2.1).	2.1	369-421
Stem elongation	First node detectable.	3.1	592-659
Anthesis	Flowering commences; first anthers of cereals are visible.	6.1	807-901
Seed fill	Seed fill begins. Caryopsis of cereal watery ripe (first grains have reached half of their final size).	7.1	1068-1174
Dough stage	Soft dough stage, grain contents soft but dry, fingernail impression does not hold.	8.5	1434-1556
Maturity complete	Grain is fully mature and drydown begins. Ready for harvest when dry.	8.9	1538-1665

Oat	Data source: Stu Brandt, Scott, SK 1993-97	Stage	GDD C
Anthesis	Flowering commences; first anthers are visible	6.1	760-947
Seed fill	Seed fill begins. Caryopsis of cereals watery ripe (first grains have reached half of their final size).	7.1	1019-1229
Dough stage	Soft dough stage, grain contents soft but dry, fingernail impression does not hold.	8.5	380-1625
Maturity complete	Grain is fully mature and drydown begins. Ready for harvest when dry.	8.9	1438-1738

Canary Seed	Data source: Perry Miller, Swift Current, SK 1995-9	Stage	GDD C
Leaf development	First two leaves unfolded.	1.2	202-259
Tillering	First tiller visible (tillering of cereals may occur as early as stage 1.3, in this case continue with 2.1).	2.1	378-452
Stem elongation	First node detectable.	3.1	574-667
Anthesis	Flowering commences; first anthers of cereals are visible.	6.1	771-920
Seed fill	Seed fill begins. Caryopsis of cereal watery ripe (first grains have reached half of their final size).	7.1	975-1140
Dough stage	Soft dough stage, grain contents soft but dry, fingernail impression does not hold.	8.5	1261-1447
Maturity complete	Grain is fully mature and drydown begins. Ready for harvest when dry.	8.9	1342-1535

Flax	Data source: Stu Brandt, Scott, SK 1993-97 Perry Miller, Swift Current, SK 1997-98	Stage	GDD C
Emergence	Cotyledons completely unfolded.	1.0	104-154
Leaf development	First two leaves unfolded.	1.2	202-259
	Four true leaves unfolded.	1.4	197-262
	Six true leaves unfolded.	1.6	243-315
Flowering	Flowering begins. First flowers open on at least 50 per cent of plants. Stage flax early in morning before flower petals fall off.	6.0	582-706
	Flowering 50 per cent complete.	6.5	758-895
Seed fill	Seed fill begins. 10 per cent of seeds have reached final size.	7.1	969-1121
Maturity	Seed begins to mature. 10 per cent of seed has changed colour.	8.1	1321-1499
Maturity complete	90 per cent of seed colour change. Seeds brown and rattle in capsules. Ready for swathing or wait until drydown complete for direct harvesting.	8.9	1603-1801

Canola (B. napus)	Data source: Stu Brandt, Scott, SK 1993-97 Perry Miller, Swift Current, SK 1995-98	Stage	GDD C
Emergence	Cotyledons completely unfolded.	1.0	152-186
Leaf stages	Two leaves unfolded.	1.2	282-324
	Four true leaves unfolded.	1.4	411-463
Flowering	Flowering begins. At least one open floret on 50 per cent or more plant.	6.0	582-666
	Flowering 50 per cent complete.	6.5	759-852
Seed fill	Seed fill begins. 10 per cent of seed has changed colour.	7.1	972-1074
Maturity	Seed begins to mature. 10 per cent of seed has changed colour.	8.1	1326-1445
Swathing	40 per cent on main stem has changed colour. Swathing recommended at this stage.	8.4	1432-1557

Canola (B. rapa)	Data source: Stu Brandt, Scott, SK 1993-97 Perry Miller, Swift Current, SK 1995-98	Stage	GDD C
Emergence	Cotyledons completely unfolded.	1.0	102-143
Leaf stages	Two leaves unfolded.	1.2	201-254
	Four true leaves unfolded.	1.4	300-365
Flowering	Flowering begins. At least one open floret on 50 per cent or more plant.	6.0	467-554
	Flowering 50 per cent complete.	6.5	630-726
Seed fill	Seed fill begins. 10 per cent of seed has changed colour.	7.1	826-934
Maturity	Seed begins to mature. 10 per cent of seed has changed colour.	8.1	1152-1279
Swathing	40 per cent on main stem has changed colour. Swathing recommended at this stage.	8.4	1249-1382

Mustard (B. juncea)	Data source: Stu Brandt, Scott ,SK 1993-97 Perry Miller, Swift Current, SK 1995-98	Stage	GDD C
Emergence	Cotyledons completely unfolded.	1.0	108-136
Leaf stages	Two leaves unfolded.	1.2	214-251
	Four true leaves unfolded.	1.4	320-365
Flowering	Flowering begins. At least one open floret on 50 per cent or more plant.	6.0	506-567
	Flowering 50 per cent complete.	6.5	679-747
Seed fill	Seed fill begins. 10 per cent of seed has reached final size.	7.1	886-962
Maturity	Seed begins to mature. 10 per cent of seed has changed colour.	8.1	1232-1322
Swathing	70 per cent on main stem has changed colour. Swathing sometimes recommended at this stage.	8.7	1440-1538
Maturity complete	90 per cent of seed changed colour. Await completion of drydown in direct harvesting.	8.9	1509-1610

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Mustard (S. alba)	Data source: Stu Brandt, Scott, SK 1993-97 Perry Miller, Swift Current, SK 1995-98	Stage	GDD C
Emergence	Cotyledons completely unfolded.	1.0	110-136
Leaf stages	Two leaves unfolded.	1.2	209-243
	Four true leaves unfolded.	1.4	308-349
Flowering	Flowering begins. At least one open floret on 50 per cent or more plant.	6.0	468-529
	Flowering 50 per cent complete.	6.5	650-718
Seed fill	Seed fill begins. 10 per cent of seed has reached final size.	7.1	868-945
Maturity	Seed begins to mature. 10 per cent of seed has changed colour.	8.1	1231-1322
Maturity complete	90 per cent of seed changed colour. Await completion of drydown in direct harvesting.	8.9	1521-1625

Chickpea	Data source: Stu Brandt, Scott ,SK 1995-97 Perry Miller, Swift Current, SK 1995-98	Stage	GDD C
Leaf stages	Two leaves unfolded.	1.2	179-243
	Four leaves unfolded.	1.4	262-337
	Six leaves unfolded.	1.6	346-431
	Eight leaves unfolded.	1.8	429-525
Flowering	Flowering begins. At least one open floret on 50 per cent or more plant.	6.0	645-724
	Flowering 50 per cent complete.	6.5	823-910
Seed fill	Seed fill begins. 10 per cent of seed has reached final size.	7.1	1037-1133
Maturity	Seed begins to mature. 10 per cent of seed has changed colour.	8.1	1394-1505
Maturity complete	90 per cent of seed changed colour. Await completion of drydown in direct harvesting.	8.9	1679-1803

Lentil	Data source: Stu Brandt, Scott, SK 1993-97 Perry Miller, Swift Current, SK 1995-98	Stage	GDD C
Leaf stages	Two leaves unfolded.	1.2	161-192
	Four leaves unfolded.	1.4	248-285
	Six leaves unfolded.	1.6	335-378
	Eight leaves unfolded.	1.8	423-471
Flowering	Flowering begins. At least one open floret on 50 per cent or more plant.	6.0	762-853
	Flowering 50 per cent complete.	6.5	931-1030
Seed fill	Seed fill begins. 10 per cent of seed has reached final size.	7.1	1133-1241
Maturity	Seed begins to mature. 10 per cent of seed has changed colour.	8.1	1470-1594
Swathing	70 per cent of seed changed colour. Recommended stage for swathing.	8.7	1673-1806
Maturity complete	90 per cent of seed changed colour. Await completion of drydown in direct harvesting.	8.9	1710-1876

Pea	Data source: Stu Brandt, Scott, SK 1993-97 Perry Miller, Swift Current, SK 1995-98	Stage	GDD C
Leaf stages	Two leaves unfolded.	1.2	198-230
	Four leaves unfolded.	1.4	301-340
	Six leaves unfolded.	1.6	404-449
	Eight leaves unfolded.	1.8	507-558
Flowering	Flowering begins. At least one open floret on 50 per cent or more plant.	6.0	724-835
	Flowering 50 per cent complete.	6.5	862-982
Seed fill	Seed fill begins. 10 per cent of seed has reached final size.	7.1	1028-1158
Maturity	Seed begins to mature. 10 per cent of seed has changed colour.	8.1	1305-1451
Maturity complete	90 per cent of seed changed colour. Await completion of drydown in direct harvesting.	8.9	1527-1686

Sunflower (depends on maturity class)	Data source: Stu Brandt, Scott ,SK 1995-98 Perry Miller, Swift Current, SK 1995	Stage	GDD C
Emergence	Cotyledons completely unfolded	1.0	138-191
Leaf stages	Two leaves unfolded.	1.2	249-313
	Four leaves unfolded.	1.4	359-435
	Six leaves unfolded.	1.6	470-558
Flowering	Flowering begins. At least one open floret on 50 per cent or more plant.	6.0	935-1077
	Flowering 50 per cent complete.	6.5	1081-1232
Seed fill	Seed fill begins. 10 per cent of seed has reached final size.	7.1	1255-1417
Maturity	Seed begins to mature. 10 per cent of seed has changed colour.	8.1	1547-1725
Maturity complete	90 per cent of seed changed colour. Await completion of drydown in direct harvesting.	8.9	1780-1972

Additional Growing Degree Day Requirements for various crops

Crop	Growing Degree Days (GDD) to Maturity
Corn	120 GDD to emergence and 800-2700 GDD to maturity
Dry Beans	1100-1300 to maturity
Sugar Beet	130 GDD to emergence and 1400-1500 GDD to maturity
Soybean	130 GDD to emergence
Sorghum	1848-1955 to maturity

Note that under drought stress, GDD requirements will be toward the low end of the reported range for each stage and wet environments delay crop advancement toward the high range values reported for each stage.

Corn Growth Stages

This identification system divides plant development into vegetative (V) and reproductive (R) stages. The (V) stages are designated numerically as V1, V2, V3, etc. through V(n) where (n) represents the number of leaves with visible collars. The first and last (V) stages are designated as VE (emergence) and VT (tasseling). The six reproductive stages are simply designated numerically.

Vegetative and Reproductive Stages

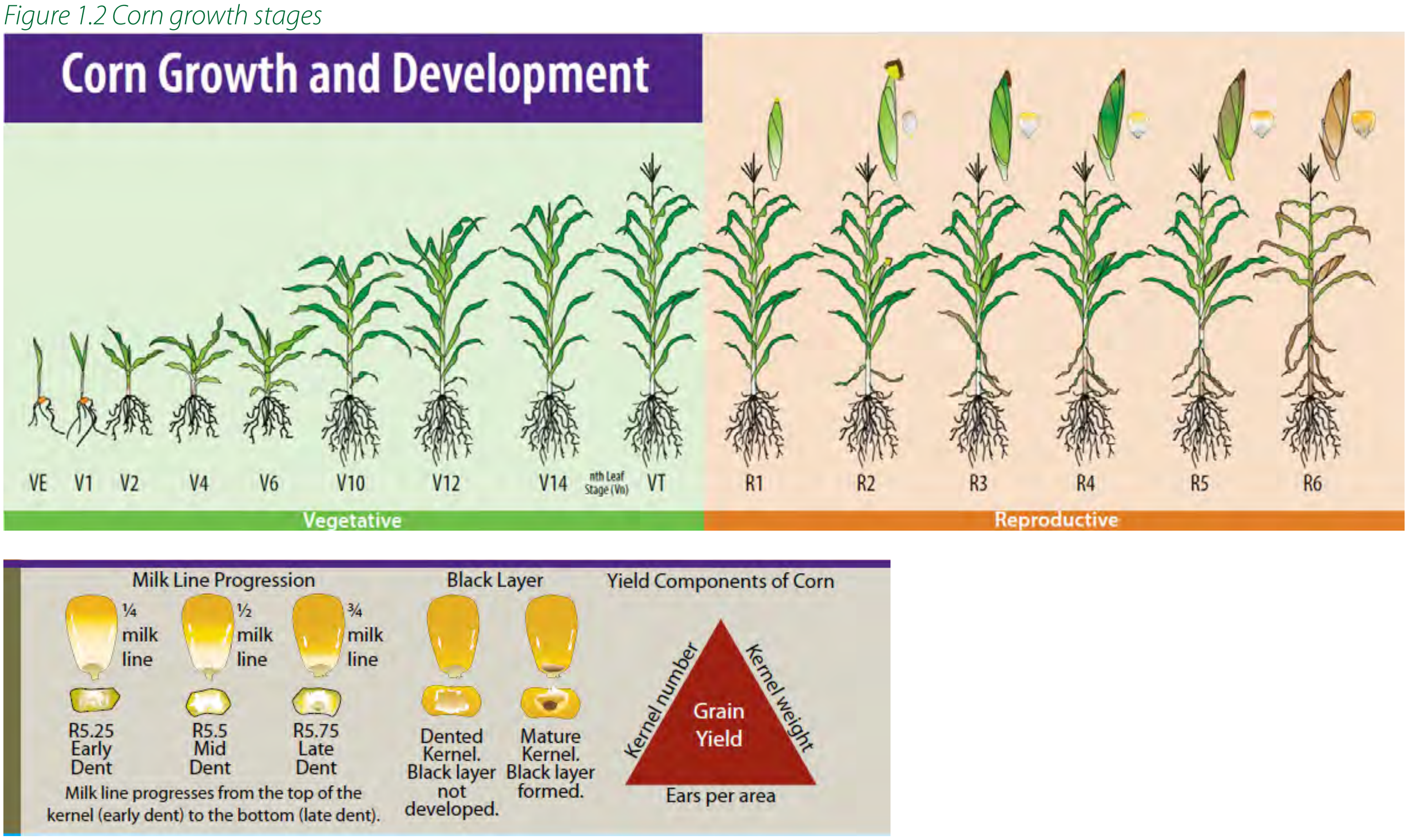
- Each leaf stage is defined according to the uppermost leaf whose leaf collar is visible.
- Loss of the lower leaves will begin about V6 due to increased stalk size and nodal root growth. To determine the proper leaf stage after lower leaf loss, split the stalk lengthwise and inspect for internode elongation.
- The first node above the first elongated internode is generally the fifth leaf node. This fifth leaf node can be used as a reference point for counting the top leaf collar.

Table 1.1 Corn development stages

Vegetative Stages		**Reproductive Stages**	
Stage	**Description**	**Stage**	**Description**
VE	Emergence	R1	Silking-silks visible outside the husks
V1	One leaf with collar visible	R2	Blister-kernels are white and resemble a blister in shape
V2	Two leaves with collars visible	R3	Milk-kernels are yellow on the outside with a milky inner fluid
V(n)	(n) leaves with collars visible	R4	Dough-milky inner fluid thickens to a pasty consistency
VT	Last branch of tassel is completely visible	R5	Dent-nearly all kernels are denting
		R6	Physiological maturity-the black abscission layer has formed

Courtesy of: Purdue University Field Crops IPM

Figure 1.2 Corn growth stages



Yield components and criticial growth stages for their definition in corn production.

	Yield Components	
Stage	**Potential**	**Actual**
VE	Ears/area	-
V6	Kernel rows/ear	"Factory"[3]
V 12	-	Kernel rows/ear
V18	Kernels/row	-
R1[1,2]	Kernel weight Ears/area	Kernel number R1 to R5
R6	-	Kernel weight

[1] Potential Kernel Weight = set when cell division takes place in the endosperm, 7 to 10 days after pollination ((R1-R2 or the "lag" phase of the sigmoidal kernel growth curve).

[2]R1 = potential kernel ovules and kernel number, if no stress is affecting pollination and final kernel development.

[3]Factory = After tassel initiation at V5, all corn plant parts are already developed to support ear grain development.

Growth stages, moisture content and total dry matter progression for corn during reproductive period.[1]

			Average per Substage	
R Stage	**Moisture %**	**Dry matter (% of total dry weight)**	**Growing Degree Days ºF**	**Days**
5.0	60	45	75	3
5.25 (1/4 milk line)	52	65	120	6
5.5 (1/2 milk line)	40	90	175	10
5.75 (3/4 milk line)	37	97	205	14
6.0 (Physiological maturity)	35	100		

1Abendroth, L.J., R.W. Elmore, M.J. Boyer and S.K. Marlay. 2011. Corn Growth and Development. PMR 1009. Iowa State University Extension. Ames Iowa.

Courtesy of: Ciampitti, I. A., Elmore, R. W., & Lauer, J. (2016). Corn Growth and Development. Manhattan, Kansas: Kansas State University

Figure 1.2 Corn growth stages

VE – Emergence

Emergence occurs when the first leaves, called the spike or the coleoptile, appear above the soil surface. The seed absorbs water (about 30 per cent of its weight) and oxygen for germination. The radicle root quickly emerges near the tip of the kernel, depending on soil moisture and temperature conditions. The coleoptile emerges from the embryo side of the kernel and is pushed to the soil surface by mesocotyl elongation. The mesocotyl encloses the plumule leaves that open as the structure approaches the soil surface.

Management

Ideal soil temperatures (10 to 13 C) and moisture conditions promote rapid emergence (five to seven days). Optimum seed placement varies from one to two inches deep. Appropriate planting depth is critical for optimal emergence. Cold, dry, and deep planting can delay emergence for several days.

V1 – First-Leaf

One leaf with collar visible (structure found at the base of the leaf). The first leaf in corn has a rounded tip. From this point until flowering (R1 stage), leaf stages are defined by the uppermost leaf with visible collars. The growing point is located below the surface until the late V5 stage.

Management

Scout for proper emergence (e.g., 30 plants in 171/2 feet for 30-inch row spacing = 30,000 plants per acre), early-season weeds, insects, diseases, and other production issues.

V2 – Second-Leaf

Nodal roots begin to emerge below ground. Seminal roots begin to senesce. Frost is unlikely to damage corn seedling, unless it is extremely cold or the corn was shallowly planted.

Courtesy of: Ciampitti, I. A., Elmore, R. W., & Lauer, J. (2016). Corn Growth and Development. Manhattan, Kansas: Kansas State University

V4 – Fourth-Leaf

Nodal roots are dominant, occupying more soil volume than seminal roots. Leaves still developing on apical meristem (primary growth of the plant).

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Figure 1.2 Corn growth stages continued

V6 – Sixth-Leaf

Six leaves with collar visible. The first leaf with the rounded tip is senescent; consider this point when counting leaves. The growing point emerges above the soil surface. All plant parts are initiated. Sometime between V6 and V10, the potential number of rows (ear girth) is determined. Potential row number is affected by genetics and environment and is reduced by stress conditions. The plant increases in height due to stalk elongation; nodal roots are established in the lowest, below-ground nodes of the plant.

Management

Scout for weeds, insects, and diseases. Rapid nutrient uptake begins at this stage. Timing nutrient applications to match this uptake enhances the potential for greater nutrient use efficiency, particularly for mobile nutrients such as nitrogen.

V10 – Tenth-Leaf

Brace roots begin to develop in the lower above-ground nodes of the plants. Until this stage, rate of leaf development is approximately two to three days per leaf.

Management

Nutrient (potassium = K > nitrogen = N> phosphorous = P) and water (0.25 inch per day) demands for the crop are high. Heat, drought, and nutrient deficiencies will affect potential number of kernels and ear size. Weed control is critical since corn does not tolerate early-season competition for water, nutrients, and radiation well.

V14 – Fourteen-Leaf

Rapid growth. This stage occurs approximately two weeks before flowering. Highly sensitive to heat and drought stress. Four to six extra leaves will expand from this stage until VT.

Management

Scout for root lodging issues, greensnap (likely to occur from V10 to VT) and diseases. Abnormal corn ears can occur and be obvious from this time until flowering.

VT – Tassel

Potential kernels per row is set, final potential grain number (number of ovules), and potential ear size are being determined. Last branch of the tassel is visible at the top of the plant. Silks may or may not have emerged. The plant is almost at its maximum height.

Management

Nutrient (K > N > P) and water (0.30 inch per day) demands for the crop are close to maximum. Heat and drought will affect potential number of kernels. Scout for insects. Total leaf defoliation severely affects final yields.

R1 – Silking

Flowering begins when a silk is visible outside the husks. The first silks to emerge from the husk leaves are those attached to potential kernels near the base of the ear. Silks remain active until pollinated. Pollen falls from the tassel to the silks, fertilizing the ovule to produce an embryo. Potential kernel number is determined. Maximum plant height is achieved. Following fertilization, cell division is occurring within the embryo.

Management

Nutrient (N and P accumulation is still progressing, K is almost complete) and water (0.33 inch per day) demands are at the peak. Heat and drought will affect pollination and final grain number. Defoliation by hail or other factors such as insects will produce a large yield loss.

Courtesy of: Ciampitti, I. A., Elmore, R. W., & Lauer, J. (2016). Corn Growth and Development. Manhattan, Kansas: Kansas State University

Figure 1.2 Corn growth stages continued

R2 – Blister

Silks darken and begin to dry out (approximately 12 days after R1). Kernels are white and blister-like in shape and contain a clear fluid. Kernels are approximately 85 per cent moisture; embryos develop in each kernel. Cell division is complete. Grain filling commences.

Management

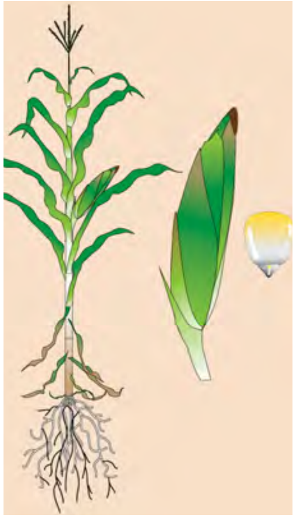
Stress can reduce yield potential by reducing final grain number (abortion).

R3 – Milk

Silks dry out (approximately 20 days after R1). Kernels are yellow, and a milk-like fluid can be squeezed out of the kernels when crushed between fingers. This fluid is the result of the starch accumulation process.

Management

Stress will still cause kernel abortion, initially from the ear tip.



R4 – Dough

Starchy material within the kernels has dough-like consistency (approximately 26 to 30 days after R1). Rapid accumulation of starch and nutrients occurs; kernels have 70 per cent moisture and begin to dent on the top. Material squeezed out of the kernel has dough-like consistency.

Management

Stress can produce unfilled or shallow kernels and "chaffy" ears. Impact of frost on grain quality can be severe when it occurs at this stage (25 to 40 per cent yield loss from light to killing frost, respectively).

R5 – Dent

Most of the kernels are dented. Kernel moisture declines to approximately 55 per cent (38 to 42 days after R1) as the starch content increases.

Management

Stress can reduce kernel weight. Silage harvest is approaching (at around 50 per cent kernel milk).

R6 – Maturity

A black layer forms at the base of the kernel, blocking movement of dry matter and nutrients from the plant to the kernel (50 to 60 days after R1). Kernels achieve maximum dry weight (30 to 35 per cent moisture) and are physiologically mature.

Management

Grain is not ready for safe storage. Frost or any biotic or abiotic stress does not impact yields after this development stage. Lodging from disease, insect damage, or hail can result in physical loss of yield. Harvest can proceed, but recommended moisture for long-term storage is 14.5 per cent. Scout fields for ear drop due to things such as European corn borer damage.

Courtesy of: Ciampitti, I. A., Elmore, R. W., & Lauer, J. (2016). Corn Growth and Development. Manhattan, Kansas: Kansas State University

Broadleaf Crops and Weeds Plant Staging

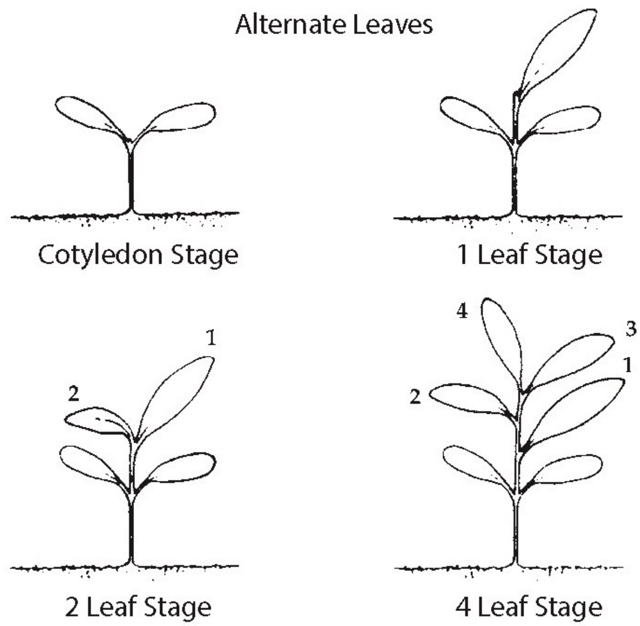
Cotyledons are the leaves that first emerge from the soil on a broadleaf plant, but are not considered the first true leaves for plant staging purposes. The first true leaves appear from the growing point directly after the cotyledons.

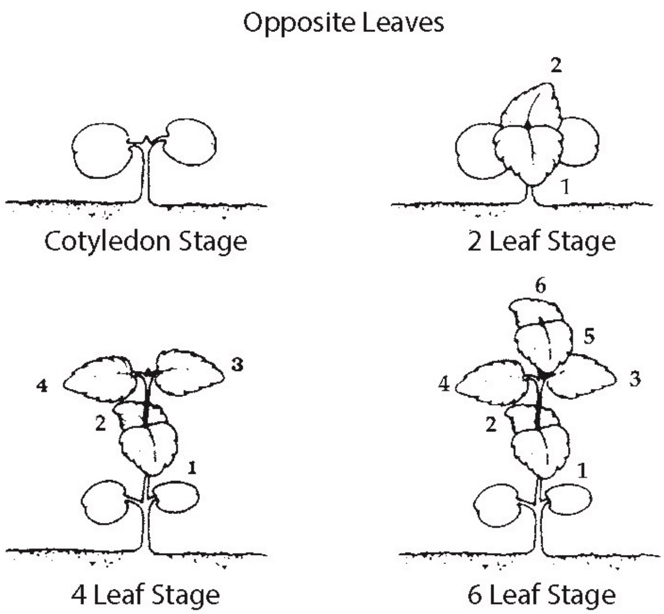
Counting Leaves

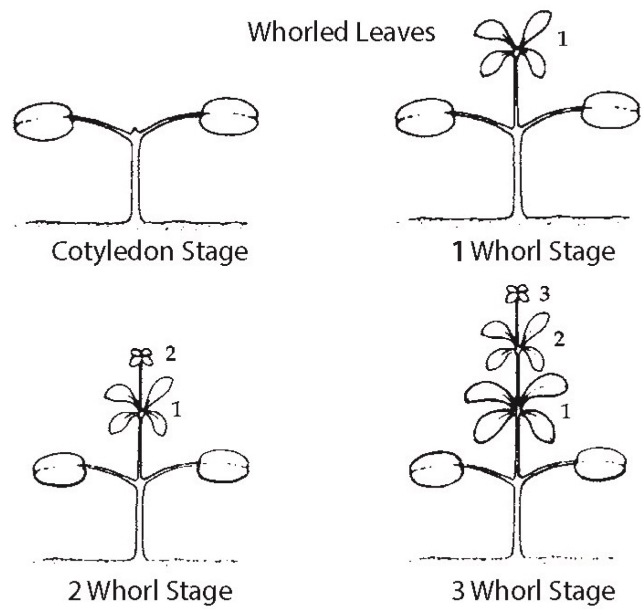
- Determine the crop/weed leaf orientations:
- Alternate leaves-one single leaf is attached individually in an alternating pattern (count leaves individually).
- Whorled leaves-more than two leaves are attached at the same point around the stem (count each whorl as a leaf).
- Some plants develop a basal rosette before developing a specific leaf orientation. Examples: canola, dandelions, shepherd's purse and night flowering catchfly.
- Do not count cotyledons as a leaf.
- Count leaves when visibly separated from the terminal bud.

Courtesy of: The Guide to Crop Protection

Figure 1.3 Broadleaf crop/weed plant staging



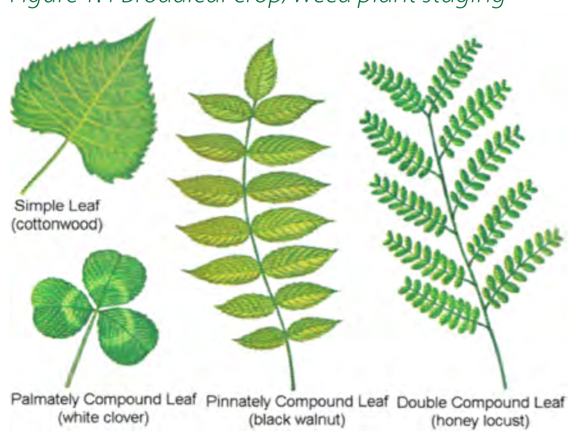




Leaf types

- **Simple leaf:** single leaf blade with veins that pan off a single midrib that are attached at the petiole.
- **Compound Leaf:** two or more leaflets attached to the midrib separately through the rachis.
- **Pinnate:** leaflets are arranged either alternating or opposite that branch directly off a rachis.
- **Palmate:** leaflets are attached from a common point at the petiole and branch off like fingers from a palm.

Figure 1.4 Broadleaf crop/weed plant staging



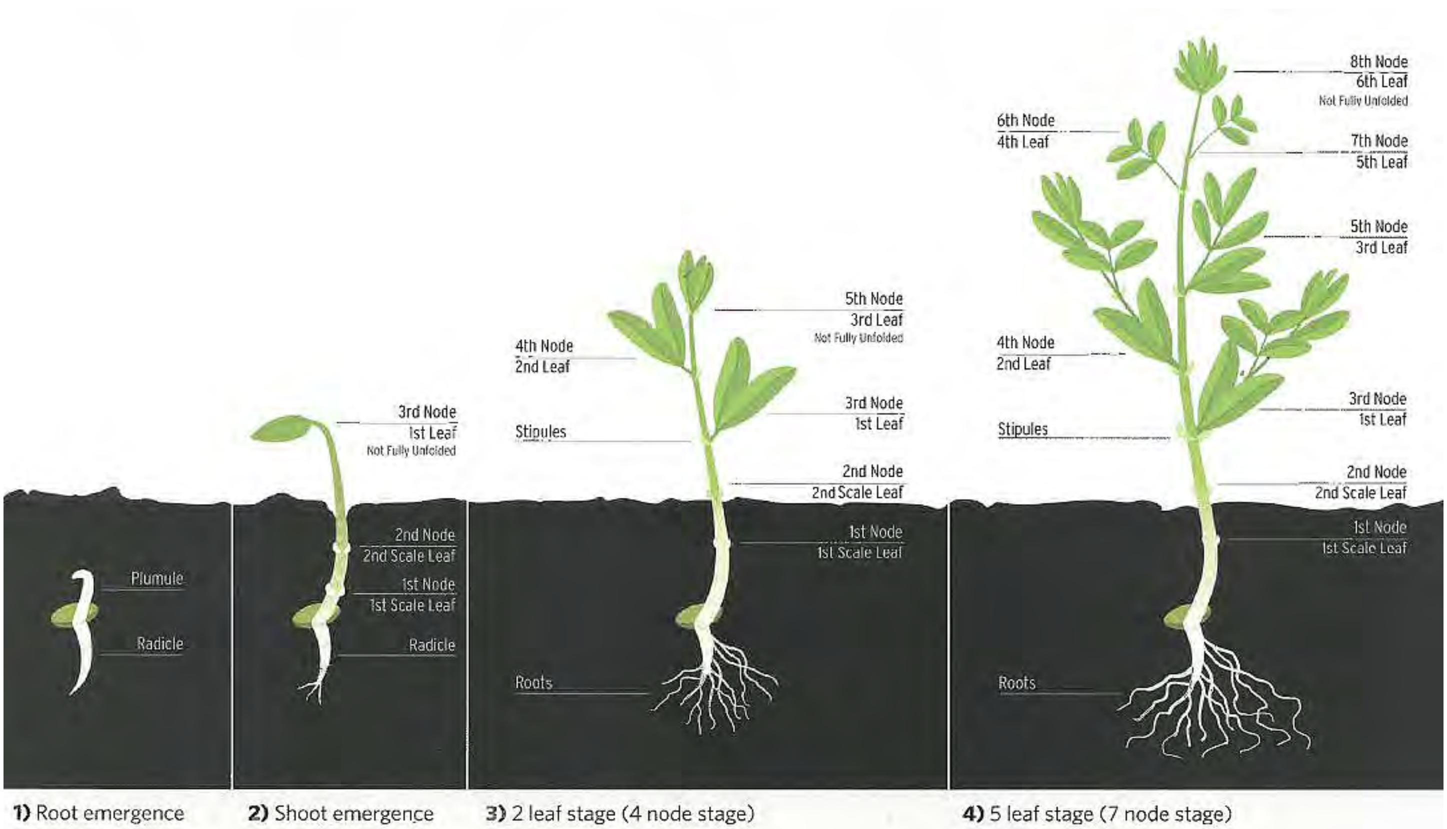
Courtesy of: @2022 Coredifferences

Pulse Plant Staging

Lentil Plant Stages and Development

- Lentil seedlings can produce a new node every four to five days under good growing conditions.
- Just prior to flowering, new leaves will develop a short tendril at the leaf tip.
- Vigorously growing lentil plants with adequate space will produce two or more primary shoots from the base of the stem.
- The first few flowers on the main stem may abort.
- Flower stalks produce one to three flowers that will develop into pods after self-pollination.
- Pods usually contain one to two seeds.
- The main contribution to yield is from flowers on secondary branches. These branches arise from the nodes immediately below the first flowering node of the main stem. Up to five of these branches may develop.
- When growing conditions are suitable for extremely high yield, the secondary branches also produce additional seed-bearing branches.
- Since lentil plants have an indeterminate growth habit, they continue to flower until they encounter some form of stress, such as drought, heat, frost, nitrogen deficiency, mechanical damage or chemical dessication.
- Pulse crops or legumes do not have cotyledons above ground and are staged by the number of nodes or number of leaves.
    - The first nodes are often below ground.
    - The first and second nodes have reduced leaves called scale leaves and are not considered true leaves.
    - The first true leaf is located at the third node position. Therefore, node and leaf stages always differ by two.

Figure 1.5 Lentil growth stages



Courtesy of: Saskatchewan Pulse Growers

Note: When staging for herbicide application, check the specific herbicide label for counting method on nodes. Most often the first above ground leaf node (not the first scale node) is considered to be the first node to begin staging from.

Field Pea Plant Stages and Development

- The first true leaf at the third node position usually has a pair of leaflets and a tendril. In semi-leafless peas, tendrils replace the leaflets.
- Under good growing conditions, two nodes can develop in seven days and basal branches will develop from one or both of the nodes with scale leaves by the six-leaf stage.
- Flowers begin to be produced at about the twelfth to sixteenth node stage.
- Usually one-to-three self-pollinated flowers are produced at each flowering node.
- Pods are fully elongated within seven to 10 days. Over 24 to 30 days the pods mature until the dry seed stage is reached.
- Pods usually have six to eight seeds.
- Varieties are relatively indeterminate and a stress is needed to bring on maturity.

Figure 1.6 Field pea growth staging guide

VE *Emergence*	**VS** *Scale leaves*	**V1** *First node*	**V2 to Vn**	**R1** *Flower bud*	**R2** *Beginning bloom*
Epicotyl pushed through the soil.	Two scale leaves present above or below ground on main stem.	First unfolded stipule, clasping the main stem.	Second stipule unfolded, third stipule unfolded, fourth, etc.	Flower bud present at one or more nodes.	Flower open at one or more nodes.

Stipules are modified leaves at the base of each above-ground node along the main stem. Tendrils replace true leaves on semi-leafless varieties.

R3 *Flat pod*	**R4** *Full pod*	**R5** *Beginning maturity*	**R6** *Mid maturity*	**R7** *Full maturity*	*Ready to harvest*
Flat pod at one or more nodes.	Green seeds fill the pod cavity at one or more nodes.	Leaves and lower pods start to turn yellow.	Yellow seeds fill the pod cavity at one or more nodes.	Most pods (75–80%) are golden brown, seed moisture is 25–30%.	All pods are golden brown, seed moisture is <20%.

Courtesy of: Manitoba Pulse and Soybean Growers

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Figure 1.6a Field pea maturity guide

R4 *Full pod*	**R5** *Beginning maturity*	**R6** *Mid maturity*	**R7** *Full maturity*	*Ready to harvest*
Green seeds fill the pod cavity at one or more nodes.	Leaves and lower pods start to turn yellow.	Yellow seeds fill the pod cavity at one or more nodes.	Most pods (75–80%) are golden brown, seed moisture is 25–30%.	All pods are golden brown, seed moisture is <20%.

FIELD VIEW

R4 *Full pod*	**R5** *Beginning maturity*	**R6** *Mid maturity*	**R7** *Full maturity*	*Ready to harvest*

Courtesy of: Manitoba Pulse and Soybean Growers

Faba Bean Plant Stages and Development

- Faba beans germinate with the cotyledon remaining below ground.
- The first two nodes with faba beans develop below or at soil surface and the small leaves associated at the nodes are called scale leaves.
- Regrowth is possible from buds at the base of these scale leaves.
- The first true leaf will be produced at the third node position.
- The first two leaves consist of two leaflets each and remaining leaves consist of three or more leaflets.
- During vegetative stages, faba bean seedlings can produce new nodes every five days.
- When determining crop stage, include nodes where the leaves or pairs of leaves are fully open or unfolded. Youngest or newly emerging leaves are not included in staging unless completely open.

Figure 1.7 Faba bean growth stages

VE *Emergence*	**VS** *Scale leaves*	**V1** *First leaf*	**V2 to Vn**	**R1** *Flower bud*	**R2** *Beginning bloom*
Epicotyl pushed through the soil.	Two scale leaves present above or below-ground on the main stem.	First unfolded bifoliate leaf and above-ground node.	Second unfolded bifoliate leaf, third unfolded bifoliate leaf, fourth, etc.	Flower buds present at one or more nodes.	First flowers open.

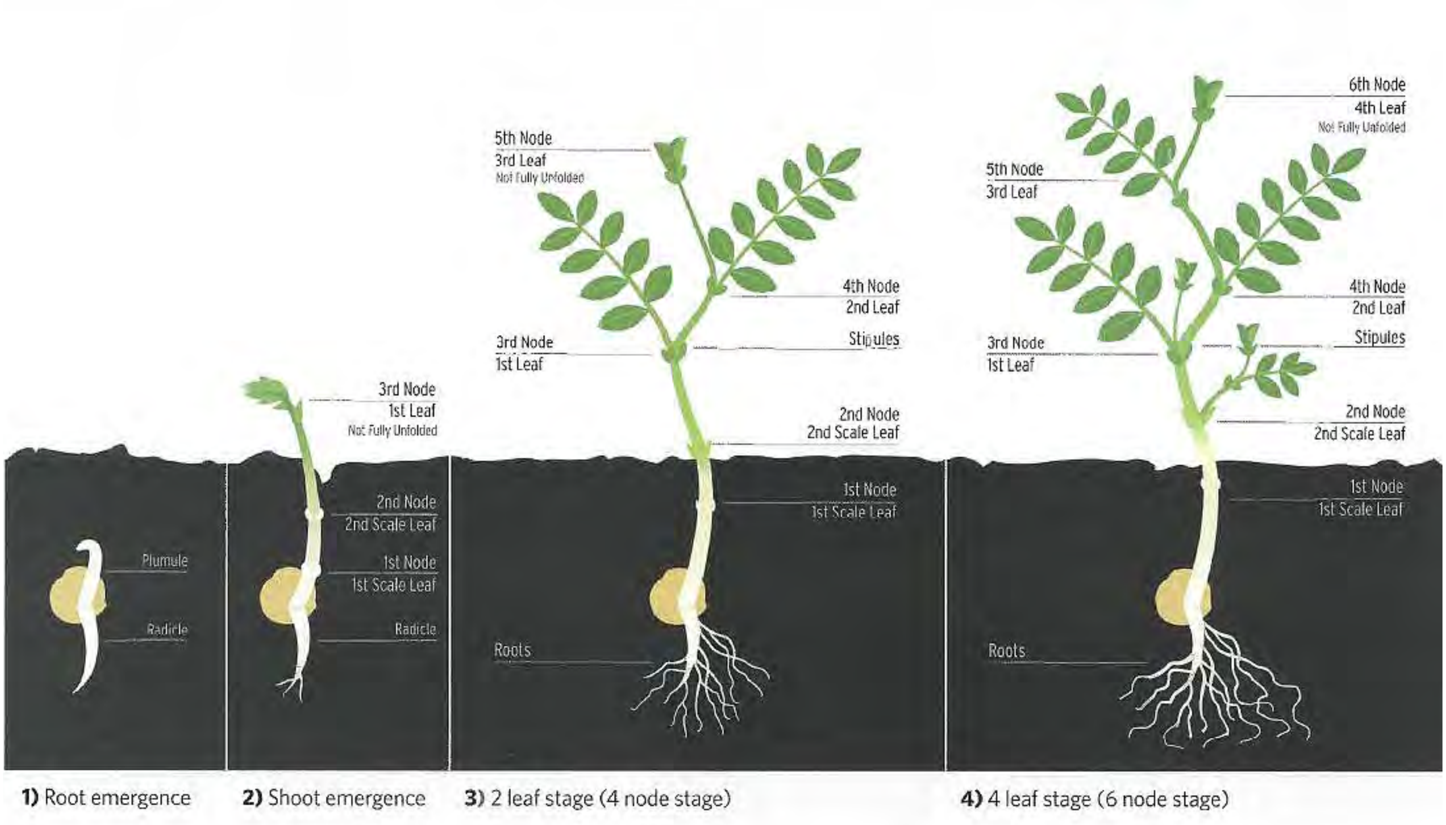
R2.5 to R3 *20–50% bloom*	**R4** *Flat pod*	**R5** *Full pod*	**R6** *Beginning maturity*	**R7** *Mid-maturity*	**R8** *Full maturity*
Flowers open halfway up the main stem. Occurs 7–10 days after beginning bloom.	Flat pod at one or more nodes.	Green seeds fill the pod cavity at one or more nodes.	Leaves and lower pods start to turn yellow.	Lower pods are dark brown/ black, seed moisture is 30%.	Most pods are dark brown/ black, seed moisture is 20% or less.

Courtesy of: Manitoba Pulse and Soybean Growers

Chickpea Plant Stages and Development

- Chickpeas germinate with the cotyledon remaining below ground.
- The first two nodes of chickpeas develop below or at the soil surface and the small leaves associated at these nodes are called scale leaves.
- Regrowth is possible from buds at the base of these scale leaves.
- The first true leaf is produced at the third node position.
- Growth is rapid during vegetative stages and chickpea seedlings can produce new nodes every three to four days.
- Chickpea plants will produce up to seven primary branches originating near ground level, usually leading to an erect growth habit.

Figure 1.8 Chickpea growth stages



Courtesy of: Saskatchewan Pulse Growers

Note: When staging for herbicide application, check the specific herbicide label for counting method on nodes. Most often the first above ground leaf node (not the first scale node) is considered to be the first node to begin staging from.

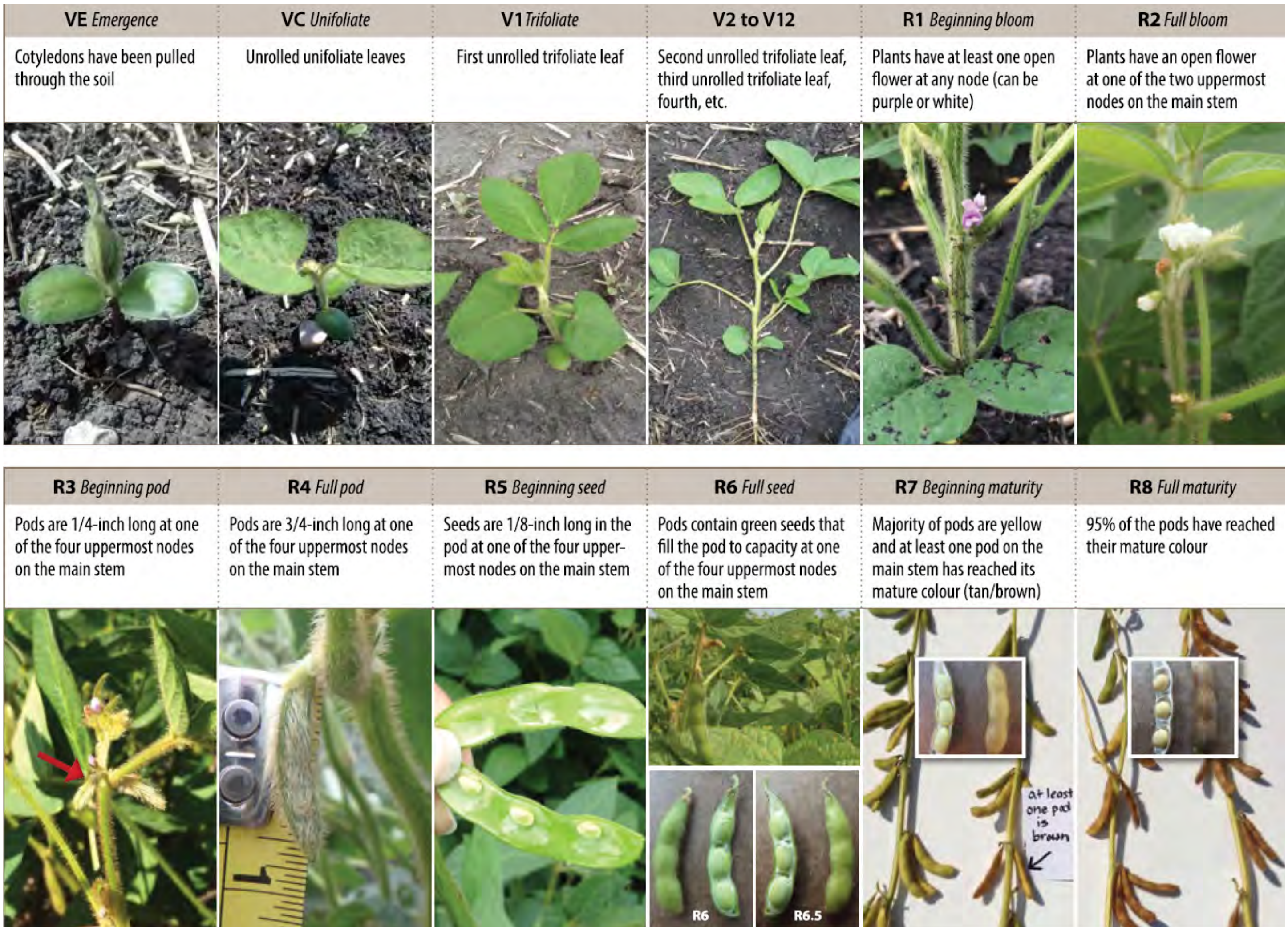
Soybean Growth Stages and Development

- This identification system divides plant development into vegetative (V) and reproductive (R) stages. With the exception of the first two stages, the (V) stages are designated numerically as V1, V2, V3, etc. through V(n) where (n) represents the number for the last node stage of a specific variety. The (n) will fluctuate with variety and environmental differences. The eight R stages are simply designated numerically.

Vegetative and Reproductive Stages

- The (V) stages following (VC) are numbered according to the uppermost fully developed leaf node. Start with the unifoliate leaf node when counting the number of fully developed leaf nodes. A leaf node is fully developed when the leaf above it has leaflets which are fully unrolled. That is, the leaflet edges are no longer touching.

Figure 1.9 Soybean growth stages



Courtesy of: Manitoba Pulse and Soybean Growers Association

Table 1.2 Soybean plant growth stages and descriptions

Vegetative Stages		Reproductive Stages	
Stage	**Description**	**Stage**	**Description**
VE	Emergence	R1	Open flower at any node on the main stem
VC	Cotyledon	R2	Open flower at one of the two uppermost nodes on the main stem with a fully developed leaf
V1	Unifoliolate and first trifoliolate leaves are fully developed	R3	Pod is 5 mm (3/16 inch) long at one of the four uppermost nodes on the main stem with a fully developed leaf
V2	Unifoliolate and first two trifoliolate leaves are fully developed	R4	Pod is 2 cm (3/4 inch) long at one of the four uppermost nodes on the main stem with a fully developed leaf
V3	Unifoliolate and first three trifoliolate leaves are fully developed	R5	Seed is 3 mm (1/8 inch) long in the pod at one of the four uppermost nodes on the main stem with a fully developed leaf
V(n)	Unifoliolate and (n) trifoliolate leaves are fully developed	R6	Physiological maturity-the black abscission layer has formed
		R7	One normal pod on the main stem that has reached its mature pod colour
		R8	95% of the pods have reached their mature pod colour

Courtesy of: Purdue University Field Crops IPM

Dry Bean Stages and Development

Figure 1.10 Drybean growth stages

VE *Emergence*	**VC** *Unifoliate*	**V1** *Trifoliate*	**V2 to Vn**	**V5** *bush/determinate* ***or*** **V8** *vine/indeterminate*
Hypocotyl emergence.	Unrolled cotyledons and unifoliate leaves.	First unrolled trifoliate leaf.	Second unrolled trifoliate leaf, third unrolled trifoliate leaf, fourth, etc.	Flower buds visible.

R1 *Beginning bloom*	**R2** *Beginning pod*	**R3** *50% bloom*	**R4** *Full Pod*	**R5** *Beginning seed*
One open flower at any node.	Pods 1/2 inch long at the first flower position (base of the plant) or *pin bean* stage.	Pods 1 inch long at the first flower position. Determinate plants becoming denser, but not taller.	Pods 2 to 3 inches long at the first flower position.	Pods 3 to 4 inches long. Seeds discernible.

Courtesy of: Manitoba Pulse and Soybean Growers Association

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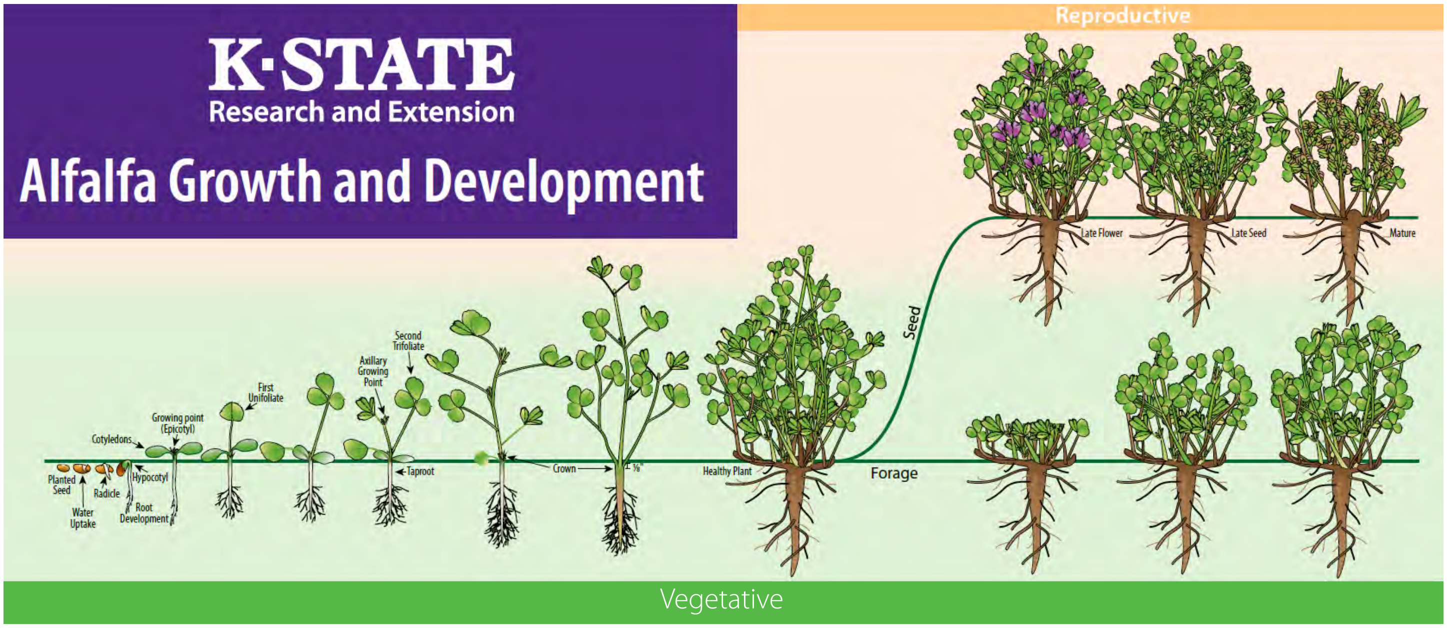
Figure 1.11 Dry bean stages

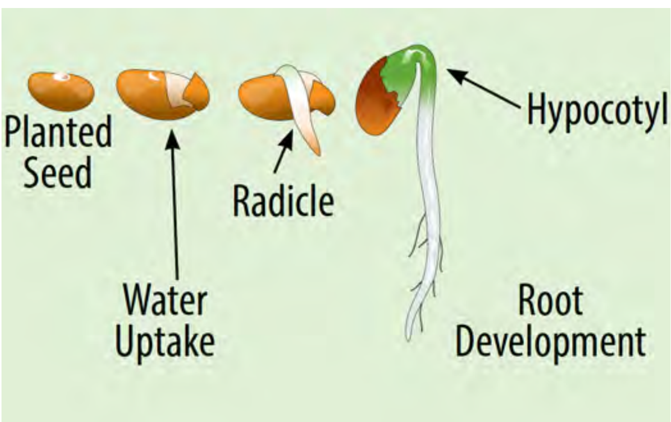
Field View	Seed Development in Pods on Upper 4 Nodes	Crop Stage	Average # of Days After Planting	Days to R8
		**R6** *Full Seed* Field remains green and seeds fill the pod to capacity. A white membrane surrounds the seed. At this stage, maximum plant height, node number and leaf area has been reached. Crop is very susceptible to yield and quality loss if frost occurs. A damaging frost may reduce yield up to 50%.	85 to 95	20 to 30
		**R6.5** General yellowing of the field. Pods turn from green to yellow and rapid leaf drop begins. Green pods are susceptible to yield and quality loss if frost occurs. A damaging frost may reduce yield up to 30%.		10 to 15
		**R7** *Physiological Maturity* Field is yellow with only some top leaves remaining. The majority of pods are yellow and at least one pod on the main stem is brown. The white membrane surrounding the seed is no longer visible/seeds have detached from the pod, making the crop safe from frost (<10% yield loss would be expected). ✓ Ensure crop reaches R7 prior to or around the typical first fall frost date.	105 to 115	8 to 10
		**R8** *Full Maturity* Field is tan-brown and 95% of the pods are brown. Seeds will rattle in the pod and all leaves will be dropped. Field is ready to harvest in 5–10 days when seed moisture is <14%.	110 to 120	

Courtesy of: Manitoba Pulse and Soybean Growers

Alfalfa Growth Stages and Development

Figure 1.12 Alfalfa growth stages



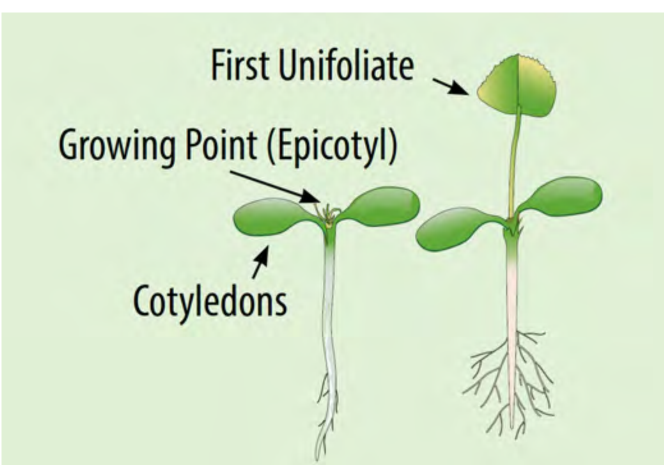


Germination and emergence

Water uptake occurs 24 to 48 hours after planting if moisture is available. Optimum temperature for germination is between 18 and 22 C. The root radicle emerges from the seed, forming an unbranched taproot and anchoring the seed to the soil. As the radicle grows, the hypocotyl (initial seedling stem) straightens and elongates, pulling the cotyledons (seed leaves) and seed coat up through the soil surface.

Management

Store seed at cool temperatures and low humidity. Re-inoculate with Rhizobium bacteria if stored beyond expiration date. Avoid direct sunlight on seeds to minimize damage to the bacteria. During the recommended planting window, sow no deeper than 1/2 inch and at the recommended seeding rate. Provide nutrients according to soil test. Do not plant alfalfa into an established alfalfa stand.



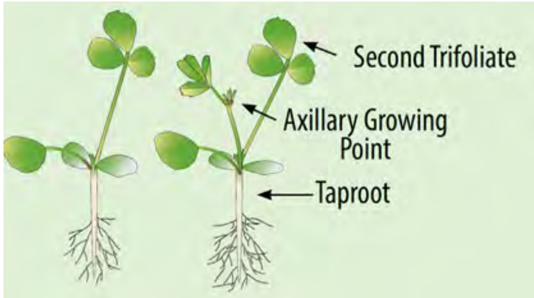
Courtesy of: Kansas State University

Seedling growth and establishment

Cotyledons are the first aboveground visible structure of an alfalfa seedling. The first true leaf produced is a unifoliate leaf (single leaflet).

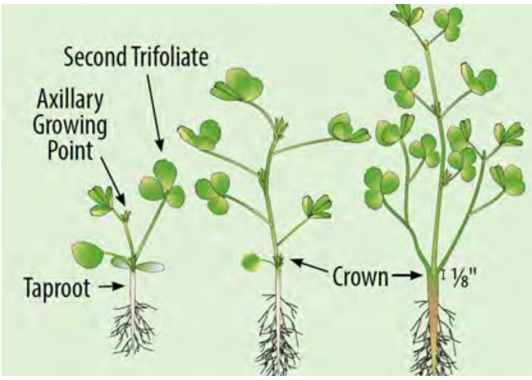
Management

Most commercially available alfalfa seed is treated with a fungicide seed treatment. If not, apply fungicide seed treatment to prevent seedling diseases. Ensure soil pH is greater than 6.5 to maximize forage yield and nitrogen fixation. Control weeds within the first 60 days to help prevent stand loss.



First trifoliate leaf and buds

The second leaf to appear has three leaflets and is called a trifoliate. As the primary shoot develops into a mature plant, it produces alternately arranged trifoliates. At the three trifoliate leaves stage, photosynthesis is enough to meet all energy requirements by the alfalfa seedling. Axillary buds develop in the axils of all leaves and can originate a secondary stem after the three-leaf stage. Primary and secondary stems increase in length due to internode elongation.

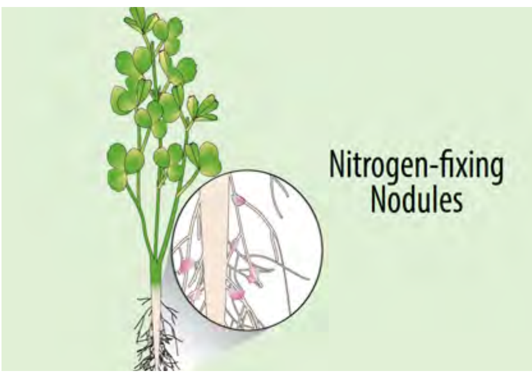


Contractile growth and crown development

Contractile growth begins one to two weeks after emergence and completes within 16 weeks. Contractile growth is a process in which the hypocotyl shortens and thickens as a result of carbohydrate storage. This change in shape pulls both the cotyledonary node and the unifoliate node beneath the soil surface to form the crown. Outer tissues of the hypocotyl do not contract, instead they fold and wrinkle above the surface, giving the appearance of contracted roots and stems.

Management

Avoid planting after the recommended window (late summer) to allow enough time for crown development during the fall. Plants without a well-developed crown will not survive the winter.



Root development and nitrogen fixation

Within four weeks from germination, root hairs become infected with the nitrogen-fixing Rhizobium bacteria and nodulation begins. Nitrogen fixation, converting atmospheric nitrogen into a plant-friendly nitrogen form, occurs within these nodules. Nitrogen fixation ranges from 40 to 400 pounds per acre per year, averaging about 175 pounds.

Management

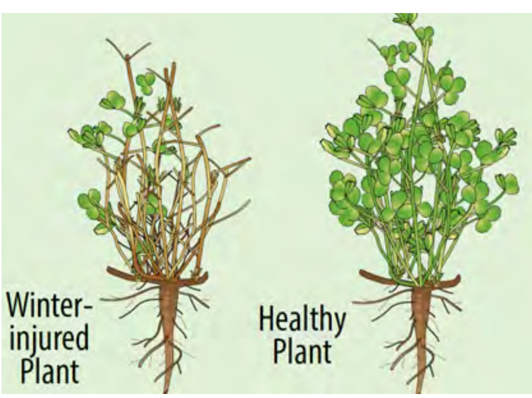
To improve nitrogen fixation, ensure soil pH is greater than 6.5 and the seed is inoculated with the Rhizobium bacteria. Adequate soil moisture is important to optimize nitrogen fixation.

Winter hardening and winter survival

Shorter days and a minimum of 2 weeks of near-freezing temperatures are needed for dormant alfalfa to cold harden. Dormant alfalfa converts some of the starch in the crown and root into antifreeze sugars during the fall to help keep the crown, crown buds, and root from freezing during the winter.

Management

The last cutting before winter dormancy should be made so that there are eight to 12 inches of stubble, or four to six weeks of growth time, before the average killing freeze date. This allows adequate time for root reserve replenishment. Adequate soil potassium levels improve the chances of winter survival.

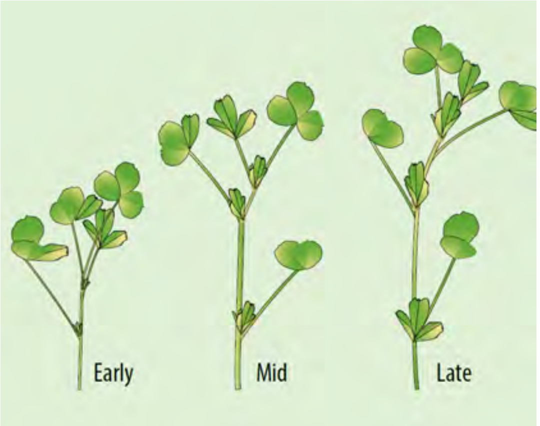


Spring green-up

Green-up occurs when crown buds start to grow in response to warm temperatures during the spring. Ideally, spring growth comes from crown buds formed during the previous summer and fall. Plant health, dormancy requirements, and fall weather conditions affect the time of spring green-up.

Management

Uneven growth indicates winter injury. Injured plants are less vigorous and lower yielding. A soil test can help determine fertilizer needs for the coming year. Potassium, phosphorus, sulfur, and boron are especially important to obtain good alfalfa production.

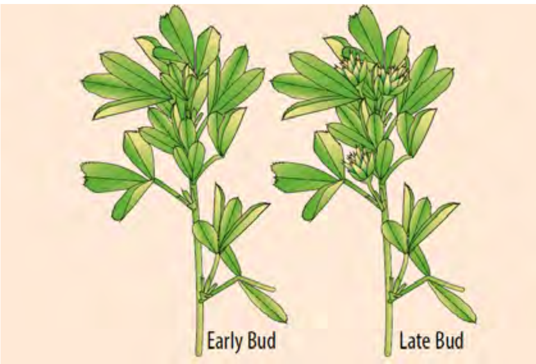


Vegetative stages

Stage 0: Early vegetative
Stem length less than six inches. No buds, flowers, or seedpods are visible. A tiny axillary bud is present in the junction between the main stem and a leaf or branch.

Stage 1: Mid-vegetative
Stem length ranges from six to 12 inches. No buds, flowers, or seedpods are visible. Axillary branch formation begins with the appearance of one or two leaves in the axil, mostly concentrated in the mid-portion of the stem.

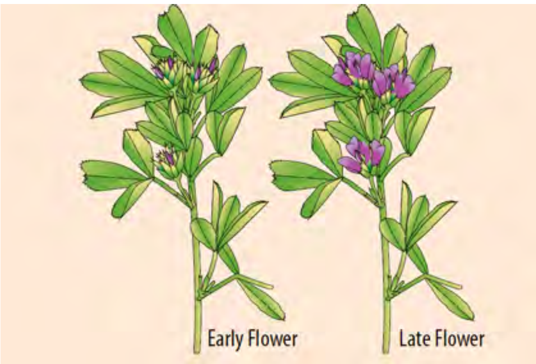
Stage 2: Late vegetative
Stem length greater than 12 inches. Buds may be felt by touch at the growing apex but are not visible, nor are flowers or seedpods. Elongating branches can be seen in the axils of the leaves.



Flower bud development

Stage 3: Early bud
One to two nodes have visible buds. No flowers or seedpods are visible. Closely spaced nodes in the stem tip give flower buds a clustered appearance.

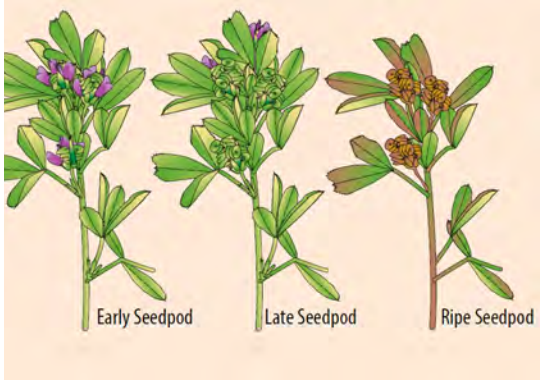
Stage 4: Late bud
The alfalfa plant has more than three nodes with visible buds. No flowers or seedpods are visible. This is generally considered to be the optimum stage to harvest high-quality alfalfa.



Flowering

Stage 5: Early flower
The alfalfa plant has one node with one open flower. No seedpods are visible. Flowering usually begins near the apex of the stem while buds are still developing rapidly above and below the point of initial flower opening. This is also a commonly recommended stage to harvest alfalfa.

Stage 6: Late flower
The alfalfa plant has more than two nodes with open flowers. No seedpods are visible.



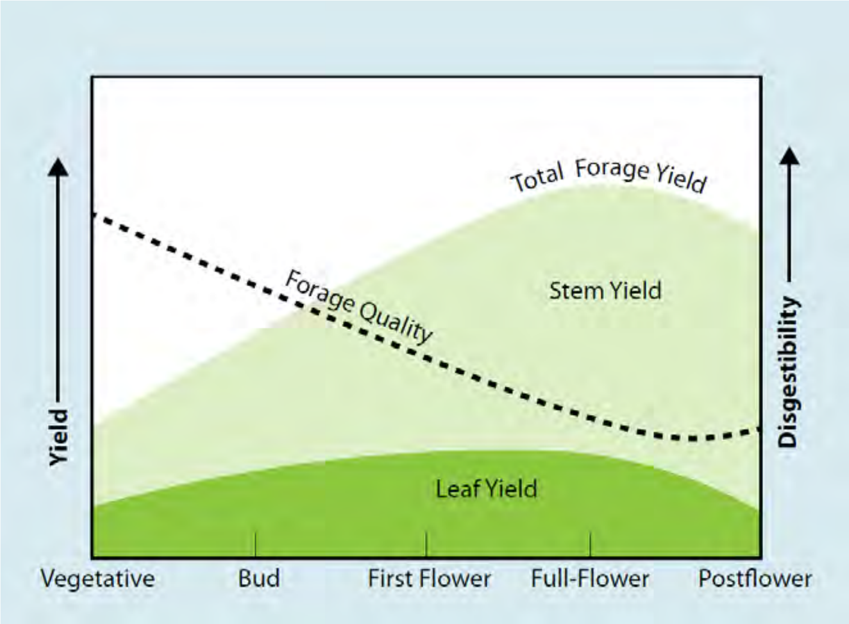
Courtesy of: Kansas State University

Seed production

Stage 7: Early seedpod
The alfalfa plant has one to three nodes with green, spiral-shaped seedpods. Pods first appear from the mid-portion to the base of the main stem while upper nodes are still flowering.

Stage 8: Late seedpod
The alfalfa plant has more than four nodes with green seedpods. The old stems are highly branched, many leaves have fallen off the plant, and the remaining ones are mostly senescing.

Stage 9: Ripe seedpod
Nodes have mostly brown, mature seedpods. Most of the leaves have been lost at this stage, and the stem is thick and fibrous. Harvest alfalfa grown for seed production at this stage.

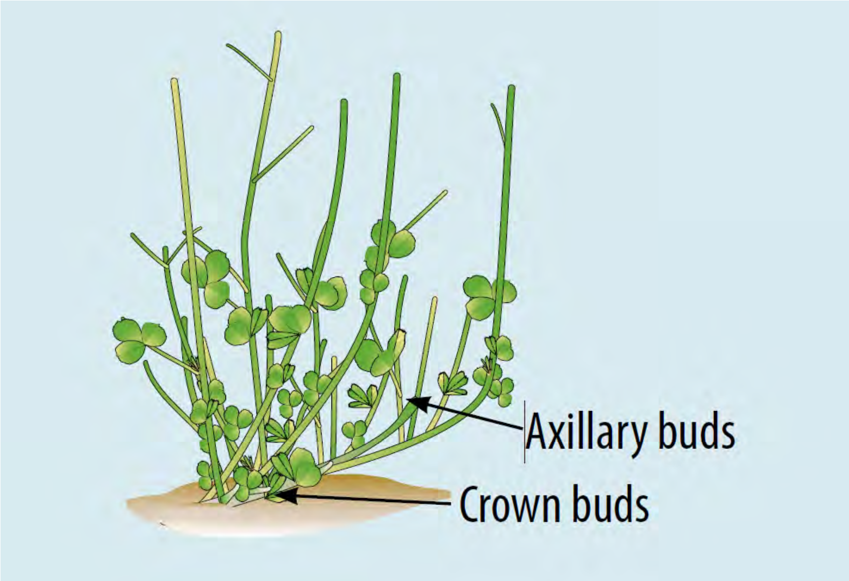


When to cut

Considerations for deciding the optimum cutting time include forage yield, quality, and stand persistence. Forage yield increases until the crop reaches full flower, while forage quality decreases with maturity. The optimum time to maximize both yield and quality is late bud to 10 per cent bloom, depending on the nutrient requirement of livestock species.

Management

Watch for insect pests such as alfalfa weevil and potato leafhopper, which might feed on alfalfa bud and flower, often causing producers to assume the alfalfa has not begun to form buds. Lactating cows and growing animals have greater nutrient requirements than dry cows or horses.



Courtesy of: Kansas State University

Growth after cutting

Following cutting, regrowth emerges from crown buds and axillary buds found in leaf axils, where the leaf joins the stem. Ideally, cutting should occur about two inches above the soil surface to preserve axillary buds and next cutting yield. Lower cuttings will force regrowth from crown buds only, and short cutting intervals (less than 28 days) will reduce next cutting yields.

Management

Ensure cutting height is at least two inches above the soil surface. Maximize stem density by avoiding cutting intervals shorter than 28 days.

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Flax Growth and Development

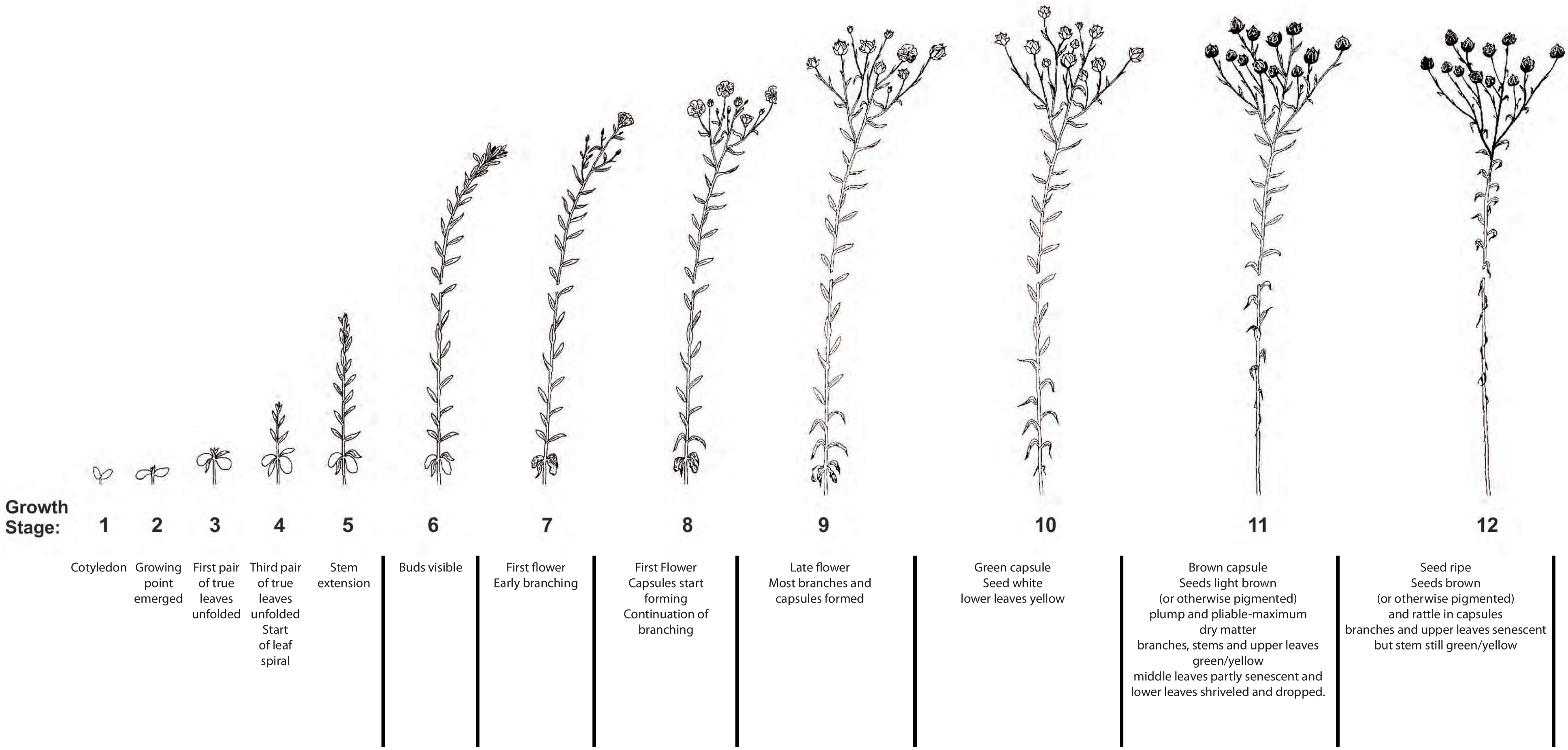
- The life cycle of the flax plant consists of a 45 to 60 day vegetative period, 15 to 20 day flowering period and 30 to 40 day maturation period.
- The flax plant has one main stem, but two or more branches may develop from the base of the plant when plant density is low and soil nitrogen is high.
- The main stem and branches give rise to a multi-branched, irregular arrangement of flowers.
- Ripening of the boll begins 20 to 25 days after flowering. The boll has five segments which are divided by a wall. Each segment produces two seeds. With complete seed set, the boll contains 10 seeds, though an average of six to eight seeds per boll is usual.

Table 1.3 Flax growth stages *(Refer to Figure 1.13)*

Growth Stage	Description
1	Cotyledon
2	Growing point emerged
3	First pair of true leaves unfolded
4	Third pair of true leaves unfolded, start of leaf spiral
5	Stem extension
6	Buds visible
7	First flower
8	Full flower capsules start forming, continuation of branching
9	Late flower, most branches & capsules formed
10	Green capsule, seed white lower leaves yellow
11	Brown capsule, seeds light brown (or otherwise pigmented), plump & pliable-maximum dry matter, branches, stem & upper leaves green/yellow, middle leaves partly senescent & lower leaves shriveled or dropped
12	Seed ripe, seeds brown (or otherwise pigmented) & rattle in capsules, branches & upper leaves senescent but stem still green/yellow

Courtesy of: SaskFlax

Figure 1.13 Flax growth stages



Courtesy of: SaskFlax

Canola and Mustard Development and Stages

Canola and both species of mustard follow a very similar life cycle and growth pattern and can be staged in a similar manner. The BBCH staging system is a uniform system that can be used to stage many different crops and weeds. It will be used as a guide to the principle mustard growth stages referred to throughout this handbook.

Throughout the life cycle, canola and mustard plants have eight principle growth stages: germination, leaf development, stem elongation, inflorescence emergence, flowering, fruit development, ripening and senescence. The staging system is organized by these principle growth stages and expanded to reflect the progression through each stage. Staging of crops is important for optimal timing of harvest and pest management strategies.

Germination

- New stem or hypocotyl extends and pushes the cotyledons to the soil surface.
- Cotyledons turn green on exposure to sunlight.
- Emergence takes four to 15 days, depending on environmental conditions.

Leaf Development

- The growing point is above the surface between the two cotyledons.
- Plant is at risk of injury from insects and frost due to exposed growing points.
- Root development occurs at a rate of about two centimetres per day.
- First true leaf develops within four to eight days of emergence.
- There is no definite number of leaves that will develop. Leaf numbers could range from nine to 30.

Stem Elongation

- Stem elongation overlaps with leaf development and flower development.
- At or just prior to stem elongation, flowering and branch initiation begins.
- The main stem reaches 30 to 60 per cent of its maximum length just prior to flowering.

Flower Development

- Flower buds remain closed during early stem elongation and can be seen by peeling back young leaves.
- Green bud stage occurs when the flower buds can be seen from above but are still not free from the leaves.
- The yellow bud stage is when the lower flower buds become yellow.
- Development of branches is not fixed until the end of flowering.
- In an average uniform *B. rapa* stand, plants can average eight to nine branches per plant. The greater number of branches leads to a less structured appearance.
- This makes identification of the main stem more difficult in the mature plant.
- *B. napus* plants grow taller and have a distinct main stem with fewer secondary branches. *B. napus* plants, in an average uniform stand, will average from four to six branches per plant.

Flowering and Podding

- Flowering begins with the opening of the lowest bud on the main stem and continues upward with three to five or more flowers opening per day.
- All of the buds that will develop into open flowers on the main stem will likely be visible in *B. napus* within three days after the start of flowering and within 10 days in *B. rapa*.
- Under reasonable growing conditions, flowering of the main stem will continue from 14 to 21 days for both species.
- Full plant height is reached at full flowering (50 per cent of flowers on main raceme open, older petals falling) due to the overlap of growth stages.
- The first buds to open become the pods lowest on the main stem or secondary branches.
- By mid-flower lower pods have started elongating.

Seed Development and Ripening

- Normally a pod contains 15 to 40 seeds.
- About 35 to 45 days after the first flower opens seed filling is complete.
- Immature seeds, when filled, contain about 40 to 45 per cent moisture. The seed coat then begins to turn from green to yellow or brown, depending on the variety.
- Seed moisture is rapidly lost at a rate of two to three per cent or more per day, depending on growing conditions.
- At 40 to 60 days after first flower, the seeds in the lower pods will have ripened and fully changed colour. As the seed coat changes colour so does the seed.
- When completely mature the seed is uniformly bright yellow or brown to black in colour.
- Optimum stage to swath for both yield and quality is up to 60 per cent seed colour change. This enables growers to delay the swathing of their first fields until at least 30 to 40 per cent seed colour change without sacrificing significant yield or quality.
- *B. rapa* varieties may be directly combined because they mature earlier and resist combining. They can be swathed at 40 per cent seed colour change on the main stem.

Table 1.4 Canola and Mustard growth stages

Code	Description
Principle Growth Stage 0: Germination	
0	Dry seed
1	Beginning of seed imbibition
3	Seed imbibition complete
5	Radicle emerged from the seed
7	Hypocotyl with cotyledons emerged from the seed
8	Hypocotyl with cotyledons growing towards the soil surface
9	Emergence: cotyledons emerge through the soil surface
Principle Growth Stage 1: Leaf Development	
10	Cotyledons completely unfolded
11	First leaf unfolded
12	2 leaves unfolded
13	3 leaves unfolded
1.	Stages continuous until...
19	9 or more leaves unfolded
Principle Growth Stage 2: Side Shoot Development	
20-29	Occur in many other species, but is of low relevance to mustard and canola
Principle Growth Stage 3: Stem Elongation	
30	Beginning of stem elongation: rosette
31	1 visible extended internode
32	2 visibly extended internodes
33	3 visibly extended internodes
3.	Stages continuous until...
39	9 or more visibly extended internodes
Principle Growth Stage 4: Vegetable Plant Part Development	
40-49	Occur in Brassicaceae, but are relevant for harvesting vegetable parts (ex: broccoli)
Principle Growth Stage 5: Inflorescence Emergence	
50	Flower buds present, still enclosed by leaves
51	Flower buds visible from above (green buds)

52	Flower buds free and level with the youngest leaves
53	Flower buds raised above the youngest leaves
55	Individual flower buds (main inflorescence) visible but still closed
57	Individual flower buds (secondary inflorescences) visible but still closed
59	First petals visible, flower buds still closed (yellow buds)
Principle Growth Stage 6: Flowering	
60	First flowers open
61	10% of flowers on main raceme open, main raceme elongating
62	20% of flowers in main raceme open
63	30% of flowers in main raceme open
64	40% of flowers in main raceme open
65	Full flowering: 50% of flowers in main raceme open, older petals falling
67	Flowering declining: majority of petals fallen
69	End of flowering
Principle Growth Stage 7: Development of Fruit	
71	10% of pods have reached final size
72	20% of pods have reached final size
73	30% of pods have reached final size
74	40% of pods have reached final size
75	50% of pods have reached final size
76	60% of pods have reached final size
77	70% of pods have reached final size
78	80% of pods have reached final size
79	Nearly all pods have reached final size
Principle Growth Stage 8: Ripening	
80	Beginning of ripening: seed green, filling pod cavity
81	10% of pods ripe, seeds dark and hard (yellow for yellow and oriental mustards)
82	20% of pods ripe
83	30% of pods ripe
84	40% of pods ripe
85	50% of pods ripe
86	60% of pods ripe
87	70% of pods ripe
88	80% of pods ripe
89	Fully ripe
Principle Growth Stage 9: Senescence	
97	Plant is dead and dry
99	Harvested product

Courtesy of: SaskMustard

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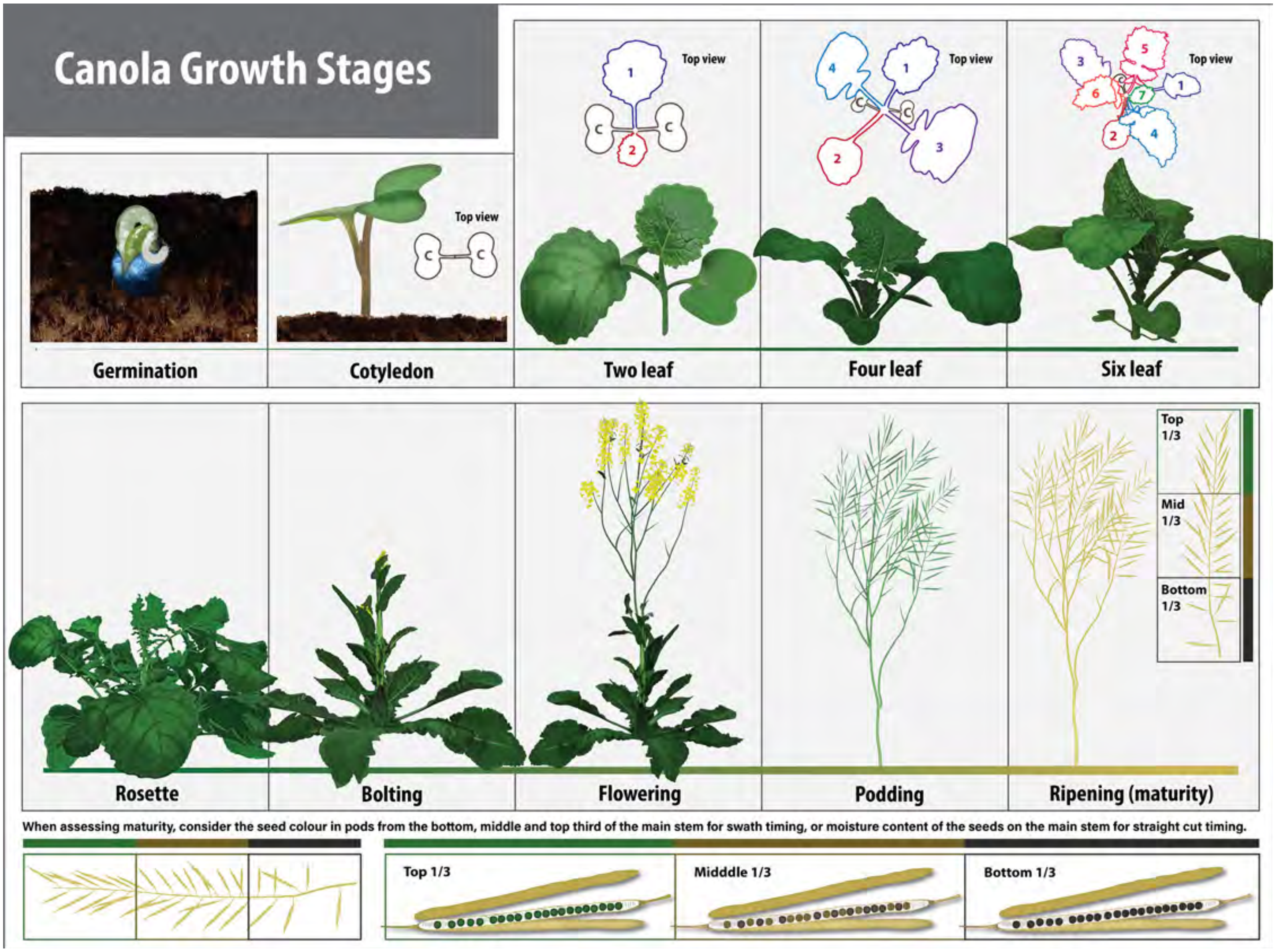
Table 1.5 How to distinguish mustard from canola

	Canola *(Brassica napus)*	**Brown or oriental mustard** *(Brassica juncea)*	**Yellow mustard** *(Sinapis alba)*
Seedling	 Heart-shaped cotyledons and hairless leaf stalks. First true leaves have a hairless upper surface with scarce hairs on the underside of the leaf.	 Heart-shaped cotyledons and hairless leaf stalks. First true leaves are covered with hairs on both the upper and lower leaf surfaces. Hairs on leaves are less dense than on yellow mustard leaves.	 Heart-shaped cotyledons have a few hairs on the edges and upper surface. Stems and leaf stalks are densely pubescent (hairy). First true leaves have a dense covering of hair on both the upper and lower surfaces.
Adult Leaves	 Adult leaves are dark bluish-green, waxy and either hairless or with a few sparse hairs near the leaf margin. The leaves are rounded and partially clasp the stem.	 Leaves are pale green with hairs on the first leaves and leaf margins. The lower leaves will be deeply lobed, while the upper leaves will be narrower and not lobed. The leaf will terminate higher up on the petiole and will not clasp the stem.	 Leaves are light-green, densely pubescent and deeply lobed. The leaf will terminate higher up on the leaf stalk and will not clasp the stem.
Stems	Hairless and smooth	Hairless and smooth	Pubescent with a lot of small hairs on the stems and petiloes.

Courtesy of: SaskMustard

Figure 1.14 Canola staging guide



Courtesy of: Canola Council of Canada

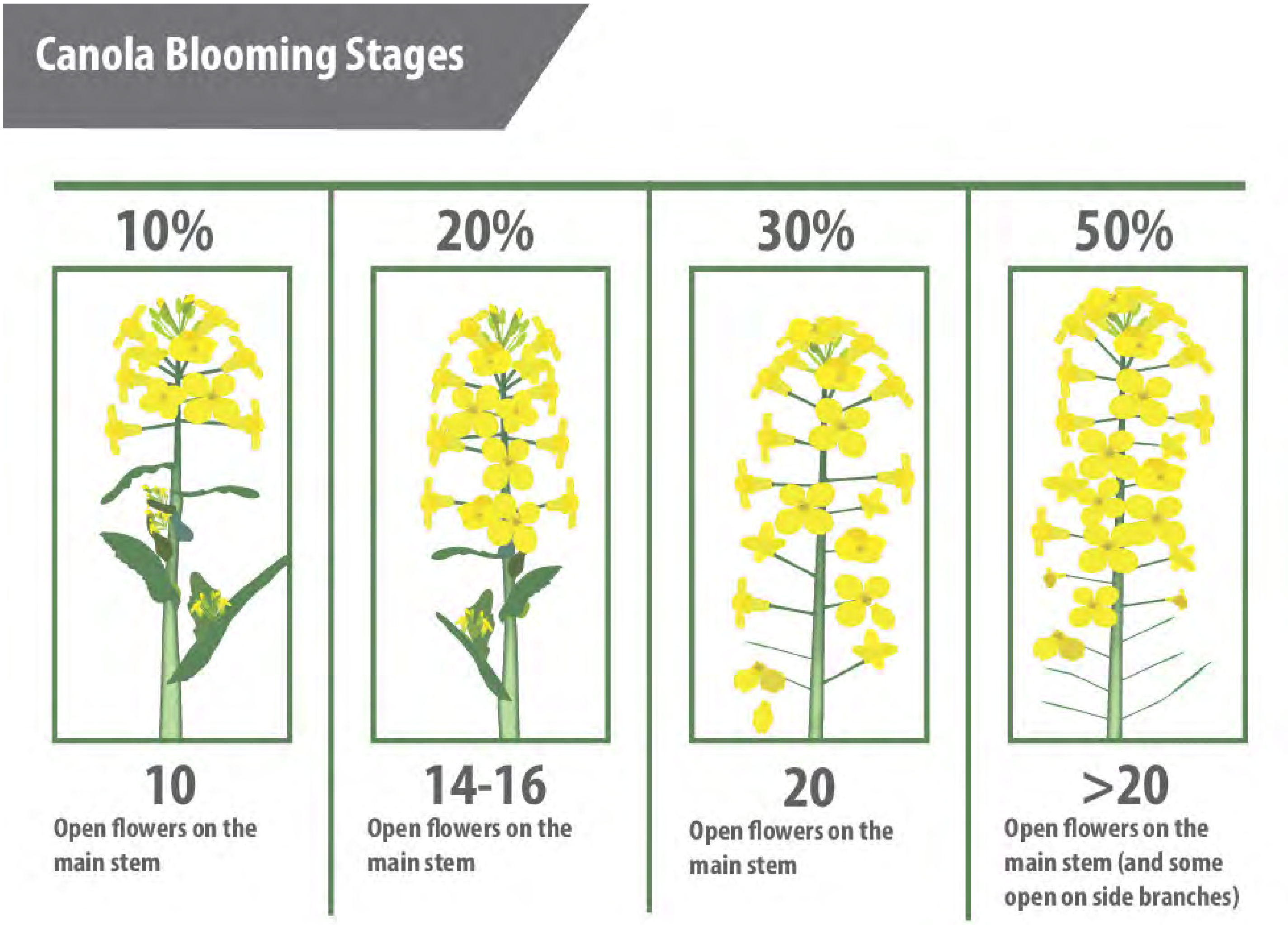
Assessment of Flower Bloom in Canola

Although different fungicides may have slightly different recommendations for spray timing, they are most effective when made at or before 50 per cent flowering. For this reason, assessing flower stages correctly is critical.

Flowering and Podding

- Flowering begins with the opening of the lowest bud on the main stem and continues upward with three to five or more flowers opening per day.
- Flowering at the base of the first secondary branch begins two to three days after the first flower opens on the main stem.
- Under reasonable growing conditions, flowering of the main stem will continue for 14 to 21 days.
- In general, the crop takes two to four days to move from first flower to 10 per cent flower:
    - One to two days from 10 per cent to 20 per cent flower,
    - One to two days from 20 per cent to 30 per cent flower, etc.
- Colour intensity steadily increases until its maximum intensity at 50 per cent flower. By 60 per cent flower, colour intensity begins to decrease.

Figure 1.15 Percentage of canola bloom



Courtesy of: Canola Council of Canada

Calculating Seeding Rates

Formula:

Seeding Rate (kg/ha) = (Target Plant Population/m^2 x Thousand Kernel Weight (TKW) in grams) ÷ Expected Seedling Survival

To convert to lbs/acre multiply seeding rate (kg/ha) x 0.89

Example: Canola Crop

Target plant population = 100 plants/m^2
TKW = 5 grams
Expected Seedling Survival = 50%

Seeding rate = [Target plant population (100 plants/m2) X TKW (5)] ÷ Seedling Survival (50) = 10 kg/ha or 8.9 lbs/ac

Table 1.6 Target plant population and thousand kernel weight (TKW) in grams for various crops

Crop	Target Plant Population (per square metre)	Thousand Kernel Weight (TKW) in grams
Wheat-Hard Red Spring	250	31-38
Wheat-CPS	250	39-50
Durum	210-250	41-45
Wheat-SWS	210-250	34-36
Wheat-winter	250	30-36
Barley-2 row	210-250	40-50
Barley-6 row	210-250	30-45
Oat	350	30-45
Triticale-spring	310	42-48
Triticale-winter	250	43-46
Fall Rye	250	30-35
Grain Corn	7	200-270
Canary Seed	500-570	7-8.5
Canola-*Brassica rapa*	80-100	2-3
Canola-*Brassica napus*	80-100	2.5-7.5
Flax	300-400	5-6.5
Camelina	210	1–1.3
Mustard-Yellow	70-120	5.5-6.5
Mustard-Brown/Oriental	70-120	2–3
Soybean	44-57	n/a
Hemp-Grain	100-125	12-18
Pea	85	125-300
Red Lentils	130	35-40
Large Green Lentils	130-190	64-75
Chickpea	44	220-450
Faba Bean	45	350-425
Dry Bean	40	160-900

Thousand kernel weights (TKW) can be determined by counting out 1,000 seeds and weighing the seed. Seed germination can be obtained through a seed test or measured at home.

Expected seedling survival rates can be determined using guidelines for average growing conditions but may need to be adjusted based on available moisture, temperature, seed quality, amount of seed placed fertilizer, weed pressure and seeding date.

- Cereals: 80-90 per cent
- Canola: 40-60 per cent
- Pulses: 80-95 per cent

Recommended Minimum Soil Temperature and Seeding Depth

Soil temperature at the depth of seeding can be used as a guide to determine when to start seeding. Minimum soil temperature recommendations are an average of morning and afternoon readings taken from representative spots in the field. Cold soil temperatures at the time of seeding can impact rate of emergence and in some cases even plant population numbers and uniformity of plant stand. The recommended minimum temperatures are those required for germination to occur. Emerged plants may be subject to frost injury depending on the crop type and where growing points are located in relation to the soil surface.

Table 1.7 Recommended Minimum Soil Temperatures and Seeding Depths

Crops	Recommended Minimum Average Soil Temperature at Seeding Depth (Celsius)	Recommended Seeding Depth (cm/inches)
Peas	5	3-8/(1.2-3.2)
Lentils	5	2.5-7.5/(1-3)
Chickpeas-Kabuli	10	3.5-6/(1.5-2.5)
Chickpeas-Desi	7	3.5-6/(1.5-2.5)
Faba Beans	3-5	5.1-7.6/(2-3)
Dry Beans	12	5-6/(2-2.5)
Soybeans	10	1.9-3.8/(.75-1.5)
Wheat	4	4.0-6.0/(1.5-2.5)
Barley	3-5	3.8-4.5/(1.5-1.75)
Oats	5	2.5-5.0/(1.0-2.0)
Canola (*B. napus*)	5	1.5-2.5/(0.5-1.0)
Mustard	5	1.5-2.5/(.5-1.0)
Flax	5	2.5-4.0/(1.0-1.5)
Canaryseed	5	<6 cm/(<2.5)
Corn	10	3.81 - 5.08/1.5 - 2.0

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Table 1.8 SCIC Establishment benefit density chart (plants/square yard))

Crop	*Not Established	*Choice	*Established
HRS Wheat	Less than 70	70-110	110 +
Durum Wheat	Less than 70	70-110	110 +
Barley	Less than 70	70-110	110 +
Oats	Less than 70	70-110	110 +
Flax	Less than 100	100-150	150 +
Hybrid Canola	Less than 12	12-40	40 +
Fall Rye	Less than 45	45-63	63 +
Sunflower	Less than 3	3-4	4 +
ESRS Wheat	Less than 70	70-110	110 +
Mustard	Less than 25	25-40	40 +
Field Peas	Less than 25	25-35	35 +
Lentils	Less than 30	30-50	50 +
Canaryseed	Less than 70	70-100	100 +
SWS Wheat	Less than 70	70-110	110 +
Spring Rye	Less than 70	70-110	110 +
Triticale	Less than 70	70-110	110 +
Winter Wheat	Less than 45	45-63	63 +
Faba beans	Less than 10	10-15	15 +
Dry Beans	Less than 10	10-20	20 +
CPS Wheat	Less than 70	70-110	110 +
Coriander	Less than 55	55-85	85 +
Chickpea (Desi)	Less than 25	25-35	35 +
Chickpea (Kabuli)	Less than 15	15-25	25 +
Soybeans	Less than 25	25-35	35 +
Canola (open pollinated)	Less than 25	25-40	40 +

**Based on the Saskatchewan Ministry of Agriculture recommended plant densities and seeding rates.*

Courtesy of: Saskatchewan Crop Insurance Corporation

Perennial Forage Seeding

Calculating Seeding Rate

Seeding rates should be calculated on the basis of Pure Live Seed (PLS). PLS determines the amount of viable seed in a seed lot by allowing for impurities and the germination percentage of the seed lot.

PLS Formula:

PLS = (per cent germination) x (per cent purity)

For example, if a seed lot has 15 per cent impurities and a germination of 89 per cent, PLS would be:
PLS = (0.89 x 0.85) = 0.76 or 76 per cent. Therefore, seeding rates should be increased by 24 per cent to obtain the desired density of viable seed.

Target PLS based on soil zone:

- 18-20 seeds/ft^2 PLS in the Brown soil zone
- 20-25 seeds/ft^2 PLS in the Dark Brown soil zone
- 25-30 seeds/ft^2 PLS in the Black/Grey-Wooded soil zone
- 30-40 seeds/ft^2 PLS under irrigation

$$\text{Seeding rate (lbs/ac)} = \frac{(\text{target \# seeds/ft}^2 \times \text{ft}^2\text{/acre}) / \text{PLS}}{\text{seeds/lbs}}$$

$$= \text{lbs/acre}$$

There are exceptions to using the recommended target PLS based on soil zone. The target PLS and calculated seeding rate is meant strictly to be a guide. Recommended seeding rates may be higher than the targeted PLS seeding rate when species have small seeds, hard seeds, low seedling vigor or high seedling mortality rates. It is important to note that most forms of seeding equipment are not designed to seed small, light seeds at very low seeding rates (less than four to five pounds per acre).

Some of the legumes (examples: alfalfa, sweet clover) may be seeded at a higher seeding rate than the calculated target PLS seeding rate to produce plants that have finer stems which are often less fibrous and more palatable to livestock.

In cases where the species has extremely large seeds, the recommended seeding rate may be lower than the calculated PLS seeding rate due to potentially lower seedling mortality rates and higher seed costs associated with the larger seeds.

For more information on calculating seeding rates for mixtures or for specific row spacing, please see the Forage Crop Production Guide on *www.saskatchewan.ca/agriculture*.

Forage Seeding Rates

Table 1.9 Forage seeding chart (Legumes)

Legumes	Stand Type	Bloat Risk	Monoculture seeding rate (lbs/ac)[1]	In Mixtures seeding rate (lbs/ac)[1 2]	Seeding Depth (inches)	Number of seeds per pound	Longevity [3 4]
Alfalfa	Hay/Pasture	yes	4-12	2-8	1/4-1/2	200,000	medium-long
Alsike Clover	Pasture	yes	4-6	1-2	1/4-1/2	700,000	short-medium
Birdsfoot Trefoil	Pasture	no	4-6	2-5	1/4-1/2	375,000	medium
Cicer Milkvetch	Pasture	no	8-12	2-5	1/2	130,000	long
Red Clover	Hay	yes	6-10	2-6	1/2	275,000	short
Sainfoin	Pasture	no	20-30	10-16	1/2-1	30,000	short
Sweet Clover	Hay	yes	8-12	5-8	1/2	258,000	short
White Dutch Clover	Hay	yes	3-6	1-3	1/2	800,000	short-medium

[1] Seeding rates may be increased 20 to 50 per cent when seeding into adverse conditions such as salinity or dormant seeding when germination may be lower and seedling mortality rates may be higher. Seeding rates are typically on the lower end of the range in drier parts of the province (Brown soil zone) and higher on the range in the wetter parts of the province (Black and Grey Wooded soil zones and irrigated land).

[2] Proportion of seed in mixture will depend on soil zone, blend diversity, conditions etc.

[3] Short (one to two years), medium (three to six years) and long-lived (seven plus years).

[4] Stand longevity may change depending on how adapted the forage species is to the site conditions and climate regime. There may be differences between varieties based on where they were developed and characteristics focused on in the breeding program. Stand life can be extended when there is a proper fertility and cutting management plan in place (all species); or mature seed set is allowed every two to three years (exception is alfalfa).

Table 1.10 Grass seeding chart

Grasses	Stand Type	Monoculture seeding rate (lbs/ac)[1]	In Mixtures seeding rate (lbs/ac)[1 2]	Seeding Depth (inches)	Number of seeds per pound	Longevity [3 4]
Kentucky Bluegrass	Pasture	10 -15	3-5	1/2	2,200,200	medium-long
Smooth Bromegrass	Hay	8-12	3-6	1/2	136,000	long
Meadow Bromegrass	Pasture	10-15	3-8	1/2	80,000	long
Hybrid Bromegrass	Hay/Pasture	10-15	3-6	1/2-3/4	90,900	long
Creeping Red Fescue	Pasture	10-12	3-5	1/2	615,000	medium-long
Meadow Fescue	Pasture	10-15	3-5	1/2	230,000	short-medium
Tall Fescue	Pasture	8-10	4-10	1/2-1	225,000	short-medium
Creeping Foxtail	Hay	5	2	1/2	750,000	medium-long
Meadow Foxtail	Pasture	5	2	1/2	577,000	medium-long
Orchardgrass	Pasture	10	2-5	1/2	654,000	medium
Reed Canarygrass	Hay	5-8	3-5	1/2	525,000	medium-long
Annual (Italian) Ryegrass	Pasture	10-15	4-10	1/2-1	105,000	short
Perennial Ryegrass	Pasture	10-12	4-10	1/2	240,000	short
Altai Wildrye	Pasture	15-20	5-8	3/4-1	55,000	long
Russian Wildrye	Pasture	8-11	3-5	1/2-1	100,000	long
Dahurian Wildrye	Hay/Pasture	12-16	1-2	1/2-1	80,000	short
Timothy	Hay	5	2-6	1/4-1/2	1,230,000	medium-long
Crested Wheatgrass	Hay/Pasture	8-10	3-6	1/2-3/4	220,000 (diploid) 175,000 (tetraploid)	long

Intermediate Wheatgrass	Hay/Pasture	8-14	2-11	1/2-1	88,000	medium-long
Pubescent Wheatgrass	Hay/Pasture	8-14	2-11	1/2-1	80,000	long
Slender Wheatgrass	Hay	8-12	1-3	1/2-3/4	160,000	medium
Tall Wheatgrass	Hay/ Reclamation	10-15	2-8	1/2-1	79,000	long
Green Wheatgrass	Hay/Pasture	5-10	2-5	1/2-3/4	111,000	medium-long

1 Seeding rates may be increased 20 to 50 per cent when seeding into adverse conditions such as salinity or dormant seeding when germination may be lower and seedling mortality rates may be higher. Seeding rates are typically on the lower end of the range in drier parts of the province (Brown soil zone) and higher on the range in the wetter parts of the province (Black and Grey Wooded soil zones and irrigated land).

2 Proportion of seed in mixture will depend on soil zone, blend diversity, conditions etc.

3 Short (one to two years), medium (three to six years) and long-lived (seven plus years).

4 Stand longevity may change depending on how adapted the forage species is to the site conditions and climate regime. There may be differences between varieties based on where they were developed and characteristics focused on in the breeding program. Stand life can be extended when there is a proper fertility and cutting management plan in place.

Table 1.11 Legumes features and tolerances

Legume	Salinity	Flooding	Poor Drainage	Acidity	Alkalinity	Drought	Soil Texture
Alfalfa1	Fair-Good	Poor	Poor	Fair	Good	Good-very good	Wide texture
Sweet Clover	Good	Poor	Poor	Fair	Good	Good	Wide texture
Alsike Clover	Poor	Very good	Very good	Good	Fair	Poor	n/a
Red Clover	Poor	Fair	Poor	Very good	Poor	Poor	Wide texture
White Clover	Poor	Poor	Poor	Fair	Poor	Poor	Loamy-clayey
Birdsfoot Trefoil	Poor	Good (short term)	Good	Good	Good	Poor	Sandy loam-clayey
Sainfoin	Fair	Poor	Poor	Fair	Good	Good	Wide texture
Cicer Milkvetch	Fair-Good	Poor	Poor	Fair	Good	Good	Wide texture

Table 1.12 Legumes features and tolerances continued

Legume	Soil Zones	Winter Hardiness	Seeding Vigor	Competitiveness	Growth Period	Regrowth	Palatability
Alfalfa1	All	Good	Very good	Very good	Spring-fall	Good	Good
Sweet Clover	All	Good	Good	Very good	Spring-summer	Poor	Fair-poor
Alsike Clover	Black, grey wooded	Fair	Good	Good	Spring-summer	Fair-good	Good
Red Clover	Black, grey wooded	Fair-good	Good	Good	Spring	Good	Good
White Clover	Black, grey wooded, irrigated	Poor-fair	Poor	Good	Late Spring-summer	Good	Good
Birdsfoot Trefoil	Black, grey wooded	Good	Poor	Poor	Spring-fall	Slow	Good
Sainfoin	Brown, dark brown, black	Fair-good	Fair	Fair	Early spring	Fair	Good
Cicer Milkvetch	Dark brown, black, grey wooded, irrigated	Good	Fair (slow establishment)	Good-very good	Early summer-fall	Fair-good	Good

[1] Variances among rooting types. In general, creeping rooted alfalfas tend to have greater salinity tolerance and drought tolerance than tap rooted alfalfa varieties; however, with an emphasis on salinity tolerance in breeding programs some tap-rooted varieties have superior salinity tolerance. Branched rooted alfalfas tend to have greater tolerance to poor drainage than other varieties.

Table 1.13 Grass Adaptations and Tolerances

Grass	Salinity	Flooding	Poor Drainage	Acidity	Alkalinity	Drought	Soil Texture
Kentucky Bluegrass	Poor	Fair	Good	Poor	Poor	Fair	Wide texture
Smooth Bromegrass	Good	Fair	Fair	Fair-good	Fair	Good	Loamy-clayey
Meadow Bromegrass	Fair	Poor	Poor	Fair	Fair	Good	Loamy-clayey
Hybrid Bromegrass1	Fair	Poor	Poor	Fair	Fair	Good	Wide texture
Creeping Red Fescue	Poor	Fair	Fair	Very good	Poor	Fair	Sandy-clayey
Meadow Fescue	Poor	Fair	Fair	Fair	Poor	Poor	Clayey
Tall Fescue	Good	Good	Good	Very good	Good	Poor	Loamy-clayey
Creeping Foxtail	Good	Very good	Good	Good	Good	Poor	Loamy-clayey
Meadow Foxtail	Poor	Very good	Fair	Good	Fair	Poor	Loamy-clayey
Orchardgrass	Fair	Poor	Poor	Good	Poor	Poor	Loamy-clayey
Reed Canaryseed	Poor-fair	Very good	Very good	Good	Poor	Poor	Loamy-clayey
Italian (annual) Ryegrass	Fair	Good	Good	Fair-good	Fair-good	Poor	Loamy-clayey
Perennial Ryegrass	Poor	Poor	Poor	Fair-good	Poor	Poor	Loamy-clayey
Altai Wildrye	Very good	Fair	Poor	Fair	Fair	Good	Loam, clay loam
Russian Wildrye	Good	Poor	Poor	Fair	Fair	Very good	Loam, clay loam
Dahurian Wildrye	Very good	Fair-good	Fair-good	Fair	Good	Good	Sandy-clayey
Timothy	Poor	Very good	Very good	Good	Poor	Poor	Loamy-clayey, peat
Crested Wheatgrass	Good	Poor	Poor	Fair	Good	Very good	Sandy-clayey
Intermediate Wheatgrass	Fair	Fair	Poor	Fair	Fair	Fair	Loamy-clayey
Pubescent Wheatgrass	Good	Fair	Poor	Fair	Good	Fair	Wide texture
Slender Wheatgrass	Very good	Good	Fair	Fair	Good	Good	Sandy loam-clayey
Tall Wheatgrass	Very good	Good	Very good	Poor	Good	Good	Loamy-clayey
Green Wheatgrass	Very good	Fair-good	n/a	Fair-good	n/a	Good	Wide texture

1 Variances in hybrid bromegrass tolerances and characteristics will be dependent on the parental lines and crosses.

Table 1.13 Grass Adaptations and Tolerances continued

Grass	Soil Zones	Winter Hardiness	Seeding Vigor	Competitiveness	Growth Period	Regrowth	Palatability
Kentucky Bluegrass	Black, grey wooded	Very good	Slow establishment	Very good	Spring-fall	Good	Good
Smooth Bromegrass	All	Very good	Good	Very good	Mid spring-mid summer	Poor	Good
Meadow Bromegrass	Dark brown, black, grey wooded	Very good	Good	Good	Spring-fall	Excellent	Very good
Hybrid Bromegrass1	All	Good	Good	Good	Spring-fall	Good	Very good
Creeping red Fescue	Black, grey wooded	Very good	Good	Good	Late spring-fall	Very good	Good
Meadow Fescue	Black, grey wooded	Poor-fair	Fair	Fair-good	Early spring-late fall	Good	Good
Tall Fescue	Dark brown, black, grey wooded, irrigated	Fair (variable)	Good	Good	Late spring-fall	Good	Good
Creeping Foxtail	Dark brown (moist), black, grey wooded	Very good	Slow establishment	Very competitive (established)	Early spring	Good	Good (early), poor (mature)

Table 1.13 Grass Adaptations and Tolerances continued

Grass	Soil Zones	Winter Hardiness	Seeding Vigor	Competitiveness	Growth Period	Regrowth	Palatability
Meadow Foxtail	Dark brown (moist), black, grey wooded	Very good	Good	Good	Early spring	Good	Good (pre-heading)
Orchardgrass	Black, grey wooded, irrigated	Fair (variable)	Poor-fair	Good	Spring-fall	Excellent	Very Good
Reed Canaryseed	All	Very good	Slow establishment	Very competitive (established)	Spring-summer	Good	Good (pre-heading)
Italian (annual) Ryegrass	Dark brown (moist), black, grey wooded, irrigated	Annual	Good	Good	Mid-summer-fall	Excellent	Excellent
Perennial Ryegrass	Black, grey wooded, irrigated	Poor	Very good	Good	Mid-late summer	Excellent	Good
Altai Wildrye	Brown, dark brown	Very good	Poor (slower establishment)	Poor	Early-mid-summer	Fair	Good
Russian Wildrye	Brown, dark brown, black	Very good	Poor-fair (difficult establishing)	Good (established)	Early spring-mid-summer	Fair	Good
Dahurian Wildrye	All	Fair	Very good	Very good	Spring-fall	Good	Good (vegetative stage)
Timothy	Black, grey wooded	Very good	Very good-good	Poor	Spring-summer	Poor	Good (pre-heading)
Crested Wheatgrass	Brown, dark brown, black	Very good	Good	Very competitive	Early spring	Poor-fair	Good (early)
Intermediate Wheatgrass	All	Fair-good	Good	Good	Late spring-mid-summer	Poor-fair	Good (early)
Pubescent Wheatgrass	All	Good	Good	Good	Spring-summer	Poor-fair	Good
Slender Wheatgrass	All	Good	Good (establishes quickly)	Fair	Early spring-mid-summer	Poor	Poor
Tall Wheatgrass	Dark brown, black, irrigated	Very good	Slow establishment	Poor	Late spring-mid-summer	Poor	Poor
Green Wheatgrass	All	Good	Good	Good	Spring-summer	Fair	Good

1 Variances in hybrid bromegrass tolerances and characteristics will be dependent on the parental lines and crosses.

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Estimating Yield Prior to Harvest

The procedure used to estimate yields prior to harvest starts by first determining the number of seeds per square yard in representative parts of the field. These are then used to arrive at an average number of seeds per square yard and converted to kilograms per square yard. For this calculation the number of seeds per kilogram must be known or estimated. The kilograms per square yard is then converted to kilograms per acre by multiplying by 4,840. A harvest loss factor is applied to reflect seeds that may not be captured or retained during the harvest operation. This is expressed as a percentage loss. The appraisal yield is in kilograms per acre and can be converted to bushels per acre.

Different crop types require a slightly different approach to determining the seeds per square yard. These procedures are described in the specific sections for pulses, canola and cereals.

Peas, lentils, faba bean, dry beans and soybean

Once pods are developed, count the number of pods per square yard instead of plants. Multiply by an average number of seeds per pod determined by counting the number of seeds per pod on five plants in a row and dividing by the number of plants. At this time, also determine the number of plants in a square yard. There should be at least three counts per field of less than 20 acres and up to 12 counts in 160 acres. More or less counts may be required depending on crop uniformity. To complete the calculations, you can use the thousand kernel weight (TKW) from the SK Varieties Guide or if crop is physiologically mature use a seed sample from the field to determine the seed weight. Harvest loss factors may be applied depending on crop, field-crop condition and harvest equipment.

Below is an example for a pre-harvest yield appraisal on yellow peas. In this example the harvest loss was estimated at 10 per cent.

Yellow peas example

Crop	Yellow peas-CDC Amarillo-TKW 230 g = 4350 seeds/kg						
Sample#	Plants Per Square Yard		Pods Per Plant		Seed Per Pod		Seeds per Square Yard
1		X	258	X	4	=	1032
2		X	240	X	4.2	=	1008
3		X	267	X	4	=	1068
4		X		X		=	
5		X		X		=	
					Total seeds	=	3108
					Divided by number of counts	divide	3
					Average seeds per square yard	=	1036
					Seeds/kg by variety	divide	4350
					Kgs seed per square yard	=	0.2382
					Square yards per acres	X	4840
					Yield kg/acre	=	1152.69 kg/acre
					Less harvest loss (100-10% loss) ÷ 100	X	0.90
					APPRAISAL kg/ac	=	1037.4 kg/ac
					Conversion to bu/ac	X	0.03674
					Imperial yield bu/ac	=	38.1 bu/ac

Canola

Canola is a one of the more difficult crops to assess yield, especially if the stand is not uniform. Pull out all the plants in a square yard and categorize them in big, medium and small plants. Count the number of pods on a representative plant from each category and multiply by the respective number of plants in that category. Don't count miss-formed and small pods, nor the top ones on the side branches. To determine the number of seeds per pod, count number of seeds in five to 10 pods for each category and arrive at an average number of seeds per pod for each category. Be sure to include mainstem and side branch pods.

Here is an example for a pre-harvest yield appraisal on hybrid canola.

Hybrid canola example

L252, TKW = 3.2 g (do not use the TKW number on the seed bag for yield calculations as this will greatly over-estimate the yield).

Crop	Canola: L 252 TKW 3.22 g = 310,000 seeds/kg						
Sample#	Plants Per Square Yard		Pods Per Plant		Seed Per Pod		Seeds Per Square Yard
1a	5	X	165	X	25	=	20625
1b	18	X	62	X	24	=	26784
1c	10	X	12	X	18	=	2160
Total 1	33						49569
2a	8	X	187	X	24	=	35904
2b	16	X	74	X	25	=	29600
2c	15	X	11	X	18	=	2970
Total 2	39						68474
3a	4	X	198	X	24	=	19008
3b	30	X	87	X	26	=	67860
3c	3	X	9	X	12	=	324
Total 3	37						87192
Average					Total of sites	=	205235
					Divided by number of counts	divide	3
					Average seeds per square yard	=	68411.66667
					Seeds per kg	divide	310000
					Kgs seed per square yard	=	0.2207 kg/yd^2
					Square yards per acres	X	4840
					Yield kg/acre	=	1068.10 kg/ac
					Less harvest loss (100-5% loss) ÷ 100	X	0.95
					APPRAISAL	=	1014.7 kg/acre
					Conversion to bu/ac	X	0.04409
					Imperial yield bu/ac		44.7 bu/ac

Cereals

In cereals, count the number of heads per square yard. For every count pull five to 10 consecutive plants in a row and rub out the kernels. Divide the total number of kernels by the number of heads to get average number of kernels per head.

Here is an example for a pre-harvest yield appraisal on Durum, Strongfield, 43g TSW .

Durum example

Durum wheat, Strongfield, TKW = 43 g

Crop	Durum Strongfield-43g TKW = 23,300 seeds/kg						
Sample#	Plants Per Square Yard		Heads Per Plant		Seed Per Head		Seeds Per Square Yard
1	210	X	1	X	24	=	5040
2	198	X	1	X	23	=	4554
3	224	X	1	X	25	=	5600
					Total seeds	=	15194
					Divided by number of counts	divide	3
					Average seeds per square yard	=	5064.6666
					Seeds per kg	divide	23300
					Kgs seed per square yard	=	0.2174 kg/yd^2
					Square yards per acres	X	4840
					Yield kg/ac	=	1052.06
					Less harvest loss (100-2% loss) ÷ 100	X	0.98
					APPRAISAL	=	1031.2 kg/ac
					Conversion to bu/ac	X	0.03674
					Imperial yield bu/ac		37.9 bu/ac

Calculating Grain Corn Yield

While there are several methods that are used to calculate grain corn yield, The Yield Component Method can be used well ahead of harvest. In fact, it can used as early as the "milk" stage. Estimates that are made earlier than this stage can end up being overly optimistic if stresses occur that can cause kernel abortion such as hail, drought, disease or nutrient deficiencies.

Four yield components are used to estimate grain yield utilizing this method. They are cobs per acre, kernel rows per ear, kernels per row, and weight per kernel. If calculations are made before the grain is mature (kernels at black layer and 15 per cent moisture), a predetermined average kernel weight is used.

1. Determine the number of harvestable ears. Measure a length of a single row equal to 1/1,000th of an acre and count the harvestable ears. For our example we counted 43 ears in our 17'5" row length.

For other row spacings, divide 43,560 sq ft/acre by the row spacing in feet and then divide by 1,000.

Example:

43,560 divided by 5 (60" row) divided by 1,000 = 8' 7".

Row length equivalent to 1/1000th acre at various row widths.	
Row width (inches)	Length for 1/1,000th acre (feet inches)
7	74' 10"
15	34' 10"
20	26' 1"
22	23' 10"
30	17' 5"
36	14' 6"
38	13' 10"
40	13' 1"

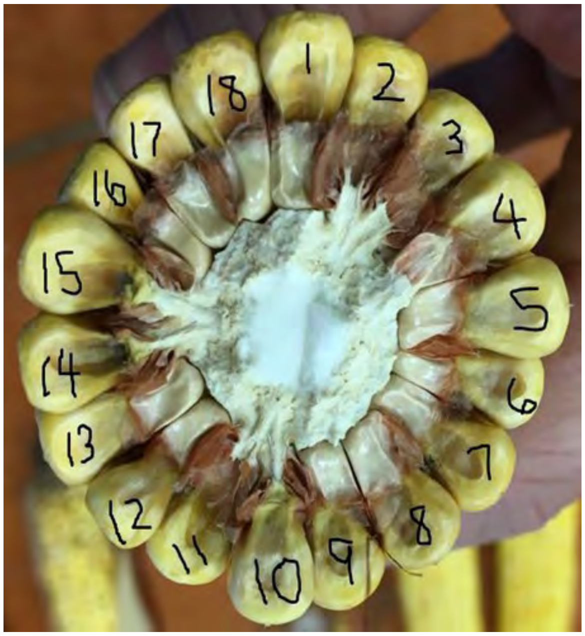
2. Determine the average kernels per ear. The more ears you are willing to check within the selected row length the more accurate your yield estimate may be. At a minimum, select 3 representative ears from the selected row length. For each ear selected, count the number of kernels per row. Do not count the extreme butt, tip kernels or aborted kernels. Count complete rings of kernels around the cob. This will end up being an average as kernel development may not be complete in each row. Next, split the cob and count the number of complete kernel rows per ear.

Figure 1.16 Counting average kernels per ear

Do not count the extreme butt, tip kernels or aborted kernels.

Estimate the yield by multiplying the average ear number/row by the average number of kernels per ear, then divide by the average kernel weight which is a given constant unless kernel weight is actually known. The constant can be 80, 90 or 100 mg/kernel. If grain filling conditions have been excellent creating larger kernels but fewer kernels per bushel, then use the value of 80 which represents 80,000 kernels in a bushel is 282.2 mg/kernel. If the growing season has been average, then 90 will represent the average 90,000 kernels in a bushel of corn at 15.5 per cent moisture weighing 282.2 mg/kernel. If grain fill has been poor with lots of small kernels, then you will have more kernels per bushel and should use 100 as your constant as 100,000 kernels is about 225 mg/kernel.

Figure 1.17 Counting kernel rows



This cob contains 18 kernel rows.

Now multiply each ear's row number by its number of kernels per row to determine total number of kernels for each ear. We had 18 rows X 30 kernels per row = 540 kernels/ear

In your representative sample of three ears you had 540, 610 and 580 for your kernel/ear counts. Add 540 + 610 + 580 = 1,730. Divide by three to get the average. 1,730 divided by 3 = 576.67 kernels/ear. If you have picked more ears to increase your accuracy, calculate accordingly.

(ear number x average number of kernels per ear)/90 = Yield (bu/acre).

We had 43 ears X 576.67 kernels per ear/90 = 275.52 bu/acre.

If you do not want to count the kernels in each row, an alternative method has you measure the length of each sample cob.

The calculation then becomes: number of ears X average ear length X average kernel number per row divided by row spacing.

For our example the three cob sample had a cob length of 10.5".

Multiply the 43 cobs X 10.5" cob length X 18 kernel rows divided by 30" row width.

43 X 10.5" X 18 / 30" = 270.9bu/acre

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Section 2: Soils, Fertility & Nodulation

Nutrient Uptake and Removal by Field Crops

The ranges in nutrient uptake and removal values given in the tables below are general estimates. They are based on typical nutrient concentrations and good growing conditions in western Canada. Actual uptake and removal will vary from year to year based on crop yield, crop variety and soil fertility.

Crop uptake of nutrients is affected by soil and climatic conditions. Low soil moisture, poor aeration from compaction or excessive moisture, low soil temperatures, nutrient imbalances and other factors may restrict uptake of plant nutrients.

Crop fertility requirements will differ from these nutrient removal values. Crops are unable to extract all plant available nutrients from the soil and fertilizer as they are not 100 per cent efficient. For any given yield, the total nutrient supply in the soil will be somewhat greater than the amount removed by the crop. Soil tests will provide the best information on soil nutrient supply and recommendations for fertilizer application.

Table 2.1 Nutrient removal and uptake in cereal grain crops in western Canada

Grain		Pounds Per Bushel Produced (lbs/bu)			
		N	P_2O_5	K_2O	S
Spring Wheat	Uptake	1.90-2.325	0.725-0.875	1.625-2.0	0.2-0.25
	Removal	1.35-1.65	0.525-0.65	0.40-0.475	0.1-0.125
Winter Wheat	Uptake	1.22-1.48	0.54-0.68	1.28-1.56	0.18-0.22
	Removal	0.94-1.14	0.46-0.56	0.30-0.38	0.12-0.16
Barley	Uptake	1.25-1.525	0.50-0.6125	1.2-1.4625	0.15-0.175
	Removal	0.875-1.0625	0.375-0.4625	0.2875-0.35	0.075-0.10
Oats	Uptake	0.96-1.17	0.36-0.45	1.31-1.60	0.12-0.14
	Removal	0.55-0.68	0.23-0.28	0.17-0.20	0.04-0.05
Rye	Uptake	1.51-1.836	0.745-0.927	2.127-2.618	0.254-0.309
	Removal	0.963-1.164	0.40-0.491	0.327-0.40	0.073-0.091
Canary Seed	Uptake	N/A	N/A	N/A	N/A
	Removal	0.5 - 1	0.45	0.14	0.14
Corn	Uptake	1.38-1.68	0.57-0.69	1.16-1.41	0.13-0.16
	Removal	0.87-1.07	0.39-0.48	0.25-0.30	0.06-0.07

Adapted from: Canadian Fertilizer Institute

Nutrient contents in harvested stover or straw are extremely variable due to variations in harvesting methods (cutting height, method of collection, timing of harvest, etc.). It is highly recommended that nutrient analyses of a representative subsample of the harvested material be conducted for more reliable estimates of nutrient removal.

Table 2.2 Nutrient removal and uptake in oilseed crops in western Canada

Oilseed		Pounds Per Bushel Produced (lbs/bu)			
		N	P_2O_5	K_2O	S
Canola	Uptake	2.857-3.514	1.314-1.629	2.086-2.543	0.486-0.60
	Removal	1.743-2.114	0.943-1.667	0.667-0.833	0.417-0.50
Flax	Uptake	2.583-3.167	0.75-0.917	1.625-2.0	0.50-0.625
	Removal	1.917-2.333	0.583-0.708	0.542-0.667	0.208-0.250
Sunflower	Uptake	1.340-1.640	0.460-0.560	0.660-0.880	0.160-0.180
	Removal	0.960-1.180	0.280-0.360	0.220-0.260	0.080-0.10

Adapted from: Canadian Fertilizer Institute

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Table 2.3 Nutrient removal and uptake in pulse crops in western Canada

Crop		Pounds Per Bushel Produced (lbs/bu)			
		N	P_2O_5	K_2O	S
Peas	Uptake	2.76-3.36	0.76-0.92	2.46-3.0	0.22-0.28
	Removal	2.10-2.58	0.620-0.760	0.64-0.78	0.12-0.14
Lentils	Uptake	2.73-3.367	0.733-0.90	2.30-2.80	0.267-0.333
	Removal	1.90-2.233	0.567-0.667	0.967-1.20	0.133-0.167
Faba beans	Uptake	5.14-6.28	1.78-2.16	4.58-5.60	0.24-0.30
	Removal	3.08-3.76	1.10-1.34	0.94-1.14	0.12-0.16
Chickpea	Uptake	2.18 lbs/ac	0.67 lbs/ac	0.87 lbs/ac	0.15 lbs/ac
	Removal	N/A	0.36	N/A	N/A
Dry bean	Uptake	4.67 lbs/CWT seed	1.39 lbs/CWT seed	3.95 lbs/CWT seed	0.34 lbs/CWT seed
	Removal	54-63 lbs/ac	20-25 lbs/ac	34-38 lbs/ac	4 lbs/ac
Soybeans	Uptake	5.25-5.80	0.875-1.0	4.125-4.40	0.34-0.35
	Removal	3.25-4.0	0.725-0.80	1.175-1.40	0.18-0.19

Adapted from: Canadian Fertilizer Institute

Table 2.4 Nutrient removal and uptake in other crops in western Canada

Crop	Yield		Pounds Per Acre (lbs/ac)			
			N	P_2O_5	K_2O	S
Potatoes	20 tons/acre	Uptake	205-251	60-73	268-327	16-20
		Removal	115-141	33-40	194-238	11-13
Alfalfa	5 tons/acre	Removal	261-319	62-76	270-330	27-33
Clover	4 tons/acre	Removal	194-237	50-61	181-222	10-12
Grass	3 tons/acre	Removal	92-113	27-33	117-143	11-14
Barley Silage	4.5 tons/acre	Removal	130-180	46-60	114-132	14-21
Corn Silage	5.0 tons/acre	Removal	140-172	57-70	181-222	12-14

Courtesy of: Canadian Fertilizer Institute

For information on how to interpret soil tests, please view these online webinars:

https://register.gotowebinar.com/register/2651032889409714955
https://register.gotowebinar.com/recording/8640457524252492290

Guidelines for Safe Rates of Seed-Placed Fertilizer

The following are considered to be approximate safe rates of urea (46-0-0) and ESN nitrogen applications with the seed in cereal grains, canola and flax. All rates are in pounds of actual nitrogen per acre. Width of spread varies with air flow, soil type, moisture level, amount of residue and other soil conditions.

Seedbed Utilization (SBU) is the amount of the seedbed over which the fertilizer has been spread. SBU is a reflection of the relative concentration of fertilizer.

SBU (%) = (Width of the spread ÷ row spacing) x 100.

For example:

If the seeding implement has a nine-inch spacing and spreads seed and fertilizer over two inches, the SBU would be (2 ÷ 9) x 100 = 22%.

Table 2.5 Safe nitrogen rates when applying urea

UREA*	**1 inch spread (disc or knife)**			**2 inch spread (spoon or hoe)**			**3 inch spread (sweep)**			**4 inch spread (sweep)**		
Row Spacing	6 in	9 in	12 in	6 in	9 in	12 in	6 in	9 in	12 in	6 in	9 in	12 in
Seedbed Utilization	17%	11%	8%	33%	22%	17%	50%	33%	25%	67%	44%	33%
Soil Texture												
Cereal Grains												
Light (sandy loam)	20	15	10	30	25	20	40	30	20	50	40	30
Medium (loam to clay loam)	30	25	20	40	35	30	50	40	35	60	50	40
Heavy (clay to heavy clay)	40	35	30	50	40	35	60	50	40	70	60	50
Canola & Flax												
Light (sandy loam)	10	5	0	20	15	10	30	10	15	40	25	20
Medium (loam to clay loam)	15	10	5	30	20	15	40	30	20	50	35	30
Heavy (clay to heavy clay)	20	15	10	40	30	20	50	40	30	60	45	40

Courtesy of: Agrium Advanced Technologies

**Rates are given in pounds per acre.*

Table 2.6 Safe nitrogen rates when applying ESN

ESN*	1 inch spread (disc or knife)			2 inch spread (spoon or hoe))			3 inch spread (sweep)			4 inch spread (sweep)		
Row Spacing	6 in	9 in	12 in	6 in	9 in	12 in	6 in	9 in	12 in	6 in	9 in	12 in
Seedbed Utilization	17%	11%	8%	33%	22%	17%	50%	33%	25%	67%	44%	33%
Cereal Grains												
Light (sandy loam)	40-60	30-45	30-45	60-90	50-75	40-60	80-120	60-90	50-75	100-150	80-120	60-90
Medium (loam to clay loam)	60-90	50-75	40-60	80-120	70-105	60-90	100-150	80-120	70-105	120-180	100-150	80-120
Heavy (clay to heavy clay)	80-120	70-105	60-90	100-150	80-120	70-105	120-180	100-150	80-120	140-210	120-180	100-150
Canola & Flax												
Light (sandy loam)	20-30	10-15	0	40-60	30-45	20-30	60-90	40-60	30-45	80-120	50-75	40-60
Medium (loam to clay loam)	30-45	20-30	10-15	60-90	40-60	30-45	80-120	60-90	40-60	100-150	70-105	90-120
Heavy (clay to heavy clay)	40-60	30-45	20-30	80-120	60-90	40-60	100-150	80-120	60-90	120-180	90-135	80-120

Courtesy of: Canadian Fertilizer Institute and Agrium

** Pounds per acre of nitrogen as ESN shown to be safe when applied with the seed. Based on 2x-3x the safe rate of urea and Ammonium Sulphate. Check the local seed-safe rates for your geography and crop.*

*** Recommended rates are based on proper handling of ESN.*

**** N rates in the table are in addition to the N in safe rates of seed-placed phosphorus fertilizer (monoammonium phosphate).*

Adapted from: Agrium Advanced Technologies

Table 2.7 Maximum safe rate of actual seed-placed phosphorus fertilizer

Crop	Actual P_2O_5 (lbs/ac)*
Cereals	50
Canola	25
Canaryseed, Pinto bean	30
Flax, Pea, Forages (Alfalfa, Bromegrass)	15
Faba bean	40
Lentil, Mustard, Chickpea	20

Courtesy of: Canadian Fertilizer Institute

** Rates are based on knife openers with a one-inch spread, nine-inch row spacing and good to excellent soil moisture. Narrow openers at wider spacings, dry conditions and sandy textured soil will increase the risk of injury and reduce the amount of fertilizer that can safely be placed in the seed row.*

Note: Recommendations are based on the use of monoammonium phosphate ($NH_4H_2PO_4$) MAP. Diammonium phosphate ($(NH_4)_2HPO_4$) DAP is much more toxic to seedlings than monoammonium phosphate and should be used with caution when placed with the seed.

Potassium

The total pounds of phosphate (P_2O_5) plus pounds of potassium (K_2O) should not exceed the maximum safe rate of seed-placed phosphate. This applies under good to excellent moisture conditions.

Sulphur

When ammonium-sulphate fertilizer is placed with the seed, add the pounds of nitrogen (N) from the ammonium-sulphate to the pounds of N from other nitrogen fertilizer being placed with the seed. The total N should not exceed the maximum safe rate of seed-placed nitrogen.

Types of Fertilizer

Table 2.8 Nitrogen Fertilizers

Urea ($CO(NH_2)_2$)	46-0-0	Volatility losses from the soil surface can be significant.
Ammonium Sulphate ($(NH_4)_2SO_4$)	21-0-0-24	Less volatile than urea and will not lose nitrogen as quickly when surface applied.
Anhydrous Ammonia (gas) (NH_3)	82-0-0	Very volatile. Needs to be injected into soil. Gases off if soil is dry and/or furrow does not close behind opener. Seldom used on forage crops.
Urea-Ammonium Nitrate Solution (UAN) ($CO(NH_2)_2 + NH_4NO_3$)	28-0-0	About 50% of N is in urea form which is volatile if surface applied. Dribble band on forage crops.
Aqua Ammonia	25-0-0	Simpler handling requirements than anhydrous ammonia, non-pressurized nature, which eliminates most hazards. Must be applied deep into the soil to prevent nitrogen loss.
Ammonium nitrate-calcium	27-0-0	Similar agronomic characteristics to ammonium nitrate. Relatively neutral in its reaction when applied to soil, unlike ammonium nitrate. It can even be applied to acidic soil.
Ammonium chloride	26-0-0	Physically similar to ammonium sulfate and is soluble in water. Can be applied prior to sowing, and as a side and top dressing when the crop is growing.
Sodium nitrate	16-0-0	For acidic soils, sodium nitrate is particularly useful. Sodium nitrate is a crystalline white substance that is highly soluble in water. Because of its low nutrient content (16 per cent Nitrogen), its use as a nitrogen fertilizer is limited, and because of the risk of nitrate leaching, it is preferably applied to actively growing crops.
Potassium Nitrate	13-0-44	Soluble form of potassium and nitrogen

Table 2.9 Phosphorous Fertilizers

Monoammonium Phosphate (MAP)	11-0-0	High-analysis fertilizer that is almost completely soluble in water. Non-hygroscopic and compatible with most other fertilizer materials that are granulated for application in the fields.
Diammonium Phosphate (DAP)	18-46-0	100% water soluble. Used in the solid form in fertilizer blends and broadcast applications Injures seedling if placed too close when applied in a band.
Ammonium Phosphate Sulphate ($(NH_4)_2H_3(PO_4)(SO_4)$)	20-20-0-13	N in the stable ammonium form. P is completely water soluble.

Table 2.10 Potassium Fertilizers

Potassium Chloride (Muriate of Potash) (KCl)	0-0-60	Contains chloride. Very high salt index. Need to limit seed placed K.
Potassium Sulphate (K_2SO_4)	0-0-52-12	Contains no chloride. Lower salt index. Used when added chloride is unwanted.
Potassium Nitrate	13-0-44	Soluble form of potassium and nitrogen
Potassium Hydroxide	0-0-70	Provides same availability as KCl. Used in solution fertilizers
Gypsum (Calcium Sulphate) $CaSO_4 \cdot 2(H_2O)$	0-0-0-(16)	Contains 15-18% sulphur.

Table 2.11 Sulphur Fertilizers

Elemental Sulphur (T90) (S8) Sulphur bentonite	0-0-0-90	Elemental form needs weathering to breakdown. Will not be available in the year of application if spring applied.
Ammonium Thiosulphate Solution (H8N2O3S2)	12-0-0-(26)	Thiosulfate not available for plant uptake until converted to sulfate. Process takes one to two weeks.
Potassium thiosulfate	0-0-25-17	Compatible with urea and ammonium poly-phosphate solutions in any ratio.
Magnesium sulfate	0-0-0-14	Water soluble.
Elemental sulfur	0-0-0-90	Elemental sulphur cannot be directly used by plants. It must first be converted to sulphate-sulphur (SO4-2 -S) by soil microorganisms.

Table 2.12 Other Fertilizers

Zinc Sulphate (ZnSO4)	36% Zn + 14% S	Dry product. Used to apply Zinc when deficient. Can be toxic if over applied.
Ferrous Sulphate (FeSO4)	20% Fe + 18.8% S	Apply as a foliar spray. Converted to unavailable forms in the soil. Iron chelates (Fe-EDDHA chelate and Fe-DTPA chelate) can be applied to the soil.
Manganese sulfate (MnSO4·3H2O)	27% Mn	Manganese fertilizer can be broadcast, banded in soil, or applied as a foliar spray.

Manure as a Fertilizer

Table 2.13 Typical nutrient contents in liquid swine effluent and fresh cattle pen manure samples in Saskatchewan

	Liquid Swine Manure (feeder hogs) Pounds per thousand gallons	**Fresh Cattle Penning Manure (with straw bedding)** % on dry weight basis
Nitrogen (N)	15 - 50	0.5 - 1.5
Phosphorus (P)	1 - 20	0.5 - 1.5
Potassium (K)	8 - 20	0.8 - 1.5
Sulphur (S)	0.1 - 3	0.08 - 0.15
Copper (Cu)	0.05 - 0.5	0.01
Manganese (Mn)	0.05 - 0.5	0.02
Zinc (Zn)	0.05 - 1.0	0.02
Boron (B)	0.01	0.005

Note: multiply P by 2.3 to convert to P2O5; multiply K by 1.2 to convert to K2O. Research by J. Schoenau, 1998-00

Table 2.14 Per cent of plant macronutrients available in hog manure overtime

	Year 1 %	**Year 2 %**	**Year 3 %**	**3 Year Total %**
Nitrogen - Mineral	100	0	0	100
Nitrogen - Organic	25	12	6	43
Phosphorus	50	12	6	68
Potassium	90	0	0	90
Sulphur	50	0	0	50

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Table 2.15 Yield increase of an oilseed (canola), a cereal (barley) and a forage grass (crested wheat grass) from injected swine manure effluent in east-central Saskatchewan.

Rate Gallons/acre	**Canola Yield** Bushels/acre	**Barley Yield** Bushels/acre	**Crested Wheat Grass** Tons/acre
0	10	38	0.48
3,300 (75 lbs N / acre)	23	75	1.10
6,600 (150 lbs N / acre)	31	80	2.02
13,200 (300 lbs N / acre)	29	74	1.98
Urea check (100 lbs N/ acre)	26	76	-

What is the safe rate for manure application?

- Safe rate of application will vary for each field and crop.
- Select a rate of applied manure that matches with crop demand and nutrient removal over time.
- Manure testing and soil testing should be done to determine the appropriate rate.
- Use application technologies that get the manure in the ground.

Should manure be injected/incorporated, or surface applied?

- Use application technologies that get the manure in the ground.
- Injecting or incorporating is recommend as surface application results in higher losses.
- However, injection has also shown to promote nitrous oxide production.
- Injecting/incorporating helps retain nutrients in soil, reduce runoff and minimize odour.

Challenges of using manures as fertilizers:

- Variability in nutrient content and low nutrient content.
- Do not necessarily match the crop's relative requirements.
- Some nutrients are present in the organic form and, therefore, are not plant available.
- Excessive manure application can cause lodging, haying off, salt loading and toxicity.
- Nutrient loading and pollution due to losses by leaching, erosion, gaseous escape.
- Sodium present in manure can decrease aggregation through particle dispersion.

Things to consider:

- Nutrient loading and escape issues do not appear to be a concern at agronomic rates. Agronomic rate is the rate of nutrient that is applied in balance with that needed by and removed by crops over the years.
- Water quality can be protected by recognizing potential for nutrient transport with run-off and leaching water, monitoring, addressing soil nutrient load through rate adjustment.
- When using manure as a fertilizer, it is important to understand that only a portion of the manure nutrients are immediately available.
- A major difference between animal manure and commercial inorganic fertilizers is that some of the nutrients in manure are in the organic form and must go through a decomposition process (mineralization) to be converted to inorganic forms available for plant uptake.
- This makes animal manure a more slowly available source of plant nutrients than commercial inorganic fertilizer N. However, it is the organic fraction of manure that also plays an important role in increasing soil organic matter content and tilth.
- Conduct soil tests to determine soil nutrient content and analyze the manure to determine manure nutrient content.
- Apply when temperatures are conducive to incorporate manure (do not apply to frozen ground).

Table 2.16 Comparison of solid manures and liquid effluents

	Pros	Cons
Solid manures	High organic matter. Improve soil tilth. Very effective in decreasing soil density. Increases pore spaces for air, water, and root exploration. Long term soil builder.	Slow availability of nutrients. Potential source of surface and groundwater contamination.
Liquid effluents	High availability in year of application.	Low organic matter. Potential source of surface and groundwater contamination.

Properties of liquid swine effluent:

- 15-50 lbs of total N per 1,000 gallons.
- 30-90 per cent of the total N is ammonium.
- Only 20-30 per cent organic N is available.
- 1-20 lbs of total P/1,000 gallons.
- 10-50 per cent of P is readily soluble.
- 8 to 20 lbs K/1,000 gallons.
- K is readily available to crops.

Properties of feedlot cattle manure:

- 10-20 per cent release of available N in year of application is typical for feedlot cattle manure.

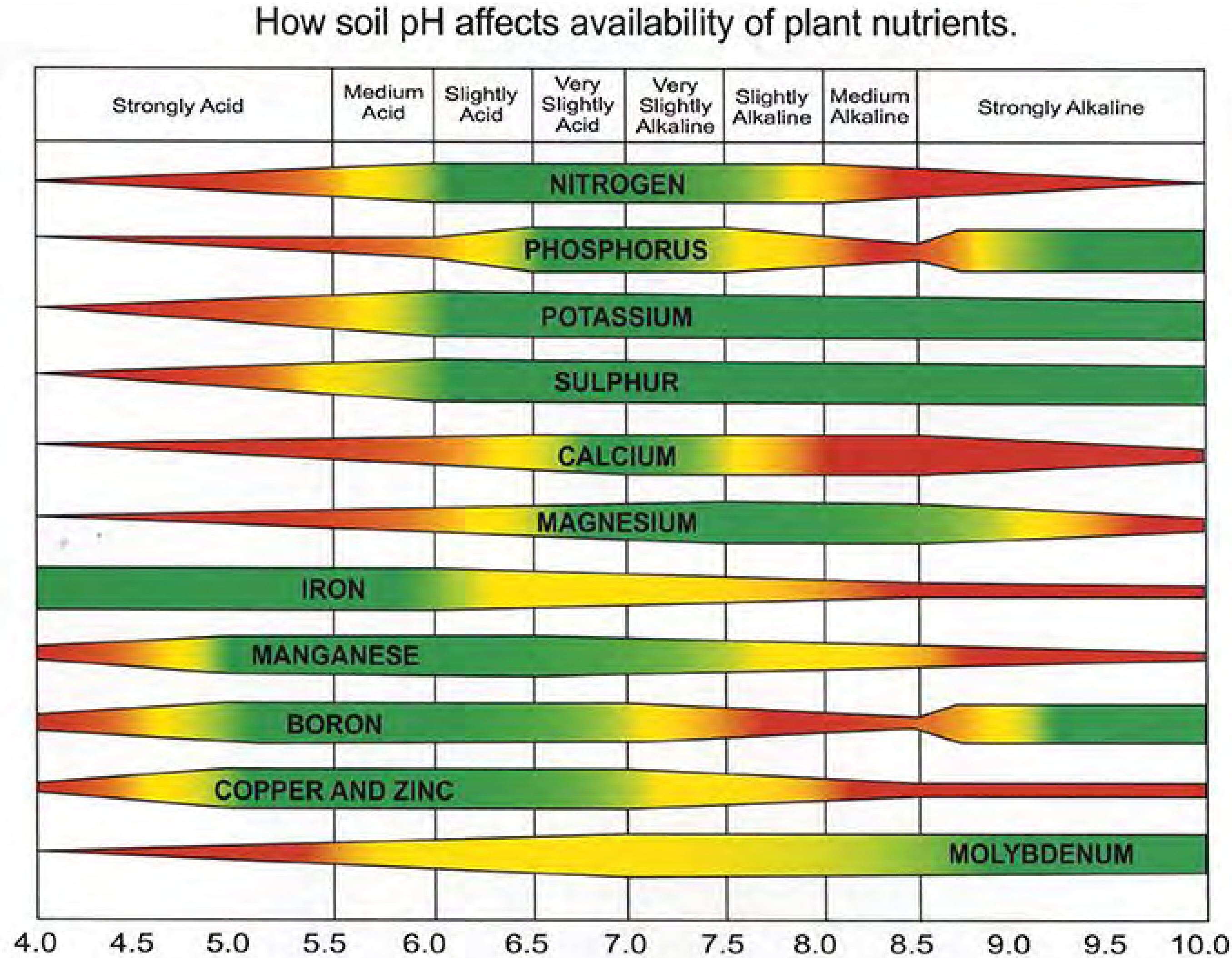
Benefits of using manure:

- Effective soil fertilizers for supplying plant nutrients and adding organic matter to agricultural soils.
- Increased crop growth from organic manure application results in increased plant residues, decaying roots and litter being returned to the soil and therefore an increase in soil organic matter (SOM).
- Increases in SOM from organic manure applications result in improved water holding capacity, infiltration, water stable aggregation, increased microbial activity and decreased bulk density and surface crusting.

The Importance of Soil pH

Soil pH is a measurement of the acidity or alkalinity of a soil. It is an often overlooked factor in a plant's overall health. Soil pH regulates the availability of nutrients in the soil, influences the chemical reactions of soil nutrients and can have an impact on herbicide effectiveness and carryover.

Figure 2.1 pH affects availability of plant nutrients



Besides affecting the availability of certain nutrients, acidic soil conditions also:

- Inhibit the growth of Rhizobium needed for effective nodulation by legumes.
- Cause herbicides in the imidazolinone family, such as Pursuit, to break down more slowly thereby increasing the risk of carryover injury.

Strongly alkaline soils will reduce the availability of phosphorus, calcium, iron, manganese, copper and zinc.

- There will also be greater losses of urea fertilizer to volatilization.
- Seed-placed urea damage is more likely to occur.
- Herbicide carryover damage is more likely to occur from herbicides in the sulfonyl urea and triazine family as breakdown of these herbicides is slowed.

Nodulation and Nitrogen Fixation Field Assessment Guide

Accurate field measurements of nitrogen fixation responses to inoculation with *Rhizobium* are often difficult, undependable and expensive. However, nitrogen fixation can be estimated through an assessment of nodulation and plant growth characteristics.

This guide will help growers and agronomists learn how to assess nodulation and nitrogen fixing potential in the field.

Nodule Assessment Timing

Nodulation assessments should be done during **early flowering**. Nodule formation begins approximately 14 days after crop emergence, but certain environmental conditions such as cool soil temperatures, pH extremes, extremely dry conditions and salinity can slow nodulation formation for up to three to four weeks.

Legume crops can be ranked according to their estimated ability to fix nitrogen: alfalfa > clover > faba bean > pea > chickling vetch > chickpea > lentil > soybean > lupin> dry bean.

Nodule numbers and nitrogen fixation rates generally are at a maximum during early-to mid-flowering. After flowering, nodule efficiency is reduced and they begin to shut down.

Assessment Procedure

- To assess the nodulation and nitrogen fixation potential of a legume crop, select five areas that are typical of that field at early flowering. Follow the steps listed below in each of the four areas:
  - » Evaluate plant growth and vigor of the area according to the assessment codes shown below.
  - » With a shovel, carefully dig up a minimum of two plants per area. Do not pull plants out of the soil as nodules are delicately attached to roots and can be easily lost.
  - » Carefully examine plant roots to assess the nodules. Depending on the soil type and condition, this may require gently agitating the roots in water.
  - » Assess the overall nodulation by comparing the calculated scores to those provided for the three categories in the assessment guide.

Assessment Codes

1. Plant and growth vigour

Assess colour and overall health of the plant:

- Plants green and vigorous 5
- Plants green and relatively small 3
- Plants slightly chlorotic (yellow) 2
- Plants very chlorotic (yellow) 1

Poor nitrogen fixation can cause nitrogen deficiency symptoms such as yellowing of the leaves at the base of the plant prior to flowering and poor plant development.

Nitrogen fixation efficiency can be estimated with nodule colour and the number of nodule clusters present. Carefully slice open the nodules. The strong pink colour of the nodules is caused by the presence of leghemoglobin, which must be present for active nitrogen fixation. If a nodule is brown, white or green it is considered non-effective.

2. Colour and abundance

- Greater than five clusters of pink pigmented nodules 5
- Three to five cluster groups of mostly pink nodules 3
- Less than three clusters of nodules OR white or green nodules 1
- No nodules OR white or green nodules 0

Figure 2.2 Faba beans in flower

Figure 2.3 Nodulation colour

3. Nodule position

- Both crown and lateral nodulation 3
- Mostly crown nodulation only 2
- Mostly lateral nodulation only 1

Crown nodulation is predominantly observed when seed is inoculated. Lateral nodulation is prevalent when native *Rhizobia* species exist in the soil or when granular inoculants are used. The crown region of a plant is generally the area of soil surrounding the seed. The approximate size of this region varies according to the crop.

Figures 2.4 Poor nodulation (left) and abundant nodulation on plant roots (center and right)

Table 2.17 Total nodulation score

11-13	Effective Nodulation	Numerous nodules that have good fixing nitrogen potential.
7-10	Effective Nodulation	Nodules present with limited nitrogen fixing potential.
1-6	Poor Nodulation	Few nodules present with very little to no nitrogen fixation potential.

In the field, a healthy plant does not always reflect effective nodulation and active nitrogen fixation. Localized soil environments, particularly with variations in soil nitrogen, may stimulate vigorous growth of the plant. Such situations are only apparent when the plants are excavated and examined for the presence of active nitrogen-fixing nodules.

To ensure that proper nodulation does occur, legumes need to be inoculated with the appropriate inoculant at the time of planting. As the table below indicates, each species of legume has its own inoculant that must be used. Using the wrong inoculant on the wrong crop will result in incomplete inoculation and poor to nonexistent nodulation.

Table 2.18 Rhizobium species required for legume crops

Pea, lentil, faba bean, chickling vetch	*Rhizobium leguminosarum*
Chickpea	*Rhizobium ciceri*
Dry bean	*Rhizobium phaseoli*
Soybean	*Bradyrhizobium japonicum*
Alfalfa, sweet clover	*Rhizobium meliloti*
Clover	*Rhizobium trifolii*
Fenugreek	*Rhizobium spp. Strain RGFU1*

Improper handling or misapplication of inoculants will also result in inoculant failure. If poor nodulation has occurred, investigate what inoculant was used and how it was stored and applied.

Inoculants are sensitive to granular fertilizer therefore, banding fertilizer to the side and/or below the seed is recommended. Inoculant should never be tank blended with fertilizer. Inoculants are also sensitive to some seed-applied fungicides. Check the labels of both the inoculant and seed treatment for compatibility. When using a combination of fungicide and inoculant, apply the fungicide to the seed first, allow it to dry, and then apply the inoculant immediately prior to seeding.

Inoculants are available in liquid, peat-based, and granular formulations.

Liquid-based products offer convenience and better control of application rate, compared to other forms. However, the rhizobia in these formulations are more susceptible to damage from environmental extremes and direct contact with seed treatments. If treated seed is planted immediately into a moist seedbed, liquid formulations perform well.

Peat-based formulations are more durable and less prone to damage from direct contact with seed treatments compared to liquid formulations, but care must still be taken. Some peat-based powder inoculants require the use of a sticker. Adhesion to the seed can be enhanced if the seed is slightly damp during inoculation.

Granular formulations offer ease of application and are less affected by environmental stress and seed-applied fungicides than other inoculant forms. These formulations should be applied in the seed row. Granular inoculants remove the risk of incompatibility with seed treatments, but care must still be taken to minimize risk of desiccation.

Note: inoculant notes- adapted from Sask Pulse Growers

Saskatchewan Soil Information System

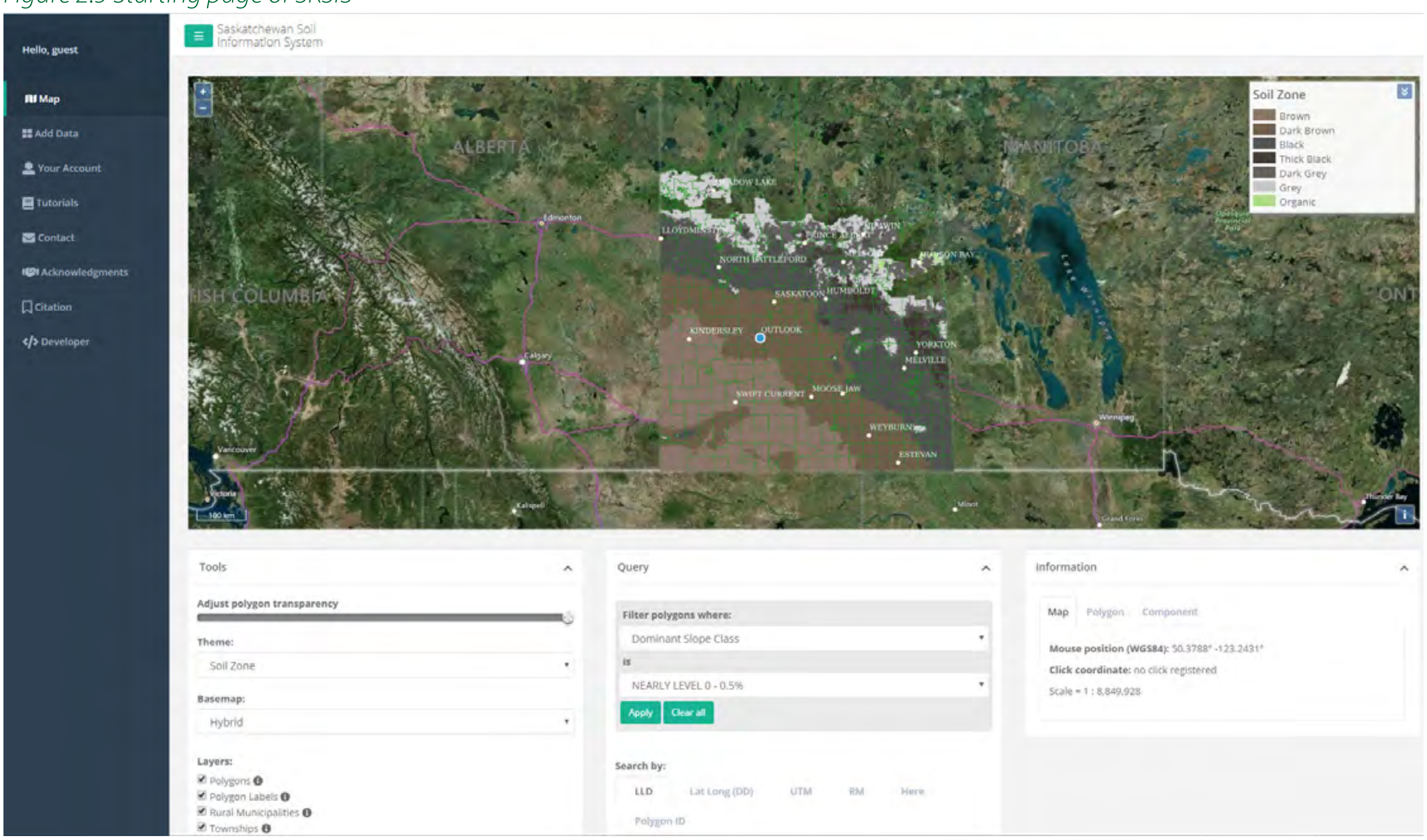
The Saskatchewan Soil Information System (SKSIS) is an interactive digital soil map evolved from the original Canadian Soil Survey Reports. The creation of this digital soil map has made soil information easily accessible to the public. You can learn about important soil and landscape characteristics by searching this database. When you type in the location details of the area you're interested in, the website automatically zooms to that area.

From there you can toggle through different map layers and see information like soil pH, soil texture, salinity, agricultural capability, slope class, stoniness and many other important soil and landscape characteristics. It is an important tool in interpreting soil tests results and developing management plans.

How to use Saskatchewan Soil Information System (SKSIS)- A digital soil map tool

1. Access SKSIS at http://sksis.usask.ca (Figure 2.5)

Figure 2.5 Starting page of SKSIS



Courtesy of: SKSIS

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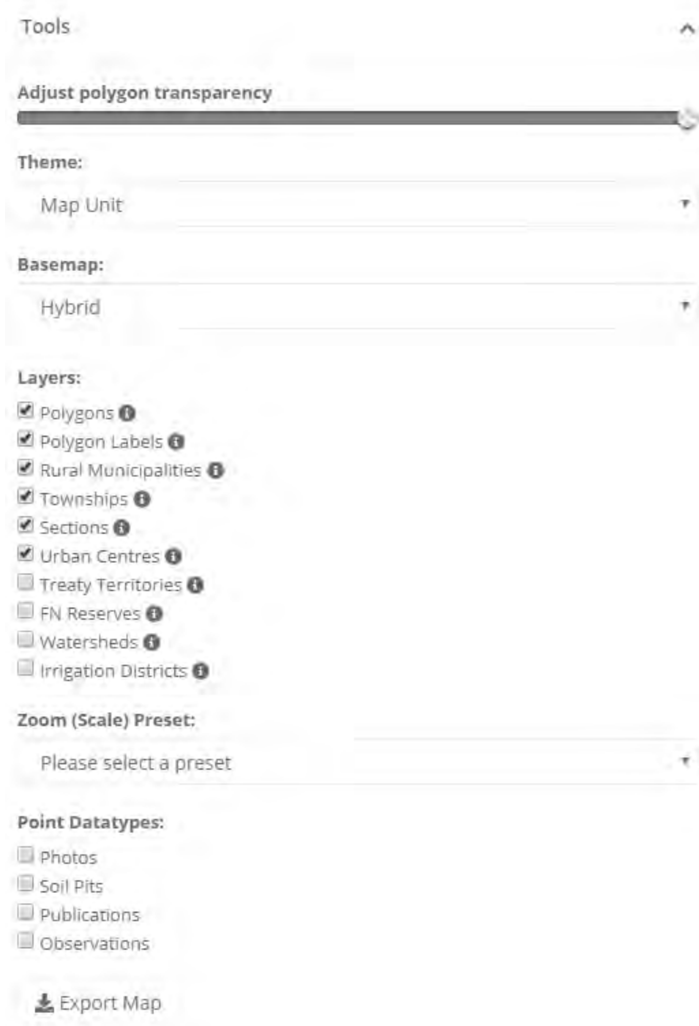
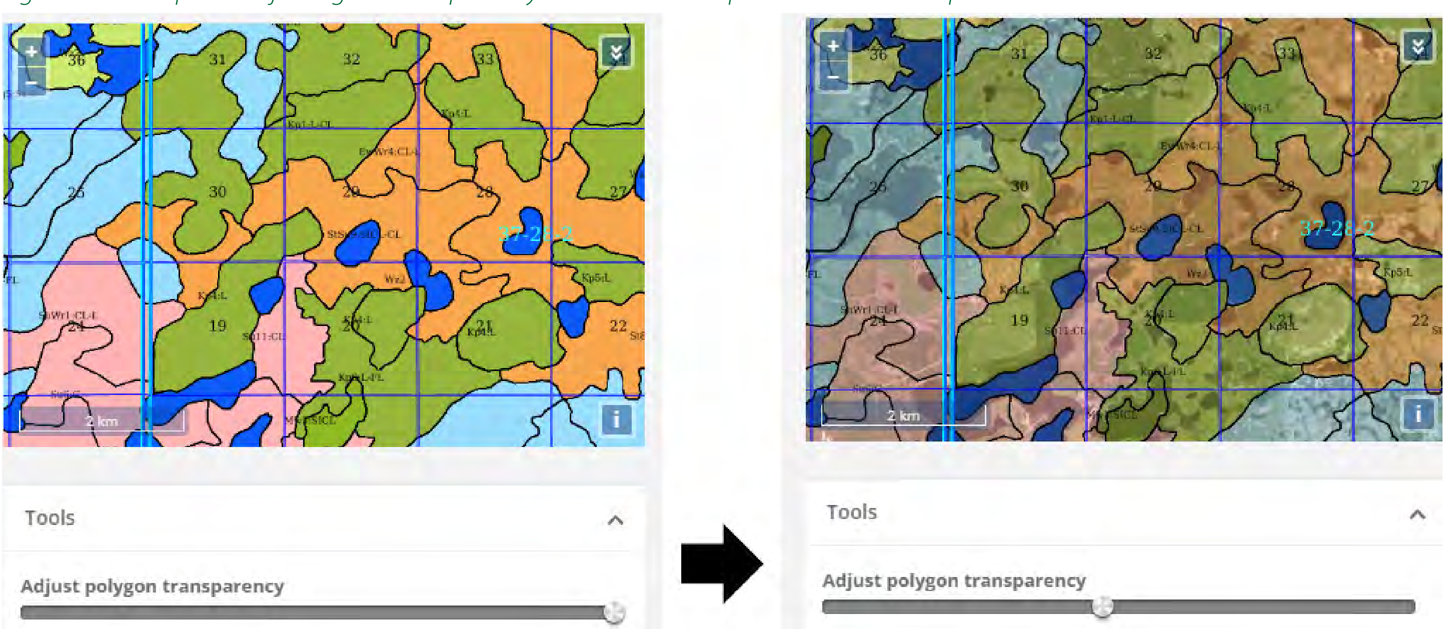
2. **First, you want to define what information you're looking for. Go to the "Tools" section. (Figure 2.6)**
   - The map theme refers to the soil information displayed by SKSIS polygons. Select "Map Unit" this is the soil survey code for the soil association and series, which describes the soil classes, parent material and texture found in the polygon. The other themes ("Soil Zone", "Ag Capability" and "Soil Texture") can be used to visually compare two or more areas by one metric (i.e. seeing soil texture change over a certain area).
   - Basemap refers to the map underlying the SKSIS information. It can be changed depending on what information you would like to see. Selecting "Hybrid" gives an aerial image with road and RM information.
   - Adjust the polygon transparency by dragging the knob along the slider. This makes the theme map transparent so you can see the basemap beneath the SKSIS polygons (Figure 2.7).
   - Leave the sections: "Layers", "Zoom Preset" and "Point Datatypes" as is unless you're looking for something specific.

Figure 2.6 Tools box showing the transparency adjustment, theme and basemap



Courtesy of: SKSIS

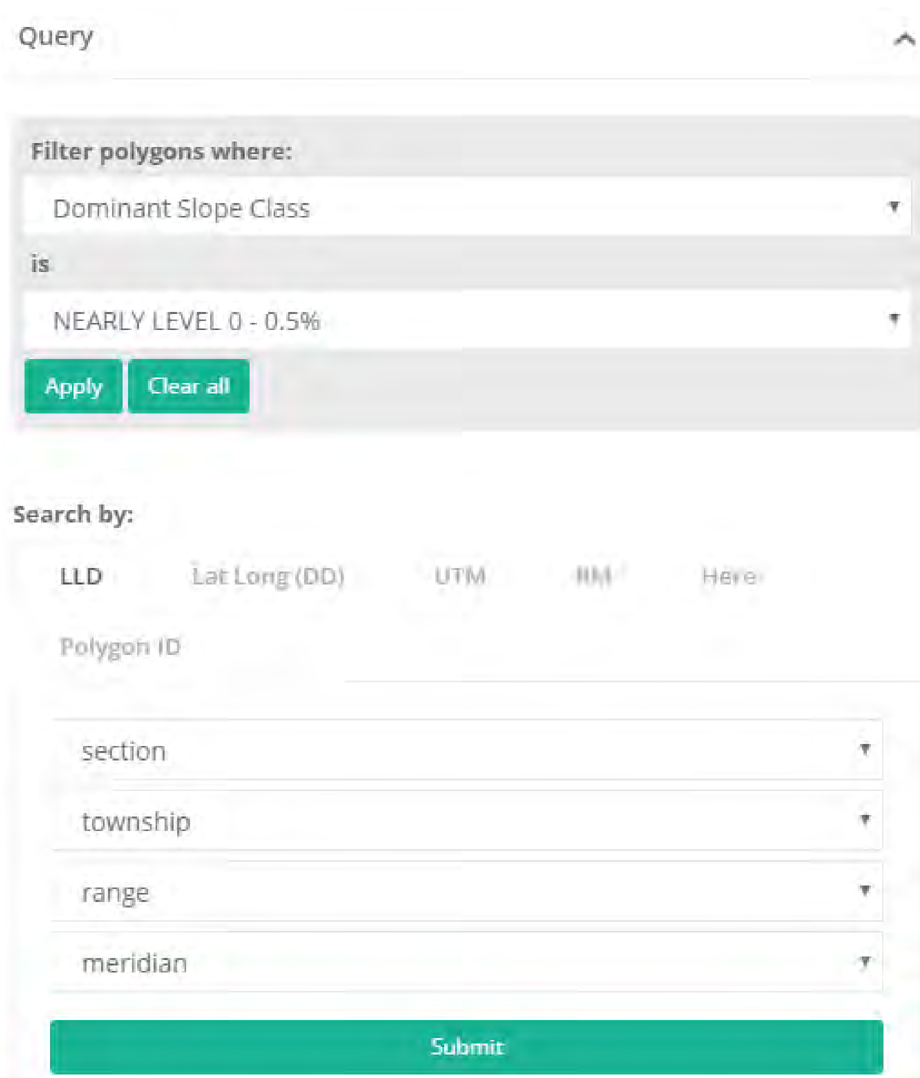
Figure 2.7 Example of adjusting the transparency of the theme map to see the basemap beneath it



Courtesy of: SKSIS

3. **Under the "Query" section, you can search by filtering out specific soils criteria or by using location details.**
    - Go to the "Search by" tab and enter in your preferred location details. This will automatically zoom to the area you're interested in (LLD, UTM, RM etc.) (Figure 2.8).

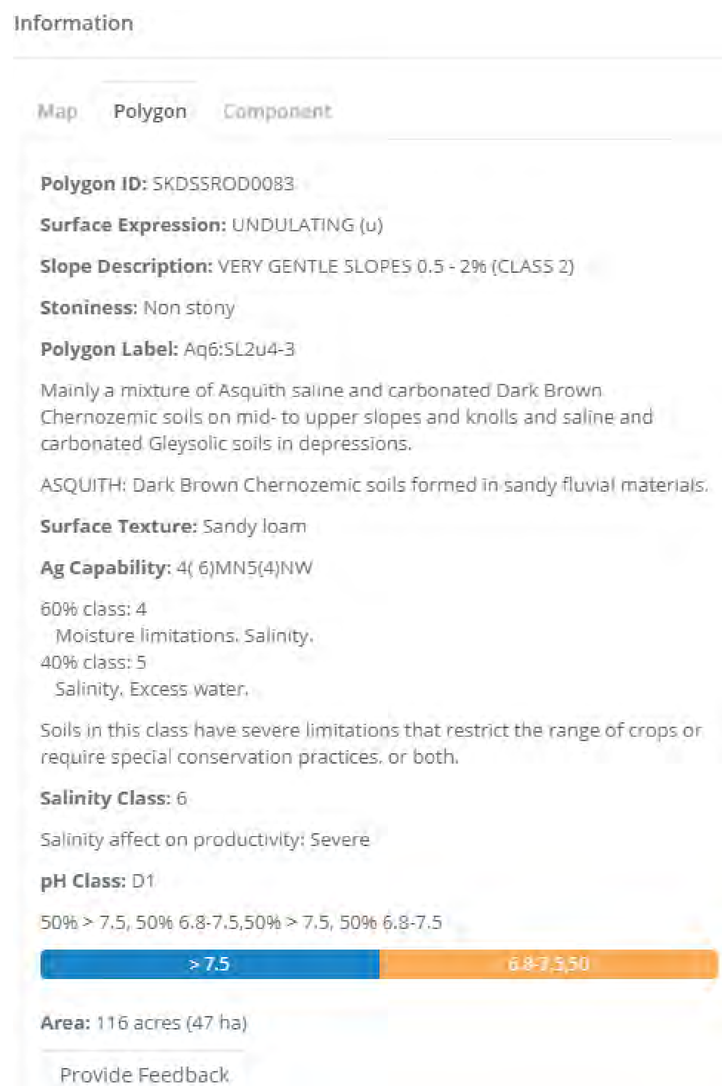
Figure 2.8 Query section showing the "Filter" tab, where you can search by specific soils criteria and the "Search by" tab, where you can search by location details



Courtesy of: SKSIS

4. **Once the map has zoomed into the area you are interested in, place a point on the map by clicking on the specific area.**
    - Under "Information: Polygon", (Figure 2.8) the soil map unit information can be found, this tab describes the soil characteristics of the polygon you clicked inside (Figure 2.9).

Figure 2.9 Information box showing the soils information of the polygon selected on the map.



Courtesy of: SKSIS

How to Interpret the Polygon Information

1. **Stoniness is an estimation of the average severity of stoniness in a polygon. Severity classes are rated zero through four.**

Table 2.19 Stone classes and descriptions

Symbol	Description
S0	Non stony
S1	Slightly stony-stones seldom hinder cultivation. Light clearing is occasionally required.
S2	Moderately stony-stones are a moderate hindrance to cultivation. Annual clearing is usually required.
S3	Very stony-stones cause serious hindrance to cultivation. Sufficient stones to require clearing on an annual basis.
S4	Excessively stony-stones prohibit cultivation or make clearing a major task. Cultivation is usually severely hindered, even after regular, heavy clearing.
U	Unclassified.

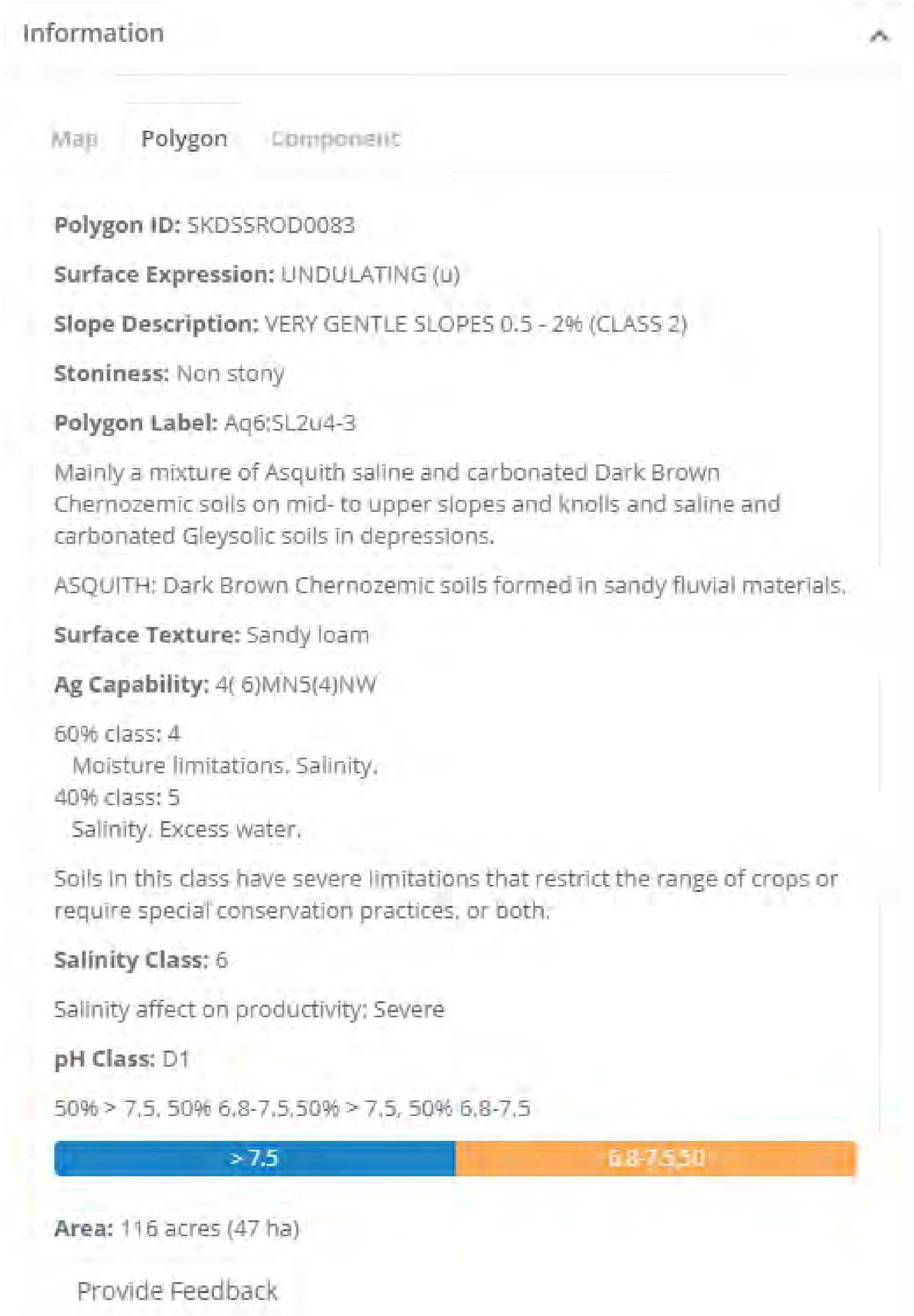
Courtesy of: Canadian Soil Information Service (CANSIS)

2. **The polygon label is a string of code that describes the soil association, soil series, soil texture, stoniness, slope class, surface expression and slope length. Beneath the polygon label is a detailed breakdown of the label (Figure 2.10).**

Figure 2.10 Polygon symbol showing what each component stands for (stoniness not depicted)

Courtesy of: (CANSIS)

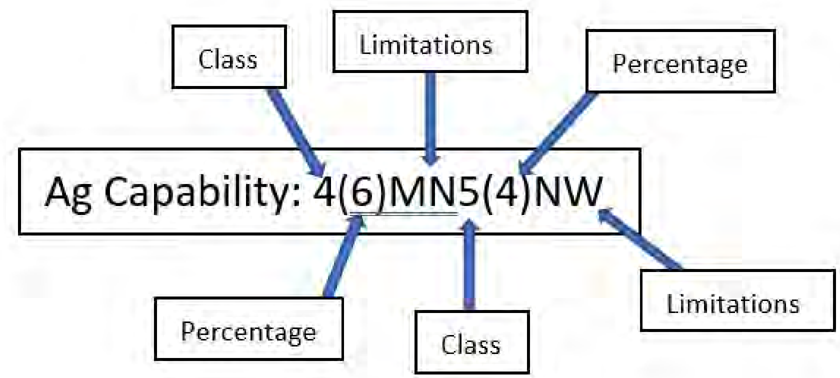
Figure 2.11 A more detailed breakdown of the soils information from the polygon label



Courtesy of: SKSIS

The agricultural capability section provides a string of text that describes the full agricultural capability rating. This label identifies the capability class, polygon percentage and specific limitations (Figure 2.12). The string is described beneath it so you don't have to interpret it (Figure 2.11). The class number refers to the severity of the limitation. The percentage describes the percentage of the area that is affected by the limitation. The limitation describes what that limitation is. Capability classes are numbered one through seven, based on severity of the limitation (Figure 2.12).

Figure 2.12 Ag capacity label showing the class, percentage and limitation



Courtesy of: SKSIS

Ag Capability explained in more detail. Showing the percentage of each class in the polygon selected and describing its agricultural limitations.

Ag Capability: 4(6)MN5(4)NW

60% class: 4
Moisture limitations. Salinity.

40% class: 5
Salinity. Excess water.

Soils in this class have severe limitations that restrict the range of crops or require special conservation practices, or both.

Courtesy of: SKSIS

Table 2.20 Agriculture capability classes

CLASS 1	Soils in this class have **no significant limitations** in use for crops.
CLASS 2	Soils in this class have **moderate limitations** that restrict the range of crops or require moderate conservation practices.
CLASS 3	Soils in this class have **moderately severe limitations** that restrict the range of crops or require special conservation practices.
CLASS 4	Soils in this class have **severe limitations** that restrict the range of crops or require special conservation practices, or both.
CLASS 5	Soils in this class have **very severe limitations** that restrict their use to the production of native or tame species of perennial forage crops. Improvement practices are feasible.
CLASS 6	Soils in this class are **capable of producing native forage crops only**. Improvement practices are not feasible.
CLASS 7	Soils in this class have **no capability for arable agriculture or permanent pasture**.

Courtesy of: CANSIS

3. **The salinity class section gives a general classification of the salinity present in the soils and a description of the salinity effect on productivity.**

4. **The pH class indicates the relative acidity or alkalinity of the surface layer of the soil (10-20cm). The surface pH classes are indicated by a letter X, A, B, C, or D ranging from moderately acidic to alkaline (Table 2.21). The class is then broken down into the percentage of the surface area in each pH range.**

Table 2.21 Surface pH classes

pH Class	pH Range	Description
X	less than 5.5	Moderately acid
A	5.5 to 6.0	Slightly acid
B	6.1 to 6.7	Slightly acid to neutral
C	6.8 to 7.5	Neutral to slightly alkaline
D	greater than 7.5	Alkaline

Courtesy of: CANSIS

Survey information presented in SKSIS is available through the Canadian Soil Information Service (CanSIS). The original Soil Survey Reports can also be accessed through CanSIS; these reports are excellent resources for descriptions of local soil associations, geology, landforms, climate, and hydrology.

Reference-SKSIS Working Group. 2018. Saskatchewan Soil Information System-SKSIS. A. Bedard-Haughn, M. Bentham, P. Krug, K. Walters, U. Jamsrandorj, and J. Kiss, eds. [Online] Available: sksis.usask.ca [March 10, 2020].

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Soil Texturing

Hand texturing is a tool you can use to get a fast and reliable texture reading on your soil. Soil textures can range from sand to clay to silt or a combination of any of these. A soil texture triangle depicts the many texture ranges of soil. Heavy textures are toward the top of the triangle and lighter textures toward the bottom as well as coarse textures toward the left side of the triangle and fine textures toward the right side (Figure 2.13). There is a simple process you can follow to find out the texture of your soil.

Figure 2.13 Soil texture triangle

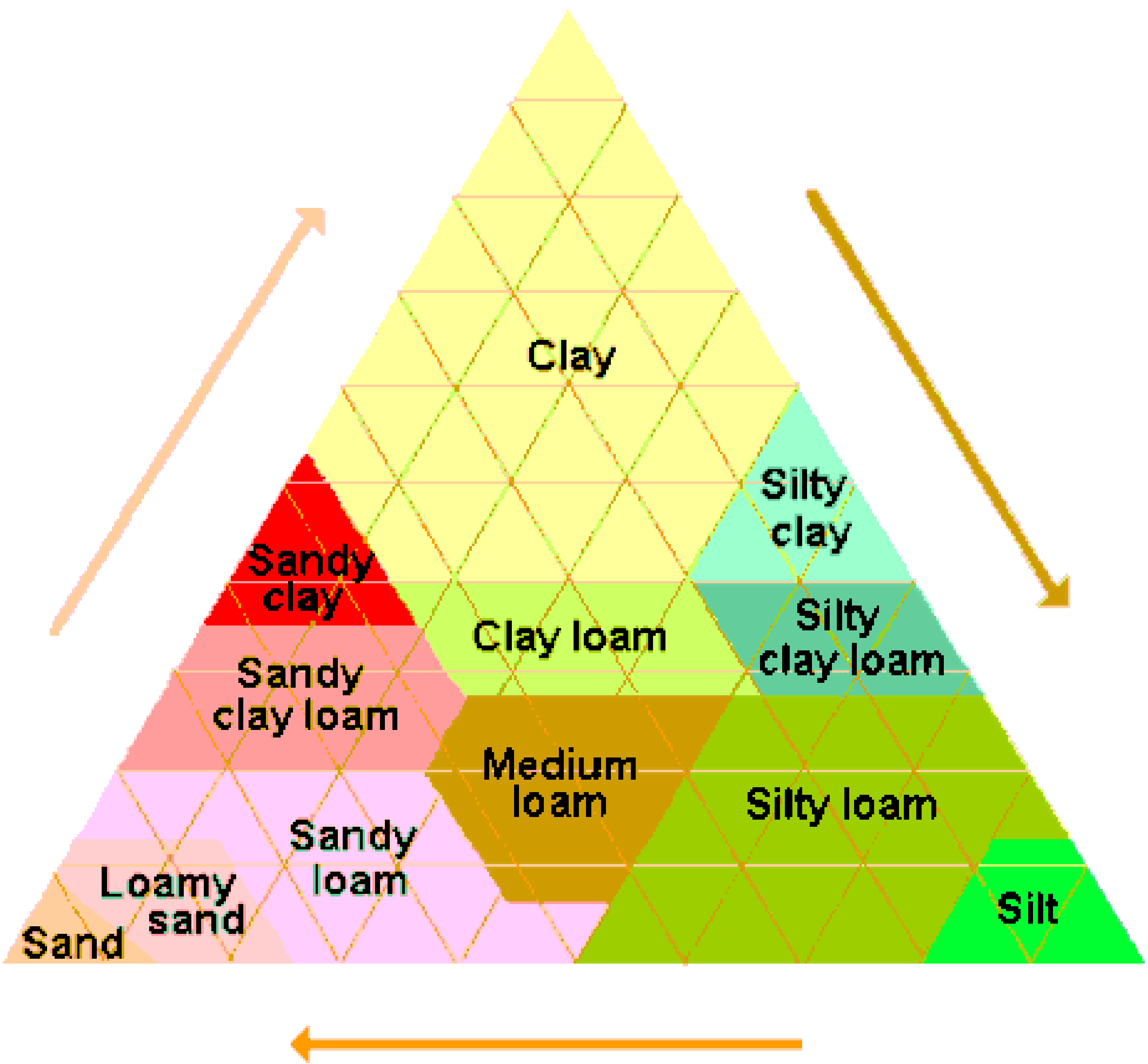


Figure 2.14 Hand texturing flow chart

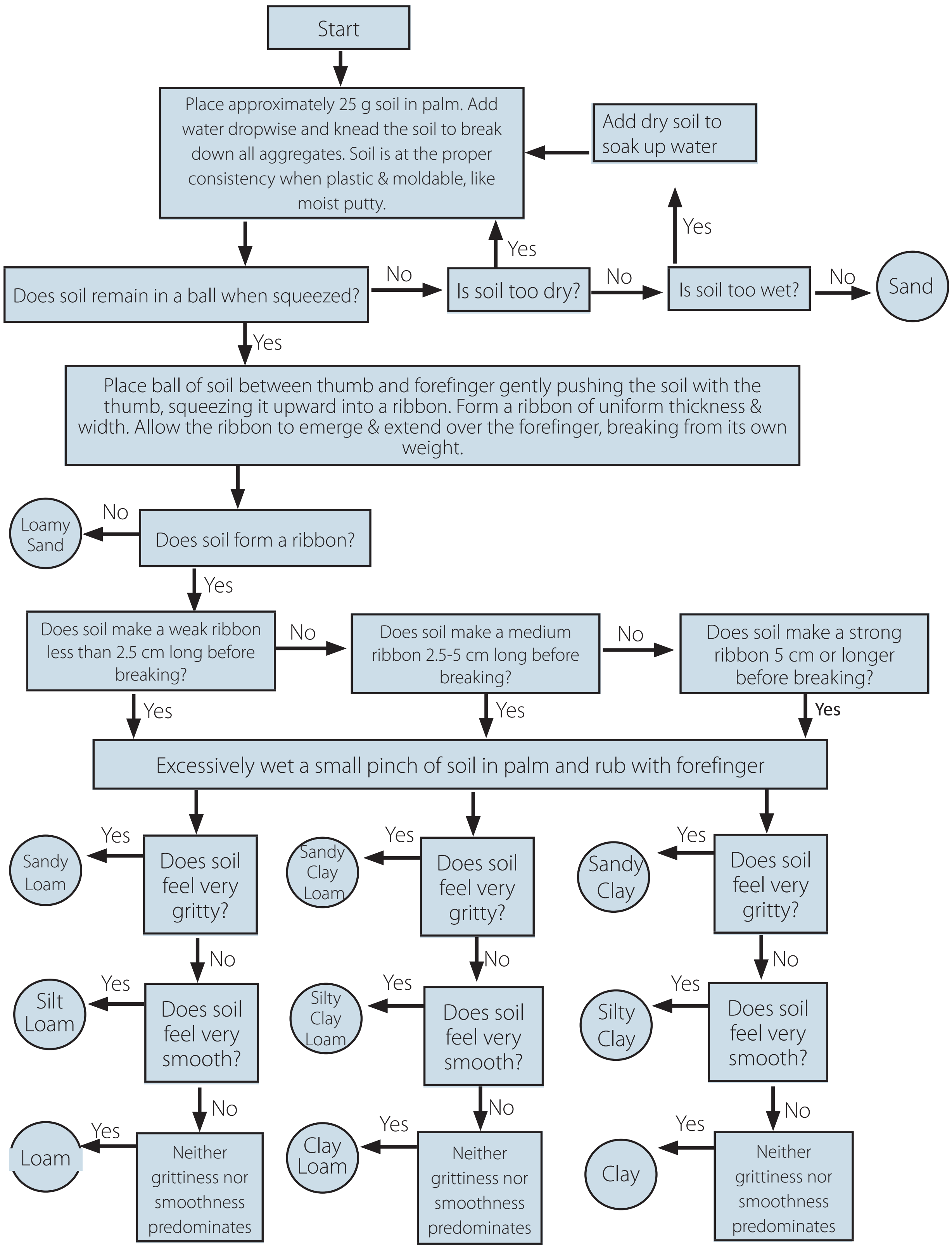


Figure 2.15 Steps for hand texturing soil

Figure A. Place approximately 25g of soil in palm.

Figure B. Soil should be moldable

Figure C. Does soil remain in a ball when squeezed?

Figure D. Does the soil form a ribbon?

Figure E. Measure the ribbon length to find category. Note: if it is close to 5cm choose the middle category rather than going up to the last category.

Figure F. Excessively wet a pinch of soil and feel for texture

For information on how to interpret soil tests, please view these online webinars:

https://register.gotowebinar.com/register/2651032889409714955
https://register.gotowebinar.com/recording/8640457524252492290

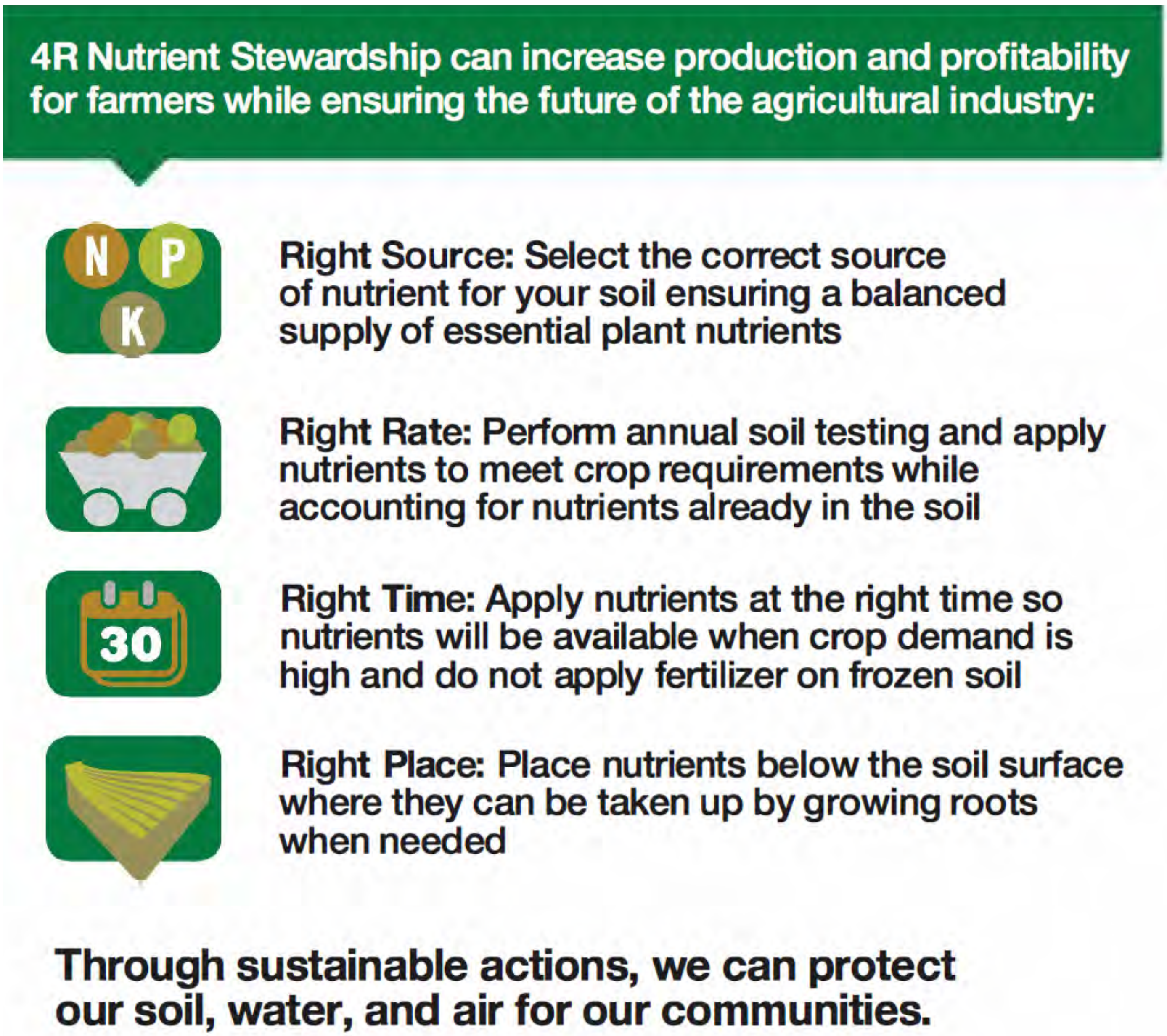
4R Nutrient Stewardship Designation

Farmers are increasingly facing pressures from the supply chain and the general public to demonstrate on farm stewardship and the 4R Nutrient Stewardship (Right Source @ Right Rate, Right Time, Right Place ®) Program can provide a strategic opportunity to meet those challenges. 4R Nutrient Stewardship provides a framework to achieve cropping system goals-increased production, increased farmer profitability, enhanced environmental protection and improved sustainability. 4R Nutrient Stewardship requires the implementation of best management practices (BMPs) that optimize the efficiency of fertilizer use. The goal of fertilizer BMPs is to match nutrient supply with crop requirements and to minimize nutrient losses. Selection of BMPs varies by location, and those chosen for a given farm are dependent on local soil and climatic conditions, crop, management conditions and other site specific factors. 4R Designation provides recognition for farmers who complete and apply 4R Nutrient Stewardship grower plans.

Minimize impact to the environment

Contribute to Canada's environmental goals by adopting 4Rs on farm. Retaining nutrients within a field's boundaries and in the crop rooting zone greatly reduces the amount that is not utilized by plants and escapes into the environment as pollution.

Figure 2.16 4R Nutrient Stewardship



Courtesy of: Fertilizer Canada

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Figure 2.17 4R Designation

Step	Grower	Agronomist	Agri-Retailer	Fertilizer Canada
1. Education	Learn about 4R Nutrient Stewardship (e.g. via web, print, workshop, conference) and see if it makes sense.	Ensure credentials are in good standing: • CCA • 4R eLearning (4R Nutrient Stewardship Training Parts 1-3 minimum, and other region-specific courses) • Other required provincial accreditations such as P.Ag/ Nutrient management planner where applicable	Corporate decision to buy-in Internal and external marketing 4R training (overarching and region-specific courses)	Fertilizer Canada maintains and communicates recent, updated programs to retailer.
2. Planning	Meet with the agri-retailer to develop 4R consistent plan along with fertilizer recommendations	Develop retailer procedures for 4R programming: • Training • Manuals • Other items of relevance Independents may have flexibility while larger companies may need ISO-type procedures	Work with 4R agronomist to provide 4R training to staff, update credentials as required and build 4Rs into agronomy software Meet grower to make NPK 4R consistent plan with CCA or equivalent advisor	Provide online system for agri-retailer to register 4R acres as they are approved by 4R agronomist
3. Reporting	Consent to have 4R consistent plan	Review and sign-off of 4R grower plan Report acres to Fertilizer Canada	-	Keep directory of 4R agronomists.
4. Implementation	Implement the 4R consistent plan	Follow up with agri-retail CCAs and growers to check on progress	-	Register information on acres, eco districts and crops under 4R Protect confidentiality of grower/agri-retailer and keep data simple.
5. Recognition	Receive 4R signage and recognition	Build relationship with customer	Support grower 4R implementation and provide recognition	Promote 4R designated agri-retailers through promotional boxes and communication pieces: press releases, industry partners, internal newsletters, etc.
6. Review	Review progress with agri-retailer	End of season tune-up with 4R consistent plan and actual implementation	Review progress with grower	Publish annual report of compiled 4R acres by crop type and region

Courtesy of: Fertilizer Canada

Nutrient Deficiency Symptoms

Nitrogen

Deficiency symptoms appear first on older leaves as light green to yellow foliage, and then develop on younger plant parts as the conditions become more severe. Other symptoms include: stunted, spindly plants, less tillering in small grains, low protein content in seed and vegetative parts and fewer leaves. Nitrogen (N) deficient plants will mature early with significantly reduced yield and quality.

Figure 2.18 Nitrogen deficiency in corn

Courtesy of: The Fertilizer Institute

Figure 2.19 Effect of starter N (UAN) in a no-till environment. Left-no starter N, Right-starter N applied with the planter.

Courtesy of: The Fertilizer Institute

Figure 2.20 Nitrogen deficiency in corn

Courtesy of: The Fertilizer Institute

Figure 2.21 Nitrogen deficiency in corn

Courtesy of: The Fertilizer Institute

Figure 2.22 Nitrogen deficiency symptoms in soybean

Courtesy of: The Fertilizer Institute

Figure 2.23 Nitrogen deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.24 Nitrogen deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.25 Nitrogen deficiency symptoms in wheat

Courtesy of: The Fertilizer Institute

Figure 2.26 Nitrogen deficiency symptoms in barley

Courtesy of: The Fertilizer Institute

Figure 2.27 Nitrogen deficiency symptoms in barley

Courtesy of: The Fertilizer Institute

Figure 2.28 Nitrogen deficiency symptoms in mustard

Courtesy of: The Fertilizer Institute

Figure 2.29 Nitrogen deficiency symptoms in flax

Courtesy of: The Fertilizer Institute

Figure 2.30 Nitrogen deficiency in pearl millet
Pale yellow chlorosis starts from the tip and proceeds down the leaf along the midrib in a V-shaped form. Chlorosis is followed by brown necrosis.

Courtesy of: The Fertilizer Institute

Figure 2.31 Nitrogen deficiency in pearl millet

Courtesy of: The Fertilizer Institute

Figure 2.32 Nitrogen deficiency in sorghum

Courtesy of: The Fertilizer Institute

Figure 2.33 Nitrogen deficiency symptoms in canola

Courtesy of: The Fertilizer Institute

Figure 2.34 Nitrogen deficiency symptoms in sunflowers

Courtesy of: The Fertilizer Institute

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Phosphorus

The first sign of a Phosphorus (P) shortage is an overall stunted plant. Leaf shapes may be distorted and tissue may be dark green in colour.

With severe deficiency, dead areas may develop on leaves, fruit, and stems. Older leaves are affected before younger ones.

Some plants, such as corn, may display a purple or reddish colour on the lower leaves and stems.

This condition is associated with accumulation of sugars in P-deficient plants, especially during times of low temperature.

Figure 2.35 Phosphorus deficiency symptoms in Chickpeas

Courtesy of: The Fertilizer Institute

Figure 2.37 Canola with phosphorus (left side of photo) and canola without phosphorus (right side of photo)

Courtesy of: The Fertilizer Institute

Figure 2.36 Phosphorus deficiency in barley

Courtesy of: The Fertilizer Institute

Figure 2.38 Phosphorus deficiency in canola leaves

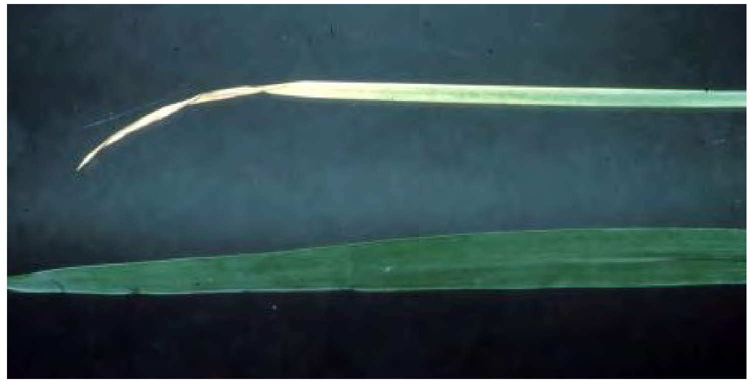
Courtesy of: The Fertilizer Institute

Figure 2.39 Phosphorus deficiency in canola leaves

Figure 2.40 Phosphorus deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.41 Phosphorus deficiency in wheat

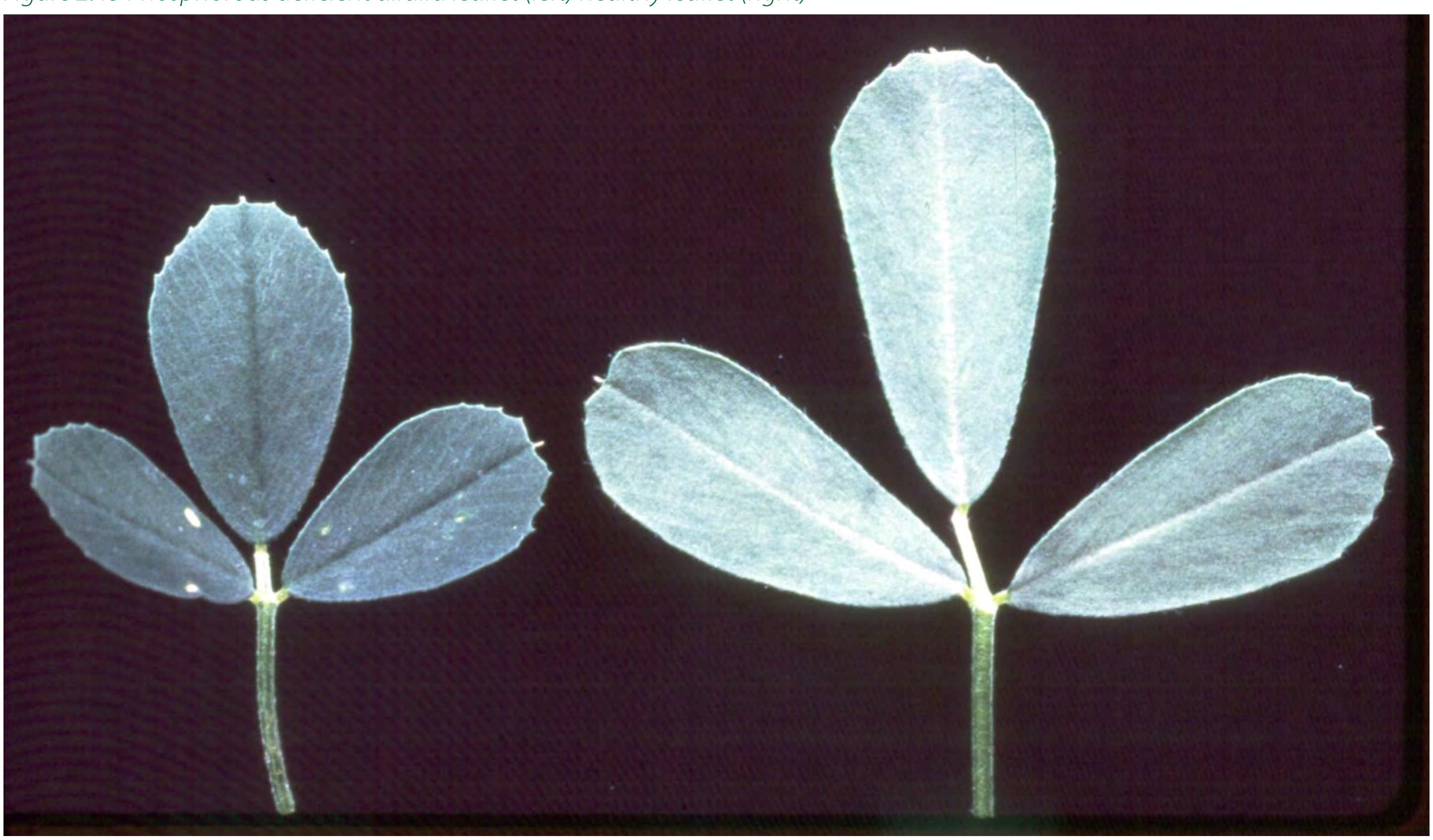


Courtesy of: The Fertilizer Institute

Figure 2.42 Phosphorus deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.43 Phosphorous deficient alfalfa leaflet (left) healthy leaflet (right)



Courtesy of: The Fertilizer Institute

Figure 2.44 Phosphorus deficiency in corn

Courtesy of: The Fertilizer Institute

Figure 2.45 Phosphorus deficiency in corn

Courtesy of: The Fertilizer Institute

Figure 2.46 Phosphorus deficiency in corn

Courtesy of: The Fertilizer Institute

Figure 2.47 Phosphorus deficiency symptoms in corn

Courtesy of: The Fertilizer Institute

Figure 2.48 Phosphorus deficiency in corn

Courtesy of: The Fertilizer Institute

Potassium

One of the most common potassium (K) deficiency symptoms is scorching or firing along leaf margins.

Since K is mobile in the plant, deficiency symptoms appear on older leaves first.

Potassium-deficient plants grow slowly and develop poor root systems.

Stalks are weak and lodging is common. Seed and fruit are small and shriveled; crops show lower resistance to disease and moisture stress.

Figure 2.49 Potassium deficiency in corn

Courtesy of: The Fertilizer Institute

Figure 2.50 Potassium deficiency in corn

Courtesy of: The Fertilizer Institute

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Figure 2.51 Potassium deficiency in corn

Courtesy of: The Fertilizer Institute

Figure 2.52 Potassium deficiency in corn

Courtesy of: The Fertilizer Institute

Figure 2.53 Potassium deficiency in soybeans

Courtesy of: The Fertilizer Institute

Figure 2.54 Potassium deficiency in soybean

Courtesy of: The Fertilizer Institute

Figure 2.55 Potassium deficiency in alfalfa

Courtesy of: The Fertilizer Institute

Figure 2.56 Potassium deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.57 Potassium deficiency in barley

Courtesy of: The Fertilizer Institute

Figure 2.58 Potassium deficiency in barley

Courtesy of: The Fertilizer Institute

Figure 2.59 Potassium deficiency in canola

Courtesy of: The Fertilizer Institute

Iron

Iron (Fe) deficiency starts with a yellowing of the leaves between the dark green veins, giving the leaves a spidery look.

Over time, the leaves become whitish and start to die back, eventually resulting in stunting and dying back of the entire plant.

Figure 2.60 Iron deficiency in chickpea

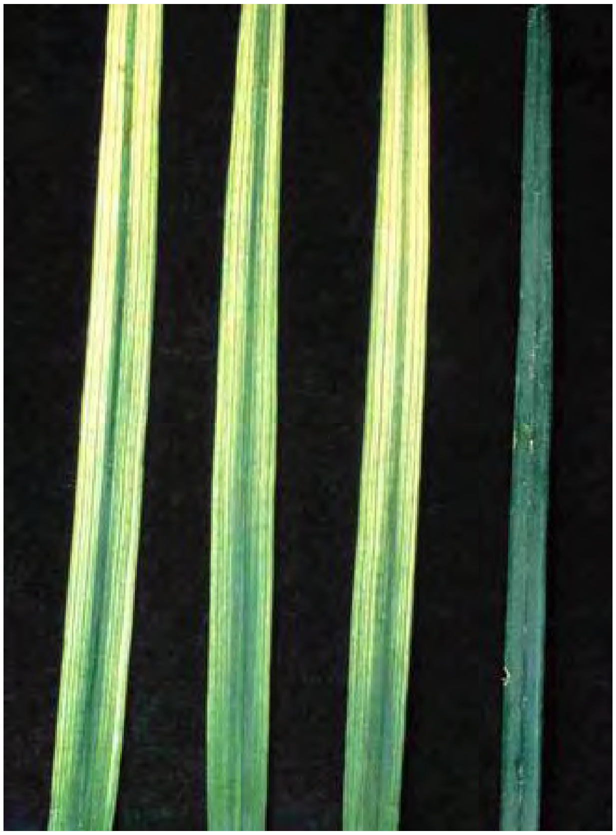
Figure 2.61 Iron deficiency in soybean

Courtesy of: The Fertilizer Institute

Figure 2.62 Iron deficiency in soybeans

Courtesy of: The Fertilizer Institute

Figure 2.63 Iron deficiency in wheat



Courtesy of: The Fertilizer Institute

Figure 2.64 Iron deficiency in wheat. Temporary fading of interveinal tissues with prominent green veins

Courtesy of: The Fertilizer Institute

Figure 2.65 Iron deficiency in barley. Deficiency symptoms first appear on younger leaves while older leaves remain normal.

Courtesy of: The Fertilizer Institute

Figure 2.66 Iron deficiency in barley.

Courtesy of: The Fertilizer Institute

Figure 2.67 Iron deficiency in corn. As Fe deficiency persists, prominent green veins fade and become light green to pale yellow.

Courtesy of: The Fertilizer Institute

Figure 2.68 Iron deficiency in pearl millet; symptoms first appear on younger leaves while older leaves appear normal.

Courtesy of: The Fertilizer Institute

Figure 2.69 Iron deficiency in canola

Courtesy of: The Fertilizer Institute

Sulphur

Sulphur (S) deficiency results in a uniform pale green chlorosis throughout the plant. Veins do not retain a green colour, and in many cases, they may be even paler than the interveinal tissue. In cultivars in which young leaves are normally green (i.e. lacking red pigmentation), the youngest leaves may appear pale earlier or more severely than mature leaves. This is not obvious in cultivars with red or purple tips.

A considerable reduction in growth may be suffered without the appearance of any visible symptoms. Clear symptoms are associated with severe stunting, accompanied by reduced leaf size, and reduced activity of axillary buds, resulting in less branching.

Figure 2.70 Sulphur deficiency in peas

Courtesy of: The Fertilizer Institute

Figure 2.71 Sulphur deficiency in canola

Courtesy of: The Fertilizer Institute

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Figure 2.72 Sulphur deficiency in canola

Courtesy of: The Fertilizer Institute

Figure 2.73 Sulphur deficient barley plant, showing pale yellow younger leaves with green older leaves.

Courtesy of: The Fertilizer Institute

Figure 2.74 Yellow chlorotic S deficient leaf (left) compared with normal green leaf (right).

Courtesy of: The Fertilizer Institute

Figure 2.75 Sulphur deficiency in wheat

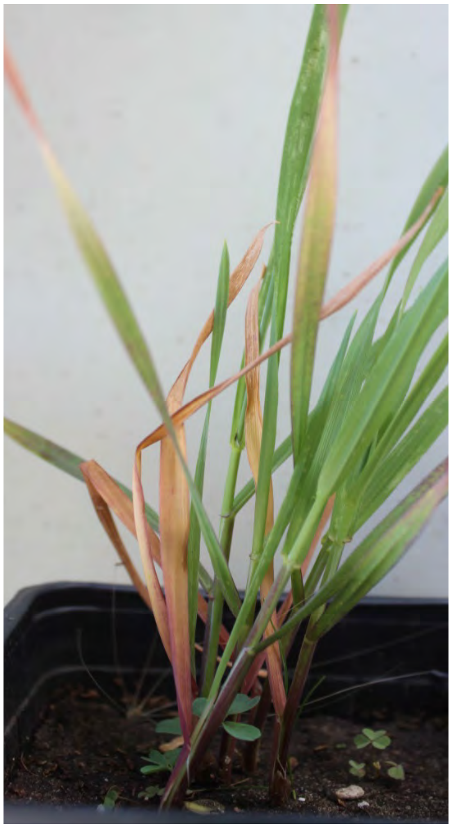

Figure 2.76 Sulphur deficiency in corn. Pale green upper leaves and darker lower leaves.

Courtesy of: The Fertilizer Institute

Figure 2.77 Sulphur deficiency in soybeans: Sulfur source trial with plot showing S deficiency

Courtesy of: The Fertilizer Institute

Figure 2.78 Sulphur sufficient alfalfa plant on the left Sulphur deficient alfalfa plant on the right

Courtesy of: The Fertilizer Institute

Figure 2.79 Sulphur sufficient (left) and sulphur deficient (right) in sunflower

Courtesy of: The Fertilizer Institute

Figure 2.80 Sulphur sufficient (left) and sulphur deficient (right) in flax

Courtesy of: The Fertilizer Institute

Figure 2.81 Sulphur deficiency in pearl millet

Courtesy of: The Fertilizer Institute

Figure 2.82 Sulphur deficiency in pearl millet. Top most, younger leaves are pale yellow, while older leaves remain green.

Courtesy of: The Fertilizer Institute

Calcium

Calcium (Ca) symptoms appear initially as localized tissue necrosis leading to stunted plant growth, necrotic leaf margins on young leaves or curling of the leaves, and eventual death of terminal buds and root tips.

Generally, the new growth and rapidly growing tissues of the plant are affected first.

Figure 2.83 Calcium deficiency in soybeans

Courtesy of: The Fertilizer Institute

Note: Notice the chlorotic leaves with cupped margins.

Figure 2.84 Calcium deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.85 Calcium deficiency in canola

Courtesy of: The Fertilizer Institute

Figure 2.86 Calcium deficiency in alfalfa (left) and a healthy plant (right)

Courtesy of: The Fertilizer Institute

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Figure 2.87 Calcium deficiency in corn

Courtesy of: The Fertilizer Institute

Figure 2.88 Calcium deficiency in corn

Courtesy of: The Fertilizer Institute

Calcium deficiency in corn may display the youngest leaves remaining rolled and joined together at their tips. Calcium deficient corn will have tip ends of the leaves glued together causing a ladder-like appearance.

Figure 2.89 Young leaf showing yellow to white lesions in interveinal tissues. The lamina tears off easily from these areas.

Courtesy of: The Fertilizer Institute

Magnesium

The first sign of Magnesium (Mg) deficiency will be the chlorosis of old leaves which progresses to the young leaves as the deficiency continues.

Figure 2.90 Magnesium deficiency in corn. Yellow to white interveinal chlorosis.

Courtesy of: The Fertilizer Institute

Note: The purpling colour along the edge of the leaves in the magnesium deficient corn images.

Figure 2.91 Magnesium deficiency in corn

Courtesy of: The Fertilizer Institute

Figure 2.92 Magnesium deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.93 Magnesium deficiency in soybeans

Courtesy of: The Fertilizer Institute

Figure 2.94 Magnesium deficiency in alfalfa

Courtesy of: The Fertilizer Institute

Manganese

Manganese (Mn) is often confused with, and occurs with, iron deficiency. Most common in poorly drained soils and where organic matter levels are high.

Manganese may be unavailable to plants where pH is high.

Figure 2.95 Manganese deficiency in soybean

Courtesy of: The Fertilizer Institute

Figure 2.97 Manganese deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.99 Manganese deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.96 Manganese deficiency in soybeans

Courtesy of: The Fertilizer Institute

Figure 2.98 Manganese deficient corn plant. Pale green young leaves with pale yellow interveinal chlorosis.

Courtesy of: The Fertilizer Institute

Figure 2.100 Manganese deficiency in corn

Courtesy of: The Fertilizer Institute

Boron

Symptoms of Boron (B) deficiency include; dying growing tips and bushy stunted growth; extreme cases may prevent fruit set.

Figure 2.101 Boron deficiency in canola deficient leaf (left) versus healthy leaf (right)

Courtesy of: The Fertilizer Institute

Figure 2.102 Boron deficiency in canola

Figure 2.103 Boron deficiency in canola

Courtesy of: The Fertilizer Institute

Figure 2.104 Boron deficiency in peas

Courtesy of: The Fertilizer Institute

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Figure 2.105 Boron deficiency in alfalfa

Courtesy of: The Fertilizer Institute

Figure 2.106 Boron deficiency in alfalfa

Courtesy of: The Fertilizer Institute

Figure 2.107 Boron deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.108 Boron deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.109 Boron deficiency in corn

Courtesy of: The Fertilizer Institute

Figure 2.110 Boron deficiency in sunflower

Courtesy of: The Fertilizer Institute

Figure 2.111 Boron deficiency in clover

Courtesy of: The Fertilizer Institute

Zinc

Zinc (Zn) deficiency appears as a chlorosis in the interveinal areas of new leaves, producing a banding appearance.

Leaf and plant growth become stunted with increasing severity of the deficiency and leaves eventually die and fall off the plant.

Figure 2.112 Zinc deficiency in soybean

Courtesy of: The Fertilizer Institute

Zinc deficiency in corn may initially display as white to yellow bands which begin at the base of the leaf. The midrib and leaf margins remain green.

Figure 2.113 Zinc Deficiency in Corn

Courtesy of: The Fertilizer Institute

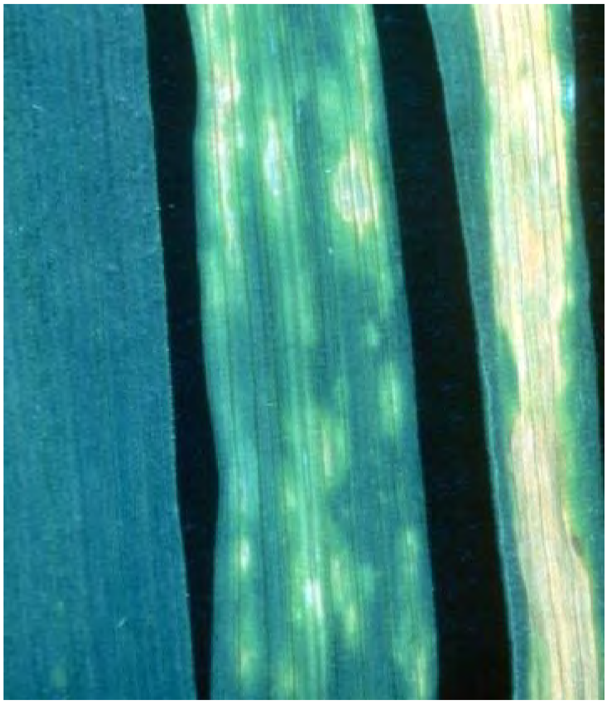
Figure 2.114 Zinc deficiency in corn

Courtesy of: The Fertilizer Institute

Figure 2.115 Zinc deficiency in corn. Close-up of leaf showing the symptomatic white band.

Courtesy of: The Fertilizer Institute

Figure 2.116 Zinc deficiency in wheat



Courtesy of: The Fertilizer Institute

Figure 2.117 Zinc deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.118 Zinc deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.119 Zinc deficiency in barley

Note: Initial Symptoms of zinc deficiency in barley may be exhibited by pale, yellow, linear, chlorotic areas.

Courtesy of: The Fertilizer Institute

Figure 2.120 Zinc deficiency in barley. Leaf showing advanced symptoms of grey or brown necrotic lesions.

Courtesy of: The Fertilizer Institute

Figure 2.121 Zinc deficiency in pearl millet; symptoms first appear on the top (younger) leaves.

Courtesy of: The Fertilizer Institute

Figure 2.122 Zinc deficiency in pearl millet. Close up of leaf showing the characteristic white band associated with Zinc deficiency.

Courtesy of: The Fertilizer Institute

Copper

Copper (Cu) deficiency may not be as easy to identify as other micro-nutrients; however, copper does not move in the plant so it appears first in younger growth. Often young growth is reduced, stunted, or distorted. Copper deficiency in wheat may exhibit as young leaves becoming pale green to yellow, as well the leaves may appear shriveled and/or broken.

Figure 2.123 Copper deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.124 Copper deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.125 Copper deficiency in wheat: Copper deficient plant showing wilting, rolling, and death of the tips of its youngest leaves.

Courtesy of: The Fertilizer Institute

Figure 2.126 Copper deficiency in barley

Courtesy of: The Fertilizer Institute

Figure 2.127 Copper deficiency in corn

Courtesy of: The Fertilizer Institute

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Molybdenum

Molybdenum (Mo) deficiency symptoms frequently resemble nitrogen deficiency. Older and middle leaves become chlorotic first, and in some instances, leaf margins are rolled and growth and flower formation is restricted.

Figure 2.128 Molybdenum deficiency in wheat

Courtesy of: The Fertilizer Institute

Chloride

Chloride (Cl) deficiency appears as chlorosis of the younger leaves and wilting of the plant.

Figure 2.129 Chloride deficiency in wheat

Courtesy of: The Fertilizer Institute

Figure 2.130 Chloride deficiency in canary seed (left) normal and (right) deficient

Courtesy of: Agriculture and Agri-Food Canada (AAFC)

Figure 2.131 Chloride deficiency in wheat showing with Cl treatment (left) vs no Cl treatment (right)

Courtesy of: The Fertilizer Institute

Section 3: Insects

Insect Pests of Canola and Mustard

Flea Beetles

Phyllotreta cruciferae (Goeze)-Crucifer flea beetle
Phyllotreta striolata (F.)-Striped flea beetle

Description

- Adult crucifer flea beetles (2-3mm) are small, black beetles with a metallic sheen. Striped flea beetles are similar in size and are black with distinctive yellow stripes down their backs.
- Larvae are grub-like with off-white bodies and a brown head. Larvae are present in mid-June to late-July and feed on root hairs and taproots of seedlings.

Figure 3.1 Striped flea beetle on canola cotyledon

Figure 3.2 Crucifer flea beetles

Damage

Adult beetles emerge from leaf litter and shelterbelts and begin feeding on whatever brassicaceae plants are available. These can sustain adults until the emergence of canola seedlings. Striped flea beetles emerge about two weeks before crucifer flea beetles and can be present in large numbers as early as mid to late-April. Adults feed on cotyledons, leaves, petioles and stems in the spring and pods of crucifer plants in late summer.

Scouting

Scout fields in early spring for damage to newly emerging seedlings. Warm, sunny, dry weather increases the intensity of feeding, particularly on days above 14 C. Continue scouting for 14 days after emergence or until plants reach the three to four leaf stage when plants can generally outgrow feeding damage. Meristem or stem feeding is most severe on new seedlings.

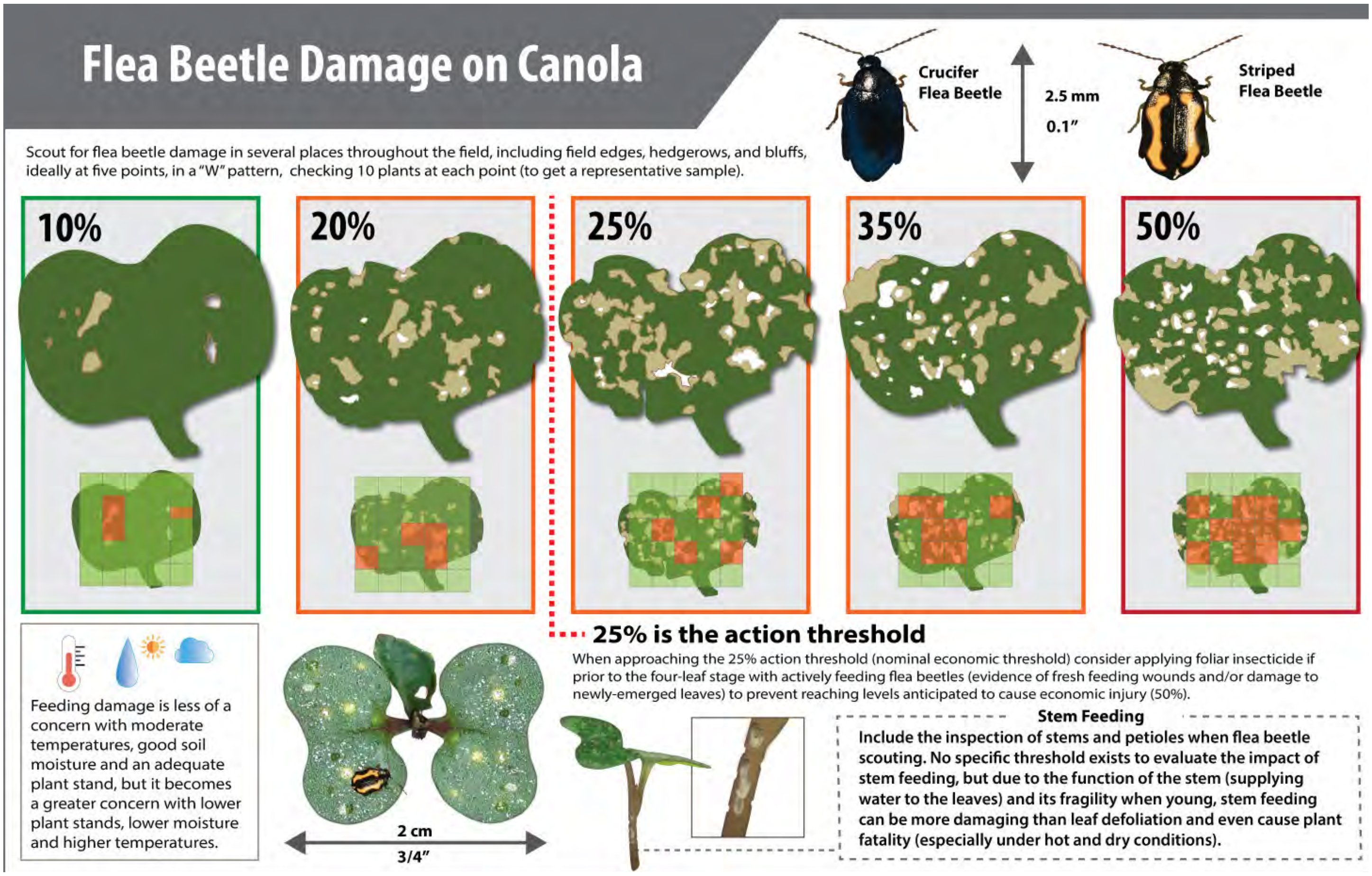
Economic Threshold

Consider foliar treatments at 25 per cent cotyledon leaf damage if flea beetles are present and actively feeding.

Mode of Transmission

Flea beetles overwinter (as adults) near the surface of the leaf litter, grass and debris beneath hedges, shelterbelts, poplar groves and in association with canola stubble and volunteer cruciferous plants belonging to the family Brassicaceae or (previously referred to as) Cruciferae.

Figure 3.3 Cotyledon damage from flea beetle feeding



Courtesy of: Canola Council of Canada

Lygus Bugs

Lygus elisus (Van Duzee)– pale legume bug
Lygus lineolaris (Palisot de Beauvois)– tarnished plant bug
Lygus hesperus (Knight)– western tarnished plant bug
L. keltoni (Schwartz)
L. borealis (Kelton)

Description

- Adults (6 mm long) vary pale green to reddish brown to black, uniform to mottled colour; display the distinctive, triangular or "V"-shaped marking in the upper center of their backs and membranous wingtips.
- Mature nymphs have a similar colouration to adults but with black dots on its back. Wingbuds are noticeable.

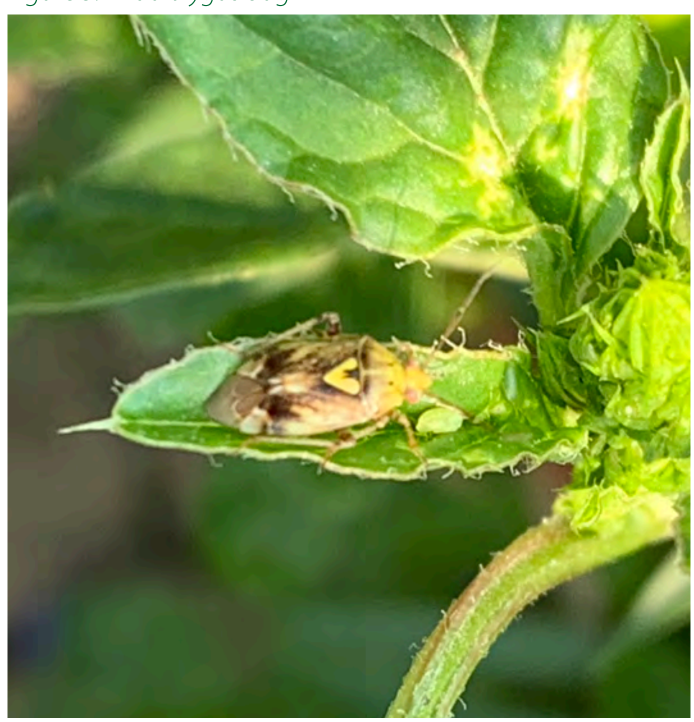
Damage

Adults and nymphs feed on new growth and flower buds, seeds and pods of plants by piercing tissues to extract fluids. Buds will turn white and fail to develop and flowers and pods can fall.

Mode of Transmission

Lygus bugs overwinter as adults by finding shelter under plant litter in shelterbelts, headlands, uncultivated areas, and field margins.

Figure 3.4 Adult lygus bug



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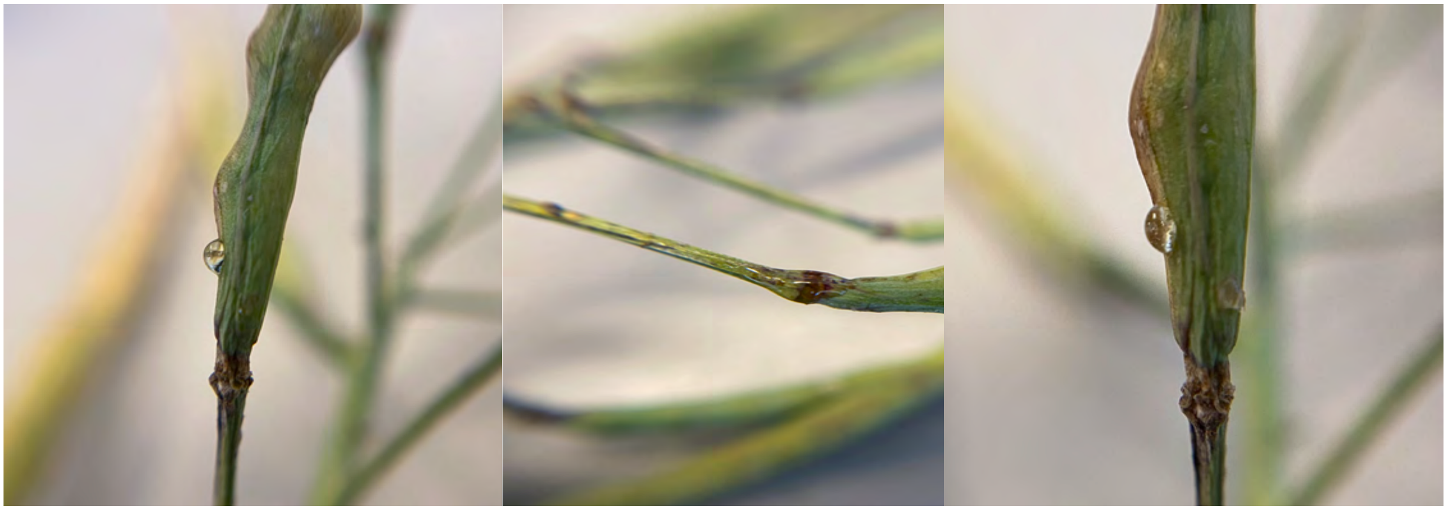
Scouting

Canola thresholds are based on the number of lygus bugs sampled per 10 sweeps. Canola should be sampled as flowering ends (Zadok stage 4.4*), particularly if precipitation is low. If densities are near but less than the threshold at stage 4.4*, canola should be re-sampled at stage 5.1* (when seeds in the lower pods are full size, translucent). If densities are sufficiently high, control is still warranted at stage 5.2* (seeds in lower pods green).

Lygus bug densities should be determined from a minimum of 15 samples of 10 sweeps or 10 samples of 20 sweeps per field. Samples can be collected from along the edge or at right angles from the edge of the field. Research has shown that samples taken along the edge of commercial fields and at various distances into the field all gave similar estimates of plant bug density. Sampling along the edge reduces effort during years when thick crop growth impedes access to the field. For edge sampling, the area selected for sampling should be at a crop stage similar to that in the main part of the field.

*Refer to Zadoks Plant Staging Guide

Figure 3.5 Damage from lygus bugs on canola pods



Recent research indicates that with modern varieties, a threshold of two to three per sweep is appropriate and avoids unnecessary applications. Include mature nymphs in counts.

Table 3.1 Economic thresholds at the end of flowering in canola

Application Cost	**End of Flowering (Canola Crop Zadok Stages 4.4-5.1)[1]**					
$/ac	Economic Injury Level (# of lygus bugs found in10 sweeps)					
8.00	11	8	7	5	5	4
10.00	13	10	8	7	6	5
12.00	16	12	10	8	7	6
14.00	19	14	11	9	8	7
16.00	22	16	13	11	9	8
18.00	24	18	15	12	10	9
Canola Price ($/bu)	6.00	8.00	10.00	12.00	14.00	16.00

Courtesy of: Modified from Wise and Lamb. The Canadian Entomologist , Volume 130, Issue 6 , December 1998 , pp. 825-836

Note: Calculated based on an assumed loss of 0.1235 bu/acre for each lygus bug per 10 sweeps.

[1]Crop stages of Harper and Berkencamp (1975):

4.4 is flowering complete, seeds enlarging in lower pods;

5.1 is when seeds in the lower pods are full size, translucent;

5.2 is when seeds in the lower pods are green.

When precipitation is greater than 100 mm from the onset of bud formation to the end of flowering, the plant may partially compensate for damage by lygus bugs. There is recent evidence that canola compensates for low numbers of Lygus (one or fewer per sweep).

Table 3.2 Economic thresholds of pod ripening in canola

Application Cost	Pod Ripening (Canola Crop Zadok Stages 5.2)[1]					
$/ac	Economic Injury Level (# of lygus bugs found in 10 sweeps)					
8.00	15	12	9	8	7	6
10.00	19	14	11	10	8	7
12.00	23	17	14	11	10	9
14.00	27	20	16	13	11	10
16.00	30	23	18	15	13	11
18.00	34	26	20	17	15	13
Canola Price ($/bu)	6.00	8.00	10.00	12.00	14.00	16.00

[1] Calculated based on an assumed loss of 0.0882 bu/acre for each lygus bug per 10 sweeps.

Courtesy of: Modified from Wise and Lamb. The Canadian Entomologist , Volume 130, Issue 6 , December 1998, pp. 825-836

Lygus Bug Economic Thresholds

In canola, economic thresholds should be considered for lygus bugs at the end of the flowering and early pod ripening stages. The commonly used economic thresholds show the number of lygus bugs (per 10 sweeps) where the cost of pest control equals the damage.

While these economic threshold tables (Table 3.1 and 3.2) are still being used, there has been more recent research that has shown that the economic threshold range of 2-3 lygus per sweep (20-30 lygus per 10 sweeps) is more appropriate for current practices along with the current canola cultivars grown.

Bertha Armyworms

Mamestra configurata (Walker)

Description

- Adult moths are predominately grey with flecked patches of black, brown, olive or white scales; active mostly at night.
- Newly emerged larvae (0.3 mm long) are pale green with pale yellow stripes along each side. Mature larvae (up to four cm long) are a green to brown or velvety black colour with a yellowish orange stripe down each side.

Figure 3.6 Bertha armyworm

Figure 3.7 Bertha armyworm

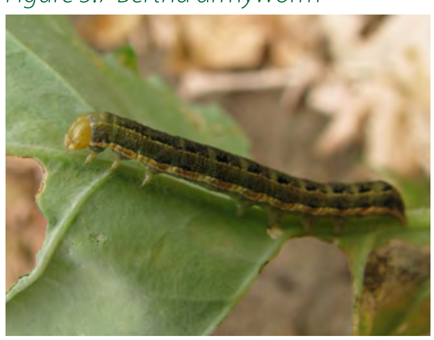


Figure 3.8 Bertha armyworm egg cluster

Damage

Larvae will chew irregular shaped holes in leaves. Feeding can also be on stems or pods, giving a striped look. Larvae will chew into pods and eat seeds.

Scouting

Larvae can be on upper or underside of leaves and will drop off plant and/or curl up when disturbed. The larvae can be difficult to see and may be hidden in soil, under leaf litter or curled in leaves. Most damage occurs from the end of July to late August.

Larvae take about six weeks to develop from egg to pupa and darken with each moult. Adult flight occurs during early June to mid-July.

Economic Threshold

The economic threshold for bertha armyworm varies with the cost of the insecticide, the method of application and the value of the crop. Using current crop value ($/bushel) and application costs ($/acre), Table 3.3 indicates the larval density (number of larva per square metre) at which an insecticide treatment in canola is warranted. For example, at a crop value of $7/bushel and a spraying cost of $8/acre, the threshold level is 20 larvae per square metre.

Mode of Transmission

Bertha armyworm overwinters as pupae in the ground at depths of five to 16 centimetres (two to 6.3 inches).

Figure 3.9 Bertha armyworm pupae

Figure 3.10 Bertha armyworm adult moth

Figure 3.11 Bertha armyworm trap

Table 3.3 Economic thresholds for bertha armyworm on argentine canola, B. napus

Spraying Cost-$/ac	Expected seed value-$/bushel										
	$6.00	$7.00	$8.00	$9.00	$10.00	$11.00	$12.00	$13.00	$14.00	$15.00	$16.00
	# larvae/ metre^2										
6.00	17	15	13	11	11	10	9	8	7	7	6
7.00	20	17	15	13	12	11	10	9	9	8	8
8.00	23	20	17	15	14	13	12	10	10	9	9
9.00	26	22	19	17	16	14	13	12	11	10	10
10.00	29	25	22	19	17	16	15	13	12	11	11
11.00	32	27	24	21	19	17	16	14	13	13	12
12.00	34	30	26	23	21	19	17	16	15	14	13

Modified from Bracken, G. K., and G. E. Bucher. Journal of Economic Entomology. 1977 Dec 1;70(6):701-5
Based on normal feeding activity: an average of 0.058 bushels/larva/acre/day

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Diamondback Moth

Plutella xylostella L.

Description

- Adult moths are approximately 8-9 mm long with a wing span of 12-15 mm. At rest, the moth folds its wings to cover the abdomen in a tent-like manner. Wings flare upward at the tips and wing tips are fringed with long hairs.
- Larvae are pale yellowish to green caterpillars covered in fine, erect hairs. At maturity larvae are spindle or cigar shaped and about 12 mm long. Larvae pupate in delicate, white open mesh cocoons attached to leaves, stems or pods.

Figure 3.12 Mesh cocoon of diamondback moth

Figure 3.13 Diamondback moth larvae

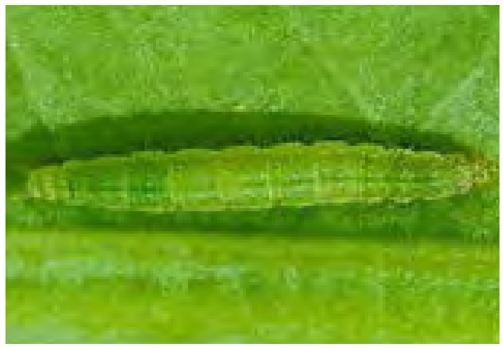


Figure 3.14 Adult diamondback moth

Damage

Crop damage is caused by the larval stage. Larvae prefer to feed on leaves but will also feed on any green tissue on host plants. Damaged leaves will have small irregular holes. Larvae can eat an entire leaf, leaving only the veins. Newly hatched larvae tunnel leaves. Larger larvae feed on buds, flowers and young pods.

Scouting

Look for crop damage in late-June to early-August on leaves, stems, flowers and pods. Crop damage is usually first evident on ridges and knolls in fields. When disturbed, larvae will wriggle violently and may drop from the plant attached with a silken thread. They will eventually return to the leaf and continue to feed. They are blown in on high-altitude winds as early as April.

Economic Threshold

- 100 -150 larvae/m^2 in immature and flowering canola
- 200-300 larvae/m^2 in podded canola

Mode of Transmission

Very few, if any, pupae survive the long, cold Canadian winters. They are blown into Manitoba, Saskatchewan and Alberta on high altitude winds as early as April. Diamondback moth does not overwinter in Saskatchewan in large numbers.

Figure 3.15 Diamondback moth hanging from plant with silken thread

Figure 3.16 Diamondback monitoring trap

Cabbage Seedpod Weevils

Ceutorhynchus obstrictis (Marsham)

Description

- Adults are approximately 3-4 mm long and ash-grey. They have a prominent curved snout that is characteristic of long-snouted weevils. It takes approximately eight weeks for cabbage seedpod weevils to develop from egg to adult. Pupation occurs in the soil in an earthen cell.
- Larvae are small, white and grub-like. Larvae hatch from eggs deposited in holes the female chews in pods and feed on developing seeds.

Damage

Adult weevils feed on developing flower buds. Larvae feed within pods and exit by chewing a small circular hole in the pod walls. Both the egg laying hole made by the female and the exit hole caused by the larvae can contribute to shatter and allow disease to enter.

Note: Yellow mustard is resistant to cabbage seedpod weevil, however economic damage can occur in brown and oriental mustard.

Scouting

When disturbed, adult cabbage seedpod weevil will drop to the ground and play dead. Monitoring for adults can be done by sweeping fields at bud to flowering stage.

Economic Threshold

- Two to four adults per sweep.
- Insecticide application targets adults when crops are in 10 to 20 per cent flower (when 70 per cent of plants have at least three to 10 open flowers) to avoid eggs being laid in newly formed pods.
- If an insecticide application is required, spray in the morning or evening when temperatures are between 15 C to 24 C for best results and to protect pollinators. Avoid spraying under a strong temperature inversion or when temps exceed 25 C.

Mode of Transmission

Adult cabbage seedpod weevils overwinter in the soil beneath leaf litter in tree shelterbelts, roadside ditches and woodlots.

Figure 3.17 Cabbage seedpod weevil adult

Figure 3.18 Cabbage seedpod weevil larva exit

Canola Flower Midge

Contarinia brassicola (Sinclair)

Description

- Although reports occur, damage is very rarely economic. Adults resemble swede midge and are small, delicate flies (1.5-2 mm), that superficially resemble tiny mosquitoes wings, often have distinct dark splotches created by fine hairs.
- Larvae are initially white and turn yellow as they mature.
- Larvae can jump.

Damage

Most damage is associated with induced flower galls on canola, however, there have been confirmed cases of larvae found feeding on seeds inside of pods.

Scouting

Scout along the field edge for galled, bottle-shaped flower buds containing larvae after crops come into flower.

Similar species

See swede midge under species of interest.

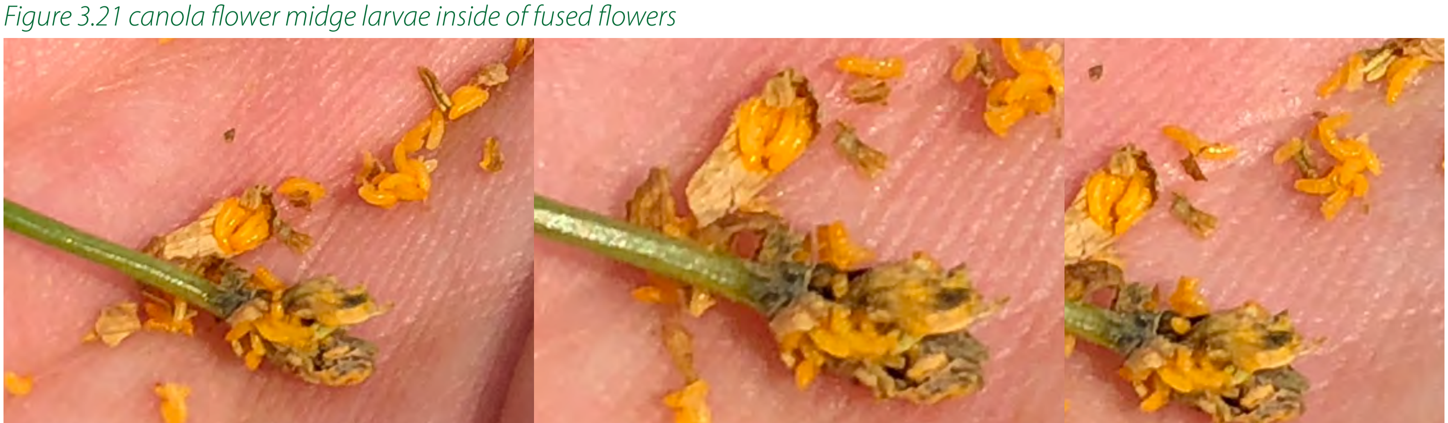
Mode of Transmission

Overwinters in cocoons in the soil. Adults emerge from soil in mid-June through to August.

Figure 3.19 Canola flower midge fused canola flowers

Figure 3.20 canola flower midge larvae inside of fused flowers

Figure 3.21 canola flower midge larvae inside of fused flowers



Red Turnip Beetle

Entomoscelis americana Brown

Description

- Adults are approximately seven to 10 mm long with a red body and black patches on the head and thorax. Red turnip beetles also have three distinct black stripes running down their back.
- At maturity, the larvae are about 10-15 mm long and are smoky black on the top and brownish underneath. They are long, hump-backed, and slow moving. Larval development is usually completed by the end of May.

Damage

Adult beetles feed on flowers, seed pods, petioles, and stems of canola, rapeseed, mustard, and cruciferous weeds. Larvae feed on volunteer host plants in the spring. When feeding, adults move in from the field margins in a band.

Scouting

In late April to mid-June, scout previously infested fields for larvae feeding on volunteer crop and weed hosts. Monitor the margins of nearby host crops after crop emergence for presence of invading adults.

Economic Threshold

No economic threshold has been developed for red turnip beetle.

Mode of Transmission

It overwinters in the soil as reddish-brown oval eggs.

Figure 3.22 Red turnip beetle

Examples of cruciferous weeds that are also hosts for the red turnip beetle

Figure 3.23 Shepherd's purse

Figure 3.25 Hoary alyssum

Figure 3.24 Green pepperweed

Cabbage Root Maggot

Delia radicum (Linnaeus)
Delia floralis (Fallen)

Description

- Adult flies are light gray in colour and are approximately 4-6 mm long. At rest, the wings overlap.
- Mature larvae are whitish in colour and are approximately 8 mm long.
- The mature larvae overwinter as puparia in the soil of host crops. Puparia are reddish-brown in colour, cigar-shaped and are about 5-20 cm below the soil surface.

Damage

Crop damage is caused by the larval stage. Damage and infestations are most severe in cool and damp soil conditions. There are three larval instars that feed on seedling roots while older maggots will create channels and tunnels into the tap root. This damage causes yellowing in lower leaves and may also promote disease; heavy infestations can delay blooming and cause severe lodging and yield loss. Infested roots are often darker than normal roots.

Multiple, overlapping generations can occur in canola with adults laying eggs from late spring into October. Maggots will feed on roots from late rosette stage until late fall.

Figure 3.26 Cabbage root maggot pupae

Figure 3.27 Cabbage root maggot larvae

Scouting

In mid-May, the adult flies emerge to mate and the females lay about 200 elongate white eggs near the base of cruciferous host plants over a five to six week period. Sweep nets and yellow sticky cards can be used to scout for the presence of adults, although no economic thresholds for control have been established.

Throughout the season, pull plants and check the roots for any signs of damage caused by root maggot larvae. Note any channels on the tap root, or tunnels throughout the tap root, and look for the presence of larvae. Yellowing of bottom leaves may also be noticed.

Canola on canola rotations will have increased levels of infestation; crop damage and yield loss will be more significant.

Management options include avoiding the planting of more susceptible Brassica rapa (Polish canola) and practicing crop rotation. At least a one-year break between canola crops is recommended to reduce significant yield loss as a result of root maggots. Thicker plant stems are preferred by maggots so increasing seeding rates and row spacing will decrease damage.

There are no chemical management options registered in Canada.

Economic Threshold

- None have been established.

Mode of Transmission

Pupae overwinter in the soil.

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Wireworms in Canola

Hypnoidus bicolor-no common name
Selatosomus aeripennis destructor-Prairie grain wireworm
Limonius californicus-Sugarbeet wireworm
Aeolus mellilus-Flat wireworm
Hadromorphus glaucus-no common name
Agriotes mancus-Wheat wireworm

Figure 3.28 Wireworm larvae

Description

- Damage is caused by the larval stage of these beetles.
- The larval stage is generally hard bodied, various shades of yellow or brown in colour, and 1-3 cm in length with three pairs of legs.
- Life expectancy of the larval stage can be from four to 11 years in the soil before they pupate in July.
- Larvae overwinter in the soil and can survive for at least two years without any food besides humus.
- There can be multiple generations in a field and regional differences exist in species behaviors therefore effective wireworm control needs to match the pest species and the environment found in a specific region.

Damage

Larval feeding occurs below ground.

Scouting

Look for bare and/or thin areas in a field. If you dig up seedlings and you find shredded stems you are more than likely dealing with a wireworm problem. Cutworms usually cut off the entire stem. Germinating seeds give off carbon dioxide which causes wireworm larvae to move up through the soil profile to feed on germinating seeds or young seedlings.

Burying baits made of cereal balls or raw potatoes about 10-15 cm deep in the soil, leaving them for about a week and then digging them back up can give you somewhat of an indication as to what species and how prevalent they are.

Economic Threshold

Official thresholds have not been established for wireworm numbers in canola.

Mode of Transmission

Adult click beetles overwinter in the soil.

Figure 3.29 Wireworm damage in canola

Aphids in Canola

Cabbage aphid (Brevicoryne brassicae L.)
Turnip Aphid (Lipaphis erysimi)

Figure 3.30 Aphids in canola

Description

Aphids are small soft-bodied insects that feed on the sap from the underside of leaves and flower buds. While aphids are a common pest, they rarely cause economical damage to canola unless their population is extraordinarily high. Their rate of reproduction is very high during the spring and summer and each phase of aphid matures quickly, allowing for multiple generations of aphids in one season. Aphids are also food for many beneficial insects that also live within canola fields. These beneficials are one of the reasons aphid populations rarely exceed economic thresholds.

Damage

Aphids damage the host plant by sucking sap, damaging stems, leaves or flowers, causing abnormal growth, wilting or flower drop. The damage is rarely significant in western Canada since most of the pod formation is completed prior to aphid populations developing, and the few damaged young green pods contribute very little to overall yield.

Scouting

Canola is most sensitive to aphid damage during bud formation through to late flowering. Crops at these stages should be checked regularly for aphids in case numbers escalate enough to cause economic damage to the crop. Aphid distribution can be patchy. Check at least five points of the field and look for aphids on a minimum of 20 plants at each point. Check plants and count the number of flowers or stems infested with aphids.

Economic Threshold

If more than 20 per cent of the stems are infested with colonies of aphids, control measures should be considered to avoid yield losses. Factors that increase the risk of economic yield losses are poor finishing rains or crops already under some degree of drought stress.

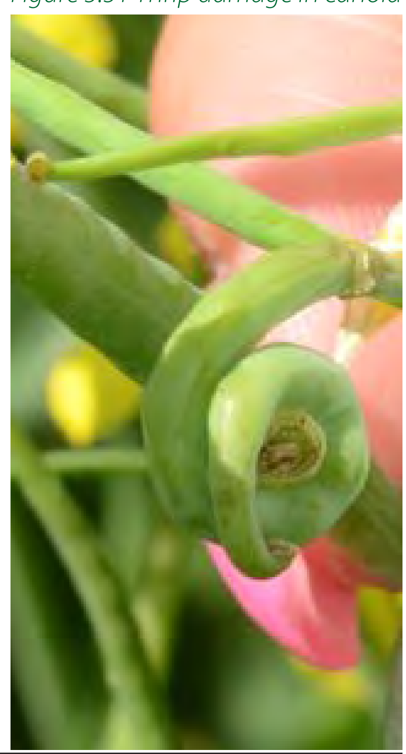
Mode of Transmission

Overwinter as eggs.

Thrips Damage in Canola

Frankliniella occidentalis-Western flower thrips
Thrips tabaci-Onion thrips
Thrips vulgatisimus-no common name

Figure 3.31 Thrip damage in canola



Description

Thrips are small, thin insects with rasping-sucking mouthparts. Their life stages are egg, two larval stages, a prepupal, a pupal and an adult stage. Life cycle completion from egg to adult takes approximately 19-20 days with temperatures at 20 C but only 13-14 days at 25 C.

Damage

Both the adult and the nymphs feed on the surface of canola buds and on flowers by rasping the surface and sucking up plant fluids. This feeding creates curled pods and pod abortion.

Economic Threshold

Research done by AAFC indicates there are no significant yield differences in yield between treated and untreated plots at any thrips density.

Mode of Transmission

Adult thrips overwinter in plant debris.

Wheat Midge

Sitodiplosis mosellana (Gehin)

Description

- Adults are small (2-3 mm), orange mosquito-like insects. Adult flies usually emerge from the soil late in June into July. They lay eggs on developing wheat heads.
- Larvae (1-2 mm) are small and orange.

Damage

Damage is most common in spring wheat. Although barley, couch grass, intermediate wheat grass and rye are also attacked, damage is rarely significant in these plants. Spring wheat is the primary host for newly hatched wheat midge. Larvae crawl into wheat glumes and feed on the developing wheat kernel.

Scouting

Scouting for the wheat midge adult is best done on a calm evening when temperatures are above 15 C. Count adults landed on wheat heads. Wheat is most susceptible to damage when egg laying occurs during heading and diminishes through heading to anthesis, however, tillering will increase this window.

Yield Consideration

An insecticide application is recommended when there is at least one adult midge for every four or five wheat heads. At this level of infestation, wheat yields can be reduced by approximately 15 per cent if the midge is not controlled. Higher midge densities will reduce yields even further.

Grade Consideration

The Canadian Grain Commission's changes to grading tolerances have prompted re-evaluation of the economic threshold for wheat midge to maintain optimum grades. In areas where growing conditions are favourable to the production of No. 1 grade wheat, chemical control may be required when midge populations reach one adult midge for every eight to 10 wheat heads during the susceptible stage.

Mode of Transmission

Larvae overwinter in soil at depths of 5-10 cm.

Figure 3.32 Wheat midge adult

Figure 3.33 Wheat midge larva

Figure 3.34 Normal wheat (left) and damaged wheat (right)

Figure 3.35 Wheat midge

Figure 3.36 Wheat midge damage

Midge Busters

Midge Busters is an in-season monitoring network developed by Tyler Wist AAFC entomologist and SeCan. It involves volunteers across the Prairies (SeCan members and staff as well as independent agronomists) using pheromone traps to count and report midge activity in real time during the growing season. Participants enter their trap catches in an online platform so everyone can immediately see counts from other areas. Midge enthusiasts can follow along on Twitter under the #midgebuster hashtag. If you are interested in participating in the #MidgeBusters program, you can email tyler.wist@agr.gc.ca.

Barley Thrips

Limothrips denticornis Haliday

Description

Adults are very narrow bodied and 1.1-1.8 mm long. Females have narrow forewings that are fringed with long hairs while males are wingless. Larvae are 0.25-1.8 mm in length with white to pale yellowish-green bodies that are wingless. They have red eye spots.

Damage

Adults and nymphs both cause damage to cereal plants. They have piercing, sucking mouthparts that are used to puncture and suck out plant cell contents. As a result, severe damage can be seen as white heads and stems and heads that are twisted and gooseneck shaped. If heavy damage occurs on the flag leaf, kernels will not fill properly and seed weight will be reduced as a result.

Scouting

Start scouting when the flag leaf is first visible and continue until total head emergence from the boot occurs. Unroll the leaf sheath away from the stem on the top two leaf sheaths for at least nine plants.

Economic Threshold

If seven to eight thrips/stem are found, spraying may be warranted. If you decide to spray, it should be done before heading is complete. The relationship of thrips numbers to damage is associated with barley thrips. Although there is evidence that they can damage wheat, the relationship of thrips numbers and damage is less clear.

Mode of Transmission

Females overwinter in bromegrass or bluegrass sod along shelterbelts.

Figure 3.37 Barley thrips adult. Unroll the stem at the leaf sheath when looking for adults

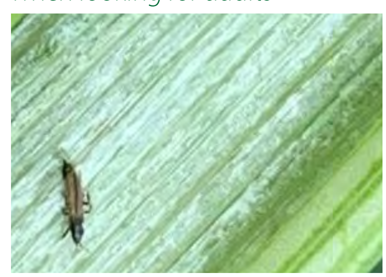


Figure 3.38 Thrips feeding on canaryseed leave a tell- tale white head as a symptom.

Cereal Aphids

Rhopalosiphum maidis (Fitch) Corn Leaf Aphid
Sitobion (Macrosiphum) avenae (Fabricus) English Grain Aphid
Rhopalosiphum padi (Linnaeus) Oat-birdcherry Aphid
Schizaphis graminum (Rodani) Greenbug

Description

Aphids of concern in cereals have varying identifying characteristics; body colour, antennae, cornicles and cauda will be the main characteristics to identify which species you are dealing with. Mature cereal aphid adults average in size from 1.5-2 mm in length (Greenbug 1-1.5 mm). Descriptions of each species and their identifying characteristics can be found in Agriculture and Agri-Food Canada's publication, *Field Crop and Forage Pests and Their Natural Enemies in Western Canada*.

Damage

Visible wilting of plants, yellow patches in fields, plants are sticky.

Scouting

Scout for aphids prior to the soft dough stage. While scouting, use a sweep net or tap plants into a tray or bucket to alert to presence and abundance of aphids. If numbers are high, conduct a more thorough examination. Count aphids on 20 randomly selected stems in five different areas. Counts should be at least 50 metres apart and observations should be taken in the middle of the field as well.

Economic Threshold

12 to 15 aphids per stem prior to soft dough stage.

Mode of Transmission

Overwinter as eggs.

Cereal aphid manager is a mobile app that helps determine populations by predicting what the population will be in seven days along with beneficial insect pressure on the population and suggests if insecticide application is necessary. *https://open.canada.ca/en/app/cereal-aphid-manager-mobile-app*

Figure 3.39 Cereal aphids

Figure 3.40 Aphids on wheat spike

Wheat Stem Sawfly

Cephus cinctus (Norton)

Description

- Adults are 8-13 mm long with a shiny body and yellow legs. At rest, they point their heads downwards. Females have a distinct ovipositor (egg-laying appendage) extending from their abdomen.
- Mature larvae are 13 mm long and are slender, whitish and worm-like with a brown head. They overwinter in the base of wheat stems in infected fields.

Damage

Crop damage is caused only by the larval stage as adults do not feed on these plants. In June the adults emerge from infested fields, with the males emerging earlier than the females. The females then fly to nearby wheat fields to lay up to 50 eggs on plant stems. The adults only live about 10 days and do not feed.

Larvae emerge after five to eight days and feed on the pith of host plant stems. As plants mature, the larvae move to the bottom of the stem to overwinter. They also carve a "V" notch in the stem wall just above ground level and stems become susceptible to breaking and falling to the ground. Field damage is often greater in field margins. There is only one generation per year but there is evidence that very high springtime temperatures may induce the larvae back into a resting stage and the generation may take two years to complete.

Scouting

Larvae feed primarily on spring and durum wheat; however, winter wheat, rye, grain corn, barley and some native grasses can support development. Oat crops are toxic to sawfly.

Use a sweep net to sample for adult sawflies in late June-early July. Count the number of sawflies per 10 sweeps but make sure to carefully examine the adults to determine sex as the females can be easily distinguished by the presence of an ovipositor. An average of two females per 10 sweeps generates about 12 per cent cut stems, while four females per 10 sweeps generates about 23 per cent cut stems.

As plant stages prior to stem elongation are not attractive for the sawfly to lay eggs, scouting can begin after this stage. Stems that develop a reddish-brown band below either the second or third node can indicate the presence of sawfly larvae. While the crop is still green, infested stems may also appear with regions of mottled discoloration. Splitting the stems lengthwise can determine the presence of larvae and any feeding on the stem. This can help provide insights into field damage prior to crop maturity. Scouting closer to harvest can also help determine swathing timing as well as the need for management practices next year.

Economic Threshold

If 10 to 15 per cent of crop in the previous year was cut by sawfly, control may be warranted. However, there are no chemical control products that have been proven effective. Instead, cultural control methods will help reduce populations. These include not seeding successive wheat or other host crops, rotating with solid-stemmed varieties, swathing earlier to avoid losses, increasing seeding rates to no more than 300 seeds/m^2, applying 30 to 60 kg/ha of N and cutting stubble to at least 15 cm during harvest. Shallow tillage in the fall can increase larval mortality rates but only when there is little to no risk of soil erosion.

Mode of Transmission

Larvae overwinter and pupate within the cocoons.

Figure 3.41 Adult wheat stem sawfly

Figure 3.42 Wheat stem sawfly larvae frass

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Wheat Stem Maggot

Meromyza americana

Description

Mature larvae are roughly 6-7 mm (1/4 in.) in length, and light green to cream coloured. They look like a fly maggot and are usually found inside the stem. The larvae pupate in the spring and the adults emerge in June. After mating, the female flies lay eggs near the sheath of the flag leaf, just one per stem, over a two to three week period. These eggs hatch out in roughly five days into the maggots/larvae. Larval development is complete in 18-21 days and can have two generations per summer.

Damage

The larvae burrow into and consume the interior of the stem, killing the upper part of the stem and the head. In the fall or spring when young tillers are attacked, they usually die. The affected plants show the "white head" or "silver top" condition, typically produced by stem-boring insects. Symptoms present themselves in mid- to late June.

Scouting

The damage is distinctive - white heads without kernels on a plant that is still green. Typically, only one to five per cent of the heads are affected and they are usually scattered randomly throughout the field. If you tug on the head it will pull out and normally there is signs of insect damage on the stem above the top node.

Economic Threshold

No thresholds have been developed for this pest. Crop rotation can help prevent build-up of populations or delaying planting.

Mode of Transmisson

In cereal plants or grasses, wheat stem maggot larvae overwinter in the lower parts of the stems.

Figure 3.43 White heads in any cereal crop are a symptom of a possible wheat stem maggot infestation

Note: If you lightly tug on a wheat stem head and it separates easily from the remainder of the stem is another sign that wheat stem maggot may be present in the field.

Wireworms

Hypnoidus bicolor-no common name
Selatosomus aeripennis destructor-Prairie grain wireworm
Limonius californicus-Sugarbeet wireworm
Aeolus mellilus-Flat wireworm
Hadromorphus glaucus-no common name
Agriotes mancus-Wheat wireworm

Description

- Damage is caused by the larval stage of click beetles.
- The larval stage is generally hard bodied, various shades of yellow or brown in colour, and one to three centimetres in length with three pairs of legs.
- Life expectancy of the larval stage can be from four to 11 years in the soil before they pupate in July and become click beetles.
- Both larvae and new adults overwinter in the soil and larvae can survive for at least two years without any food besides humus.
- There can be multiple generations in a field and regional differences exist in species behaviors therefore effective wireworm control needs to match the pest species and the environment found in a specific region.

Damage

Larval feeding occurs below ground.

Scouting

Look for bare and/or thin areas in a field. If you dig up seedlings and you find shredded stems you are more than likely dealing with a wireworm problem. Cutworms usually cut off the entire stem. Germinating seeds give off carbon dioxide which causes wireworm larvae to move up through the soil profile to feed on germinating seeds or young seedlings.

Burying baits made of cereal balls or raw potatoes about 10-15 cm deep in the soil, leaving them for about a week and then digging them back up can give you somewhat of an indication as to what species and how prevalent they are.

Economic Threshold

Official thresholds have not been established for wireworm numbers in cereals. Seed treatments formulated for wireworm protection are the best preventative. Cultural practices include keeping summer fallow fields free of green growth during June-July to starve out newly hatched larvae.

Mode of Transmission

Adult click beetles overwinter in the soil.

Figure 3.44 Shredded stems are a sign of wireworm infestations

Figure 3.45 Wireworms will eat out the center of seed

Insect Pests of Pea and Faba Bean

Pea Leaf Weevil

Sitona lineatus (L)

Description

- Adults (5 mm long) are grey with three alternating light and dark stripes on their back or underside. Pea leaf weevils have a relatively short, broad snout, characteristic of the subfamily.
- Larvae (3.5-5.5 mm long) are "C" shaped, pale white in colour with dark brown heads.

Damage

Adults consume foliage from the leaf margins leaving characteristic notches. Larvae feed under the soil on the nitrogen fixing nodules of peas and faba bean.

Scouting

When scouting crops in the seedling stage, look for characteristic feeding notches on the leaves.

Economic Threshold

- 30 per cent of seedling with notching on the clam leaf during the second to fifth node stage.

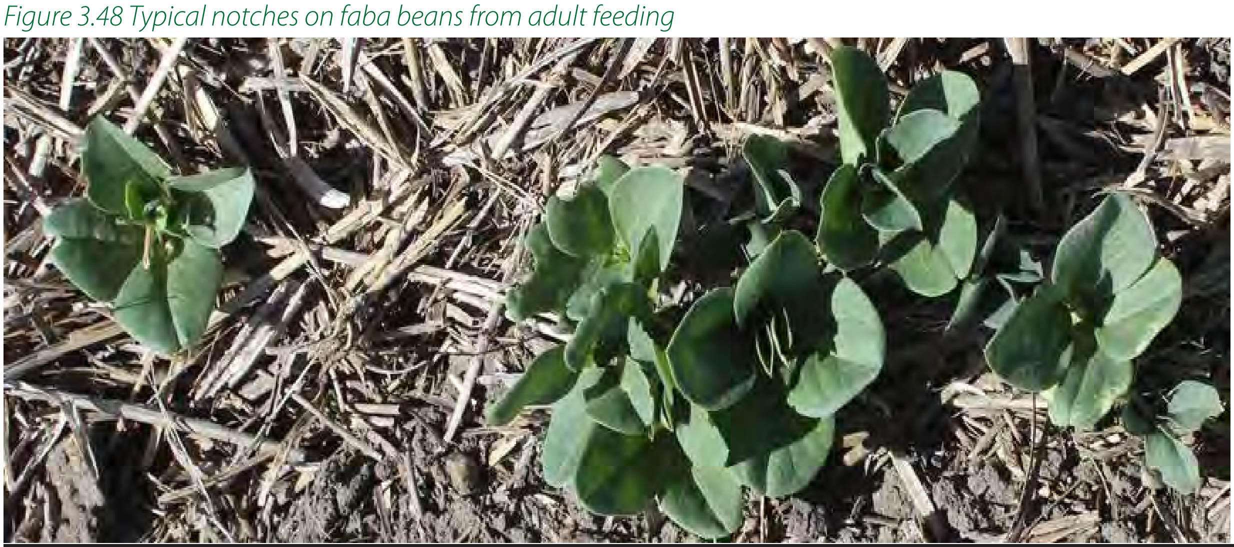
Mode of Transmission

The adults overwinter in alfalfa or other perennial legumes.

Figure 3.46 Pea leaf weevil adult with eggs

Figure 3.47 Typical notches on pea leaves from adult feeding

Figure 3.48 Typical notches on faba beans from adult feeding



Pea Aphid

Acyrthosiphon pisum (Harris)

Description

- Adult pea aphids are 3-4 mm long with a soft, pear-shaped body. They have long slim legs, and they range from light to dark green in colour. The antennae of the pea aphid have narrow dark bands at the tip of each segment.
- Mature nymphs have a similar appearance to the adults but are smaller in size.
- Pea aphids can produce seven to 15 generations per year. A single female can produce 50-150 young, attributing to a fast population growth.

Damage

- Pea aphids cause damage to their host plants by sucking plant sap.
- Aphids feed on the growing points of plants, draining the nutrients of the plant.
- Adult and nymph stages of the pea aphid feed on leaves, petioles, stems, flowers, and young pods.
- Feeding during the flowering and early pod stages of the pea plant result in yield loss due to reduced seed formation and seed size.

Scouting

Scout when 50 to 75 per cent of the pea plants are in flower, take five 180 degree sweeps in five locations or check at least five, eight-inch (20 cm) plant tips along at least four-well spaced (50m/150ft) stops in the field.

Economic Threshold

Two to three aphids per eight-inch (20 cm) plant tip, or nine to 12 aphids per sweep.

Mode of Transmission

Overwinter as eggs on the leaves and stems of perennial legumes.

Figure 3.49 Pea Aphid

Figure 3.50 Pea Aphid

Lygus in Faba Bean

L. lineolaris
L. keltoni

Description

Lygus bugs infest multiple crops grown in Saskatchewan, namely faba beans, canola and alfalfa. They pose a substantial threat to faba bean production that is grown for human consumption since the grading factors are very strict for lygus bug damage in faba beans. In the southern regions of the prairies, the first-generation adults first appear in the end of June. There are normally two generations of lygus bugs in the southern regions and one in the northern regions, the central region will experience a partial second generation if conditions are acceptable.

Damage

Lygus bugs use their piercing-sucking mouthparts to pierce the pod which allows them to feed on plant sap from the undeveloped seed. This feeding causes dark spots on the seeds and can result in downgrading and has the potential to impact yield.

Scouting

Scouting for lygus bugs should start in mid-July. Use a standard 15-inch sweep net and take 10, 180 degree sweeps at 10 spots in the field. Scout regularly in a representative number of spots in the field making sure to include thicker areas of the field.

Economic Threshold

There are no current economic thresholds for lygus bugs in faba bean, but there is Saskatchewan based research being conducted to establish threshold numbers.

Mode of Transmission

Adult lygus bugs overwinter under plant debris and emerge from hibernation once the snow melts in the spring.

Figure 3.51 Lygus bean damage in faba bean

Alfalfa Weevil

Hypera postica (Gyll.)

Description

- Adult weevils (4-5 mm long) are silvery brown with a darker brown stripe down the center of the dorsal (upper) side.
- Mature larvae (about 8-9 mm long) are bright green with a black head and a distinct white stripe down the middle of the dorsal side.

Damage

Both adults and larvae feed primarily on alfalfa. In late spring and early summer larvae feed on growing tips. Growth of the plants can be stunted. Larvae remove leaf surface tissue causing a silver appearance to heavily infested crops.

Scouting

Look for larvae or feeding damage to plant leaves. Peak feeding of larvae is mid-June to mid-July. Monitor fields with a sweep net.

Economic Threshold

Hay Crop-alfalfa

- < 30 cm in height = one larvae per stem
- < 40 cm in height = two larvae per stem
- Any height = three larvae per stem

Seed Crop

- 20 to 30 larvae/seed or 35 to 50 per cent leaf tip showing damage.

Mode of Transmission

Adult weevils overwinter under plant debris and soil, in and around alfalfa fields.

Figure 3.52 Alfalfa weevil adults and larvae

Figure 3.53 Alfalfa weevil eggs

Courtesy of: AAFC

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Figure 3.54 Alfalfa weevil feeding damage

Figure 3.55 Alfalfa field heavily damaged by weevil larvae feeding

Blister Beetles

Lytta nuttalli-Nuttall's blister beetle
Epicauta pennsylvanica-Black Blister Beetle
Epicauta fabricii-Ash grey blister beetle

Description

Larvae go through a complex series of development states referred to as 'hypermetamorphosis'. Adults vary in size between 12-25 mm depending on species. Their pronotum or 'neck' is narrower than their head and abdomen. They have chewing mouthparts. They overwinter as pseudo pupae in the soil. Females lay four or five batches of eggs in the soil which take two to three weeks to hatch.

Damage

Nuttall's blister beetle larvae feed on bee larvae found in the family Apidae and on the food the bees have stored for their own larvae. *Epicauta spp. triungulin* larvae will feed on grasshopper eggs. Black blister beetle adults feed mostly on alfalfa flowers but will also consume leaves. Blister beetles have cantharidin in their haemolymph (blood) that can cause blistering to skin that it comes in contact with.

Scouting

Adults can easily be seen feeding on alfalfa plants. Blister beetles may also be found in soybean, faba bean, canola, sweet clover, potato and sugar beet fields. Blooming alfalfa fields are very attractive to adult blister beetles. To reduce the chance of contaminating hay with dead beetles, cutting should occur at early five to 10 per cent bloom stage. Adults will also feed on pigweed and kochia.

Economic Threshold

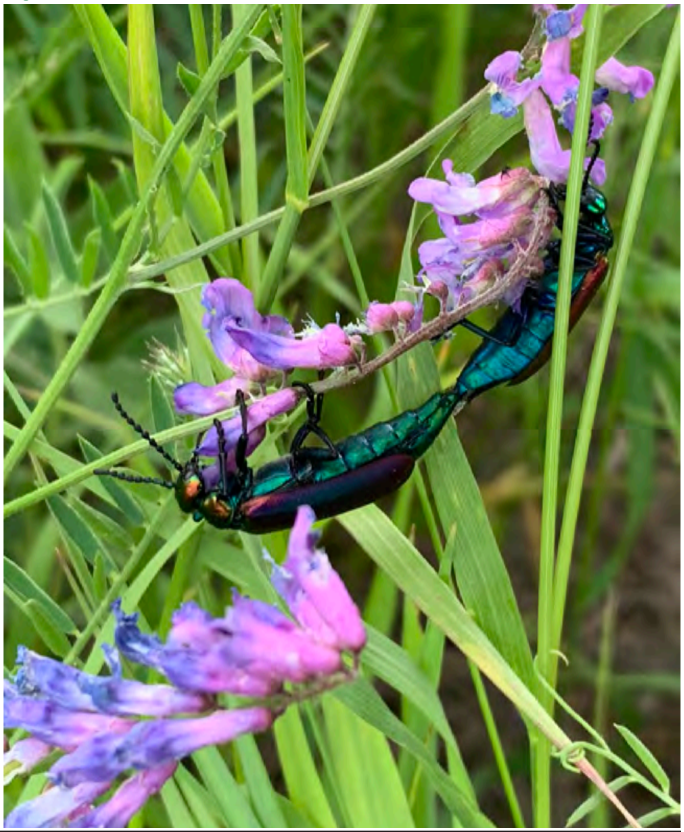
No thresholds have been established. Blister beetles are extremely toxic to horses. As little as four to six grams of blister beetles can be deadly to a full-size horse. Even small pieces of blister beetles can be toxic to horses, as may be present in hay bales. Death can occur rapidly after exposure to blister beetles.

Mode of Transmission

Larvae overwinter in the soil.

Figure 3.56 Black blister beetles

Figure 3.57 Nuttall's blister beetle



Sweet Clover Weevil

*Sitona cylindricollis (*Fahraeus)

Description

Larvae are grub like, white in colour and 5-6 mm in size. Adults are 4-5 mm in size, dark grey to brown and with the traditional weevil snout.

Damage

Larvae will feed on roots, but major damage can be done by adult weevils feeding on leaves. First year sweet clover plants are extremely vulnerable especially in dry years when plants are stressed for moisture. Adult weevils may also feed on stems and developing seeds. Studies done in Ontario, show sweet clover weevil may be of importance in spreading sweet clover root rot disease *Phytophthora cactorum*.

Scouting

While sweet clover is their preferred crop, sweet clover weevils will also be found feeding on alfalfa and cicer milkvetch. Larvae generally start to show up around the first of June but fortunately there is only one generation per year. Pupation occurs in July and August with new adults showing up around the first part of August.

Economic Thresholds

For a first-year stand, one adult weevil/three seedlings. In a dry year, the threshold should be one adult weevil/five seedlings. For a second year stand the threshold is nine to 12 adult weevils/plant.

Mode of Transmission

Adults overwinter in crop debris or in soil cracks.

Figure 3.58 Sweet clover weevil

Insects Pests of Corn

European Corn Borer

Description

- The European corn borer (ECB), *Ostrinia nubilalis* was first reported in Saskatchewan in 1949.
- In Canada there are two common biological types of corn borer, univoltine and bivoltine. Univoltine ECB produce one generation per year and bivoltine ECB produce two generations per year. Single generation, or univoltine, ECB are present in Saskatchewan.
- Older larvae are flesh coloured with black spots and commonly tunnel stalks and ears.

Damage

There are five larval instars. The first two instars are whitish with black heads and feed within the whorl and cause shothole and window pane damage. The first two instars complete development in seven to ten days. The third instar larvae bore into the stalk. Once inside the stalk, it is too late to achieve effective chemical control.

The later instars (third to fifth) feed within the stalk and ear shanks, disrupting the normal movement of nutrients, which results in decreased yield. Tunneling and boring may permit secondary infection and damage by rotting of the stalk and ear.

Scouting

Should begin in late July to the end of August. Economic thresholds vary.

Management of ECB starts with corn product selection. Products with the *Bacillus thuringiensis (*B.t.) corn borer trait have provided control of ECB. B.t. corn hybrids produce an insecticidal protein derived from the bacterium *Bacillus thuringiensis*. Managing corn residue to reduce overwintering can also greatly reduce ECB numbers as well as crop rotation. Scouting for frass piles (excrement) will provide an indication that larvae may be present.

Mode of Transmission

Mature larvae overwinter in corn stalks, cobs and plant debris on the soil surface.

Figure 3.59 Shot holes in corn

Figure 3.60 Poor ear development in corn

Figure 3.61 Shot holes in kernels

Figure 3.62 Stalk lodging in corn

Figure 3.63 Scouting for frass piles (excrement)

Figure 3.64 Later (third to fifth) instar

Figure 3.65 Adult corn borer moth

Figure 3.66 Monitoring trap for ECB adult moths

Insect Pests of Multiple Crops

Cutworms

Euxoa ochrogaster (Guenée)-redback cutworm
Agrotis orthogonia (Morrison)-pale western cutworm
Feltia jaculifera (Guenée)-dingy cutworm. *F. subgothica* and *F. herilis* are included in this complex

Description

- There are typically six larval instars.
- Mature larvae burrow into the soil to pupate.

Damage

Plants (weeds or crop) appear notched, wilted, cut-off or completely missing. Damage is often patchy in a field.

Scouting

Check seedlings on a weekly basis from mid-May to mid-June. Feeding occurs at night. During the day cutworms may be found in soil near damaged areas.

Economic Thresholds (redback and pale western)

- Five to six larvae per square metre in cereals and grain corn, four to five larvae per square metre in flax and canola, two to three per square metre in peas, one small larva per metre of row in soybean and dry bean.

Mode of Transmission

Overwinter as eggs and larvae.

Figure 3.67 Dingy cutworm

Figure 3.68 Dingy cutworm adult

Figure 3.69 Redback cutworm

Aster Leafhopper

Macrosteles quadrilineatus (Fbs.)

Description

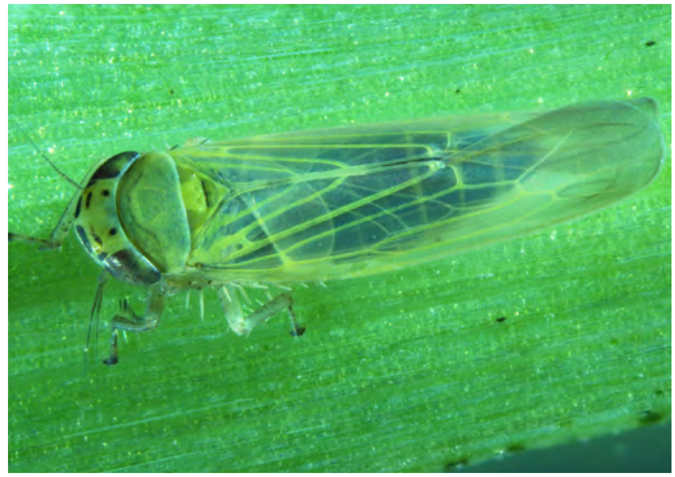
- Adults (3.5-4 mm) are light green to yellowish green with paired spots on head. They have smoky grey wings.
- Larvae: Nymphs are similar but without wings.

Damage

They transmit a variety of diseases including aster yellows. Feeding occurs earlier in the season with aster yellows symptoms becoming visible later on.

The active, jumping insects often fly up when disturbed in the crop canopy.

Figure 3.70 Aster leafhopper



Courtesy of: AAFC

Susceptible Crops

Aster yellows is most prominent in canola and camelina. Flax plants also show noticeable symptoms. The disease commonly infects cereals but symptoms are rare.

Mode of Transmission

Very few, if any, adults manage to overwinter in the Canadian Prairies. Adults arrive from the US in mid May to mid June on southerly winds.

Figure 3.71 Aster yellows in canola

Figure 3.72 Aster yellows in flax

Figure 3.73 Strongfield durum plant with very malformed head, twisted awns along with purpling and yellow streaked leaves.

Courtesy of: AAFC

Figure 3.74 Aster yellows in durum

Courtesy of: AAFC

Left-Sliding scale of aster yellow effects in strongfield durum from least affected to most affected (left to right). The first three plants show signs of purplish and reddish leaves and shorter stature plants. The last plant was infected early on, stayed dwarfed and did not produce heads.

Figure 3.75 Aster yellows in sunflower

Courtesy of: AAFC

Grasshopper

Most Common Species:

Melanoplus bivittatus (Say)-two striped grasshopper
Melanoplus packardii (Scudd)-packard's grasshopper
Melanoplus sanguinipes (F.) -lesser migratory grasshopper
Camnula pellucida (Scudd)-clear-winged grasshopper

Description

- Eggs are laid in clusters 1-3 cm in the soil and look like brown rice. Egg hatching can extend over four to six weeks, depending on species and temperature.
- Grasshoppers go through five instars before they become mature adults with wings. The colours of the immature stages can be variable as they develop.

Damage

Pest grasshopper species feed on the above ground crop. They are most destructive when feeding on developing pods of lentil and bolls of flax.

Scouting

Begin scouting in late May or June when pest species hatch. Walk through field margins and observe number of grasshoppers jumping along a transect. Look for damage along the field margins.

Economic Threshold

- Varies by crop. Typically ten to twelve per square metre in most crops. Flax in boll and lentil are more sensitive to their feeding so two per square metre should be used.

Mode of Transmission

All pest species in Saskatchewan overwinter as eggs.

Figure 3.78 Clear-winged Grasshopper

Figure 3.76 Packard's grasshopper fourth instar

Figure 3.77 Two striped grasshopper fifth instar

Figure 3.79 Two striped grasshopper

Courtesy of: AAFC

Grasshoppers in Saskatchewan

Their hind legs are marked with a series of black bands.

They have a spur on thier throat.

They have two light-coloured stripes that extend from just behind the eyes but don't continue down the wings.

Their forewings are uniformly grey and lack distinctive stripes.

Adults are brownish or greenish with black or brown markings.

Two pale stripes extending back from the eyes to the tip of the forewings.

They are yellow to brown, have mottled forewings and transparent hindwings and light stripes that converge.

They have a characteristic camouflage pattern on their hindwings.

THREE TO FOUR SPECIES OF GRASSHOPPERS ARE PESTS

If they have wings before late June, they are not a pest. *Wings in the spring, not a pest.*

If they have brightly-coloured hind wings they are not a pest.

NOT PESTS

Visit https://www.saskatchewan.ca/sask-ag-now for the latest webinars on grasshoppers

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Stink bugs

There are beneficial stink bugs as well as damaging ones. Some of the species found in Saskatchewan are:

Chlorochroa uhleri-Uhler's stink bug
Euschistus servus-Brown stink bug
Acrosternum hilare-Green stink bug
Aelia americana-no common name

Description

Stink or shield bugs belong to the order of true bugs. Their name is a reference to the smell they emit when disturbed or squashed. They have a life cycle of egg, nymph, and adult stages. Females lay their eggs in clusters on the undersides of leaves and stems. Once they hatch, wingless nymphs will molt several times before they become winged adults. They usually complete only one life cycle in northern climates.

Damage

With their piercing sucking mouthparts, stink bugs feed on stems, leaves, fruit and developing seeds. These species have broad host ranges. While soybeans and field corn are crops of choice for both nymphs and adults, they have also been found feeding on cereals, canola, pea, and sunflower. Shriveled seeds and flattened pods result when they feed on soybeans while discoloured and shrunken kernels will be found on corn and cereals. If soybean fields are heavily infested in late summer to early fall, fields can display a "stay green" syndrome due to a delay in ripening.

Scouting

Feeding damage generally starts in the outer 10-12 metres of a field and moves inward.

Economic Threshold

There are no established economic thresholds for stink bugs.

Mode of Transmission

Stink bugs overwinter in tree barks or get into homes/shelters to survive the winter.

Figure 3.80 Stink bug in cereal

Figure 3.81 Stink bug feeding on cereals

Figure 3.82 Stink bug feeding on corn

Figure 3.83 Stink bug feeding on soybean

Thistle Caterpillar

Vanessa cardui (L)

Description

- Adults are medium sized butterflies with pointed wings spanning 42-66 mm and salmon-pink in colour with complicated dark markings on the upper surface.
- Mature larvae (40-45 mm long) are yellowish green or purple mottled with black and a broad white stripe along each side. There are many yellow spines and the head is black.

Damage

Adults feed on nectar of flowers. Larvae feed together in leaf-nests created near the terminals of host plants.

Scouting

If butterflies are very abundant, inspect the crop weekly until caterpillars are noticed feeding on the plants. They are usually heavily parasitized and subject to bacterial disease. Some birds, rodents, dragonflies, wasps and spiders attack the larvae and adults.

Mode of Transmission

Migrate into the Prairies from overwintering sites in Southern California and Mexico.

Figure 3.84 Adult stage is the painted lady butterfly

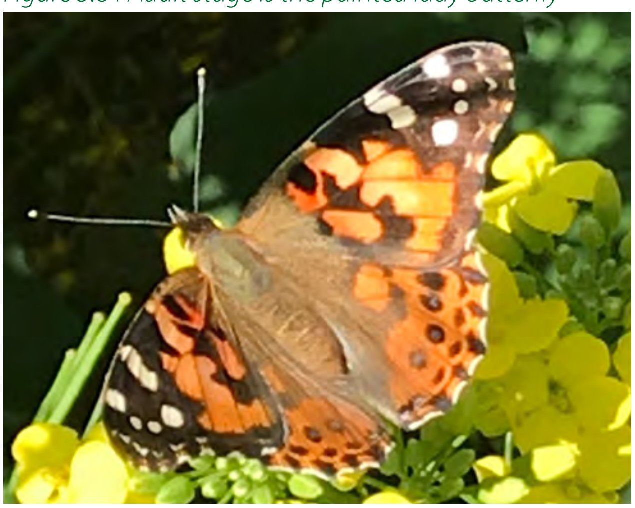


Figure 3.85 Painted lady butterfly larvae

Figure 3.86 Leaf nest in soybeans

Alfalfa Caterpillar

*Colias eurytheme (*Boisduva)

Description

Adult butterflies can be white, yellow, or orange in colour with a distinguishing black border on the upper surface. Mature larvae are green caterpillars with a prominent white stripe along each side that has a fine reddish line in the middle. They can be up to 30 mm in length and are velvety in appearance.

Damage

Adults feed on flowers for their nectar. Larvae feed on soybeans, alfalfa, vetch, and milkvetch trefoil as well as sweet and white clover causing defoliation.

Scouting

There are two generations a year. The first larvae normally start showing up in mid-May and the second-generation mid-June.

Economic Thresholds

There have been no thresholds established however in most years this pest is controlled by natural predators. Pathogenic fungi and a naturally occurring virus along with spiders also serve to keep these pests in check.

Mode of Transmission

Adult alfalfa butterflies are blown in during summer.

Figure 3.87 Alfalfa Caterpillar feeding on soybean

Grey Field Slug

Description

The slugs are mollusks that travel by secreting mucus from the underpart of their body. The slugs will have a pair of tentacles where their eyes are located. They can range from a grey to brown in colour and will usually be an issue in cool wet conditions.

Damage

Slugs can emerge right after seeding. They will feed on the embryo of the seed hollowing it out. This type of damage can typically be seen in winter wheat crops and will result in poor crop stands. Later in the season, slugs will feed on the foliage of the plant which will result in streaking damage that looks very similar to an iron deficiency in a wheat crop.

Scouting

Typically, field slugs will appear in wet conditions. As they prefer cooler temperatures, they can generally be found feeding from dusk until dawn. Scouting should be performed during the evening as slugs will climb up the plants to commence feeding. Due diligence is required when scouting, as juvenile slugs can be quite difficult to spot. The slugs will lay their small orb like eggs near the surface of the soil or slightly buried. These eggs can overwinter in the straw residue that could pose for an issue in seasons to come.

Economic Threshold

There is currently no economic threshold. Bait options are available for minimal control, while foliar options seem ineffective. Tillage may be an effective way in controlling slugs for the following season.

Figure 3.88 Field slug damage

Figure 3.89 Grey slug

Figure 3.90 Field slug

How to Use a Sweep Net

Sweep nets are used to collect insects that are difficult to see in a crop canopy. Sweeping allows you to count and identify the insects that are currently found in the crop. A typical sweep net is 38 cm (15 inches) in diametre.

Pick undisturbed areas of the field to sweep. A sweep is made by swinging the net firmly through the crop canopy. One sweep should be a 180 degree pass (unless a 90 degree sweep is specified); take at least one complete step forward between sweeps to get a better representative catch.

Figure 3.91 Sweeping diagram

After the last sweep, instantly swing the net back and forth rapidly through the air, well above the canopy, to force the insects to the bottom of the net. Shaking the net rapidly, after the last sweep, is another option to gather the insects at the bottom of the net.

Once the insects have fallen deeply in the sweep net, grab the net approximately 15 to 20 cm from the bottom to prevent insects from escaping. Invert the net through the rim of the net to put the insects in a clear bag for close identifying or counts.

Note: Sweep nets can be ordered through Pro Metal Industries Ltd. in Regina, SK. (306-525-6710, info@prometal.ca).

Sweep Net Tips

- Taking an increased number of sweeps in the field will give a better idea of what composition of insects are in the overall field. Pick different spots to sample throughout the field and be careful not to overemphasize field margins as they can be quite different from the rest of the field.
- Sample bags containing sweep samples can be sealed and frozen for counting later if the insect of interest is hard bodied such as the cabbage seedpod weevil, but not immature larvae.
- The best time to survey for most insects is during the day when the temperatures are not too cold but not extremely hot either. Windy conditions will also affect sampling as insects may move lower in the canopy or drop to the ground until conditions improve. Monitoring time will depend on the insect.
- When buying or making a sweep net, make sure the hoop, as well as the handle, are strong and well secured for sweeping through heavy crops. Butterfly nets are not recommended for use as a sweep.

Economic Thresholds

Table 3.4 Economic thresholds for various insects and crops

Crop	Insect	Economic Threshold
Canola	Flea beetles	25% of the cotyledon surface is destroyed and flea beetles still present. If damage is only along field margins, and beetles are still congregated there, then control measures should be applied to the damaged areas only.
	Grasshoppers	10-14/m^2 if damage is being caused.
	Cutworms	Threshold of a 25-30% stand reduction. It is economical to just treat infested patches, and not whole fields.
	Diamondback moth	Threshold of 100-150 larvae/m^2 in immature to flowering plants, based on 150-200 plants/m^2 200-300 larvae/m^2 in plants with flowers/pods, based on 150-200 plants/m^2
	Bertha armyworm	Refer to Table 3.3 on page 111.
	Cabbage seedpod weevil	25 to 40 weevils per 10 sweeps.
	Aphids	Control may be justified when at least 10-20% of the stems are infested with a cluster of aphids in flowering to early pod stages or 25 aphids/10 cm shoot tip after flowering. Rarely an economic issue in Saskatchewan.
	Lygus bug	A threshold of 20-30 Lygus bugs per 10 sweeps is suitable for good growing conditions. Using the lower end of the threshold (about 20 per 10 sweeps) may be appropriate for stressed canola with less ability to compensate for feeding. When most pods become leathery and when seeds inside are firm, lygus bugs can no longer penetrate the pods or seeds with their mouth parts and are no longer an economic threat.
Flax	Aphids	3 aphids/main stem at full bloom. 8 aphids/main stem at green boll stage.
	Cutworms	4-5 larvae/m^2. Sometimes it is most economical to just treat infested patches, and not whole fields.
	Grasshoppers	2 grasshoppers/m^2 (green boll stage)
Cereals	Aphids	12-15 aphids/stem prior to soft dough stage
	True armyworms	10/m^2
	Cutworms	Pale western cutworm 3-4 cutworm/m^2, redback and army cutworm 5-6 cutworm/m^2. Well established fall-seeded crops or spring seeded crops with good moisture conditions can tolerate higher numbers. Sometimes it is most economical to just treat infested patches, and not whole fields.
	Grasshoppers	8 to 13 grasshoppers/m^2. Early in the season, when grasshoppers are small, 18 grasshoppers/m^2 and visible crop damage may be a more appropriate threshold.
Wheat	Wheat midge	Conventional wheat: approximately 1 adult/4-5 heads for yield; 1 adult/8-10 heads for grade
Barley	Barley thrips	Insecticide treatments are only effective when applied before heading is complete. 7-8 thrips/stem prior to head emergence indicates it's time to spray. For more precision, use the following formula: # Thrips/stem = (cost of control/expected $ per bu)/0.4
Canaryseed	Aphids	10-20 aphids on 50% of the stems prior to soft dough stage
Lentils	Aphids	30-40 aphids/sweep, few natural enemies present and when aphid numbers do not decline over a two-day period
	Grasshoppers	2 grasshoppers/m^2 (blooming and podding stage)
Peas	Aphids	If, at the beginning of flowering, there are 9-12 aphids per sweep or 2 to 3 aphids per 8 inch (20cm) plant tip, an insecticide application when 50 percent of plants have produced some young pods will be cost-effective.
	Pea leaf weevil	30% of seedlings with damage (leaf notching) on the clam leaf during 2nd to 5th node stage. The crop is not susceptible to damage after the 6th node stage or it is too late to attempt control.
	Cutworms	2-3 cutworms/m^2
Alfalfa	Lygus bug	Seed production: 4-5 lygus bugs/sweep at bud and early bloom
	Alfalfa plant bug	Seed production: 4-5 plant bugs/sweep
	Alfalfa Weevil	One of the best control strategies is to cut fields for hay early. If early cutting of the hay crop is not possible, treatment thresholds are based on the following measurements of plant height and levels of larvae. Hay: <30cm plant height, 1 larva/stem; <40cm plant height, 2 larvae/stem; 3 larvae/stem is generally economical to control regardless of crop height. On regrowth for second crop, 2 or more active larvae per crown (4 to 8 larvae per square foot) will require insecticide application Seed: 20-30 third or fourth instar larvae larvae/sweep (90 degree = straight sweep) or 35-50% leaf tips showing damage. In some cases it may be practical to just treat hotspots and not entire fields.
	Pea Aphid	Seed: 100-200 aphids/sweep (when dryland crop is moisture stressed or until mid-August)
	Potato leaf hopper *	Seed: for <9 cm stem height=0.2 adult leafhoppers per sweep; 9-<15 cm stem height=0.5 adults per sweep; 15<25 cm stem height=1 adult or nymph per sweep; 25-<36 cm stem height=2 adults or nymphs per sweep
Sweet clover	Sweet clover weevil	1st year stands: 1 adult weevil/3 seedlings (1/5 seedlings under dry conditions) 2nd year stands: 9-12 weevil adults per plant

Sweep refers to a 180 degree sweep with a 38 cm (15 inch) diametre net, unless otherwise noted. Supplementary information can be found in the Guide to Crop Protection
** These insects are rarely found in Saskatchewan.*

Pollen Beetles

Brassicogethes aeneus

- There are two members of this genus that are important in European Oilseed Rape (OSR) and should be watched for here in Saskatchewan; both look very similar.
- Note the size, as well as clubbed antennae and short elytra, both characteristic of the family (Nitidulidae).
- If pollen beetle is suspected to be present in the field you are surveying, please immediately contact James Tansey: 306-787-4669 or *james.tansey@gov.sk.ca*.

Figure 3.92 Pollen beetle in canola

Swede Midge

Contarinia nasturtii (Kieffer)

Description

- Adults are small (1.5-2 mm), brown coloured, mosquito-like insects.
- Adult flies emerge from soil in May to June.
- Larvae (2 mm) are yellow coloured and can jump.

Damage

Larval feeding at growing points causes abnormalities. Depending on the crop stage at time of feeding this can appear as swollen, distorted or twisted young shoots, premature bolting, multiple branching, or "caper-shaped" flower buds that remain closed and are usually green in colour.

Similar species

The canola flower midge (CFM), (*Contarinia brassicola* Sinclair) can be easily confused for the swede midge; however, to date, the only damage symptom associated with CFM infestation is "bottle-shaped" flower buds that remain closed and usually stay yellow in colour. Scouting can be done when canola is in bloom. * Proposed common name currently under review.

Scouting

Swede midge pheromone traps are available and the most reliable way to positively determine species identification. Swede midge was first identified in Saskatchewan in 2007, but has not been positively identified since this time.

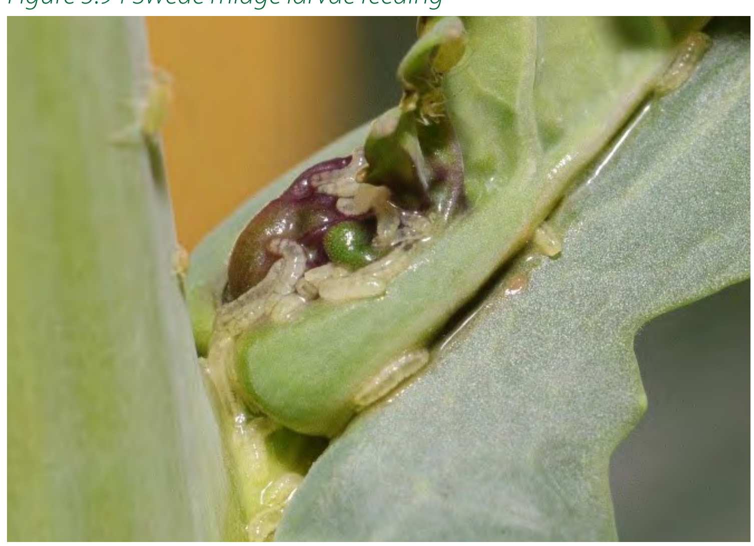
Scouting

Overwinters in soil in Ontario; Not found in Saskatchewan, yet.

Figure 3.93 Swede midge bud damage

Courtesy of: Jon Williams, AAFC

Figure 3.94 Swede midge larvae feeding



Courtesy of: Jon Williams, AAFC

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Section 4: Diseases

Common Diseases of Canola and Mustard

Blackleg

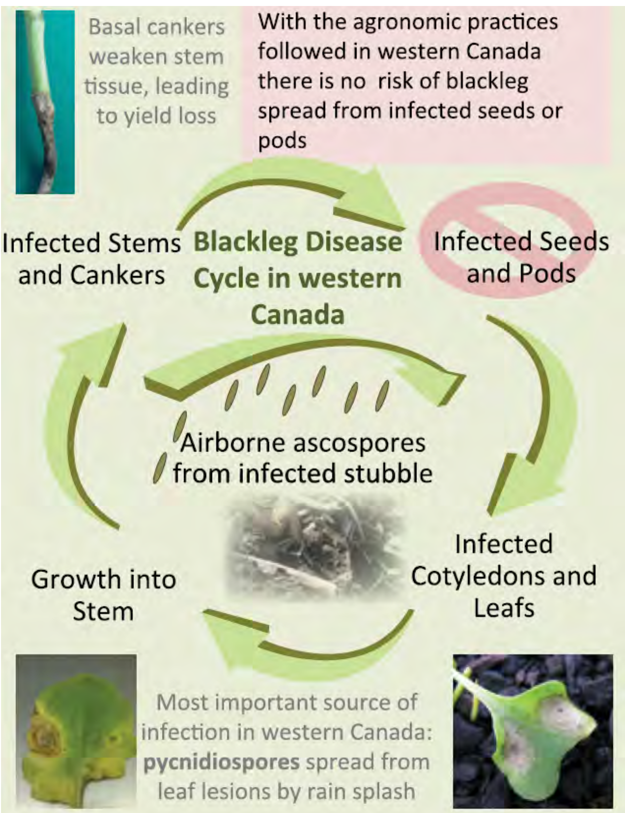
Leptosphaeria maculans or *Leptosphaeria biglobosa* (less virulent)

Blackleg *Leptosphaeria maculans* attacks cotyledons, leaves, stems, and pods. Leaf lesions are greyish white, round to irregular, and usually dotted with numerous black pycnidia (asexual fruiting bodies). Poorly defined, white or grey lesions later form on stems, often beginning at the scar left by a fallen, infected leaf. In wet weather, pycnidia on stem and leaf lesions exude pink or purple spore masses. In severely infected plants, the stem bases develop dry sunken cankers often with a black border. Cankers completely girdle the stem bases during pod filling and the plants ripen prematurely, producing shriveled seed. Pods on plants with cankers shatter before healthy plants are ready to be swathed and cankers sometimes sever plants at the stem base. The weakly aggressive fungus, *L. biglobosa*, infects plants near maturity causing shallow lesions and only slight injury.

Yield Loss

Up to 50 per cent.

Figure 4.1 Blackleg disease cycle



Courtesy of: Blackleg in Western Canola Factsheet

Figure 4.3 Pycnidia under a microscope

Figure 4.2 Leaf exhibiting blackleg lesions

Figure 4.4 Blackleg basal lesion with pycnidia

Figure 4.5 Blackleg stem lesion

Figure 4.6 Blackleg leaf lesion

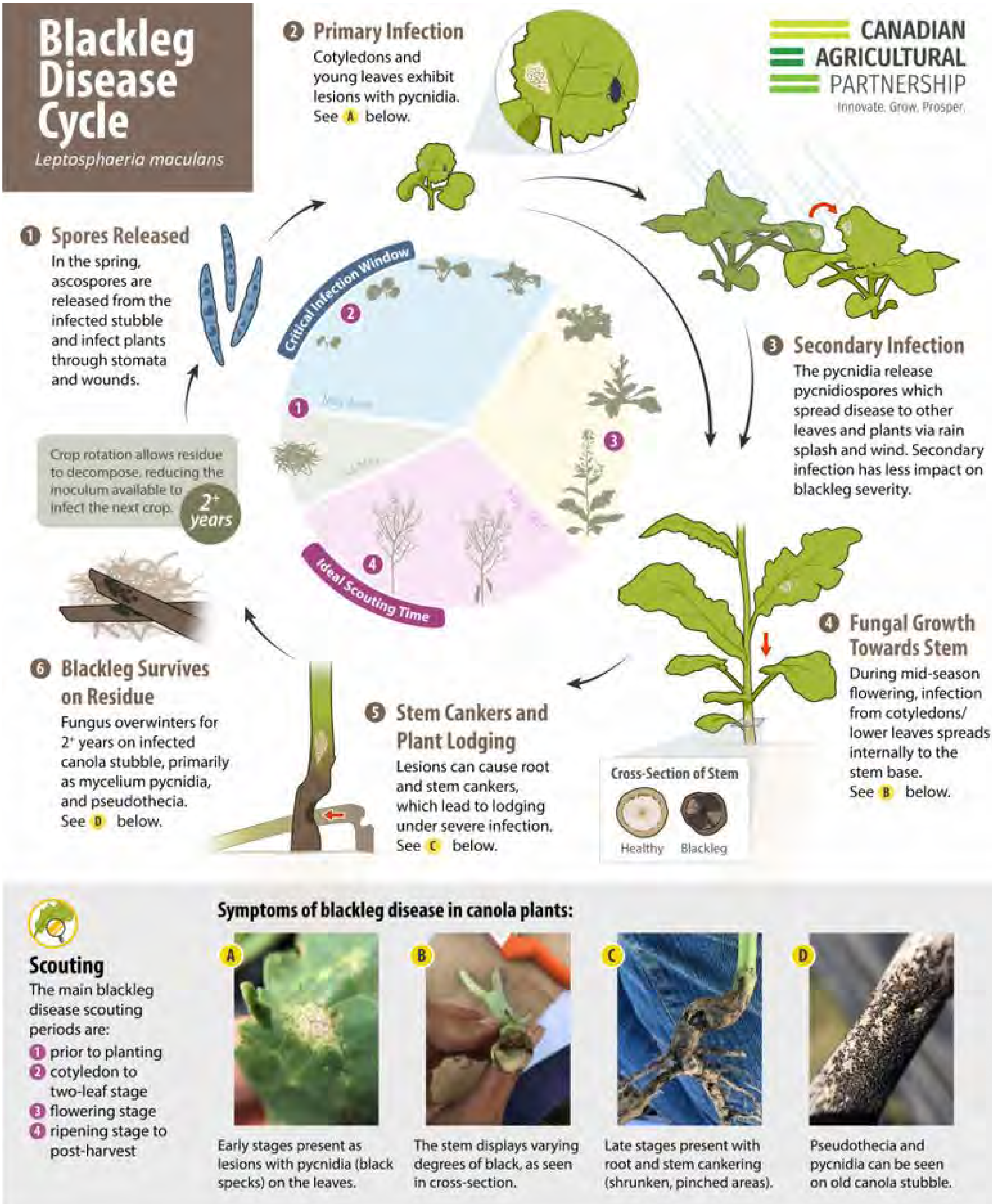
Figure 4.7 Blackleg leaf lesion

Figure 4.10 Blackleg infected plant

Figure 4.8 Blackleg lesion on canola cotyledon

Figure 4.9 Cross section showing blackleg

Figure 4.11 Life cycle diagram of blackleg



Courtesy of: Canola Council of Canada

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Blackleg Scouting Tips

Source: Canola Council of Canada's Canola Encyclopedia

There are three main scouting periods for blackleg disease during the growing season:

Prior to planting:

- Examine canola residue to see if pseudothecia are present.

Vegetative stage (three to six leaves):

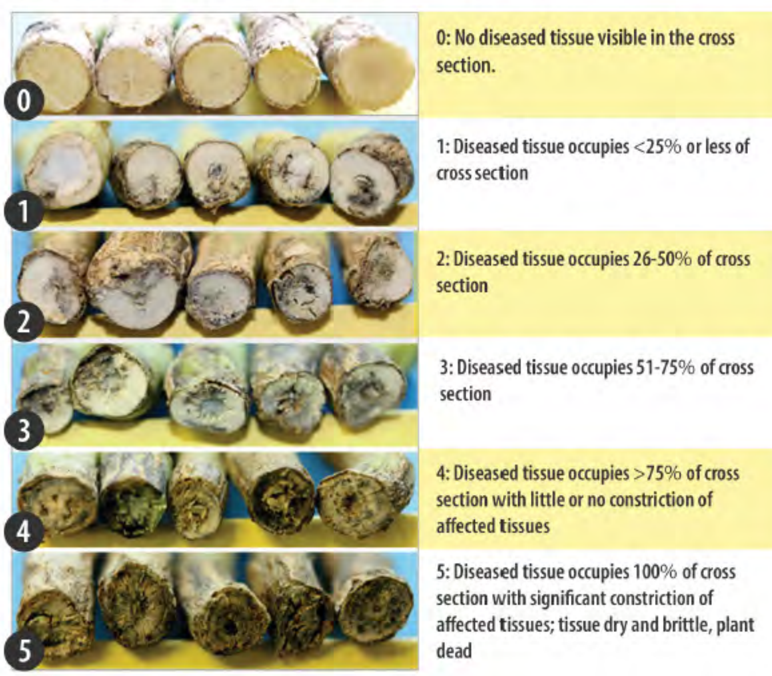
- Scout using a 'w' pattern through the field, starting at the field's edge. Focus on edges where new canola residue may be present in the adjacent field.
- Examine at least 50 plants for the presence of lesions. If lesions are found on more than 10 per cent of plants, then there is a risk of significant disease development.

At swathing:

- This is the best time to scout for the disease as the basal cankers which cause significant yield loss are easily seen.
- Pull up at least 50 plants in a 'w' pattern as described above.
- Using a pair of hand clippers, clip at the base of stem/top of root and look for blackened tissue inside the crown of the stem. The amount of infection present will help assess the level of risk and determine the best management practices for that field in following years.
- Disease severity determined using the rating scale below can be used to assess the effectiveness of the blackleg resistant canola variety used and can help guide variety rotation decisions.

The blackleg rating scale can be used to assess the severity of the infection at swathing time:

Figure 4.12 Blackleg rating scale



Courtesy of: Canola Council of Canada

The severity of infection within the field will help to assess the effectiveness of the blackleg-resistant cultivar grown. This will impove the ability to make informed major gene deployment decisions, which can reduce potential yield loss and the risk level for growing canola the next time.

Substantial yield loss typically occurs in plants showing a disease rating of '2' or greater.

High-disease situations should consult levels 3 and 4 (below) for management strategies that will help to reduce the risk of blackleg in future canola crops.

Table 4.0 Blackleg risk assessment chart

Activity	Low risk	Moderate risk	High risk
Scouting	scouting for disease beginning, middle and end of season	scout for disease only at end of season	no scouting throughout season
Evidence of disease (pseudothecia)	none		present on canola residue
Crop rotation	four years or more	three years	two years or less
Variety Blackleg label	resistant	moderately resistant	MS or Susceptible
Variety rotation	new variety		same variety
Canola volunteers	no volunteers		no volunteer control
Seed source	certified treated	bin run cleaned and treated	bin-run
Fungicide	prophylactic spray	none	none
Weed control	no brassica weed issues in rotation	brassica weed issue	brassica weeds with blackleg infection

Courtesy of: AAFC

Figure 4.13 Best Managment Practices for reducng the risk of blackleg

LEVEL 3: Best management practices can reduce the risk of blackleg

If the previous canola crop was infected severely, resulting in yield loss from blackleg, the following practices should be considered to assess the risk and manage the disease.

Canola in rotation.
Tightened canola rotations allow for blackleg inoculum to build within the field. Extending canola rotations (greater than a two-year break from canola) will allow more time for inoculum levels to decline, as old canola stubble decomposes.

Scout for the disease.
Look for internal stem blackening at ground level during swathing or straight cutting, and for pseudothecia on previous year's canola residue prior to seeding. The presence of either will help determine the risk of infection in the next canola crop.

Field resistance used.
Plant either "Resistant" (R) or "Moderately Resistant" (MR) cultivars. Resistant cultivars outperform susceptible or bin run seed.

Resistance source rotation.
Rotate cultivars by their major blackleg resistance gene. Similar to herbicide group rotation, rotating blackleg major resistance genes will slow the *L. maculans* races from becoming resistant towards these genes. Use a *L. maculans* race identification test to determine predominant *L. maculans* races in the field to help match appropriate resistance sources.

Fungicide use.
The option to add a fungicide seed treatment is available for many canola cultivars. A seed treatment fungicide protects plants from blackleg when they are most susceptible. An early season foliar fungicide application can help to prevent yield losses if applied during the cotyledon to two-leaf stage. Later foliar applications can help to reduce the inoculum in the field.

Courtesy of: Canola Council of Canada

blackleg-management-guide (canolacouncil.org)

Figure 4.14 Decoding blackleg resistance

LEVEL 4: Decoding blackleg resistance identification

Blackleg resistance is composed of two main components: major gene (seedling) resistance and quantitative (adult plant) resistance. Many cultivars on the market use both components to help manage blackleg.

Major gene resistance
is race-specific, meaning it needs to match the specific blackleg races within the field for a defense response in the plant to be induced. Once this happens, the plant stops the disease from spreading past the site of infection.

Quantitative resistance
is race non-specific, meaning it will help reduce the infection caused by any blackleg race within the field by slowing infection as it moves into or down the plant stem.

• Canola cultivars can have different combinations of blackleg resistance genes. Over time, growing cultivars with the same blackleg resistance genes can lead to changes (natural selection) in the blackleg pathogen's virulence (ability to cause disease), enabling it to overcome the resistance deployed in the cultivars. Rotation of cultivars with different resistance sources reduces resistance erosion and minimizes disease severity in your field.

• Blackleg resistance gene information enables producers to make better informed cultivar selection decisions.

Blackleg resistance labels can be composed of two parts: the existing field resistance label and a major gene resistance label which is voluntary for seed developers to apply to their cultivars.

Courtesy of: Canola Council of Canada   blackleg-management-guide (canolacouncil.org)

Figure 4.15 Blackleg vs. Verticillium

Courtesy of: Canadian Canola Council

blackleg-management-guide (canolacouncil.org)

Table 4.1 Blackleg vs. Verticillium Stripe

Plant Disease	Blackleg	Blackleg	Verticillium Stripe
Species	Leptosphaeria maculans	Leptosphaeria biglobosa	Verticillium longisporum
Stem Symptoms and distinguishing features	Stem lesions with pycnidia (black spots) forming inside the lesion. Base of stem (crown) becomes woody. Cross section cut reveals blackening.	Shallow stem lesions with pycnidia	Shredding of the stem tissue. Tiny black microsclerotia form beneath the peeling outer layer.
Pod	No symptoms	No symptoms	No symptoms
Crown (base of stem) exterior	Cankering		
Crown cross-section	Solid black sections, often pie shaped. Fully black in extreme cases.	Typically does not reach stem in time	Greyish hue across entire cut. Gets darker as microsclerotia build up. Can extend many inches up the stem.
When to scout	Prior to swath timing, 60% seed coat change (SCC).	Prior to swath timing, 60% SCC	Easier to ID post-harvest
Yield Loss	For every unit of increase in disease severity, a 17% loss in plant seed yield can be expected.	Comes in too late in the season to cause a significant impact	Does occur but no system to measure at this time.

Verticillium Stripe

Verticillium longisporum

- This disease was identified in Canada on canola for the first time in 2014. In 2015, the Canadian Food Inspection Agency (CFIA) conducted a national survey and confirmed the presence of the pathogen, *Verticillium longisporum*, in Saskatchewan, Alberta, Manitoba, British Columbia, Ontario and Quebec.
- Host crops include brassica crops with canola being a major host. Verticillium stripe develops in the same way and has similar symptoms as fusarium wilt.
- Yield loss potential is similar to other diseases that affect water and nutrient uptake.
- Symptoms include chlorosis of lateral branches and leaves, early senescence and stunting of plants, a vertical yellow or brown stripe up one side of the stem and at the end of the season there will be peeling back of the epidermis to reveal tiny black microsclerotia. The presence of these microsclerotia can be used to distinguish verticillium stripe from fusarium wilt.
- The best time to scout for verticillium stripe is late in the season, at, or after harvest.

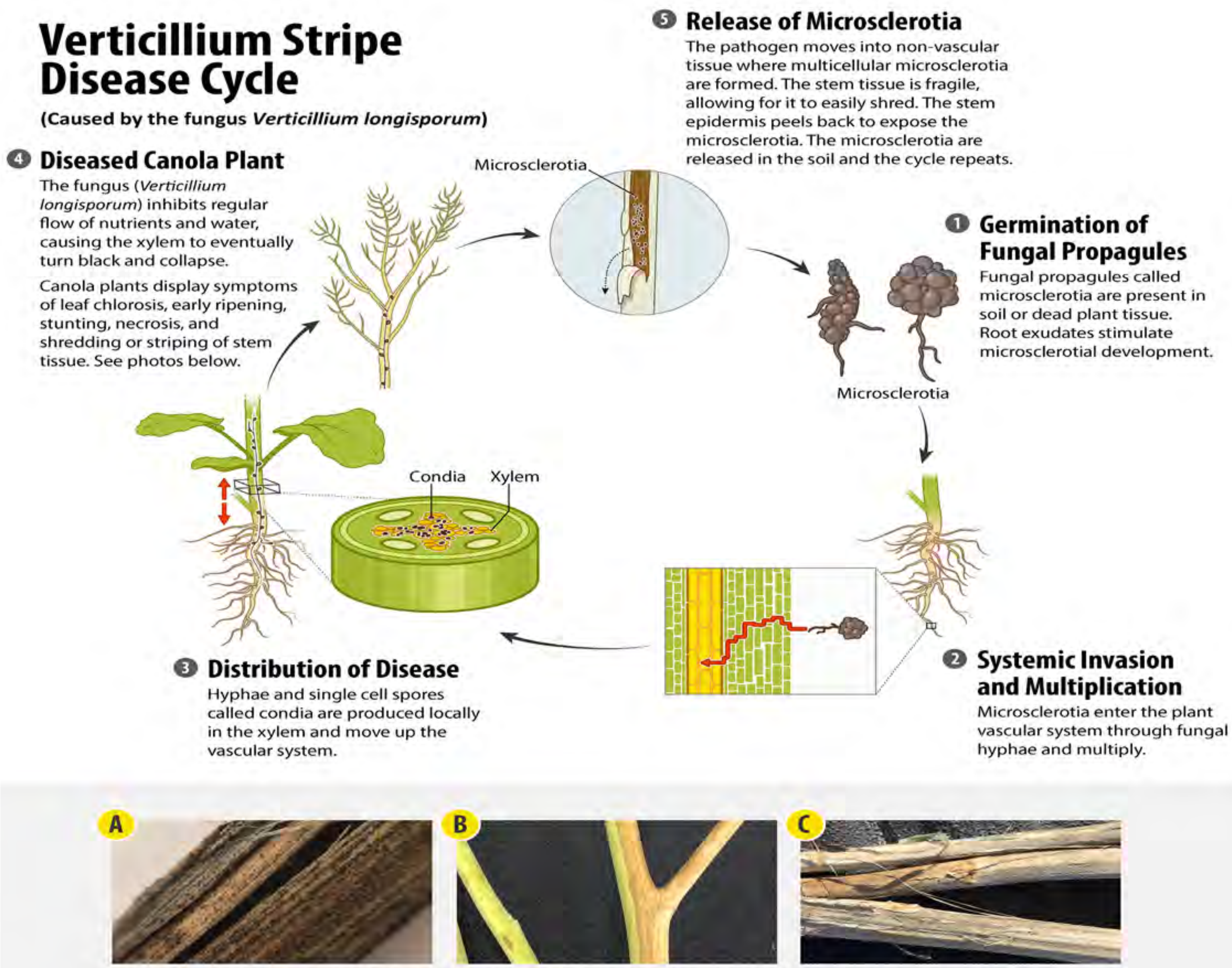
Yield Loss

Research done in Alberta found in some cases, Verticillium stripe caused greater yield losses than blackleg.

Figure 4.16 Verticillium stripe on canola stem

Figure 4.17 Verticillium stripe, peeled back epidermis revealing microsclerotia

Figure 4.18 Life cycle diagram of Verticillium longisporum



Symptoms of verticillium stripe disease spotted in canola plants: **(A)** microsclerotia, **(B)** half stem senescence (unilateral streaking), and **(C)** striping of the stem tissue.

Courtesy of: Canola Council of Canada

Fusarium Wilt of Canola

Fusarium avenaceum
Fusarium oxysporum

- Symptoms can be on one side of the leaf or stem and include: chlorosis (yellowing) and necrosis, vascular discoloration, poor seed set and premature ripening.
- Lightly infected plants show only yellow or reddish brown streaks on the stems, often only along one side or affecting only one branch. There are no visible lesions. Peeling back the surface tissue in these areas can show the vascular discoloration.
- Pods are smaller than normal and contain no seed; severely diseased plants die prematurely and may have orange discoloration at the stem base and a greyish-brown colour to the stem compared to a normal ripened plant.
- Fusarium oxysporum usually winters as soil-borne spores in the soil or on infected crop residues. Spores germinate and penetrate roots directly or through cracks formed by emerging lateral roots. Fusarium oxysporum is very long-lived in the soil with spores remaining over 10 years. The pathogen moves through the soil by wind or water movement, or on equipment.

Yield Loss

It is not a very common disease due to the successful introduction of a resistant gene in the early 2000s.

Figure 4.19 Fusarium wilt on canola stem

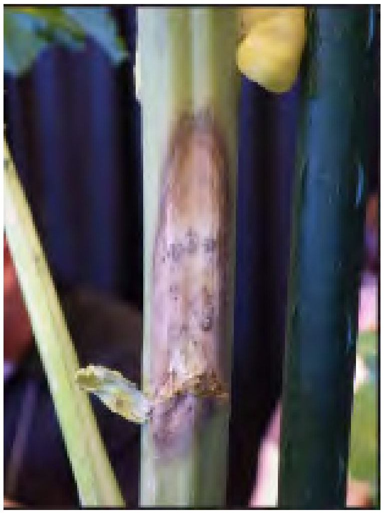
Figure 4.20 Vascular discoloration from fusarium wilt on canola

Sclerotinia Stem Rot (White Mould)

Sclerotinia sclerotiorum

- Infection begins as a soft, watery rot on leaves or stems.
- When a lesion completely girdles the main stem, the plant wilts and dies.
- The lesion will become bleached and will often have ringed markings. The infected tissue within the lesion will become dry and will shred when twisted or scratched. Under conditions of high humidity, white mycelia may be seen on the external surface of infected plant parts.
- Infected plants are most conspicuous when a crop is fully podded. This is the best time to scout for sclerotinia stem rot.
- Diseased plants ripen prematurely and contrast with adjacent healthy green plants.
- Diseased plants may remain more erect than healthy plants, which lodge from the weight of filling pods.
- The pathogen forms hard black sclerotia (resting bodies) in the hollow center of diseased stems. During harvest, diseased tissue shreds and releases the sclerotia to the soil surface.

Figure 4.21 Sclerotinia stem rot on canola stem



Yield Loss

Up to 50 per cent.

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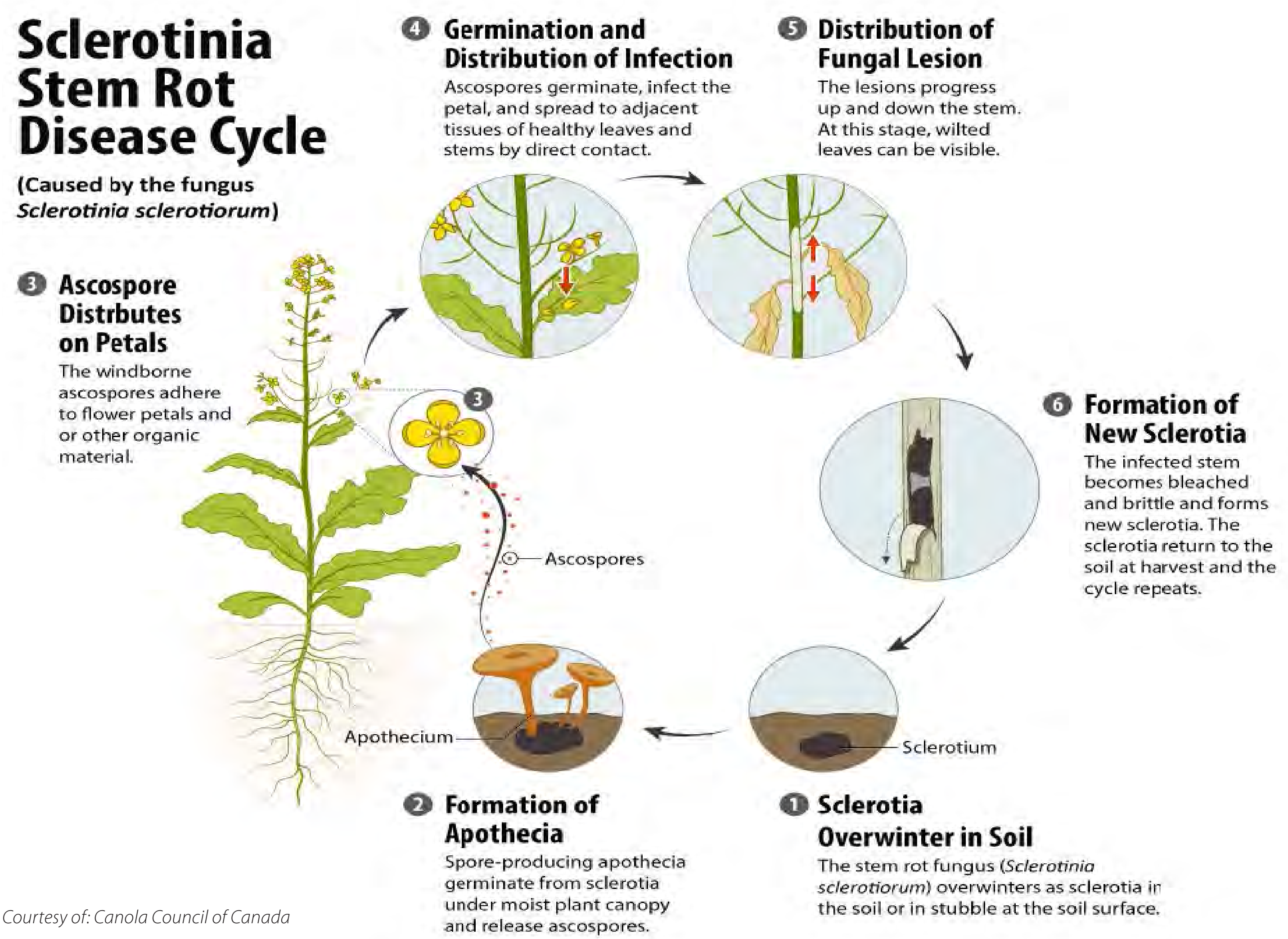
Figure 4.22 Sclerotia bodies inside canola stem

Figure 4.23 Sclerotinia on canola

Figure 4.24 Sclerotinia infected stem

Figure 4.25 Life cycle diagram of Sclerotinia sclerotiorum



Courtesy of: Canola Council of Canada

Sclerotinia Rating Scale

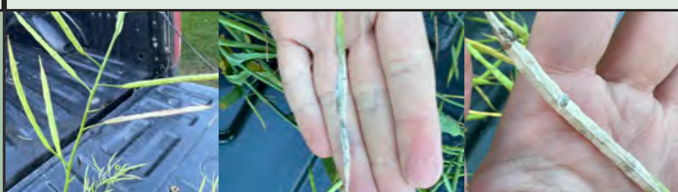
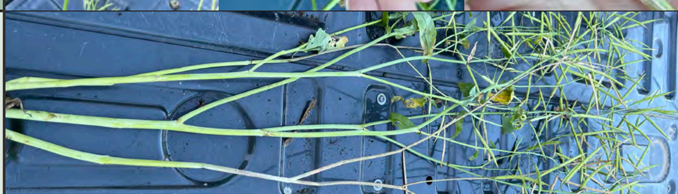
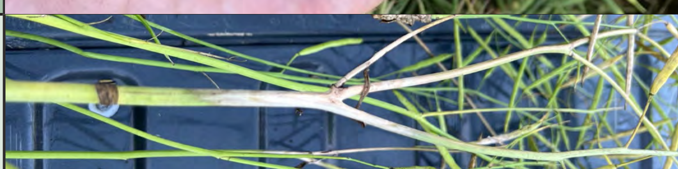
For sclerotinia stem rot of canola, severity assessments are based on the possible impact of an infection on yield. The severity ratings will take into account the position of the lesion and the potential of that lesion to impact the yield of the infected plant. Lower main stem lesions have the potential to affect the entire plant and will lead to higher levels of yield loss than pod or branch infections which only impact a part of the plant.

As a rule of thumb, the potential yield loss in a field can be determined by:

per cent potential yield loss = per cent disease incidence x 0.5
(where disease incidence = per cent of plants infected)

For example, a canola field with 50 per cent of the plants infected with sclerotinia stem rot would have an approximate yield loss of 25 per cent (50 per cent disease incidence x 0.50 = 25 per cent). The actual yield losses depend on the environmental conditions, canopy structure, cultivar and time of infection.

Table 4.2 Sclerotinia severity rating scale

Disease Rating	Lesion Location	Symptoms
0	None	No symptoms
1		Infection of pods only
2		Lesion situated on main stem or branch(es) with potential to affect up to 1/4 of seed formation and filling on plant
3		Lesion situated on main stem or on a number of branches with potential to affect up to 1/2 of seed formation and filling on plant
4		Lesion situated on main stem or on a number of branches with potential to affect up to 3/4 of seed formation and filling on plant
5		Main stem lesion with potential effects on seed formation and filling of entire plant

Adapted from Kutcher, H.R. and T.M. Wolf. 2006. Low-drift fungicide application technology for sclerotinia stem rot control in canola. Crop Protection 25: 640-646

Clubroot

Plasmodiophora brassicae

Clubroot is a soil-borne disease, caused by *Plasmodiophora brassicae*, that affects the roots of cruciferous field crops and vegetables including (but not limited to) canola, mustard, camelina, broccoli, cauliflower, radish and turnip. Cruciferous weeds (for example: stinkweed, shepherd's purse and wild mustard) can also be infected by *P. brassicae*. Clubroot is a regulated pest under the Saskatchewan *Pest Control Act*. Clubroot can affect canola yield and quality to a similar degree as other diseases that affect water and nutrient uptake. Its impact depends on soil conditions and the growth stage of the crop when infection occurs. Early infection of seedlings tends to result in great yield losses. Spore germination, infection and disease development are favoured by warm soils, high soil moisture and low soil pH.

Figure 4.26 Large and small clubroot galls

Symptoms

Clubroot infection leads to swelling of the infected root tissue (galls). Clubroot galls will initially appear white and fleshy. Later in the season, clubroot galls will start to decompose, releasing the resting spores back into the soil, and will appear rotten. Decomposing tissue may have a sawdust or peat moss-like appearance.

Figure 4.27 Mature clubroot gall on canola

When clubroot infection inhibits the plant's ability to obtain water and nutrients, above ground symptoms of yellowing, premature ripening and wilting may occur. These symptoms can occur with other diseases or physiological disorders. To determine if clubroot is the cause, it is important to dig up the plants and examine the roots for clubroot galls. Below ground infection may occur even in the absence of above ground symptoms. As a result, it is important to uproot plants to look for symptoms even if the above ground plant appears healthy.

Figure 4.28 Variety of clubroot gall shapes and sizes

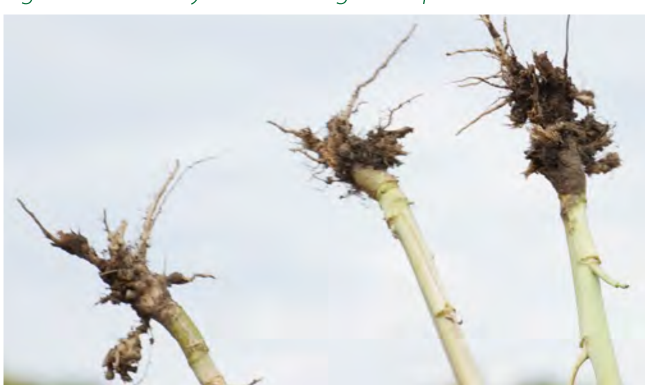


Figure 4.29 Variety of clubroot gall shapes and sizes

Clubroot Disease Cycle

The clubroot pathogen overwinters in the soil as long-lived, hardy resting spores that can survive in the soil for up to 20 years and have been documented to have a half-life of two to four years. In the spring, the resting spores germinate to produce zoospores. Zoospores have two flagella (tails) that enable them to swim very short distances in water or water film which is how they come in contact with and infect root hairs.

During this initial stage of infection, no symptoms will be visible with the naked eye. Within the infected root hairs, the pathogen will multiply and form a plasmodium (a naked mass of protoplasm with numerous nuclei), which will divide to form secondary zoospores. The secondary zoospores will be released back into the soil as the root hairs begin to decompose.

These secondary zoospores will then re-infect the plant roots and are able to cause infection in the interior of the root (root cortex). At this stage, the pathogen will form secondary plasmodia in the infected cells and cause hormonal changes that lead to increased cell division and growth. This leads to swelling of the infected tissue producing clubroot galls. These deformed roots have a reduced ability to absorb water and nutrients leading to stunting, wilting, yellowing, premature ripening and shriveling of seeds. At low pathogen levels, galls will be smaller and have a minimal impact on yield compared to large galls, which occur when pathogen levels are high.

As the plasmodia mature they will divide into many resting spores, which fill the cells of the infected root tissue. At the end of the growing season, the galls will start to decay and release the resting spores back into the soil to cause infection the next time a susceptible crop is grown. Every time a susceptible crop is grown, more resting spores will be returned to the soil, increasing the pathogen population and potential yield loss the next time a susceptible crop is grown.

Scouting

Clubroot is best managed when detected early. Scouting for clubroot should take place at swathing and focus on field entrances, low spots (where higher moisture conditions occur), water runs, areas of the field with low pH, high traffic areas and patches with above ground symptoms. When scouting for clubroot, it is important to examine plant roots for the presence of clubroot galls. If you are in the center of a patch with premature ripening and notice that the roots are rotten, move to the outer edges of the patch and examine plant roots for intact galls.

To confirm a clubroot diagnosis, you can submit a sample to the Ministry of Agriculture's Crop Protection Lab for visual confirmation or you can submit a sample to a private laboratory for DNA-based confirmation.

Soil testing can be used to detect the pathogen in the soil at levels lower than required for the development of visible symptoms under field conditions. This early detection can enable proactive management focused on keeping the clubroot pathogen levels low and thus minimizing the impact of clubroot on canola yields. Prior to soil sample collection, it is important to contact the laboratory for the sampling protocol as the location and soil sample collection methodology will influence the ability of the test to detect low levels of the pathogen and reduce the likelihood of a false negative test result.

Yield Loss

Up to 75 per cent.

Clubroot Prevention

Clubroot is a relatively new disease on the prairies and was first found in canola in Alberta in 2003. Proactive management through an integrated approach which includes extended crop rotations, monitoring and early deployment of clubroot resistant varieties (in extended crop rotations) can be used to keep spore levels low and minimize yield losses. For optimal management, these strategies should be implemented before clubroot symptoms are identified in a field. Preventive measures can be taken to deter the introduction of the pathogen into new areas or fields where it is not already present.

The clubroot pathogen is soil-borne and can move any way that soil can be moved. The pathogen can be spread within fields and to neighboring fields by any method that moves soil including: earth tag on agricultural or industrial field equipment, vehicles/tires, animal/manure, water erosion and wind. Activities that move large volumes of soil between fields or regions (particularly from regions thought to have clubroot) are considered to be the highest risk. Using sanitation and other practices aimed at minimizing soil movement can be used for clubroot prevention.

Figure 4.30 Premature ripening caused by clubroot on canola

Interpreting a Clubroot Soil Test Result

The results of a clubroot test may look different depending on the lab conducting the test. Some labs offer a "yes" or "no" type of test (PCR) while other tests will indicate the concentration of the pathogen in the soil (expressed as spores per gram of soil: qPCR).

- For a PCR test, a positive result indicates that the pathogen is present in the field. When this occurs, it is important to implement proactive management strategies to keep pathogen levels low and prevent spreading the pathogen to new fields or new areas.
    - A negative test result means that the pathogen was not detected in the area where the soil was collected. This does not mean that the pathogen is not present in the field, due to the limitations of the test and the potential for a false negative.
- When the concentration of the pathogen is determined, it can provide you with an estimate of the pathogen level in the field. If pathogen levels are high, this indicates that there is a higher potential for larger yield losses. However, due to variable occurrences of the pathogen in the field and the limitations of DNA-based testing, this information cannot be used to estimate the potential yield loss due to clubroot.
    - A minimum two-year break (three-year crop rotation) from a susceptible crop or weed species will allow the pathogen population to reduce over time. When pathogen levels are high, greater than 100,000 spores per gram of soil, additional clubroot management strategies are necessary, as crop rotation on its own will not effectively reduce spore levels to a manageable level.
    - The level of the pathogen may vary over the growing season, particularly when a susceptible host crop is grown. If you use DNA-based soil testing to monitor pathogen levels over time, always collect soil samples from the same location and at the same time of the year.
- It is important to remember that clubroot management needs to be proactive and should include the use of clubroot-resistant varieties in extended crop rotations to keep pathogen levels low whenever the pathogen is present in the field or within the region.

For specific details on sample testing, please inquire with your commercial or provincial crop protection lab.

Types of DNA Soil Testing

- Polymerase Chain Reaction (PCR): PCR soil testing for clubroot relies on the amplification and detection of the clubroot pathogen DNA. This test gives a positive or negative result and can be used to indicate whether or not the clubroot pathogen is present above the limit of detection in the area where the soil was collected.
- Quantitative Polymerase Chain Reaction (qPCR): qPCR testing relies on the same basic principles of a PCR test, but allows for the quantification of the amount of pathogen DNA present in the soil sample. The amount of DNA detected is then used to approximate how many spores are present in a gram of the soil tested.

The limit of detection for both PCR and qPCR clubroot tests are approximately 1,000 spores per gram of soil. These tests are not able to differentiate between different strains or pathotypes of clubroot.

Courtesy of: Governments of Alberta Saskatchewan and Manitoba interpreting a clubroot soil test results factsheet

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Grey Stem in Canola

Pseudocercosporella capsellae

- Fungus overwinters as thick-walled mycelium on crop residue and produces wind-borne spores in the spring that infect canola plants. Lesions develop on lower leaves and produce wind-borne spores that re-infect other plant tissues, causing the rapid spread of the disease in the ripening crop.
- Wide host range among cruciferous weeds, including shepherd's purse, stinkweed, mustards as well as volunteer brassicas.
- Large purple to grey-speckled stem and pod lesions. At harvest some plants may be completely discoloured and entire field may turn purple or grey colour.
- Can cause mature canola crops to lodge at stem lesion. Usually occurs too late in the growing season to create yield loss.
- Managed through crop rotation, control of other host plants, integrated weed management and best management practices to promote a healthy, vigorous crop.

Yield Loss

Usually develops too late in the growing season to affect crop yields significantly.

Figure 4.31 Grey stem in canola

Figure 4.32 Grey stem in canola

Powdery Mildew in Canola

Fungus Erysiphe cruciferarum

- Symptoms appear as fine, powdery white fungal growth on canola leaves, stems and pods.
- Ascospores or conidia land on the upper surface of leaves or stems and penetrate the tissue and spread inside the epidermal cells, taking nutrition from the plant.
- White clouds of dust or powder can be released from canola plants infected by powdery mildew when swathing and equipment can become coated with white powder.
- The pathogen overwinters as cleistothecia, which germinate in the spring to produce sexual ascospores. Asexual spores (conidia) are produced on infected plants and can be wind-blown to new fields.

Yield Loss

Most infections occur too late in the season to cause significant yield loss.

Figure 4.33 Powdery mildew spores on combine

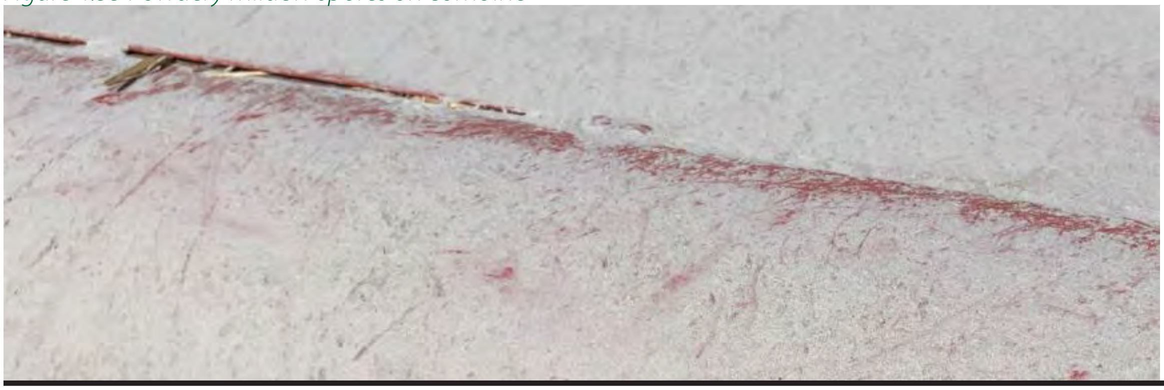


Figure 4.34 Powdery mildew in canola

Figure 4.35 Powdery mildew in canola

Root Rot Diseases of Canola

Brown Girdling Root Rot

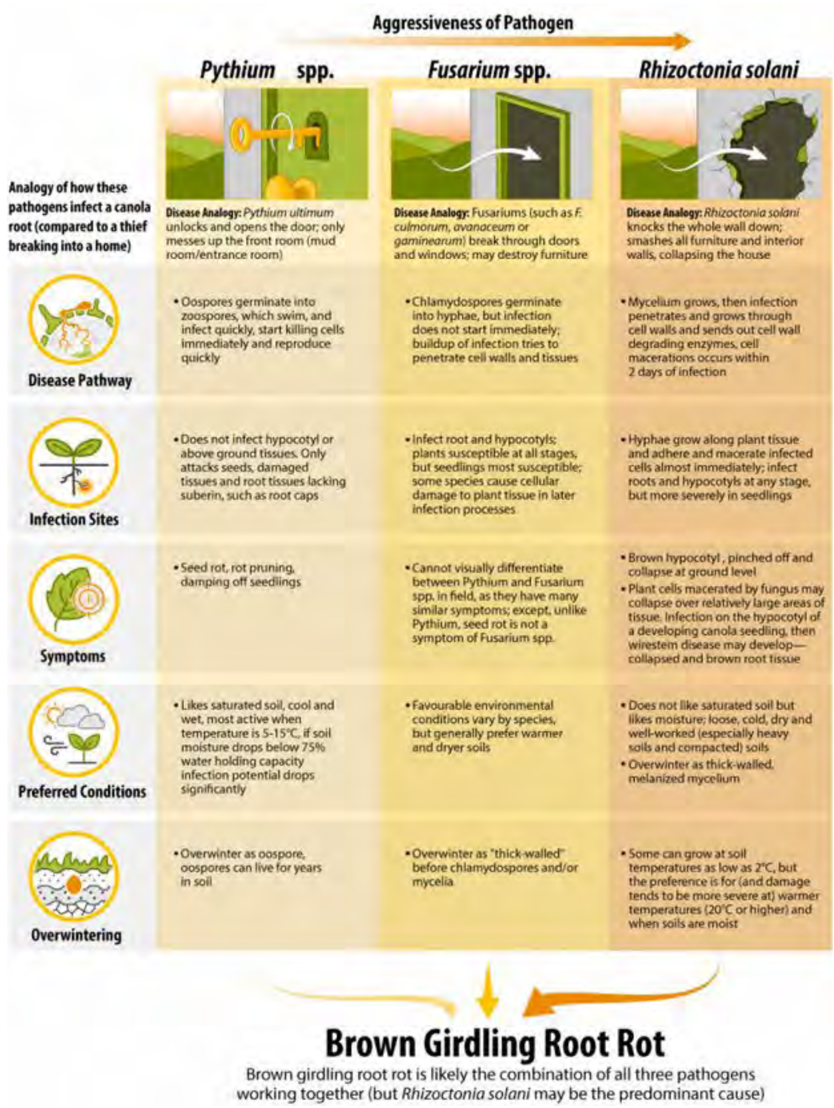
Rhizoctonia solani

Brown girdling root rot is the only root rot of canola that is of major economic importance in Canada. It occurs mainly in the Peace River region of Alberta and British Columbia, where it is the most important disease of canola and is found in virtually all fields. On average, yield loss is eight to 18 per cent region-wide, but can be up to 55 per cent in some fields. Yield loss is proportional to the amount of root system lost by the girdling. Low levels of brown girdling root rot occur throughout the prairies, especially on heavy clay soils.

Symptoms

Infection occurs below ground and symptoms are confined to the roots. Light brown lesions with irregular margins form on the tap root or main laterals at any depth below the crown. As they develop, lesions become darker and sunken, often in vertical streaks. They may coalesce and girdle the tap root. Roots below the girdled zone rot and break away and the decay may progress up the tap root. Under moist conditions, the whole tap root is destroyed up to ground level. Under dry conditions, plants with girdled tap roots dry up and shrivel, but in moist soils they may survive and set seed if they are not blown over. Root lesions first appear during flowering and may girdle the tap root by the end of flowering. New lesions and girdling continue to develop until senescence.

Figure 4.36 Root rot pathogens that infect canola



Courtesy of: Canola Council of Canada

Control

Use B. napus cultivars where the average growing season is long enough for the crop to reach maturity, since they have better tolerance than B. rapa. Lesions formed on B. napus varieties are less likely to girdle the tap root. It is recommended to control canola and cruciferous weeds in fields and use a three to four year rotation to break up the disease cycle.

Yield Loss

One to five per cent.

Common Diseases of Flax

Pasmo

Septoria linicola

Early in the growing season, brown spots indicative of pasmo, appear on the leaves of flax. As the lesions develop, older leaves may fall off, while others remain attached to the stem. Later in the season, small brown spots appear on the infected stems at the site of leaf attachment. The spots enlarge and join together to form brown bands that encircle the stem. These bands alternate with healthy green bands to produce a mottled appearance (see image below). Severely infected plants turn completely brown and die. Flowers and young bolls may die, older bolls may be discolored and the seed is shriveled or dead. Pasmo may weaken the slender stalks that carry the bolls; as a result, strong winds or heavy rain may cause bolls to drop. As pasmo is seed borne, it is extremely important to have flax seed tested each year to keep levels of this disease from causing severe damage in your fields and to practice a crop rotation of at least four years between flax plantings. The fungus overwinters in the soil on infected flax stubble.

Yield Loss

It reduces both the quality and quantity of flax, and when severe, it can reduce seed yield by as much as 60 to 70 per cent.

Figure 4.37 Pasmo infection on stems and bolls

Figure 4.38 Pasmo infection on stem

Figure 4.39 Pasmo infection on flax (right) vs. no infection left)

Fusarium Wilt of Flax

Fusarium oxysporum f. sp. Lini

Infection can occur throughout the growing season and most commonly occurs in patches, although it can also be found in random plants scattered throughout the field. Infected seedlings may die before or shortly after emergence while older plants will have yellowing and wilting of leaves, followed by browning and eventual plant death. Plants can also be partially wilted, with leaves on one side of the stem showing wilt while those on the opposite side are healthy. The tops of wilted plants often curve downward, forming a shepherd's crook that is distinctive of this disease. Once considered a devastating disease, modern breeding efforts have developed wilt-resistant cultivars.

Flax wilt or Fusarium wilt is caused by the seedborne and soilborne fungus *Fusarium oxysporum f.sp lini*.

Yield Loss

Severe infection under cold wet weather can reduce yields by up to 50 per cent from these fungi.

Figure 4.40 Classic shepherd's crook found on young plants infected with fusarium

Common Diseases of Field Pea

Ascochyta Leaf and Pod Spot

Ascochyta pisi

- Lesions on leaves, stems and pods are tan or brown in the center, with distinct dark margins. Large stem and pod lesions tend to be sunken.
- The centers of lesions may be speckled with black fruiting bodies (pycnidia) that contain spores (conidia).
- Severe pod infection often results in seed discoloration.

Yield Loss

Up to 70 per cent.

Figure 4.41 Ascochyta blight on pea

Courtesy of: University of Saskatchewan

Figure 4.42 Ascochyta on pea leaves

Courtesy of: University of Saskatchewan

Figure 4.43 Ascochyta on leaf

Courtesy of: AAFC

Figure 4.44 Ascochyta pisi lesions with pycnidia on pod

Mycosphaerella Blight

Mycosphaerella pinodes

- Lesions are on leaves, stems, flowers and pods. On leaves, small, purplish spots with irregular margins that can enlarge, coalesce and cause tissues to dry up.
- Lesions on petals are small but infected blossoms may drop.
- Lesions on stems often coalesce to cause extensive blighting and foot rot.
- On pods, lesions are initially small and may expand on ripe pods to produce extensive purplish brown discoloration. Infected seeds may show no visible symptoms.

Yield Loss

Severe infection under cold wet weather can reduce yields by up to 50 per cent from these fungi.

Figure 4.45 Mycosphaerella blight on peas

Downy Mildew in Field Pea

Peronospora viciae

- Fluffy, greyish white growth develops in patches or occasionally covers the entire lower surface of the leaflets.
- Leaf becomes chlorotic to light brown on the side opposite to the infected area.
- Systemic infection leads to severe stunting, foliar distortion and seedling death.
- Pod infection causes seed abortion and discoloration.

Yield Loss

Up to 75 per cent.

Figure 4.46 Downy mildew on pea leaves

Figure 4.47 Downy mildew damage on pod and seeds

Powdery Mildew in Field Pea

Erysiphe pisi

- Symptoms appear as fine, powdery white spots on upper surface of leaves that spread rapidly over the entire surface of leaves, stems and pods.
- Tissue below the mildew may show a purplish discoloration.
- As the plant ages, pinhead-size sexual fruiting bodies develop on the infected tissue. They are golden brown at first, but turn black at maturity.

Yield Loss

Now rarely of significance because most commonly grown varieties of peas are resistant to this disease.

Figure 4.48 Powdery mildew on peas

Sclerotinia Stem Rot (White Mould) in Field Pea

Sclerotinia sclerotiorum

- Soft rot of leaves, stems and pods within the canopy.
- Under humid conditions a fluffy white mycelium is visible on surface of rotting tissue.
- Stems wilt or ripen prematurely. Under dry conditions the infected portions appear bleached and shred easily.
- Sclerotia bodies can be found on and inside infected stems and pods.

Yield Loss

Sclerotinia was formerly a serious problem when the old full heavy pea crops lodged. In the new dwarf leafless types of pea, this disease is much less of a problem.

Figure 4.49 Sclerotinia stem rot in field pea

Pink Pea in Field Pea

Erwinia rhapontici

- Caused by an opportunistic bacterial plant pathogen (Erwinia rhapontici).
- Infects peas, beans, lentils, chickpeas, faba beans, wheat, durum and many other crops.
- Has the ability to cause significant yield and quality losses during years where rainfall is above average.
- Seed infection is associated with damage to pods from hail, wind or insect feeding, followed by a moisture event or high humidity.
- The pathogen can overwinter on seed and residue of infected crop even under harsh Canadian Prairie winter conditions.

Figure 4.50 Pink pea in field peas

Symptoms:

- Infected seed will be shriveled and turn an intense pink or red colour, the colouring is like that of seed treatments.
- Symptoms on yellow peas are more noticeable due to the harsh contrast in colour.

Management:

- Fungicidal seed treatments are not effective since the disease is caused by a bacteria rather than a fungal pathogen.
- Since the range of crops that are affected by this pathogen are quite broad, crop rotation may not be an effective method of controlling the disease.
- The best control method is to use clean, certified seed, as research has shown that planting infected seed resulted in an average of 33 per cent reduction in plant emergence.

Common Diseases of Lentil

Ascochyta Blight

Ascochyta lentis

- Spot-like lesions, which are initially light grey, that become tan with a darker brown margin.
- Lesions are found on leaflets, petioles, stems, peduncles and pods.
- Pod lesions are usually darker than those on other structures.
- Peduncle lesions cause flower and pod abortion and are the major cause of yield loss.
- Centers of lesions become speckled with pycnidia. This is similar to septoria but septoria lesions contain concentric markings and are mainly confined to lower leaflets.
- Causes premature leaf drop and stem dieback giving the crop a brown blighted appearance.
- Pod infection may lead to seed infection and discoloration.

Yield Loss

Ascochyta blight/complex is the most common disease of field pea in Western Canada. The disease can produce yield losses of more than 30 per cent.

Figure 4.51 Ascochyta-infected lentil

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Anthracnose in Lentil

Colletotrichum truncatum

- White to grey, oval lesions develop on the lower leaflets then spread upward. The first symptoms may appear at the seedling stage, but are more common when the crop canopy begins to close. Lesions become tan, the margins darken and the leaflets fall.
- Stem lesions are tan to brown and sunken. They develop near the stem base but spread both vertically and horizontally and soon girdle the stem. Girdled stems die causing extensive leaf drop and yield loss.
- Anthracnose appears as yellow patches in fields after the canopy has closed. The patches enlarge as the disease spreads and plants in the center die and turn dark brown.
- The stem bases of plants that are killed by anthracnose often have a blackened appearance which persists on the stubble after harvest. The blackening is due to the development of tiny, black microsclerotia (resting bodies) which are visible with a magnifying glass.
- Microsclerotia are irregular in shape and smaller, more numerous, and more closely clustered than pycnidia of ascochyta.

Yield Loss

Anthracnose is capable of causing yield losses in excess of 50 per cent.

Figure 4.52 Anthracnose lesion on lentil

Figure 4.53 Anthracnose on lentil stem

Figure 4.54 Anthracnose lesion on lentil stem

Sclerotinia Stem and Pod Rot (White Mould) in Lentil

Sclerotinia sclerotiorum

- Wilting, stem infection, bleaching of tissues and the presence of white mould and black sclerotia (resting bodies) are similar to the symptoms on pea.
- In dense, lodged stands, the disease develops in patches due to plant-to-plant spread.
- When scouting, lift plants up and the mould will be apparent.

Yield Loss

Yield losses due to this disease can be greater than 50 per cent if inoculum levels are high and the environment favours disease development.

Figure 4.55 White mycelial growth on lentil stems and leaves caused by Sclerotinia sclerotiorum.

Figure 4.56 Sclerotinia sclerotiorum infection on lentil leaves

Stemphylium Blight in Lentil

Stemphylium botryosum, Stemphylium spp.

- Leaflet lesions appear at all stages of crop development. They are light cream in colour, usually with angular patterns of lighter and darker areas that spread across, or along, the entire leaflet.
- After wet weather in late summer, crops may appear grey due to extensive infection on the upper foliage.
- Leaflet abscission follows, which may be beneficial in drying down the crop.

Yield Loss

It has not yet been confirmed as causing significant yield losses because the disease tends to show up later in the growing season.

Figure 4.57 Stemphylium blight infected lentil leaves

Figure 4.58 Stemphylium blight on lentils

Botrytis Stem and Pod Rot (Grey Mould) in Lentil

Botrytis cinerea

- Both seed and stubble-borne. Infected seed can lead to seedling blight. Spores are wind-borne and cool, wet weather promotes sporulation and infection.
- Premature ripening due to infection of lower stems, infected portions are light brown or bleached and covered with a grey, mouldy growth. Infected pods will be brown, rotten, and covered with the same grey, mouldy growth while infected seeds may be shriveled and discolored.
- In dense, lodged stands, the disease develops in patches due to plant-to-plant spread. Pod lesions frequently develop from areas in contact with dead petals as Botrytis colonizes dead tissue first.
- When scouting, looks for areas of premature ripening and grey mouldy growth on stems and pods. Clouds of grey spores will rise from heavily infested mouldy tissue when disturbed.

Yield Loss

Botrytis grey mould causes stem and pod rot during the flowering and seed filling stages and can cause economic losses. Soil-borne inoculum is present in all fields, but this disease is typically only a problem in heavy vegetative stands that have lodged due to wet, cool weather.

Figure 4.59 Botrytis Stem and Pod Rot in Lentil

Figure 4.60 Botrytis Stem and Pod Rot in Lentil

Courtesy of: Cheryl Cho

Common Diseases of Chickpea

Ascochyta Blight

Ascochyta rabiei

- Symptoms develop on the lower leaves as light brown lesions, often with dark margins, and spread upwards as the plants grow.
- On stems, the lesions are usually darker, so the dark colour of the margin is not always as prominent.
- The lesions may coalesce, and quickly become dotted with small, black fruiting bodies (pycnidia) that often develop in concentric rings.
- Stems that are girdled by expanding lesions soon break, and the foliage above the break off point dies.
- Circular patches of dead and dying plants are highly visible in fields where the disease is spreading quickly.
- On resistant cultivars, dark brown pinprick lesions develop, but do not progress.
- Lesions on pods may lead to infection, discoloration and shrinkage of the seed.

Yield Loss

If ascochyta spreads to the top of the canopy and wet conditions prevail, infection may lead to flower and pod abortion, resulting in significant yield losses - as much as 50 per cent.

Figure 4.61 Ascochyta blight lesions on chickpea

Figure 4.62 Ascochyta blight on chickpea leaflets

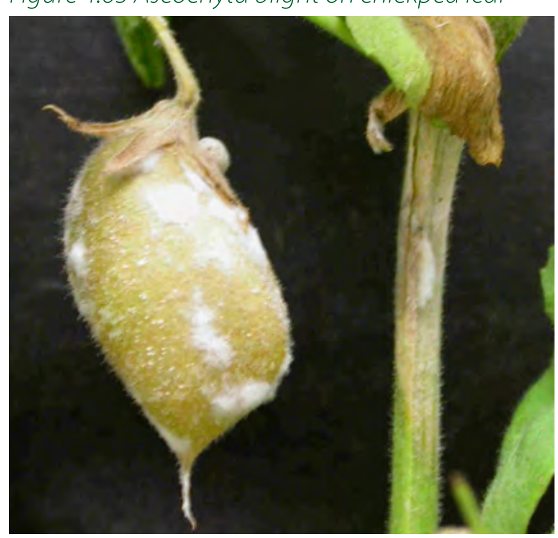
Sclerotinia Stem and Pod Rot (White Mould) in Chickpea

- Symptoms usually appear after canopy closes.
- Watery white lesions will appear on stems, petioles, leaves, stems, pods and seeds.
- Lesions will develop into fluffy white mycelium under wet conditions.
- Infection often starts on leaves or flowers then spreads to girdle the stem or to infect pods and seeds.
- Sclerotia (hard, black, irregularly shaped bodies) will form on the surface and inside the plant.
- Stems will become brittle and bleached.
- Foliage above the lesion dies, leaving prematurely ripened plants scattered in among healthy green plants.

Yield Loss

Yield losses due to this disease can be greater than 50 per cent if inoculum levels are high and the environment favours disease development.

Figure 4.63 Ascochyta blight on chickpea leaf



Courtesy of: University of Saskatchewan

Root Rot in Pulse Crops (Pea, Lentil, Soybean & Chickpea)

Many fusarium species can cause root rots in pulse crops including (but not limited to): *F. avenaceum, F. solani, F. redolens, F. oxysporum, F. graminearum,* and *F. culmorum*. Recent research suggests that *F. avenaceum and F. solani* are the most aggressive fusarium root rot pathogen in peas in Alberta and Saskatchewan.

Fusarium root rot starts near the seed on the taproot and infects the cortex of the root causing reddening. External lesions are brick red, dark reddish brown or chocolate coloured and spread up the stem and down the root. Infected plants become stunted, roots turn greyish then yellow and the lower leaves will wither and die.

Fusarium species isolated from pulses in Saskatchewan include *F. avenaceum, F. solani, F. redolens,* F.*oxysporum, F. graminearum, F. equiseti, F. culmorum* and *F. poae*. These and non-specialized pathogens can also infect cereal crops, causing root rot and head blight.

Yield Loss

Early infections are the most devastating in terms of yield loss, as the infection starts at the seedling stage before any yield is set. Infections can also occur later in the season and may not show up in yield loss or symptoms above ground.

Figure 4.64 Red discoloration from fusarium root rot

Figure 4.65 Fusarium acuminatum

Figure 4.66 Initial Fusarium infection on soybean seed

Figure 4.67 Advanced Fusarium infected soybean seed

Fusarium Wilt of Pea

Fusarium oxysporum f. sp. pisi

Infection can occur throughout the growing season at any growth stage. Infected plants will often exhibit an orange or dark red discoloration of the root vascular tissue and lower stem. Above ground symptoms include yellowed leaves that wilt and curl downward during flowering to pod-fill. Symptoms will first present on lower leaves and will progress from the base of the plant to the top until the entire plant turns yellow and dies. Seedling death may occur with early infection.

Yield Loss

Plants affected by pea wilt often do not produce pods, or pods are small and underdeveloped.

Figure 4.68 Fusarium infection on pea field

Figure 4.69 Fusarium infection on pea

Fusarium Wilt of Lentil

Fusarium oxysporum f. sp. lentis

Infection can occur throughout the growing season at any growth stage and most commonly occurs in patches. Infected plants will appear stunted with leaves that turn yellow and curl from the upper part of the plant to the lower parts. Other above ground symptoms may include wilting and dropping of the top leaves and shrinkage and curling of leaves without premature leaf drop with plants eventually dying and turning yellow. Below ground symptoms include reduced growth, yellowish brown discoloration, poorly developed nodules, damage at the tip of the taproot, and proliferation of secondary roots above the injured area of the taproot. The discoloration of the vascular tissue is not always present.

Yield Loss

Fusarium wilt causes yield loss up to 50 per cent (no yield loss data available for Saskatchewan).

Figure 4.70 Post-emergent damping-off of lentil caused by Fusarium

Fusarium Wilt of Chickpea

Fusarium oxysporum f. sp. ciceris

Infection can occur throughout the growing season at any growth stage with affected plants appearing in patches or spread across the field. Above ground symptoms include flaccidity of individual leaves which is followed by a dull green discoloration, desiccation and death of the plant. With later infection, symptoms may include drooping of the petiole and leaflets followed by yellowing and necrosis of the foliage. Below ground, the plant may not demonstrate any external root discoloration. However, if the root is split open vertically the xylem tissue may have a dark brown discoloration.

Yield Loss

Yield loss up to 60 per cent.

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Aphanomyces Root Rot

Aphanomyces euteiches

The causal agent of aphanomyces root rot, is a fungal-like organism that is particularly adapted to wet and waterlogged soils. A distinguishing feature of aphanomyces root rot is the development of caramel coloured roots. After infection, the roots become slimy and turn grey with the entire roots eventually turning brown. Later in the season the root cortex may rot off leaving a string of vascular tissue. The decay may extend up the stem slightly above the soil line. Plants can appear stunted with leaves yellow from the bottom up and with few pods and small seeds. If infection occurs later in the season the plant may appear normal above ground.

Pea and lentil are susceptible to aphanomyces root rot and if fields are found to be infected, crop rotations should be expanded to a six or eight-year rotation for pea and lentil. Faba beans are partially resistant, chickpeas are considered moderately resistant and soybeans are considered to be non-hosts. As a result, faba bean, chickpeas and soybean are good pulse crop options in fields where aphanomyces root rot is found.

Yield Loss

Yield losses vary from year to year depending on moisture conditions, but some estimates peg losses at 50 per cent or higher in cases of severe infestation.

Figure 4.71 Caramel coloured roots from aphanomyces root rot.

Courtesy of: AAFC

Figure 4.72 Aphanomyces pea root

Courtesy of: AAFC

Pythium Root Rots

Pythium Root Rots are caused by Pythium species, which like *Aphanomyces euteiches* are fungal-like organisms that are commonly referred to as water moulds.

Yield Loss

Losses can be as high as 50 per cent.

Note: Black discoloration of taproot and lack of lateral roots.

Figure 4.73 Roots of lentils rotted by Pythium irregular

Common Diseases of Faba Bean

Chocolate Spot

Botrytis cinerea and Botrytis fabae

The main disease that we have been finding to date in faba bean fields is chocolate spot-*Botrytis*. There are two species known to cause chocolate spot in faba. *Botrytis cinerea* is also known to cause disease in lentil. Work is currently being carried out by a pathologist at the University of Saskatchewan to identify which pathogen is most problematic or has the most impact on yield. Research projects are underway to understand the pathogens involved, when they infect plants, impact on quality and yield and timing of fungicide applications.

Yield Loss

Disease development early in the season or during flowering may cause more damage and result in large yield losses. Mid– to late season infections, which are more often observed and correspond to low dew point temperatures (10 to 15 C), may cause little to no yield loss.

Figure 4.74 Chocolate spot faba bean leaf

Figure 4.75 Chocolate spot on faba beans

Ascochyta Blight in Faba Beans

Ascochyta fabae

Ascochyta blight is a seed-borne or residue-borne disease of faba beans in western Canada. It is not the same ascochyta species which infects other pulses and is specific to faba beans.

Lesions appear as tan or grey spots with dark margins, and tiny black fruiting bodies (pycnidia) in the center. Cool, rainy weather is conducive for spread and infection of the disease, and is most damaging to maturing pods and seeds if prolonged wet weather occurs during July and August.

Yield Loss

In severe infections, seeds developing in the pods become discoloured and shriveled. Severely infected seed lots may not be marketable or will be downgraded severely due to discoloration.

Figure 4.76 Ascochyta blight on faba beans

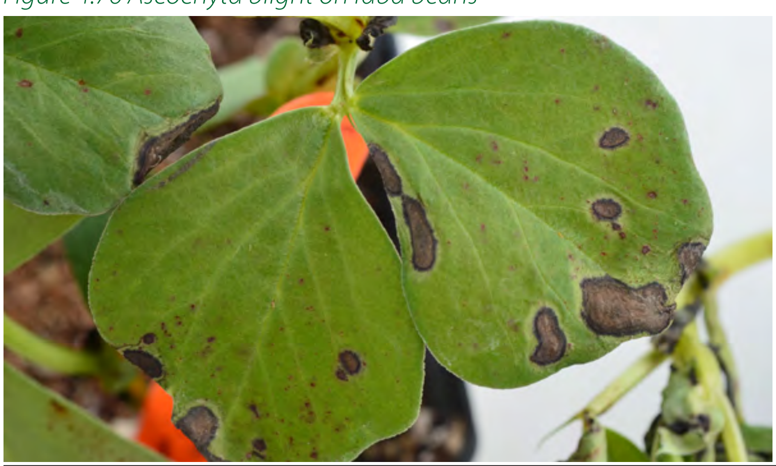


Figure 4.77 Ascochyta blight on leaves

Alternaria Leaf Spot in Faba Beans

Alternaria alternata

Alternaria leaf spot is caused by a fungal pathogen. This is a minor disease of faba beans occurring late in the season and is often confused with chocolate spot. Dark brown leaf spots which often have a zoned pattern of concentric brown rings with dark margins. Control of alternaria alone is usually not warranted. There is no major impact on yield.

Stemphylium Blight in Faba Beans

Stemphylium vesicarium

Stemphylium blight in faba bean is considered a minor disease and its impact on yield is not yet known. There are no fungicides registered for control.

Figure 4.78 Alternaria leaf spot on faba leaf

Courtesy of: AAFC

Figure 4.79 Stemphylium blight

Courtesy of: Alberta Agriculture and Forestry & GRDC

Sclerotinia Stem Rot in Faba Beans

Sclerotinia sclerotiorum

Sclerotinia stem rot is common in many broadleaf crops in western Canada, but so far is less of a problem with faba beans. This disease may appear late in the season with minimal impact to yield.

Figure 4.80 Sclerotinia stem rot on faba bean

Courtesy of: Alberta Agriculture and Forestry

Seed Rot, Seedling Blight, Damping-off and Root Rot

These fungal pathogens are widespread, but disease incidence is usually low. With more frequent planting of susceptible crop species, the incidence of disease increases.

Symptoms

- May include poor emergence, root decay, root lesions, stunting, yellowing, and death of shoots.

Control

- No in-crop control.
- Crop rotation. Pulses once in four years but may have a limited effect in managing seedling blight and root rot.
- Disease free seed and/or use a seed treatment.

Figure 4.81 Faba bean root rot caused by species of Rhizoctonia, Pythium, Fusarium, and Botrytis

Courtesy of: Alberta Agriculture and Forestry (AAF)

Figure 4.82 Faba bean root rot caused by species of Rhizoctonia, Pythium, Fusarium and Botrytis

Courtesy of: Alberta Agriculture and Forestry (AAF)

Bean Yellow Mosaic Virus (BYMV)

One of the most common viral diseases of Faba bean. Pre-bloom infection may reduce yield substantially, because it reduces nodulation.

Symptoms

- Leaves may have a mosaic pattern of light and dark green areas.
- Leaves may be rolled or cupped.
- Necrotic leaf spotting.
- Necrotic stem streaking, extending to shoot tip.
- Infected plants may die.

Figure 4.83 The bean yellow mosaic virus in faba bean

Courtesy of: Alberta Agriculture and Forestry & GRDC

Common Diseases of Soybean

Phytophthora Root Rot (PRR)

Phytophthora sojae

Conditions conducive to disease formation:

- Heavy, tightly compacted soil; low and wet spots in the field.
- Common in fields or parts of fields with poor drainage i.e., high clay content (where water drains slowly).
- Soil that has an impervious shallow hard pan and subject to saturation and flooding.
- Warm soil and periodic rains at weekly intervals are ideal conditions.
- Most severe with wet warm springs (25-30 C)
- Can also occur in well-drained fields where pathogen is present and soils that are saturated for 7-14 days due to heavy rains or irrigation.

Symptoms

- Wilting of plants followed by death; leaves will remain attached.
- Dying seedling remnants scattered throughout the field (empty spaces in the crop stand) may be found.
- Environmental conditions impact level of infection.
- Water soaked lesions that progress up the stem accompanied by yellowing of leaves may be observed.

Yield Loss

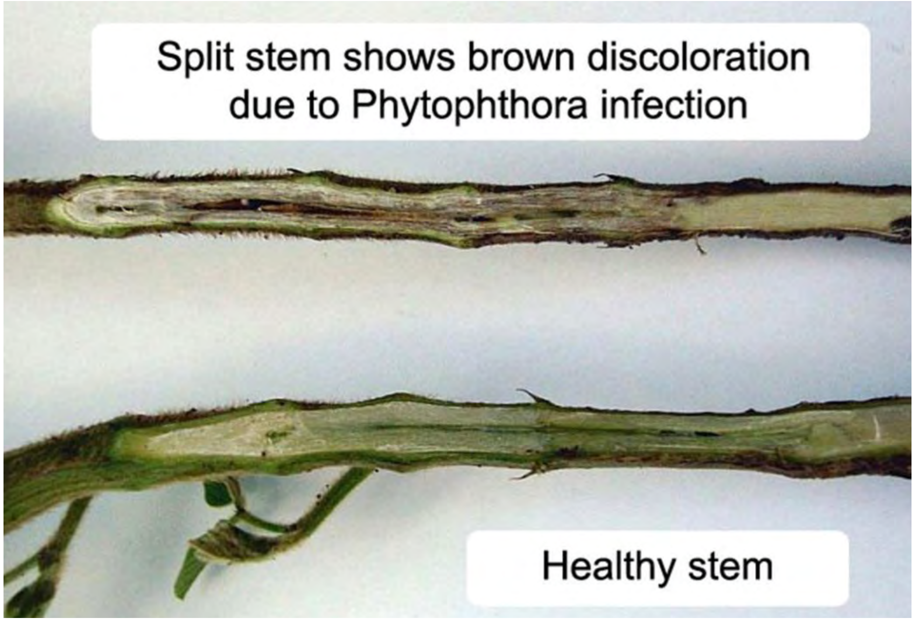
Phytophthora root rot may cause plant stand losses and complete yield reductions in very susceptible soybean cultivars. The severity of losses depends on cultivar susceptibility, rainfall, soil type, tillage and compaction.

Figure 4.84 Phytophthora root rot

Figure 4.85 Phytophthora Root Rot

Figure 4.86 Phytophthora root rot

Figure 4.87 Split stem phytophthora infection



Courtesy of: AAFC

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White Mould (Sclerotinia Stem Rot)

Sclerotinia sclerotiorum

This disease is common in cool, moist regions but it tends to be sporadic, causing severe losses in certain fields and none in adjacent fields. The disease is most likely to occur in crops with a high yield potential. Plants are killed in patches after the crop canopy closes. Soybean seed containing sclerotia of the fungus are not marketable as food grade. This pathogen has a wide host range, which includes many crop and weed species.

Symptoms

- White, bleached lesions on stems, leaves, and petioles.
- Cottony-white mycelium is visible on the lesions.
- Rapid wilting.
- Infected plants turn grey, then brown.
- Hard, black sclerotia are produced in the stem and pods.

Yield Loss

Its impacts can range from 10 to 20 per cent yield loss in a moderate infection or as high as 10 to 20 bushels per acre in severe infections.

Figure 4.88 White mould fungal growth on soybean

Figure 4.89 Stem lesions caused by white mould

Figure 4.90 Stem shredding and sclerotia bodies

Bacterial Blight of Soybean

Pseudomonas savastonoi

Symptoms

- Will first be observed in upper canopy of the plant.
- Small, water soaked and angular leaf lesions that can be present on leaves, stems and petioles.
- Lesion centers will turn brown and are surrounded by a bright yellow halo.
- Lesions will often coalesce and give leaves a tattered appearance similar to hail damage.

Yield Loss

This disease rarely causes yield loss, but it occasionally causes defoliation.

Figure 4.91 Bacterial blight infected leaves on soybean

Figure 4.92 Bacterial blight infected leaves on soybean

Note: This disease is sometimes mistaken for hail damage. Hail damage will not have the yellow halo around the brown lesion.

Septoria Brown Spot of Soybean

Septoria glycines

Symptoms

- Dark brown spot lesions less than 3 mm diametre (on soybean leaf) appear starting in the lower part of the plant then move up.
- Spots will coalesce as disease progresses.
- Irregular brown and yellow patches will be present on the top side of the leaf only.

Yield Loss

It does not typically cause a major yield impact, but losses of up to 10 per cent have been observed in very susceptible varieties that have been infected early and under prolonged stress conditions.

Figure 4.93 Septoria infection just beginning at the bottom of the soybean plant

Figure 4.94 Septoria infection moving up the plant

Downy Mildew in Soybean

Peronospora manshurica

Symptoms

- Lesions start as inconspicuous green to light yellow spots on top side of leaves.
- Fluffy tan tufts of fungal growth occur opposite lesions on the underside of the leaf.
- Later, the chlorotic spots become dark brown and brittle.
- In infected pods, seeds will be covered with cream to grey masses of oospores.

Yield Loss

The disease is typically superficial and causes no yield loss but can cause defoliation of plants and reduced yields under rare conditions.

Figure 4.95 Light green spots caused by downy mildew infection on soybean

Figure 4.96 Early sign of downy mildew infection on soybean leaf

Alternaria Leaf Spot of Soybeans

Alternaria spp.

Leaf symptoms are brown necrotic spots sometimes with concentric rings on foliage.

Along with soybeans and dry beans, *Alternaria spp*. infections can occur on canola, mustard, safflower, sunflower, flax, potatoes, all cereals and on hemp along with numerous vegetable species.

This fungal disease is considered a secondary infection that follows a mechanical injury, insect damage, hail, or some other disease. It generally occurs later in the season and as such, creates minimal yield loss. It prefers wet conditions and should excess moisture occur during harvest time, it can cause seed discoloration. Mycotoxins can also be produced.

Mode of Transmission

Alternaria is generally considered a seed born pathogen although it can survive on plant residue.

Figure 4.97 Alternaria on soybeans

Common Diseases of Wheat

Fusarium Head Blight (FHB)

Most common species in Saskatchewan: *Fusarium graminearum, Fusarium avenaceum, Fusarium culmorum*

- Hosts include wheat, barley, oat, corn, rye and wild grass species.
- *Fusarium graminearum* and *F. culmorum* produce deoxynivalenol (DON, vomitoxin), a toxin that renders grain unfit for human food or animal feed. *Fusarium avenaceum* produces the toxin moniliformin, which poultry are highly sensitive to.
- Fusarium head blight causes premature bleaching of one or more of the spikelets in a head; infected spikelets may be sterile or contain shrunken fusarium damaged kernels.
- Infection of the rachis may result in seeds above the point of infection not filling, and grain from blighted heads is often shriveled, light-weight and chalky white or occasionally pink (known as fusarium damaged kernels or tombstone kernels).
- Superficial white mycelium with an orange to pinkish cast can often be seen on bleached spikelets.
- Orange or pink sporodochia (asexual spore clusters) may be visible on the glumes.
- The symptoms of fusarium head blight in barley may be more difficult to recognize. The affected kernels tend to be an overall tan colour, darker than the light straw coloured heads and spikelets in wheat.

Yield Loss

FHB results in 40 to 50 per cent yield loss when severe. Symptoms may occur over the entire head or on just a few spikelets and can result in a poor yield and the formation of fusarium damaged kernels (FDK), also known as "tombstone kernels".

Figure 4.98 White mycelium with an orange cast found on heads infected with FHB

Figure 4.99 Fusarium head blight on wheat heads. Note the pink colouration

Figure 4.100 Fusarium damaged kernels (FDK)

Figure 4.101 Fusarium head blight disease identification

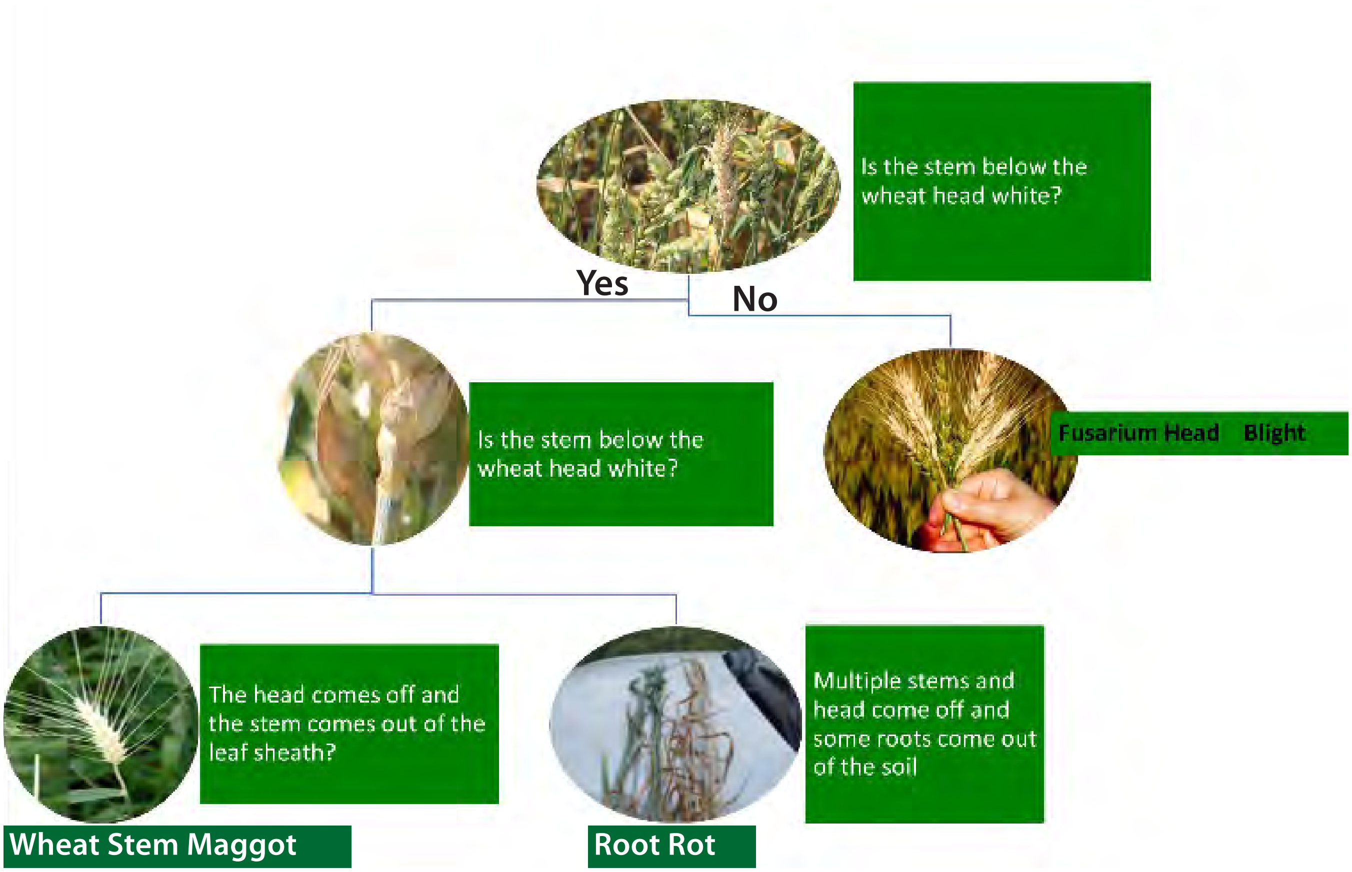

Figure 4.102 How to determine whether or not to apply registered seed treatment

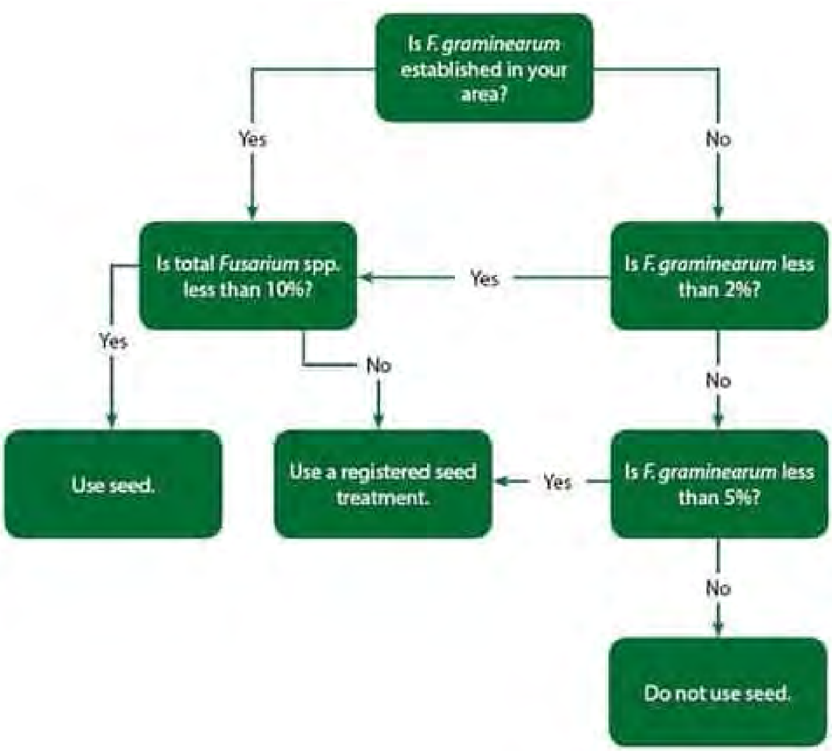

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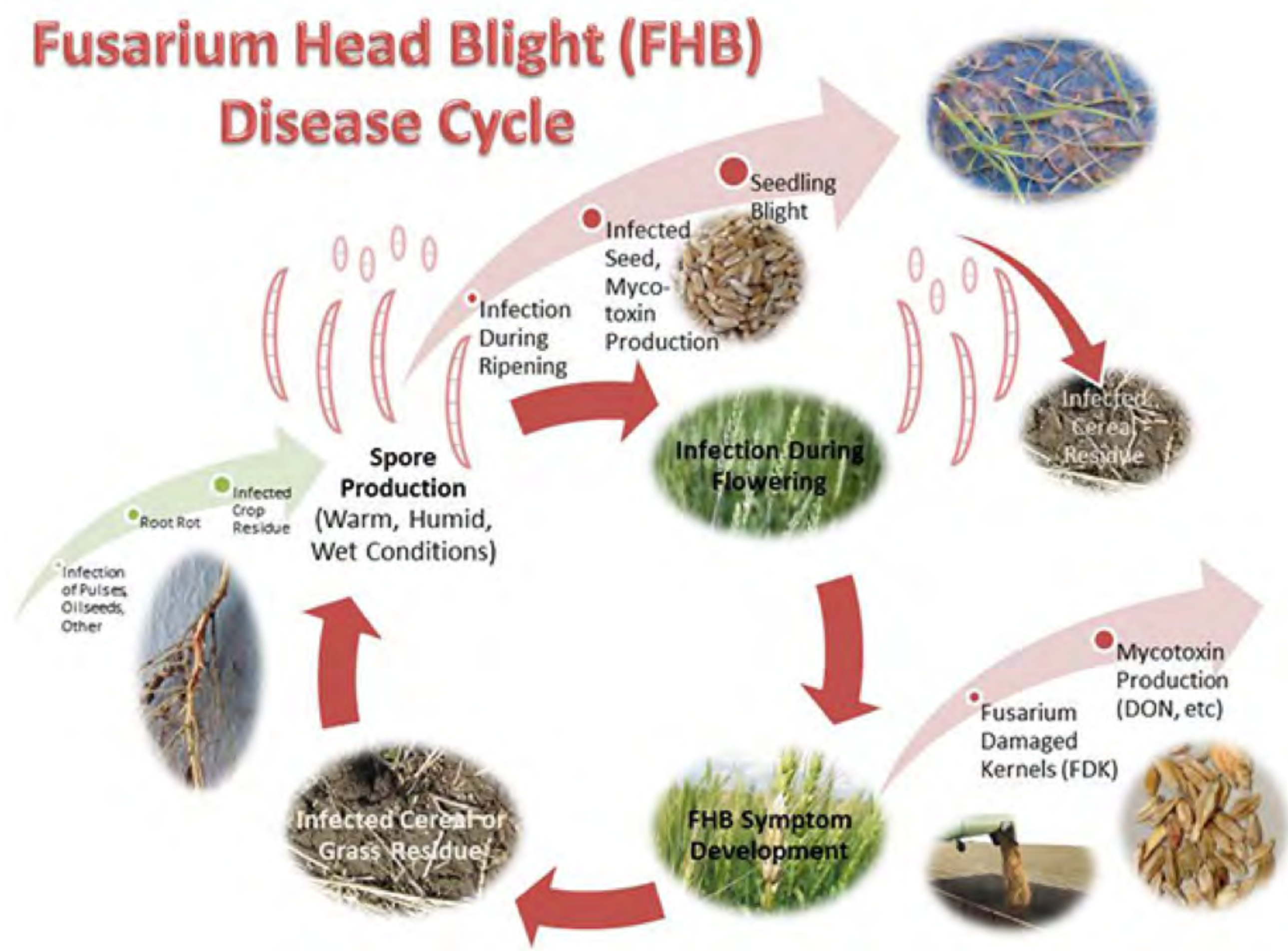
Figure 4.103 FHB disease Cycle



Courtesy of: Government of Alberta

Figure 4.104 FHB host tolerance from most tolerant (left) to least tolerant (right)

Table 4.3 Assessing fusarium head blight risk

Assessing Fusarium Head Blight Risk in Saskatchewan		Lower Risk	Medium Risk	Higher Risk
Step 1: Predict Pathogen is *Fusarium* established here?	Has wheat produced in this field been downgraded due to fusarium damaged kernels? Has >5% *F. graminearum* been isolated from seed produced in this field? Has >10% other *Fusarium* species been isolated from seed produced in this field? Have any crops produced in this field experienced root rots due to *Fusarium* spp?	No No No No	By a grade >4 years ago >2 years ago >2 years ago	By >1 grade Within 4 years Within 2 years Within 2 years
Step 2: Stage Crop When crop will be susceptible?	Stage crop at least one week before expected flowering date. Use experience or estimate GDD from seeding date. Anticipate Day 0, when 75% of the heads on main stems to be fully emerged, to be 1-2 days before flowering. Also consider susceptibility of crop. Seeding Date +807 to 901 GDD C or 1484 to 1653 F = Expected Flowering Date	Even Crop, FHB Rating G or VG	Uneven Crop, More Tillers, FHB Rating F	Uneven Crop, Many Tillers, FHB Rating P or VP
Step 3: Watch Weather Check FHB Map	Select the FHB forecast map for the estimated head emergence date (Day 0), and determine risk for the area. At least 12 hours of precipitation or high humidity (above 80%) is required for *Fusarium* spore germination and infection, as well as favouring temperatures ranging from 16 to 30 C (*F. graminearum* optimum is 24 to 82 C)	Low	Moderate	High
Step 4: Crunch Numbers	Estimated Yield (unit/acre) x Estimated Yield Savings (%) x Selling Price ($/unit) MINUS the Fungicide Application Cost ($/acre) = Expected Net Return ($/acre)	Negative Net Return	Net Return $0	Positive Net Return
Step 5: Make a Decision	Note that foliar fungicides are registered for the suppression of FHB on wheat, rather than control. Flowering may be variable, but aim for when at least 75% of the heads on the main stems are fully emerged to 50% of the heads on main stems are in flower. Ensure adequate water volumes and spray coverage to get the most benefit from application.	Mostly Low Risk? Do Not Spray	Medium Risk? Pencil it in; reassess risk before spray day	Mostly High Risk? Likely to see a benefit from a FHB fungicide

GDD = Growing Degree Days
VG = Very Good
G = Good
F = Fair
P = Poor
VP = Very poor

A fungicide application may be warranted for suppression of FHB if:

- The pathogen is established in a region.
- The grower has experienced losses due to FHB in the past two years.
- If planting next to infected residue from the year before or in a field that had durum or wheat in rotation within the last two years.
- Conditions have been wet and warm at crop heading stage. These conditions are forecast to continue during cereal flowering.

Fungicide must be applied at early flowering to protect the opening florets. If it is not applied at the proper stage the fungicide will not provide adequate or economical protection. Fusarium risk assessment maps and tools can be found at *www.saskwheat.com.*

Once symptoms are observed on cereal heads then it is too late for the use of control measures. Fusarium Head Blight (FHB) is a monocyclic disease and will only occur once during the growing season. If conditions have been hot and dry at crop heading stage and these conditions are forecast to continue during cereal flowering, the fungicide applications may not be warranted.

Powdery Mildew on Winter Wheat

Blumeria graminis f.sp. tritici

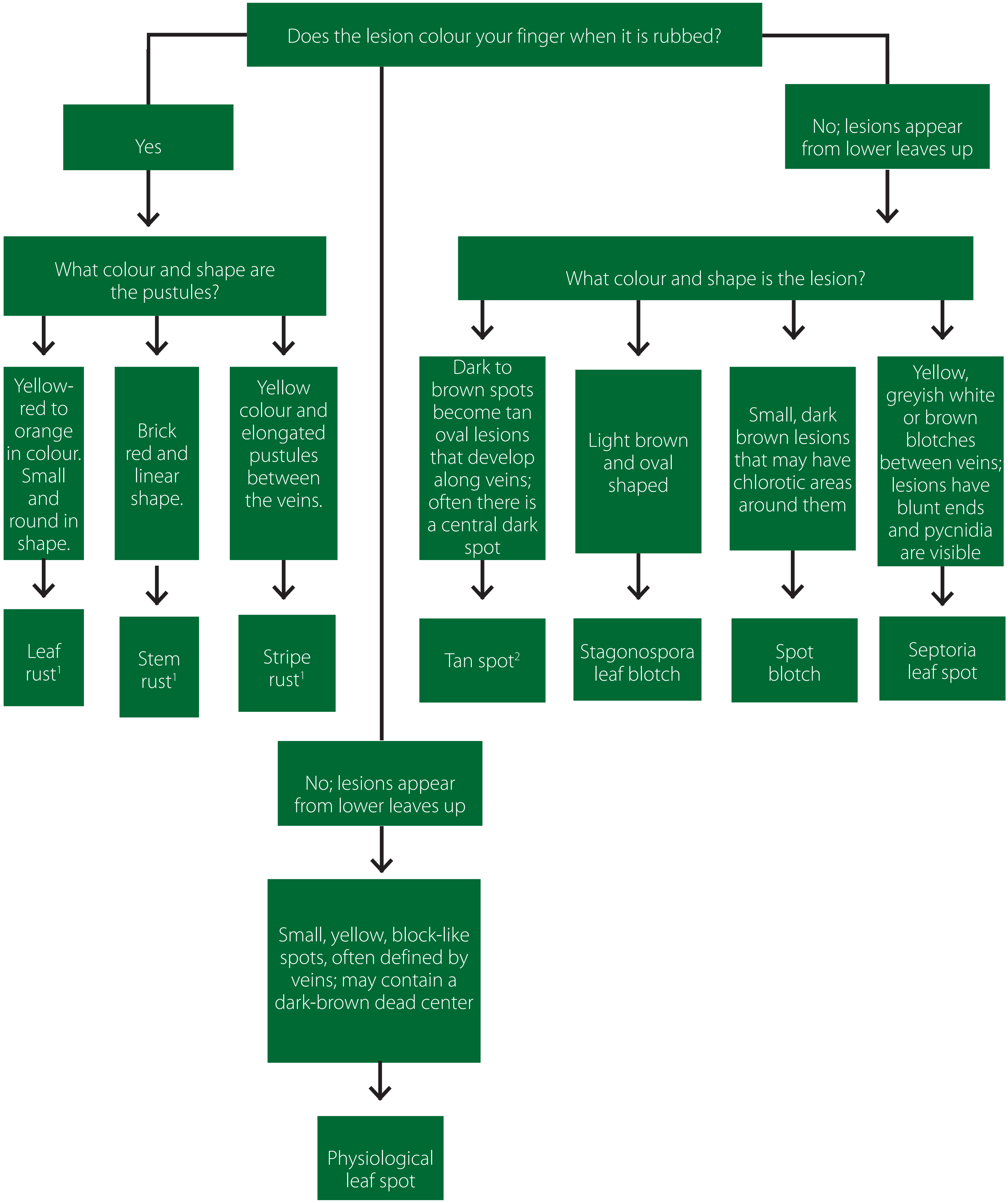
- Symptoms appear as powdery white fungal growth on wheat leaves, stems and heads.
- The fungal growth can be detected on the upper leaf surfaces and the white colonies of mycelium will then spread across to the stems and leaves of the plant.
- The white fungal growth will turn grey with age and become spotted with small black cleistothecia, which are the sexual fruiting bodies of the fungus.
- Disease is both stubble borne and carried over on green bridge (secondary spread by wind borne spores).

Yield Loss

Yield losses from powdery mildew may be as high as 45 per cent.

Figure 4.105 Powdery mildew on winter wheat

Figure 4.106 Identification key for wheat leaf lesions



[1] *Pustules turn black later in the season when teliospores are formed*

[2] *Tan spot can be confused with Stagonospora nodorum or Stagonospora leaf blotch*

Leaf Rust (Brown Rust) in Wheat

Puccinia triticina

- Leaf rust lesions (pustules) are largely confined to the leaves; they may also occur on leaf sheaths, but do not penetrate the stem tissue.
- The pustules are nearly round and much smaller than those of stem rust. They are yellowish red to brown and may be so closely spaced on heavily rusted plants giving the leaves an orange red appearance. Rust of oats is more orange in colour.
- The colour is due to hundreds of orange red urediniospores within each pustule. As the plants ripen, the pustules darken due to the formation of thick-walled, black teliospores.
- First infections are usually observed in June and the disease reaches a peak in August.
- Leaf rust overwinters in the southern USA and is blown into the southern Prairies by prevailing winds . It is recognized by its characteristic orange-red pustules that erupt from the upper surface of leaves.
- Yield Loss - Leaf rust can cause up to 25 per cent yield loss under favourable conditions.

Stem Rust (Black Stem Rust) in Wheat

Puccinia graminis f.sp. triticia

- Brick red pustules are formed mainly on the stems but can also be on both sides of the leaves and even on the heads. As the plants ripen, the pustules darken until they are almost black.
- The change in colour is caused by a change from the red-spored (urediniospore) summer stage to the black-spored (teliospore) overwintering stage.
- The teliospores are responsible for the disease sometimes being called black stem rust. The two kinds of spores are two phases in the complex life cycle of the pathogen.
- Yield Loss - The genetic resistance in wheat varieties has adequately controlled stem rust.

Stripe Rust (Yellow Rust) in Wheat

Puccinia striiformis f. sp. tritici

- Elongated yellow pustules on leaves, stem and heads. Pustules are restricted to along the veins of the leaf.
- Late in the season, the yellow urediniospores in the pustules are replaced by dark brown teliospores.
- Nine to 12 C is the optimum temperature for development. Above 20 C sporulation is inhibited.
- Yield Loss - This disease can result in yield losses of 10 to 90 per cent.

Figure 4.107 Leaf rust on wheat (left, middle) stem rust (right)

Figure 4.108 Stripe rust on wheat

Septoria/Stagonospora Leaf Blotch Complex in Wheat

Septoria tritici

- On young plants of both winter and spring wheat, yellow flecks first appear on the lower leaves, especially those touching the soil.
- They develop into yellowish, greyish white or brown blotches on all above ground parts. On leaves, yellow-bordered lesions with grey/tan centers are restricted by the veins and develop rectangular lesions parallel to the veins (compare with tan spot). These elongated blotches range up to 5 x 15 mm and eventually coalesce. Leaves infected at the base may be killed.
- Septoria blotch affects wheat, barley, canary seed and oats.
- Overwinters on crop residue.

Stagnospora nodorum

- Initial symptoms are yellow flecks on leaves, which enlarge to oval or lens-shaped blotches about five mm in length.
- A zone of yellow tissue usually surrounds the light brown blotches and the centers may appear greyish brown. Pycnidia are inconspicuous and lesions may resemble tan spot.
- Glume infections often begin at the tip and spread downward as purplish brown to grey lesions with dark pycnidia. Kernels may be severely shriveled.

Stagonospora avenae

- First appear as small, dark brown to black spots on the lower leaves.
- Develop into tan, oval-shaped lesions with a central dark spot. In some cultivars, a chlorotic (yellowed) halo may develop around the lesion.
- When moisture and temperature are favorable, lesions coalesce and form irregular blotches similar to stagonospora/septoria leaf blotches. However, tan spot lesions never develop pycnidia, in contrast to *Septoria tritici* blotch.
- Most cultivars grown in western Canada develop tan necrotic (dead) lesions. However, a generalized chlorosis develops in some cultivars.
- If heads are infected, mature kernels may develop a reddish colour (red smudge) or blackening on the end. Seed discoloration is most common in durum wheat, and is favored by late-season rainfall, irrigation and warm weather.

Figure 4.109 Septoria tritici infection with pycnidia in the lesion

Courtesy of : Dr Constanza Fleitas University of Saskatchewan

Yield Loss

Up to 25 per cent.

Figure 4.110 Septoria tritici infection with pycnidia in the lesion

Courtesy of : Dr Constanza Fleitas University of Saskatchewan

Figure 4.111 Septoria tritici infection with pycnidia in the lesion

Courtesy of : Dr Constanza Fleitas University of Saskatchewan

Figure 4.112 Stagnospora nodorum

Common Bunt

Tilletia spp.

Common bunt and other dwarf bunts are caused by members of the fungal genus Tilletia. While wheats including winter wheat, are the main hosts, rye, triticale, and several grass species can also be infected.

Conditions that favor infection and germination of this disease are low soil temperatures (5-15 C) and moisture. Bunt can be hard to notice in a standing group until shortly before maturity. Bunt balls will originally be bluish green in colour but change to grey brown at maturity. They look like ordinary kernels but will be more spherical. At harvest, the bunt ball covering will rupture and reveal masses of black teliospores along with releasing a fishy odour. It is this fishy odour that leads to grain downgrading. It also makes it difficult to even sell infected grain for livestock feed.

Mode of transmission: This disease is transmitted when the teliospores are released from the bunt balls and stick to the surface of healthy grain thus contaminating the seed. These teliospores can also persist in the soil for as long as a year and will infect susceptible crops. Infection occurs in response to moisture and infection occurs through the coleoptile before emergence. Control methods that can be utilized are bunt free seed, crop rotation and the use of resistant varieties. There are also seed treatments available that are effective in controlling this disease. Disease incidence can also be reduced by seeding spring wheat into warmer soils and winter wheat before soils become too cool.

Figure 4.113 Common Bunt. The kernels are replaced with "bunt balls" containing the pathogen spores.

Tan Spot

Pyrenophora tritici-repentis

Tan spot is a stubble-borne disease which is associated with tan spot lesions on leaves and can also cause red (or pink) smudge on wheat kernels.

Lesions first develop as small, tan, brown flecks, or spots mainly on lower leaves.

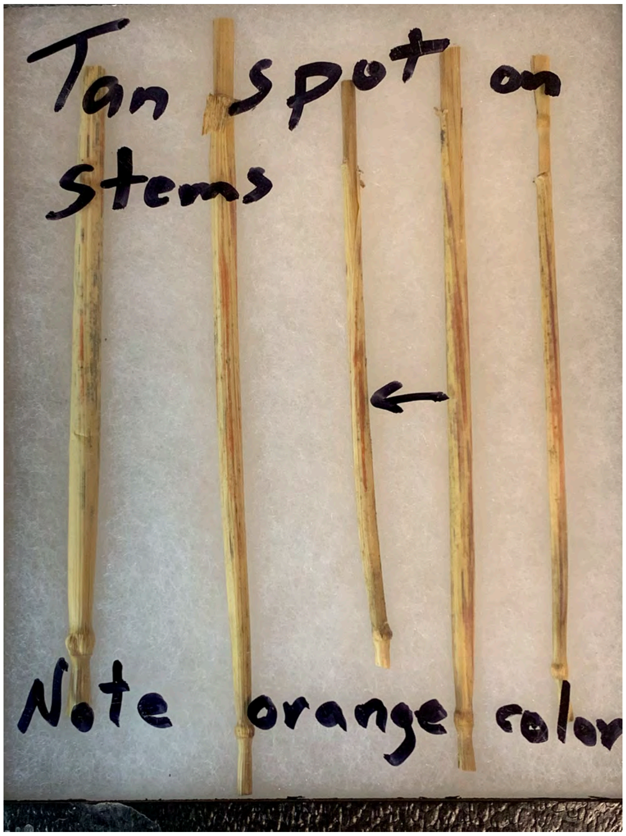
The spots then enlarge into tan, irregular lens-shaped lesions with a dark brown spot in the center and a bright yellow zone surrounding the tan lesion.

Lesion type and symptoms can vary from a tan blotch with a dark brown center and no surrounding yellow zone to a tan blotch surrounded by a yellow zone without a dark brown center.

Tan spot lesions usually remain small on actively growing young leaves; however, when spots are abundant, the leaves turn yellow which gives the field an overall yellow cast.

Red smudge on wheat kernels is favoured by wet weather during grain filling if large numbers of air-borne spores are present. Infected kernels appear red or pink and occasionally slightly smaller and wrinkled.

Figure 4.114 Tan spot on wheat leaves



Yield Loss

Up to 25 per cent.

Figure 4.115 Tan spot on wheat leaves

Figure 4.116 Tan spot on wheat stems

Figure 4.117 Tan spot on wheat leaves

Bacterial Leaf Streak (BLS)/Black Chaff of Wheat

Xanthomonas translucens pv. undulosa

Bacterial leaf streak (BLS) is an economical disease of wheat that can reduce yield significantly. The disease can be found in warm and humid conditions or under sprinkler irrigation and was frequently reported from Saskatchewan during the 2022 growing season.

Symptoms can be seen primarily on leaves and glumes/grain. Leaf symptoms include initially water-soaked lesions/streaks that may be translucent. Lesions ultimately enlarge and take on a brownish necrotic appearance. Humid conditions sometimes result in oozing masses of bacterial cells (honey-like exudates) on lesions. Dried masses of bacteria may give the lesion a glazed appearance. When wet, affected tissues may be slippery.

Glume blotch phase include shiny purplish brown/black streaks on glumes, awns, and the upper stems. Seed infections can occur resulting in brownish discoloration of kernels.

The disease has been reported from across the prairies including Saskatchewan. Sources of the BLS pathogen include seed-borne infections and potentially residue-borne bacteria. Like any other foliar bacterial diseases, irrigation is a significant risk factor, when the BLS pathogen can spread from plant-to-plant, like rain splashing. Severe weather events such as strong winds, hail and heavy rain can result in plant tissue damage providing more access points for the BLS bacterium.

Management options for BLS are limited currently. Seed-borne infection is one of the main inoculum sources for BLS. Producers should avoid seed known or suspected to be infected with the BLS pathogen. Extended rotational intervals to at least two years between cereal crops may prove beneficial to reduce the amount of infected residue, which can be another potential BLS source.

Courtesy of: N. Kaur, C. Ishimaru, B. Vinatzer, and H. Mehl. 2020. Bacterial Leaf Streak of Wheat. The Plant Health Instructor and Prairie Crop Disease Monitoring Network.

Figure 4.118 Bacterial leaf streak (BLS) was frequently reported from Saskatchewan in 2022 growing season. The disease causes lesions that ultimately enlarge and take on a brownish appearance as they dry.

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Stem Melanosis

Pseudomonas cichorii

This spring wheat disease is characterized by bleached heads with shriveled kernels along with blackening of the rachis, peduncle, and stem immediately beneath the nodes. Soils that are deficient in copper predispose wheat to this disease. As the causal agent is a bacterium, fungicide applications are of no value.

Research done in Alberta has shown this disease can be minimized or eliminated with small applications of foliar copper (0.25 lb/acre) or larger amounts of soil applied copper (10 lb/acre).

Figure 4.119 Stem melanosis wheat heads

Common Diseases in Barley

Net Blotch

Pyrenophora teres

- This disease affects leaves, leaf sheaths and glumes.
- Early symptoms on the leaf are minute, light green or brown spots that soon enlarge into longitudinal brown streaks up to several centimetres in length.
- Net form-within these lesions, darker longitudinal and horizontal lines may develop, giving the blotches a characteristic netted appearance.
- Spot form-some strains of the fungus produce only elliptical brown spots, about 0.5 x 0.3 cm that can easily be confused with the symptoms produced by spot blotch. The spot-producing strains are found primarily in west-central Saskatchewan.
- Some leaf tissues surrounding the brown (necrotic) area of either type of lesion may become yellow (chlorotic). If the blotches are numerous, they can cover much of the leaf surface, causing the leaf to wither and die prematurely.
- Overwinters on crop residue.

Yield Loss

Up to 25 per cent.

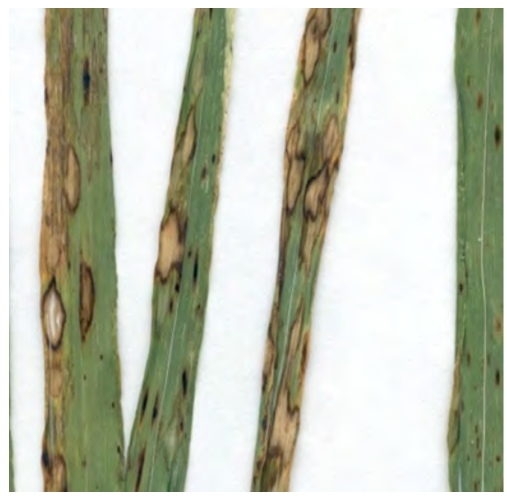
Figure 4.120 Net form of net blotch on barley

Scald in Barley

Rhynchosporium secalis

- Scald affects leaves and sheaths of plants. Infections appear at first as water-soaked, greyish green spots 1.0-1.5 cm long.
- Conspicuous oval spots develop rapidly as the tissue in the center of the lesion dries out and becomes bleached, resulting in a characteristic light grey or tan to straw-coloured spot with a dark brown margin.
- The pale central areas of older lesions may collapse and fall out. The spots are not limited by the veins and often coalesce, so that the entire leaf may be destroyed.
- Symptoms similar to those on the leaves can also be found on glumes and harvested seed.
- A stubble and seed-borne fungal foliar disease.

Figure 4.121 Scald on barley leaf



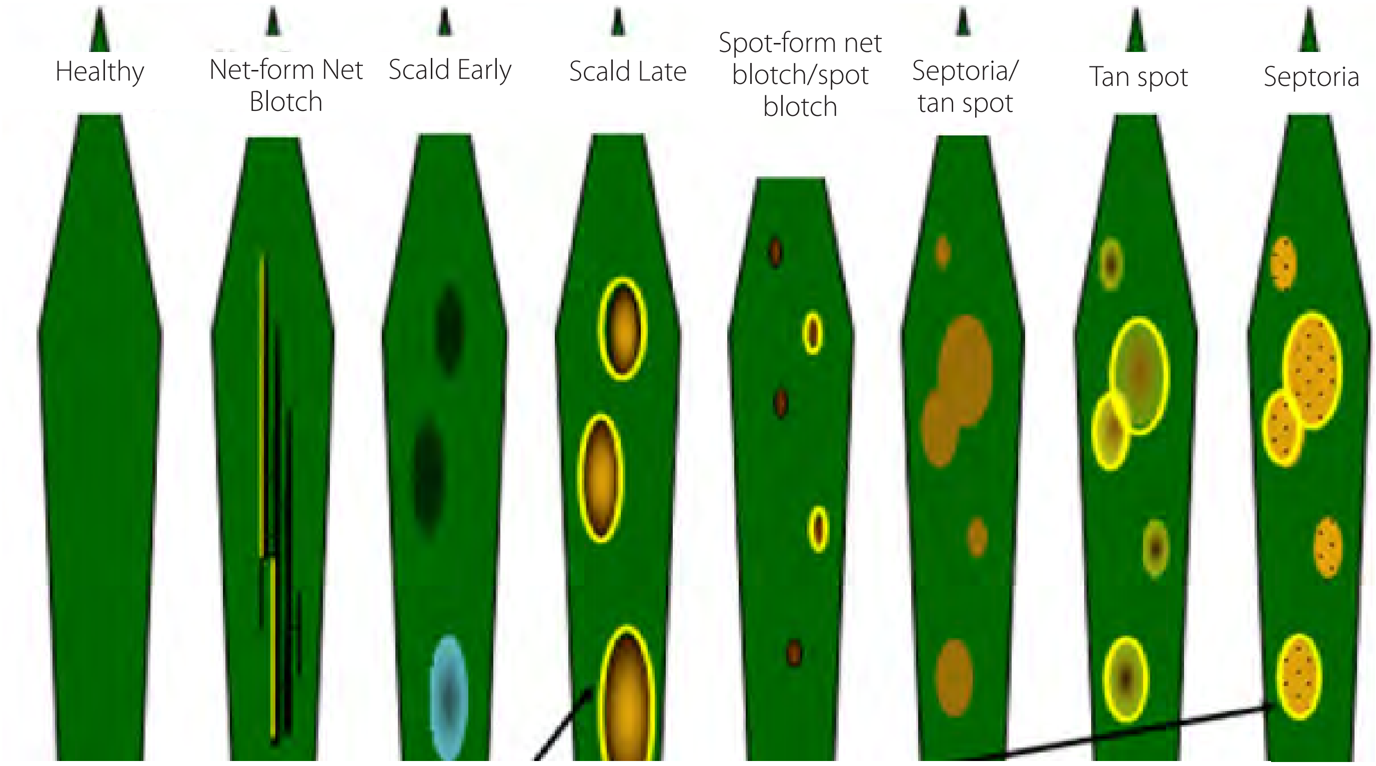
Spot Blotch in Barley

Cochliobolus sativus

- Lesions first appear as small brown spots that enlarge into elliptical, uniformly dark brown blotches, 0.5-1 cm long with distinct margins.
- These may extend longitudinally on the leaf blade and be bound by the leaf veins, but they do not become long, narrow streaks as in net blotch.
- The spots may be surrounded by a zone of chlorotic (yellow) tissue of varying width. Dark spots may also appear on the leaf sheath, necks and heads of the plants.
- Lesions can also occur on the stalk, especially at the nodes and can result in "neck break"
- Infection of heads can result in a dark seed discoloration, termed black point or smudge.

Figure 4.122 Spot blotch on barley leaves

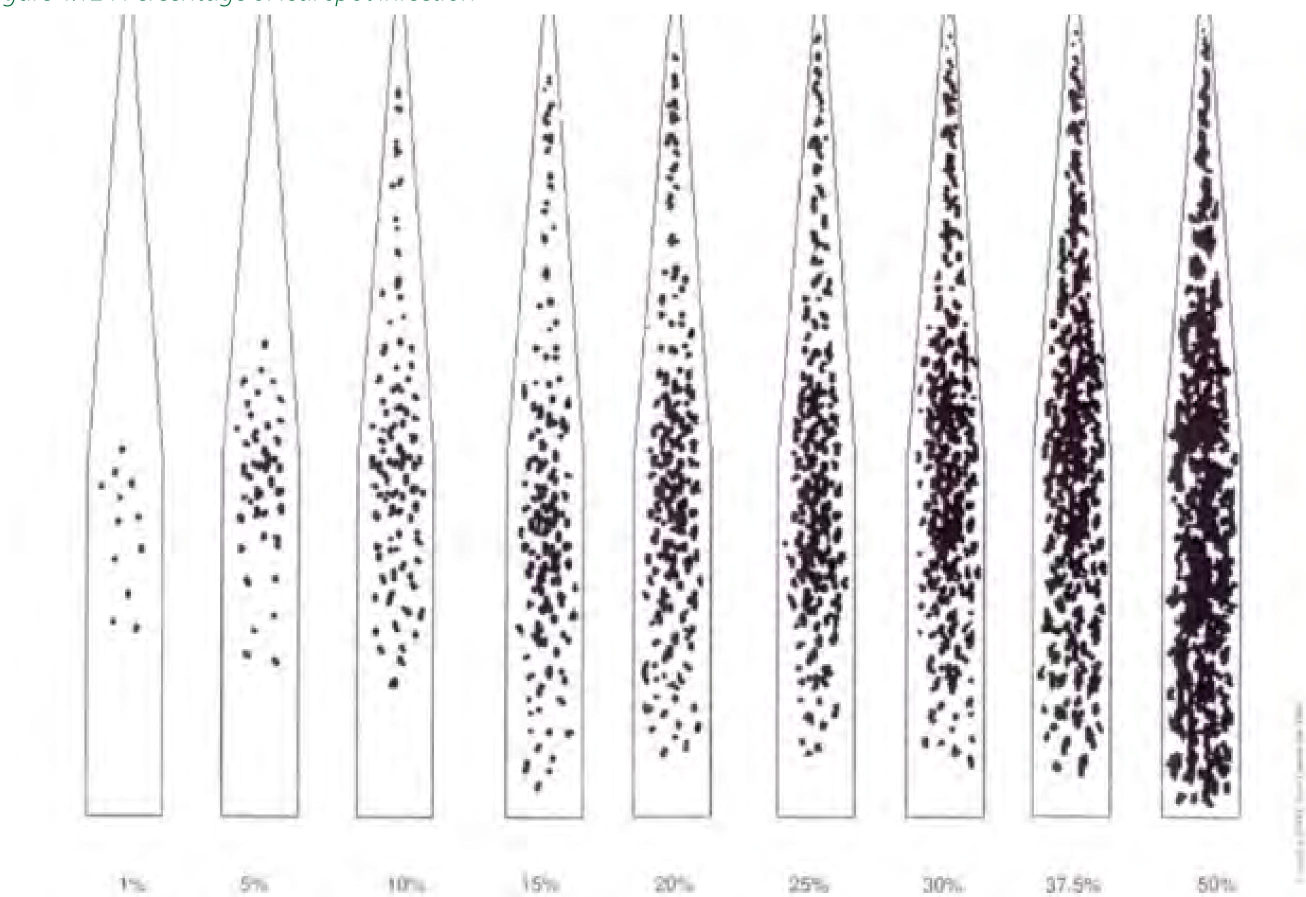
Figure 4.123 Typical symptoms of cereal leaf spot diseases



Note the development of chlorosis (yellowing) around well-developed symptoms.

Courtesy of: AAFC

Figure 4.124 Percentage of leaf spot infection



Courtesy of: AAFC

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Ergot

Claviceps purpurea

Ergot is one of the most important diseases in rye and is easily recognized in the field. Ergot affects most grains and grasses in Canada such as wheat, barley, oats, triticale and rye. Rye is the most susceptible cereal because it is open pollinated. Unpollinated, open florets provide easy access for the fungus to enter and replace the ovary with a hard structure called a sclerotium or ergot body. Economic losses to the grower result not only from yield reductions but from rejection and/or downgrading at the elevator. As little as 0.01 per cent ergot bodies by weight will result in downgrading in wheat, any contamination greater than 0.01 per cent will result in heavy economic losses to the grower. Wheat, with these levels of ergot, is considered unfit for both human and livestock consumption. Sanitation and cultural management are the best options for controlling ergot. Although there are differences in susceptibility among cultivars, none are resistant to this disease.

Symptoms

Ergot is most easily recognized by the dark purplish sclerotia that replace kernels in diseased heads. In rye, the sclerotia usually grow much larger than in wheat or barley, and often protrude from the head. Heads may contain one or several sclerotia. In uncleaned grain, sclerotia are readily identified by their size, shape and colour. Early in the season, before sclerotia are visible, ergot infection can often be detected by close observation of the developing heads.

Disease cycle

The sclerotia is the over-wintering body of the pathogen. When the crop is mature, the sclerotia are easily detached from the florets and many fall to the ground during harvest; others are picked up in the swath and contaminate the harvested grain. Under favourable weather conditions during the spring and summer, sclerotia on or near the surface will germinate and start to produce ascospores. These ascospores are wind-blown sexual spores that land on open florets, penetrate the ovary and begin the disease cycle over again.

Figure 4.125 Ergot bodies (sclerotia) on triticale

Figure 4.126 Ergot bodies among harvested triticale

Figure 4.127 Ergot bodies (sclerotia) on smooth brome grass

Figure 4.128 Ergot bodies (sclerotia) on wheat

Figure 4.129 Ergot bodies (sclerotia) on canaryseed

Figure 4.130 Ergot bodies (sclerotia) in wheat

Take All

Gaeumannomyces gramminis

- Take all is a serious root disease caused by a soil dwelling fungal pathogen called Gaeumannomyces gramminis. This fungus can infect cereals such as wheat, barley, triticale and rye.
- The disease may appear in a wheat crop after breaking of native or cultivated grassland, and is likely to be most severe when wheat is grown continuously in the same field for two to four years.
- Lightly infected plants may remain undetected but yield losses of 20 to 30 per cent can occur when disease is severe.

Symptoms

- Severely infected plants are stunted, produce fewer tillers and "white heads", and often die prematurely.
- Whiteheads will often occur in conspicuous patches, the heads will be empty or contain shriveled seed, the heads will darken later from the growth of saprophytic growth.
- Heavily infected plants will often lodge.
- Infected stem and root tissues will be dark brown to shiny black, roots may be completely rotted, and plants will be easily pulled from the soil.

Management

- Reduced tillage decreases disease frequency and using rotations with two years of resistant crops, such as canola, flax, corn or oats.
- Proper soil fertility, including adequate phosphorus, potassium and sulphur is beneficial.
- Spring applied nitrogen will normally lower levels of disease than fall applications, on acidic soils nitrogen applied in the ammonia form can enhance disease control.
- There are no resistant cultivars of wheat or barley available.
- There are seed treatments available however they do not provide full protection throughout the growing season.
- Grassy weeds and volunteer wheat act as reservoirs for the pathogen so it is important they are controlled.

Figure 4.132 Note the empty seed heads caused by take all

Figure 4.131 Take All

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Loose Smut

Ustilago nuda (barley) and U. tritici (wheat)

Synonyms: true loose smut, common loose smut

Loose smut is quite common, although losses are usually low when smut-free seed, improved cultivars and systemic seed treatments are used. Wheat and barley are most typically infected, with durum infection being minimal due to being grown in traditionally drier areas.

Since loose smut is seed-borne and the fungal mycelium remains dormant in the seed, visual field symptoms are a result of seed that was infected in previous years. When the infected seed germinates in the spring, the fungus breaks dormancy and the mycelium colonize the growing point of the plant. As the head begins to form, it is extensively invaded by the fungus. Cool, moist weather conditions during flowering, along with 95 per cent relative humidity and 20 to 25 C favour the development of loose smut. The disease is not noticeable until a mass of dark brown spores appears in place of a normal head. These spores will travel to nearby healthy heads and will infect the florets; however, the seed's appearance or quality will not be affected but the infection will remain dormant until the next year.

Symptoms can appear from heading to maturity and can also be present on tillers that may be stunted. Infected heads are black and filled with dusty spores and tend to emerge shortly before the healthy green ones. As the crop matures, the spores are blown away or washed off and a bare rachis left. Often there will be traces of dark spores and some greyish remnants of glumes or awns on the bare rachis if the tissue has not completely broken down.

Figure 4.133 Loose smut on wheat

Figure 4.134 Loose smut on slender wheat grass

Sooty Mould

Sooty moulds are not considered true crop diseases as the fungi that cause it cannot infect healthy tissue. Instead, they are the result of secondary, saprophytic fungi that colonize dead or dying plant tissues under moist conditions. Thus, sooty mould can be caused by species of *Alternaria, Cladosporium, Stemphylium* and *Epicoccom*.

Sooty moulds can appear as a speckled black, grey or dark green growth on the surface of cereal grain heads. They are most likely to develop when rain has fallen in the final stages of crop maturation, or when harvest is delayed into the fall when humidity levels are higher.

Figure 4.135 Sooty mould on rye (left) microscopic view of sooty mould on rye (right)

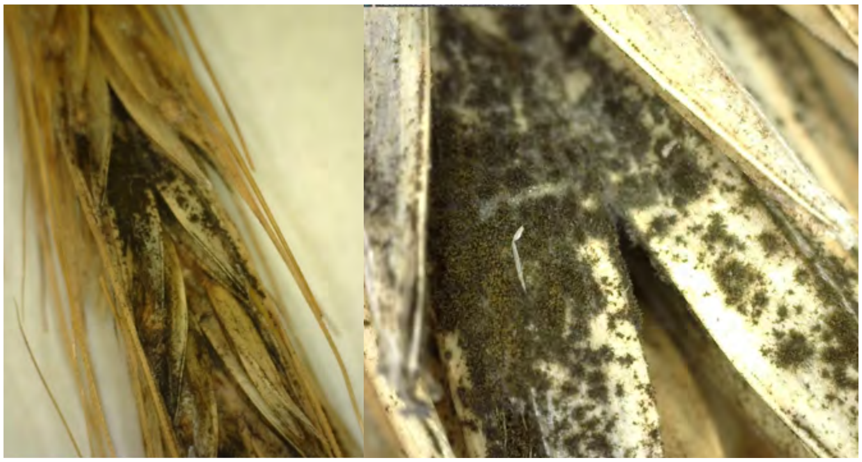

Figure 4.136 Sooty mould on wheat

Common Diseases in Oats

Crown Rust

Puccinia coronate f.sp. avenae

- Orange pustules (uredinia) form on both the upper and lower surfaces of leaves. Pustules contain masses of orange urediniospores that are exposed by the rupture of the leaf epidermis.
- In severe epidemics, sheaths and glumes also become infected.
- As the infected plants mature, urediniospores are replaced by shiny black teliospores.
- Each teliospore has prong-like projections, which form a crown around its apex, hence the name crown rust.
- The pathogen has a life cycle that requires an alternate host, buckthorn, to complete its sexual life cycle.

Figure 4.137 Crown rust

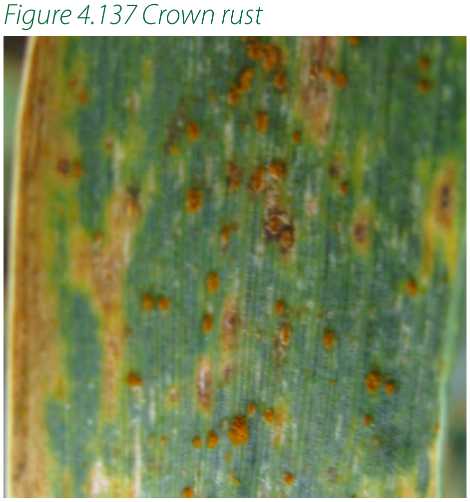

Figure 4.138 Crown rust on oat leaf

Figure 4.139 Crown rust teliospores

Common Diseases in Corn

Fusarium Complex

- *Fusarium graminearum* is the causal agent for Gibberella Stalk Rot and Gibberella Ear Rot.
- Infected plants wilt and the leaves change from a light to dull green colour.
- There will be a tan to dark brown discoloration of the lower internodes and a pink to reddish discoloration within the stem.
- Blue black perithecia or pink conidia are produced on the stalk surface.
- The lower stalk will become dry and the tissue will shred and disintegrate.
- Plants may lodge when infection is severe.

Figure 4.140 Fusarium Ear Rot

Courtesy of: Dr. White, Professor Emeritus at the U of Illinois

Figure 4.141 Slicing open the stalk to look for orange or red colouration is a necessity

Figure 4.142 Infected stalks will snap at the nodes causing lodging

Figure 4.143 Black fruiting bodies known as perithecia

Figure 4.144 Salmon coloured stem tissue is an indicator of Fusarium Stalk Rot

Note: Perithecia, produced by the fungus can be seen on the stalk and can be easily scraped off with a fingernail.

Goss's Wilt in Corn

Clavibacter nebraskensis (bacterium)

- Disease symptoms first appear as water-soaked streaking on infected leaves.
- Later, the leaf may have shiny exudate on it and the lesions will develop a long, greyish, wavy pattern following leaf veins.
- Dark specks, sometimes called freckles, may be present within the lesion. The freckles and shiny exudate are distinct symptoms of Goss's Wilt. The lesions may have sticky exudates which will make the lesions appear shiny when dry.
- The pathogen infects corn leaves primarily through wounds but can also infect leaves through natural openings such as stomata. Mechanical leaf damage due to strong winds, heavy rain, hail damage or insect feeding can contribute to disease development when the pathogen is present in the environment.
- The Goss's Wilt pathogen overwinters on infected crop residues. Fields with high levels of infection in crop residue, which may occur with short corn rotations, will have the highest disease severity.
- Extended crop rotations will be beneficial in reducing the risk of Goss's Wilt
- Fungicides are not effective at managing bacterial diseases, including Goss's Wilt.

Figure 4.145 Dark specks from Goss's Wilt

Figure 4.146 Water soaked streaking from Goss's Wilt

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Corn Smut

Ustilago maydis

Corn smut infects both field and sweet corn. It is caused by the fungus Ustilago maydis. Fungal spores called sporidia are spread by the wind and rain. They can infect a corn plant anywhere, but infections of the ear are the most common. Spores land on the silks and grow down into the ear. The fungal bodies infect the kernels and within a few days, as they multiply and grow, they form a spongy, greenish-white gall. The gall increases in size over time and eventually bursts. This bursting releases thousands of black, powdery teliospores which are the resting spores for this disease. These teliospores then overwinter in the soil and on corn residue and provide the inoculum for the following year's infection.

Teliospores can survive in the soil for several years which is why crop rotation is the most successful way to combat this disease along with planting resistant varieties. Teliospores will germinate in the spring when temperatures are 10-35 C and moisture is available. These teliospores form structures that produce the sporidia which are then dispersed by wind and rain. Teliospores can also infect corn plants directly.

As sporidia can infect any parts of a corn plant, insect feeding and/or weather events such as hail or strong winds that cause plant wounds during the developing stages of the plant can increase the likelihood of a smut infection outbreak.

There are no fungicide treatments available to use when dealing with corn smut.

Figure 4.147 Corn smut damage

Figure 4.148 Corn smut damage

Sclerotinia in Sunflower

Sclerotinia sclerotiorum

Sclerotinia or white mould in sunflower is caused by the fungus *Sclerotinia sclerotiorum*.

As with any disease, you must have a favorable environment, a susceptible host, and a disease-causing organism. Sclerotinia sclerotiorum infects many broad-leafed crops including soybeans, dry beans, canola, mustard, and sunflower along with many vegetable crops. As such, rotations must be carefully considered that have susceptible broadleaf crops planted at least three years apart and preferably five years as the sclerotia which are the overwintering form of the disease can survive for at least five years in the soil.

In sunflower, there are three distinct diseases caused by this organism on sunflower. These are: Sclerotinia root rot, which includes basal stalk rot and wilt; Sclerotinia stem rot and Sclerotinia head rot including midstalk rot.

When looking for Sclerotinia root rot, Basal stalk rot and wilt, the first symptom that will appear is sudden wilting that will appear before or during flowering. Wilted plants will oftentimes be found in clumps. Sclerotinia sclerotiorum has invaded through the affected plants roots and adjacent plant roots can be infected. As time goes on, tan-coloured, water-soaked lesions will develop at the base of infected plants. These lesions can girdle the stem leading to noticeable lodging particularly with high winds. The disease progresses with stem bleaching and stem shredding. Examination of the inside of the stem will show decayed pith and black sclerotia bodies being present. Once plants start to wilt, death usually occurs within four to seven days.

Sclerotinia stem rot can appear any time during the growing season but mostly is seen from mid to late growing season. Small, water-soaked lesions start to develop on plants near the soil line. Secondary symptoms that may also appear are wilting, bleaching, and shredding of the stem. Examination of the stem will reveal the stem pith beneath the lesions containing mycelial growth and black sclerotia. Sclerotia will also be present on the outside of the stem. The discovery of the sclerotia inside and outside on the stem, are a symptom to aide in distinguishing Sclerotinia stem rot from Phomopsis stem canker.

Sclerotinia head rot and midstalk rot can be seen before or after flowering. Dark-coloured, water-soaked lesions can be found on the backside of sunflower heads or white mycelial growth may be present in the head itself. As the disease progresses, the inside of the head will rot and large sclerotia will be found below the seed layer and around the seeds. With time, the sunflower head will disintegrate and shred. Large sclerotia will be present and drop to the ground. To distinguish this disease from Rhizopus head rot, the presence of the sclerotia is the key.

The development of these diseases prefers 30 C temperatures or less, prolonged wet conditions; rain, fog, heavy dews and/or irrigation and wet soils. How badly this disease complex can affect yields is dependent on what growth stage the crop is at when infected, what agronomic practices are being done such as extended rotations between susceptible crops, and whether the environmental conditions that are conducive to disease development are present and for how long.

Figure 4.149 Sclerotinia infected sunflower plant

Downy Mildew on Sunflower

Plasmopara halstedii

Downy mildew in sunflowers is caused by the Plasmopara halsteadii pathogen which is an oomycete or water mould. There have been several races of the disease identified in western Canada. There are several hosts for this disease including more than 140 species of perennial and annual grasses.

Symptoms

There are three main symptoms which can develop at almost every growth stage with this disease. When this pathogen infects through the roots, a seedling blight will cause infected seedlings to manifest a pale green or yellowish blotch that spreads out from the leaf midribs or damping off. Along with the blotch, plants may show wrinkling and distortion along with stunting. These plants can be solitary, in groups or in large patches. Both conditions can kill the plant. Localized angular leaf spots may also be present. If infection occurs at flowering, heads will be normal in size but will contain only empty seed and instead of hanging down like normal heads will remain upright. The plants may be also severely stunted.

Figure 4.150 Downy mildew on sunflower. Under surface of the leaf reveals white mycelium and spores of the disease.

Figure 4.151 Downy mildew on sunflower

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Figure 4.152 Common cocklebur and common ragweed have been shown to act as significant wild hosts.

Mode of Transmission

This fungal pathogen is seed borne as well as wind and soil borne. It can survive in the soil for 5-10 years. As a result, extended crop rotation is a very important. When this disease is spread through the roots, the prevalence of wet soil which allows the disease pathogen to move in the soil and infect plants during the seedling stage, has a direct correlation as to incidence and severity.

Management

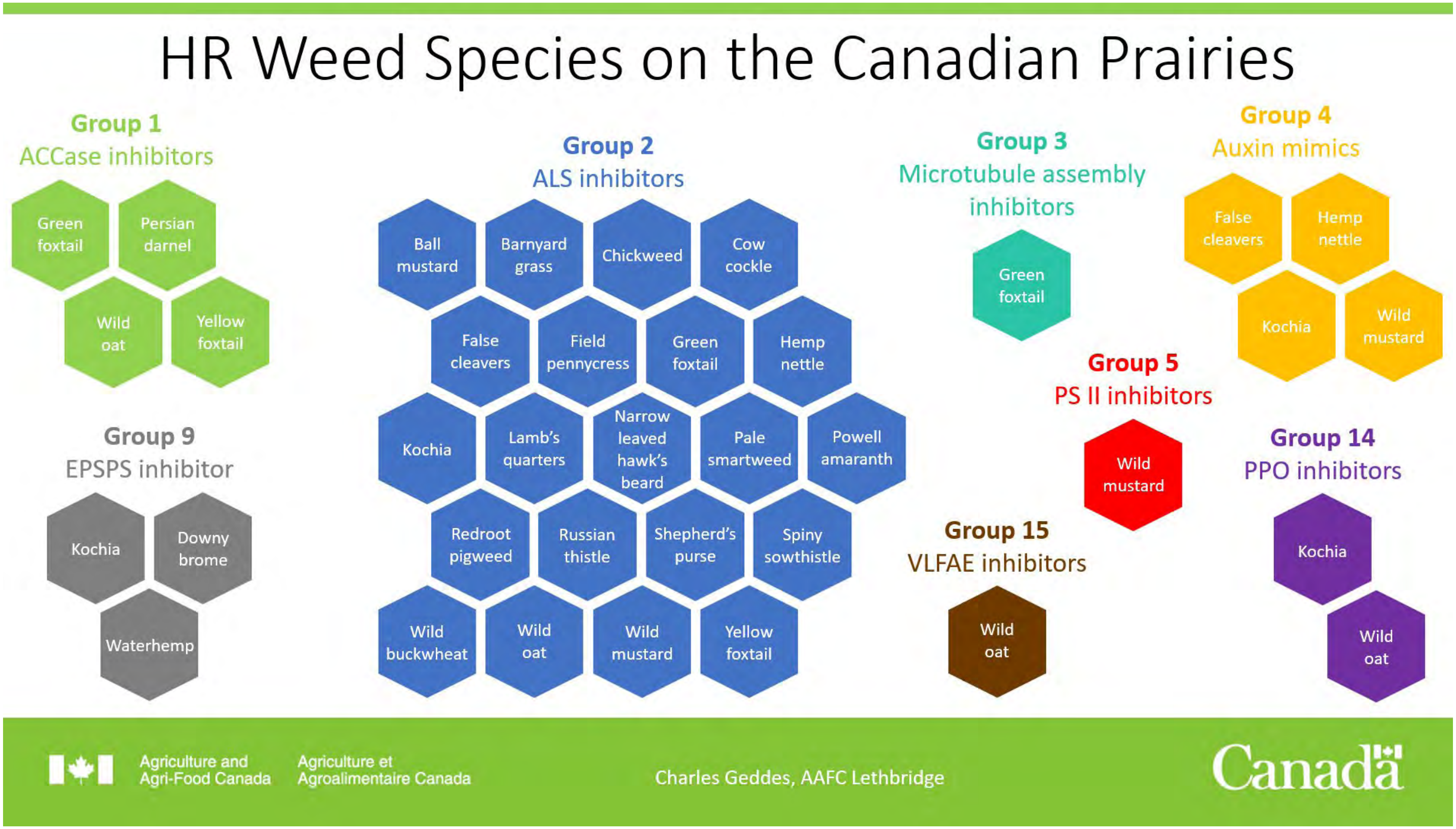
Once downy mildew infects a field, the use of resistant hybrid varieties becomes paramount. Controlling weed hosts along with avoiding planting into fields with drainage issues are further strategies. Seed treatments designed for controlling root infection also provide additional protection. If using seed treatments, producers need to rotate the fungicide group used as downy mildew fungicide resistance has been reported.

Yield loss

This will directly correlate to what stage the plant was at when infected. Early seedling infections can result in a 100 per cent loss with dead plants being blown away.

Section 5: Herbicide Groups and Injury

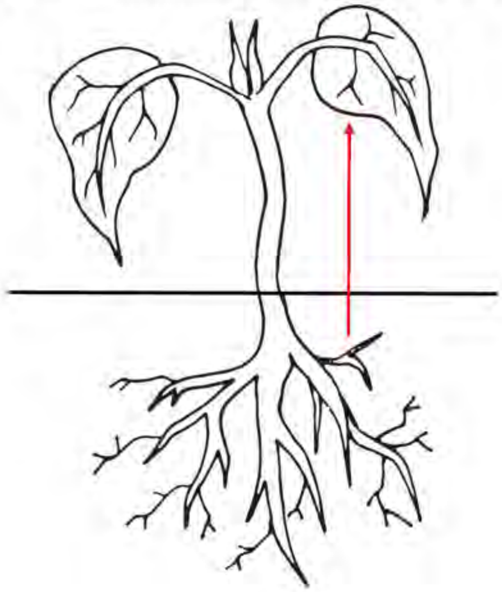
Useful summary of herbicide resistant weed species documented on the Canadian Prairies. Now shown here is that some weed populations exhibit resistance to multiple modes of action. Some populations exhibit variable cross-resistance to different active ingredients within mode of actions. Herbicide resistance is not simple. Accurate as of February 2023.



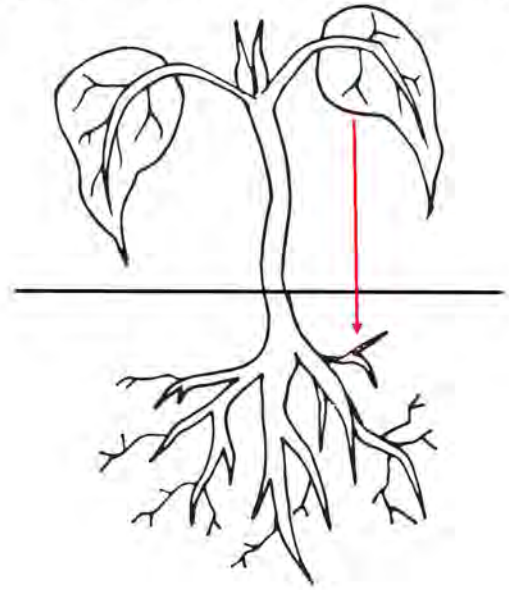
Courtesy of Charles Geddes- Agriculture and Agri-Food Canada

Movement of Herbicides in the Plant

Acropetal – material is moving up in the plant



Basipetal – material is moving down in the plant

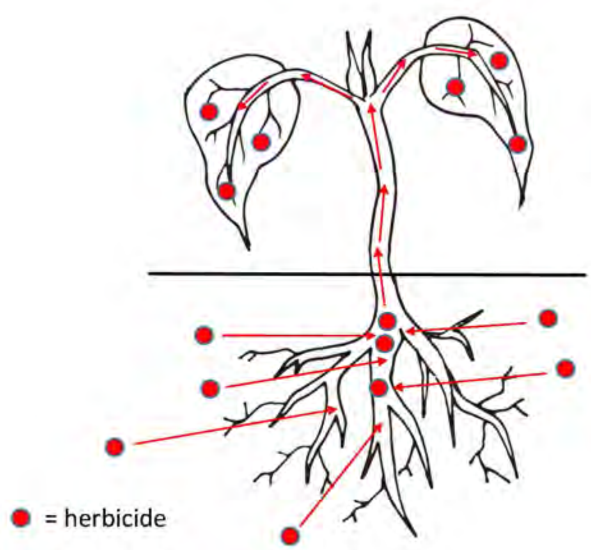


For example-In perennial plants, herbicides that move to the growing points will move up in the spring and move down in the fall.

Movement of Soil Active Herbicides in the Plant

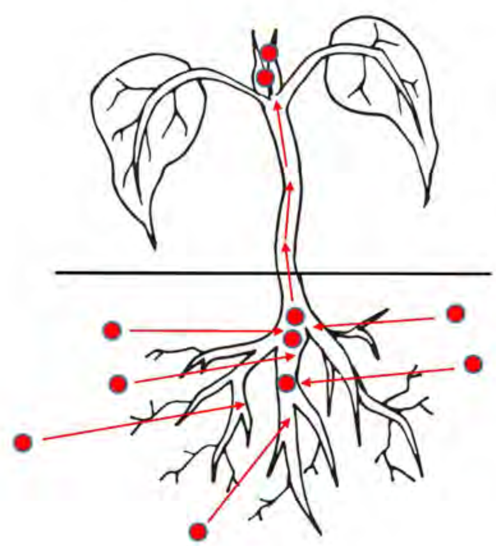
Apoplastic – movement driven largely by evapotranspiration = **passive**

The herbicide moves to the more mature leaves that are driving evapotransporation



Symplastic – movement driven by plant to facilitate movement of building blocks for growth (ie. sugar) = **active**

The herbicide moves to the active growing points



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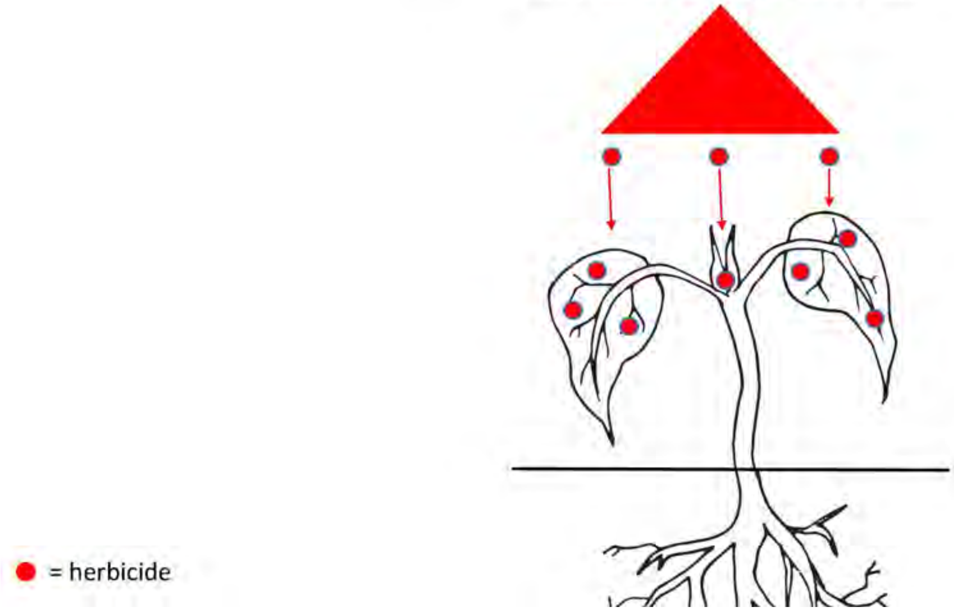
Movement of Foliar Applied Herbicides in the Plant

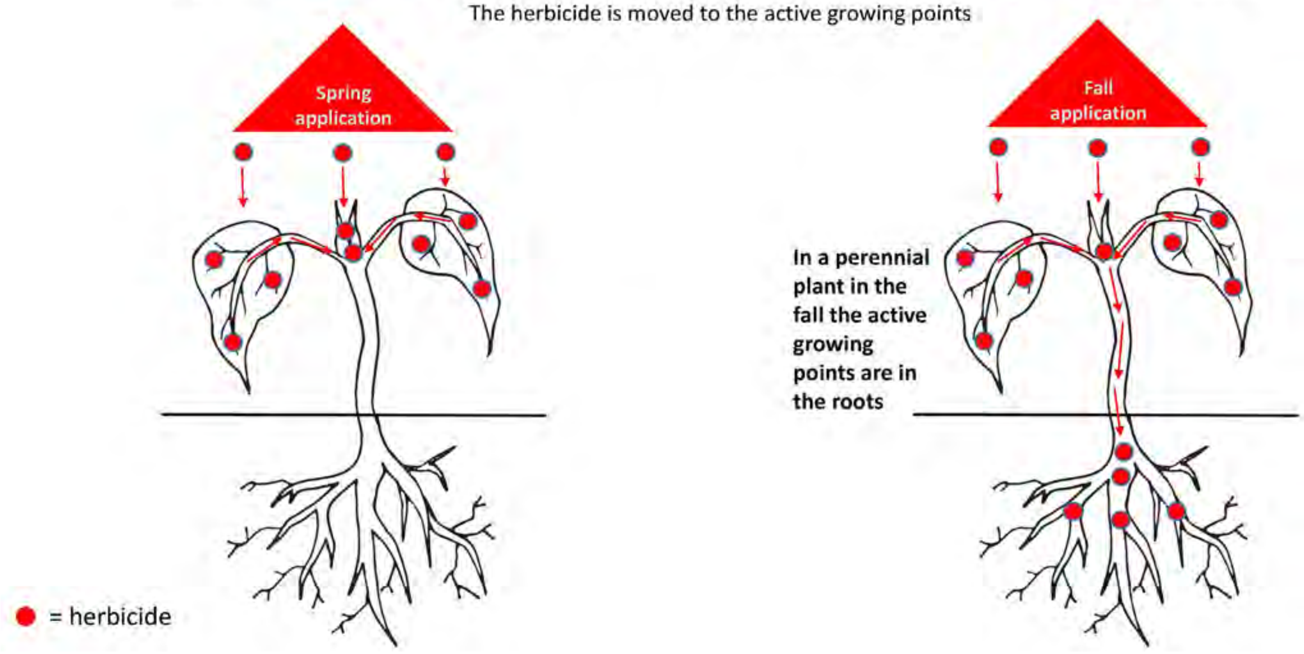
Apoplastic – movement driven largely by evaporation = **passive**.

The herbicide mainly stays where it lands

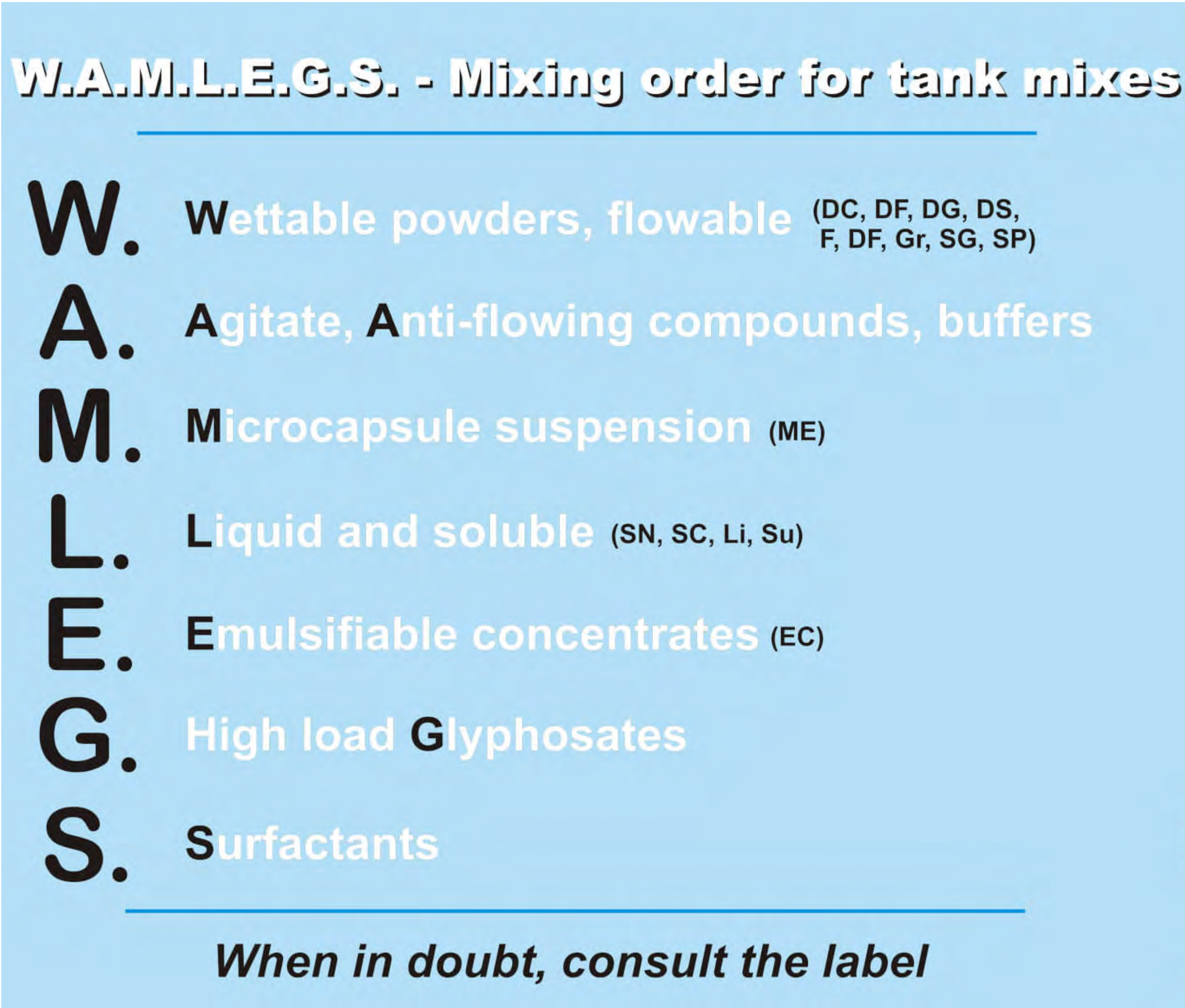


Symplastic – movement driven by plant to facilitate movement of building blocks for growth (ie. sugar) = **active**

The herbicide is moved to the active growing points



Mixing Order For Tank Mixes



Courtesy of BASF

If tank mixing is not done in the correct order, the result could be a tank-load of material that may not control the target pests, cause injury to the crop, plug nozzles, or leave an undesirable residue in the tank that will require extensive cleaning. Mistakes like these are costly, could put the user at unnecessary risk of exposure to the products, or create an environmental disposal problem. To avoid mixing that may result in incompatibilities, always consult the label of the products that are being used to learn the correct order. Remember to add all like components at the same stage of mixing. Learn more in the latest Guide to Crop Protection.

Herbicide Groups and Injury

Group 1 Herbicides (ACCase Inhibitor)

- **Target:** Inhibits the Acetyl Coenzyme A Carboxylase pathway
  - » Blocks the production of fatty acids used in the production of membranes and waxy substances like cuticular wax.
  - » The plant can have trouble defending itself from drying out.
- **Selectivity:** Grasses only.
  - » Products for cereal crops are selective to grassy weed species.
  - » Products for broadleaf crops are non-selective to grassy plants.
  - » May be adjuvant/solvent related effects on broadleaf plants.
- **Plant Uptake:** Largely foliar.
- **Movement in Plant:** Symplastic/active to areas of new growth.
- **Soil activity:** Little to none.
- **Binding to Soil:** Low to strong (product dependent).
- **Breakdown:** Rapidly in soil by:
  - » UV radiation (also on leaf surface-"dims").
  - » Microbial degradation.
  - » Hydrolysis (a water molecule cleaves the active ingredient molecule in half and deactivates it as a herbicide) in some cases.
- **Symptoms:** Whitening and interveinal chlorosis at the growing point and new growth followed by growth of the growing point stopping progression.

Figure 5.1 Clethodim applied 10 days earlier

Group 1 Injury Symptoms on Tolerant Crops:

- Symptoms often associated with cold or saturated soils.
- Plant is temporarily unable to break down herbicide normally.
- Bands occur proportional on each leaf to where it was at the time of the cold weather event.
  - » i.e. lower on older leaves and higher on newer leaves.
- Reduced growth and yellowing of the growing point within one to three weeks. Within three to five days, the newest leaf of affected plants can be pulled out easily.
- If there is green growth below the band, the plant will recover and there usually is not yield loss.

Figure 5.2 Group 1 injury symptoms to tolerant crop-white or yellow banding

The "pull test" for Group 1 activity on susceptible species:

- Tug on youngest leaf. If it pulls out easily and the base is discolored, the herbicide is working (as early as five to seven days after treatment (DAT)).

Figure 5.3 Pull test on susceptible species

Courtesy of: University of Saskatchewan

Assure II on Wild Oats:

Figure 5.4 Assure II on wild oats 1x rate 9 DAT

Courtesy of: University of Saskatchewan

Figure 5.5 Base of a wild oat, 26 days after application with 0.1 times the recommended rate of Assure II

Courtesy of: University of Saskatchewan

Group 2 Herbicides (ALS/AHAS Inhibitors)

- **Target:** Inhibits Acetolactate Synthase (ALS) also called Acetohydroxy Acid Synthase (AHAS).
  - » Blocks production of the essential branched chain amino acids leucine, isoluecine and valine. This prevents the plant from creating essential proteins necessary for development of new tissues and repair of old tissues.
- **Selectivity:** both grass and broadleaf crops.
  - » Controls a range of grasses and/or broadleaves (active specific).
- **Plant Uptake:** Both foliar and root uptake.
- **Movement in Plant:** symplastic/active to areas of new growth.
- **Soil Activity:** Significant.
- **Binding to Soil:** Little. Persistent products can be very mobile in the soil.
- **Breakdown:**
  - » Little to significant soil persistence (from very quick breakdown to years).
  - » Both hydrolysis and aerobic microbial breakdown-product dependent.
  - » Imidazolinone products are bound more by acid soils and will breakdown slower.
  - » Sulfonylurea products are bound more by high pH soils and breakdown will be slower, especially with hydrolysis.
  - » Triazolopyrimidines and sulfonylaminocarbonyl-trazolinone products have some binding to organic matter that can buffer some soil activity.
- **Symptoms:**
  - » Symptoms in grass weeds include yellowing of the newest leaves within three to 10 days followed by plant death in one to three weeks.
  - » Symptoms in broadleaf weeds include a discoloured (red/yellow/purple) growing point and new growth of plant. Yellow discoloration spreads to the whole plant within one to three weeks.
  - » When there is soil residue, seedlings will emerge but once they run out of these amino acids from the seed they may start to show symptoms.

Figure 5.6 Refine Extra 1x on beans 4 DAT

Courtesy of: University of Saskatchewan

Figure 5.7 12 DAT

Courtesy of: University of Saskatchewan

Figure 5.8 Odyssey on canola 7 DAT

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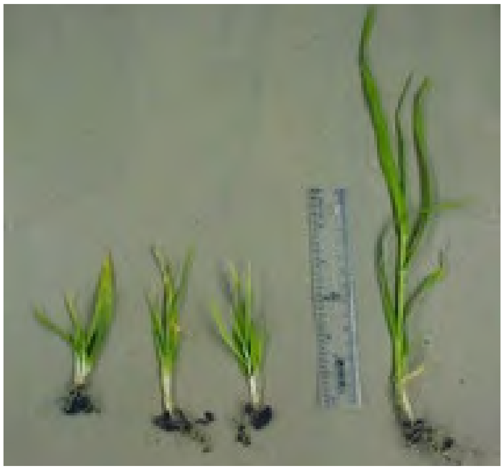
Group 2 Injury Symptoms on Tolerant Crops:

- Symptoms often associated with:
    - Cold or saturated soils.
    - Soil residue carryover from dry conditions the previous season followed by moderate to heavy rain.
- Stunting, shortened blade to sheath ratio, shortening of internode regions of the stem for broadleaf crops. The space between nodes for broadleaf crops will be affected for growth after the herbicide application but not before.
- Loss of apical dominance with prolific branching.
- Inter-veinal yellowing beginning in the newest growth.
- Plant is unable to break down herbicide normally (temporarily in cold weather event).
- Depending on severity and persistence of exposure, the plant may or may not recover.
- Symptoms in grass weeds include yellowing of the newest leaves within three to 10 days followed by plant death in one to three weeks.
- Symptoms in broadleaf weeds include a discoloured (red/yellow/purple) growing point and new growth of plant. Yellow discoloration spreads to the whole plant within one to three weeks.

Figures 5.9 Group 2 injury symptoms tolerant cereal crops (untreated on right)



Figures 5.10 Group 2 injury symptoms on tolerant cereal crops

Figures 5.11 Group 2 injury symptoms on pea

Figures 5.12 Group 2 injury symptoms on chickpea

Group 3 Herbicides (Microtubule Inhibition)

- **Target:** Bind to tubulin preventing polymerization into microtubules
  - » Microtubules are a critical part of cell division and cell wall formation.
- **Selectivity:** Impacts both grasses and broadleaves.
- **Plant Uptake:** Through roots.
- **Movement in Plant:** No appreciable movement past roots.
- **Soil Activity:** Significant-soil applied herbicide.
- **Binding to Soil:** Bound tightly (Edge) to very tightly (trifluralin) to clay and organic matter.
- **Breakdown:**
  - » Anaerobic microbial degradation is rapid.
  - » Aerobic breakdown is moderate to slow.
- **Half-life:** Edge-24 to 47 days; trifluralin-average 164 to 544 days (dependent on environmental field conditions and strength of binding to soil).
  - » Volatilization (requires soil incorporation to prevent).
  - » UV degradation (requires soil incorporation to prevent).

Figures 5.13 Edge 1x rate (1100g active ingredient (ai)/ha) on barley

Courtesy of: University of Saskatchewan

Figures 5.14 Edge 1x rate (1100g ai/ha) for fall pre-plant incorporates on wheat (untreated on left)

Courtesy of: University of Saskatchewan

Group 3 Injury Symptoms:

- The primary symptoms are in the roots:
  - » Stubby and clubbed roots that fail to elongate.
  - » Symptoms in the upper part of the plant are a result of the deficiencies caused by damage to the roots.
- There can be stunting in young shoots.
- Symptoms in grassy weeds include reduced emergence and poor root development of emerged plants. Roots are often swollen or stunted and root tips are darkened.
- In broadleaf weeds, symptoms include reduced emergence and poor root development of emerged plants.
- Symptoms in the upper part of the plant are a result of the deficiencies caused by damage to the roots.

Group 4 Herbicides (Synthetic Auxin)

- **Target:** Several-mimics functions of Indole Acetic Acid (IAA) but susceptible plants are unable to metabolize.
  - » Results in unregulated cell elongation and production of undifferentiated (callus) tissues particularly at the root/stem interface.
- Sub-lethal symptoms include epinasty, cupping, leathery appearance.
- Initial symptoms within hours, three-four weeks until plant death.
- **Selectivity:** Broadleaves most sensitive; grass physiology tolerates but not resistant.
- **Plant Uptake:** Through both roots and shoots.
- **Movement in the Plant:** Symplastic/active to the same sites as natural plant hormones.
- **Soil Activity:** Little to significant, dependent on product persistence.
- **Binding to Soil:** Low.
- **Breakdown:**
  - » By aerobic soil microbes.
  - » Short to very long persistence in soil.

Group 4 Injury Symptoms:

- Broadleaves the most susceptible. Symptoms include:
  - » Epinasty-twisting of stems & petioles.
  - » Stem swelling particularly at lower stem/upper root.
  - » Stem elongation-promotes cell expansion in stems as with natural auxin.
  - » Cracks and splits in bark-growth of undifferentiated cells (callus tissue).
  - » Leaf "warting" resembling virus infection.
  - » Brittleness of affected plants (stems, petioles, mid-ribs of leaves).
  - » Chlorosis in growing point.
  - » Cupped and curled leaves.
  - » Wilting and tissue death (necrosis)-as a result of crushing of xylem transport vessels.
- Initial symptoms within hours, three to four weeks until plant death.
- Sub-lethal symptoms include epinasty, cupping and leathery appearance.
- Grasses are tolerant but not immune and symptoms are typically associated with improper timing or excessive rates. Symptoms include:
  - » Physiology of the water transport vessels resist crushing (under moderate rates).
  - » Metabolism is faster than for broadleaf crops.
  - » Plants can appear drought stressed even when there is enough moisture.
  - » Too early application when the seed head is being formed or an application too late can result in floret abortion and head kinking which can reduce yield and flag leaves "pig-tailing".
  - » Too high of rates can result in symptoms similar to drought, including older leaves dying, blue-grey leaf surfaces form thicker/ waxy cuticles, stunting and shorter flag leaf.

Figures 5.15 2,4-D on dandelion

Courtesy of: University of Saskatchewan

Figure 5.16 2,4-D (420g ai/ha) on sunflower 4 DAT

Courtesy of: the University of Saskatchewan

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Figure 5.17 Clopyralid soil residue on soybean

Figure 5.18 Group 4 injury on canola

Figure 5.19 Clopyralid soil residue on peas

Figure 5.20 2,4-D drift on canola

Figure 5.21 Phenoxy damage on cereals' head that can result in "pigtail" appearance

Figures 5.22 Phenoxy damage on cereals' head

Courtesy of: the University of Saskatchewan

Figures 5.23 Phenoxy damage on cereals' head

Courtesy of: the University of Saskatchewan

Figure 5.24 Dicamba damage on common bean

Courtesy of: University of Saskatchewan

Figure 5.25 Clopyralid gradient showing effects on peas

Courtesy of: University of Saskatchewan

Figure 5.26 2,4-D corn root damage

5.27 2,4-D corn root damage

Note: This damage only occurs if 2,4-D is sprayed after the sixth leaf stage

Group 5, 6 and 7 Herbicides (Photosystem II Inhibitors)

- **Target:** Inhibit photosynthesis by blocking electron transport:
  - » Rapidly ruptures cell membranes.
  - » Rapid chlorosis transitioning quickly to necrosis of leaf tissue (two days in warm, sunny weather).
- **Selectivity:**
  - » Group 5 and 7-both grasses and broadleaf sensitivity. Grasses at higher rates typically.
  - » Group 6-primarily broadleaves but grasses may be injured.
  - » Application at high temperatures can result in injury to crops that should be tolerant. The herbicide acts faster than the plant can metabolize it.
- **Plant Uptake:** All by shoots; roots only by groups 5 and 7.
- **Movement in the Plant:** Acropetal/passive.
  - » Move upward and outward in plants.
  - » Concentrates herbicide in leaf margins or tips at sub-lethal rates.
- **Soil Activity:** Group 5 and 7-significant; group 6-none.
- **Binding to Soil:**
  - » Group 5 and 7 low to moderate binding; available for root uptake.
  - » Group 6 bound tightly to soil and not available for root uptake.
- **Breakdown:** Primarily aerobic microbial; some group 5 also via hydrolysis.

Group 5 Injury Symptoms:

- Symptoms on weeds from soil application include wilting and yellowing of the oldest leaves. Plants die in seven to 10 days.
- On grassy weeds that have received a foliar application, symptoms include yellowing of the oldest leaves and plant death within days.
- On broadleaf weeds that receive a foliar application, the oldest leaves become bleached and death occurs within days.

Group 6 Injury Symptoms:

- When applied to grassy weeds, some leaf burn is possible.
- When applied to broadleaf weeds, leaves are yellowed in two to four days, and plants die in one to two weeks.

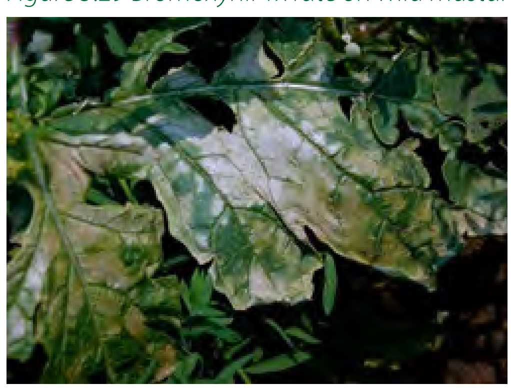
Group 7 Injury Symptoms:

- Symptoms when soil applied include yellowing and stunted plants followed by plant death in 10 to 14 days.
- Symptoms when foliar applied include inter-veinal yellowing on the oldest leaves and plant death within days.

Figure 5.28 Bromoxynil 0.1x rate on sunflower 4 DAT

Courtesy of: University of Saskatchewan

Figure 5.29 Bromoxynil 1x rate on wild mustard 4 DAT



Courtesy of: University of Saskatchewan

Figure 5.30 Sencor uptake by roots after heavy rain

Figure 5.31 Injury from bentazon applied to lentils

Figure 5.32 Linuron damage on soybeans

Courtesy of: University of Saskatchewan

Group 8 Herbicides (Lipid Synthesis Inhibitors)

- **Target:** Inhibits the production of fatty acids (non-ACCase).
  - » Other unknown impacts in the plant.
  - » Susceptible seedlings fail to form a cuticle layer and fail to emerge.
  - » Grass leaves roll tightly along length (onion-leafing) and leaf tips get stuck in the sheath of the previous leaf (buggy-whipping).
  - » Broadleaf leaves are crinkled (drawstring effect) and leathery.
- **Selectivity:** Eptam-grass and broadleaf; Avadex-wild oats.
- **Plant Uptake:** Mostly absorbed by coleoptile (grass) or hypocotyl arch (broadleaves), a little via roots.
- **Movement in the Plant:** Very little from the point of uptake. If there is, it is some symplastic movement toward the growing point
- **Soil Activity:** Significant.
- **Binding to Soil:** Strongly to dry soil.
- **Breakdown:** Primarily aerobic microbial; volatilization when exposed to water (requires soil incorporation to prevent).
  - » Short to moderate soil persistence.

Group 8 Injury Symptoms:

- Symptoms for soil applied include reduced emergence, stunted and swollen coleoptiles and where emergence occurs, the leaves are dark green/blue.
- Symptoms for foliar application to grassy weeds include yellowing of leaves in three to seven days and stunted plants.

Figure 5.33 Triallate symptoms on oat (injured plants are on the right)

Courtesy of: University of Saskatchewan

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Group 9 Herbicides (EPSPS Inhibitor)

- **Target:** Inhibits 5-enolpyruvyl shikimate-3-phosphate synthase.
  - » Results in depletion of tryptophan, tyrosine, and phenylalanine.
  - » Similar type of impact on plants as group 2 herbicides. The main difference is:
    - Glyphosate remains active in the plant for 24 to 48 hours before it is bound up within the plant and growth ceases very soon after application.
    - Group 2 herbicide symptoms can appear and progress repeatedly in affected plants and the plants do not recover because they can persist in the plant and soil.
- **Selectivity:** Non-selective, except genetically engineered plants bred to tolerate.
- **Plant Uptake:** Foliage only.
- **Movement in the Plant:** Symplastic/active-moves to most actively growing points in the plant.
  - » In the spring, movement is to top growth
  - » In the fall in perennial plants, movement is to the roots.
- **Soil Activity:** None in most soils-may be some effects with high rates in low cation exchange category soils (low organic matter sand).
- **Binding to Soil:** Strongly to both organic matter and clay.
- **Breakdown in Soil:** Aerobic microbes.
  - » Moderate persistence in soil but the herbicide is tightly bound so it doesn't impact crops.

Group 9 Injury Symptoms:

- Immature leaves in growing point are affected first (five to seven days) and older leaves follow as they require repair (up to three weeks).
- Symptoms include wilted and yellowed leaves in seven to 10 days. The newest growth is impacted first, followed by the rest of the plant.
- Sub-lethal effects include:
  - » Yellowing of the new growth (first to experience the deficit of essential amino acids for growth).
  - » Stunting and mineralization of new growth.
  - » Loss of apical dominance and the eruption of lateral buds.
  - » Compression of the newest internodes.
  - » Before deciding that there has been glyphosate injury, make sure it isn't just the crop that is affected. Check leaves of weeds and other plants. Colour change can be due to a number of reasons.

Figure 5.34 Glyphosate symptoms on canola

Courtesy of: University of Saskatchewan

Figure 5.35 Glyphosate (0.5L/ac) on barley 4 DAT

Courtesy of: University of Saskatchewan

Figure 5.36 Sublethal glyphosate injury on ash

Figure 5.37 Sublethal glyphosate injury on flax

Figure 5.38 Damage to pea by glyphosate

Figure 5.39 Glyphosate damage from drift that occurred after three trifoliate stage of growth in soybean

Group 10 Herbicide (Glutamine Synthase Inhibitors)

- **Target:** Glutamine synthase inhibition.
  - » Rapid accumulation of ammonia cell rupture = rapid necrosis.
  - » Depletion of amino acids (glutamine, glutamate and others).
  - » Growth inhibition & chlorosis or bleaching.
- **Selectivity:** Non-selective, except genetically modified plants bred to tolerate.
- **Plant Uptake:** Foliar.
- **Movement in the Plant:** Would be symplastic/active; but rapid leaf necrosis prevents movement out of leaf.
- **Soil Activity:** Limited.
- **Binding to Soil:** Weak.
- **Breakdown in Soil:** Rapid aerobic microbial breakdown.
  - » Glufosinate (Liberty and generics) is the only active relevant to western Canada in this group.

Group 10 Injury Symptoms:

- Symptoms are varying degrees and speeds of:
  - » If dry down of plant tissue is very fast, the movement out into the plant will be minimized.
  - » Slower cell rupture means that more product can move within the plant and limit amino acid formation. This results in a bleaching effect.
  - » Both of these symptoms can occur at the same time in a plant and the amount of one may determine the amount of the other.
- Desiccated tissue looks whiter than desiccated tissue that is a result of application of other membrane disrupting herbicides.

Figure 5.40 Liberty on canola 4 DAT

Figure 5.41 Liberty on sunflower 7 DAT

Courtesy of: University of Saskatchewan

Figure 5.42 Liberty on oat 5 DAT

Courtesy of: University of Saskatchewan

Group 11 Injury Symptoms:

- Symptom is bleaching in leaves and shoots, particularly in new tissue. Bleached tissue eventually wilts and dies.
- Sublethal doses result in bleaching of new growth.

Group 13 Herbicides (DOXP Inhibitors)

- **Target:** Inhibitors of 1-deoxy-d-xylulose 5-phosphate synthase.
  - » Inhibits pigment production (including carotene and chlorophyll).
  - » Results in colourless (white) tissue production.
  - » Also may inhibit gibberellin synthesis.
  - » Causes internode stunting or dwarfism.
- **Selectivity:** Corn and soy have high tolerance, canola tolerant at lower rates for prairies.
- **Plant Uptake:** Root.
- **Movement in Plant:** Acropetal/passive translocation.
- **Soil Activity:** Significant.
- **Binding to Soil:** Moderate.
- **Breakdown:** Broken down by microbes.
  - » Short to moderate persistence.
  - » Clomazone (Command, Merit) the only active in this group.

Group 13 Injury Symptoms:

- Susceptible plants typically emerge from the soil white, often becoming translucent at the leaf tips, and turn necrotic and die in short order.
- Plants exposed after emergence exhibit bleaching symptoms.

Figure 5.43 Canola showing damage from Clomazone

Figure 5.44 Wheat showing damage from Clomazone

Group 14 Herbicides (PPO Inhibitors)

- **Target:** Inhibitors of protoporphyrinogen oxidase (PPO).
  - » Inhibit heme and chlorophyll biosynthesis.
  - » Inhibits Protox enzyme → singlet oxygen in cytoplasm attacks and ruptures cell membranes.
- **Selectivity:** Some chemistries selective; others → not.
- **Plant Uptake**: Foliar and root (product dependent).
- **Movement in Plant:** Acropetal/passive movement for products with soil activity.
  - » Rapid necrosis from foliar products limits phloem movement.
- **Soil Activity:** Little to significant (product dependent).
- **Binding to Soil:** Light.
- **Breakdown in Soil:** Aerobic microbes.
  - » Very short to long persistence.

Group 14 Injury Symptoms:

- Symptoms when products are soil applied are bleaching and yellowing and seedling death prior to or shortly after emergence. If the herbicide moves up with water into the plant during the day, there can be veinal chlorosis and symptoms spread from the veins out.
- Symptoms for foliar application to grassy weeds include leaf burn at contact points or leaf edges, rapid desiccation and necrosis.
- For broadleaf weeds, symptoms include yellow leaves and desiccation in one to three days when application is after seedling emergence.
- Regular banding or bleaching and pinching along leaf similar to heat banding that only occurs under very saturated soils and sunny conditions that liberate the sulfentrazone from soil near the plant. If this happens during the day, the banding or bleaching and pinching occurs. If the product moves into the leaves at night, the plant has enough time to break down the herbicide.
- Sub-lethal doses can result in the herbicide being concentrated at the leaf margins.

Figure 5.45 Sulfentrazone symptoms on sunflower

5.46 Sulfentrazone symptoms on pea

Figure 5.47 Sulfentrazone symptoms on barley

Courtesy of: University of Saskatchewan

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Group 15 Herbicides (Long-chain Fatty Acid Inhibitor)

- **Target:** Very long-chain fatty acid (cell membrane, cuticle formation).
  - » Root and shoot growth inhibitors that prevents elongation of roots and shoots.
  - » Susceptible plants typically do not emerge.
- **Selectivity:** Small seeded weeds are more susceptible. The larger the seed size, the less activity there is on that plant.
- **Plant Uptake:** Emerging shoot through treated layer.
- **Movement in Plant:** Acropetally/passive but not very far from the point of uptake. In larger plants, there is acropetal movement but there is no impact on the plant.
- **Soil Activity:** Significant; moderately persistent.
- **Binding to Soil:** Light.
- **Breakdown in Soil:** Primarily by aerobic microbes.

Group 15 Injury Symptoms:

- Crop injury.
  - » Grasses-onion-leafing, buggy whipping.
  - » Broadleaves-"drawstring effect" mid-vein prevented from expanding with the rest of the leaf and tip appears restricted.
- Symptoms are reduced emergence and stunted plants and are similar to Group 8, especially non-triallate products.
- Seedlings are largely impacted where the product is absorbed by the emerging shoot.

Figure 5.48 leaf tip caught in sheath of prior leaf and leaf rolling

Group 19 Herbicides (Auxin Transport Inhibitors)

- **Target:** Concentrates both natural and synthetic auxins (Group 4) in meristematic tissues.
  - » Interfere with plant hormone movement from the top of the plant to the rest of the plant.
  - » Acts as a synergist to non-phenoxy Group 4 herbicides (i.e. dicamba, picloram, aminopyralid, etc.) resulting in efficacy at lower use rates.
- **Selectivity:** Primarily broadleaf (diflufenzopyr); annual grass and broadleaf weeds (naptalam).
- **Plant Uptake:** Foliar and root.
- **Movement in Plants:** Both apoplast/passive and symplast/active.
- **Soil Activity:** Little to significant.
- **Binding to Soil:** Light.
- **Breakdown in Soil:** By microbes in soil.
  - » Non-persistent in soil (diflufenzopyr) to slightly persistent (naptalam).
  - » Naptalam (Analap), diflufenzopyr (Distinct, OverDrive).

Group 19 Injury Symptoms:

- Injury symptoms include twisting of older leaves and new leaves that fail to expand. Plant death occurs in two to four weeks.

Distinct symptoms on dicamba tolerant soybeans:

Note: symptoms of reduced leaf growth and clustering of growth around nodes. Blank internodes. May also be other epinasty (cupping, curving, puckering) symptoms.

Figure 5.49 Group 19 injury to dicamba tolerant soybeans from an application of Distinct

Figure 5.50 Soybean damage caused by Distinct

Group 22 Herbicides (Photosystem I Inhibitor)

- **Target:** Inhibits electron transport.
  - » Rapid membrane disruption ➔ rapid desiccation.
- **Selectivity:** Non-selective, contact herbicides.
  - » Paraquat (Gramoxone); Diquat (Reglone).
- **Plant Uptake:** Foliar. Good coverage is needed so the product goes into the leaf axils where new leaves are forming.
- **Movement in Plants:** Apoplastic/passive; movement limited due to soil binding.
  - » Possible diffusion in darkness.
- **Soil Activity:** None.
- **Binding to Soils:** Extremely strongly bound to soils-nearly irreversible.
- **Breakdown:** Soil-microbial; on plant tissues by sunlight.
  - » Very persistent (but not active since so strongly bound).

Group 22 Injury Symptoms:

- Injury symptoms in grassy weeds include wilted leaves within hours of application and plant death occurs in one to three days.
- Symptoms in broadleaf weeds include wilted leaves within one to three days after application and the plant desiccates and dies within three to seven days.

Figure 5.51 Initial symptoms of diquat activity

Courtesy of: University of Saskatchewan

Figure 5.52 Figure 5.55 Diquat 1x rate on Desi chickpea 2 DAT

Courtesy of: University of Saskatchewan

Figure 5.53 Paraquat on wheat 1 DAT

Courtesy of: University of Saskatchewan

Figure 5.54 Paraquat on wheat seedlings 2 DAT

Group 26 Herbicides (Unknown)

- **Target:** Suggested cell wall biosynthesis inhibitor.
  - » Research also suggests the stimulation of 1-aminocyclopropane-1-carboxylic acid resulting in overproduction of ethylene and cyanide.
  - » This is seen in some other auxinic herbicides as well.
  - » Causes sub-lethal sterility in oats (domestic and wild).
- **Selectivity:** Quinclorac has activity on grasses.
- **Plant Uptake:** Absorbed by roots and shoots.
- **Movement in Plants:** Both in apoplast/passive and symplast/active.
- **Soil Activity:** Significant; moderately persistent (may injure the year after treatment).
- **Binding to Soil:** Limited, so herbicides can be fairly mobile.
- **Breakdown:** Primarily degraded by microbes in soil.

Figure 5.55 Group 26 on green foxtail

Courtesy of: University of Saskatchewan

Group 26 Injury Symptoms:

- Systemic herbicide absorbed by germinating seeds, roots and leaves of seedlings.
- Symptoms in sensitive monocots start to appear seven to 10 days after application. Plant growth is then inhibited followed by the chlorosis of young leaves. Necrosis of the aerial part of the plant occurs next.
- Purpling can be caused by the cyanide in the plant.

Group 27 Herbicides (HPPD Inhibitors)

- **Target:** Inhibit 4-hydroxyhenyl-pyruvatedioxygenase ➔ indirect inhibition of carotenoid (pigment) production.
  - » Carotenoid pigments protect chlorophyll from decomposition by sunlight.
  - » Without carotenoid pigments, chlorophyll is photo-oxidized and chloroplasts break down.
- **Selectivity:** Grass & broadleaf in both grass and broadleaf crops.
- **Plant Uptake:** Both foliar and root.
- **Movement in Plants:** Acropetal/passive-sublethal accumulation at leaf edges.
- **Soil Activity:** Somewhat to significant.
- **Binding to soil:** Little.
- **Breakdown:** Aerobic microbes in soil.

Group 27 Injury Symptoms:

- Symptoms on grassy weeds include some bleaching and whitening of leaves.
- Symptoms in broadleaf weeds include bleaching and whitening of leaves within two to 10 days and the plant dies in seven to 10 days.
- Water transport only, which means upward and outward movement and results in halo effects on leaves.
- Older leaves are impacted.

Figure 5.56 Pyrasulfatole and bromoxynil on canola

Figure 5.57 Pyrasulfatole and bromoxynil on lentil

Note: Lentil in Figure 5.57 is also suffering from Group 2 injury caused by Pursuit (imazethapyr) applied prior to seeding.

Figure 5.58 Pyrasulfatole soil residue on lentil

Figure 5.59 Pyrasulfatole soil residue on pea

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Sprayer Tank Cleaning

- When pesticide application is completed each day, it is important to empty and clean the sprayer thoroughly to prevent the breakdown of certain pesticides, prevent adhesion of the pesticide to the sprayer, and to maintain the sprayer parts in good condition.
- Certain pesticides break down very quickly when left in solution, and several pesticide solutions can be corrosive to sprayer parts.
- Sprayer cleaning is especially important when changing from one crop to another or from one pesticide to another. To avoid the risk of contamination, sprayers should be cleaned as soon as possible after application is completed.

Cleanout Methods

The Ammonia Rinse

- Fill spray tank and add 1L of household ammonia three per cent for every 100 L of clean water needed for the rinse and begin agitation. Allow solution to flush through the booms until the boom is completely filled with ammonia solution and top up the tank with water. Circulate the ammonia solution through the tank and pump system for 15 minutes. Flush hoses and booms with ammonia rinse solution again (minimum five minutes) before emptying. Remove nozzles and screens and scrub with 0.1L household ammonia per 10 L clean water with an old toothbrush. Perform clean water rinse to remove ammonia solution prior to next spray load. Some herbicides recommend leaving the ammonia rinse in the tank over night to improve cleaning potential.
- Drain contents of tank-one two times, water rinse-two times, ammonia rinse-two times, water rinse (one just prior to the next spraying event).

The Fresh Water Rinse

- The spray tank cleaning should begin and end with a fresh water rinse to remove the majority of potential contaminants prior to the cleansing process or prior to the next round of spraying. Drain the tank of its previous contents and fill the tank with clean water. Open nozzle valves and pump clean water through the booms and hoses. Top up the tank with more clean water and circulate/agitate for at least 10 minutes and empty the tank of waste water. If this is the first rinse after spraying, a high pressure hose could be used to clean residue from all surfaces in the tank.
- Drain contents of tank; complete several repetitions of the water rinse with nozzles and screens removed and checked for debris.

The Detergent Rinse

- After rinsing with clean water, fill spray tank and add a heavy-duty detergent at 0.25 L per 100 L of water (some suggest a non-ionic surfactant such as Agral 90 or Agsurf at 0.6 L per 100 of water). Circulate the mixture for a minimum of five minutes and spray out through sprayer nozzles. Nozzles and screens are removed and cleaned individually with the same detergent solution in a small container. Soaking in this solution for several hours also helps to loosen any deposits.
- Drain contents of tank-two times, water rinse-two times, detergent rinse-two times, water rinse.

Figure 5.60 Sprayer with tank

Special Considerations

- In the case of products that have no cleaning recommendations on the label, there are some basic principles that can be applied:
  - » Products that are water based formulations can usually be cleaned from spray tanks using the fresh water rinse.
  - » Products that are formulated as an emulsifiable concentrate (EC), suspension concentrate (SC) or flowable (F) or use a petroleum based adjuvant should at least use the detergent rinse. The detergent breaks down the oil that may be sticking to the side of the tank.
  - » Products in Group 2 (most will already have a recommendation), with the exception of the 'IMI' products, will require the use of the ammonia rinse. The ammonia either increases the solubility of the product allowing it to be easily removed from the tank surfaces or speeds the breakdown of these products in water.
  - » If the product that is to be cleaned out of the tank is a combination of these elements, use a combination of methods to clean the tank. In these cases, use a good commercial tank-cleaning product from a recognized source, with both ammonia and detergent as components.

Group 2 Cleaning

Group 2 compounds are highly active on sensitive plants so even a small amount remaining in the sprayer can present a risk of injury. They can also occasionally be trapped on the tank walls and plumbing by petroleum based formulations or adjuvants when tank mixed with other products, resulting in tank residues that may be tougher to remove.

- A way to reduce the chance of this occurring is to add detergent at 0.25 L per 100 L to the ammonia rinse portion to assist with the breakdown of the petroleum coating so that the ammonia may rid the tank of Group 2 product.
- It is very important to clean sprayers immediately after every use. With a more diverse rotation, the likelihood of damage from lack of care increases dramatically.

Figure 5.61 Sprayer nozzle

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Section 6: Environmental Stresses

General Information

It's important to remember, while scouting, there could be multiple issues in a field even if the initial search was only for one. Environmental stresses can be confused with other problems and sometimes it can be difficult to distinguish one specific stress over another.

General Frost

- Frost damage will depend on the temperature, length of exposure time, humidity levels and how long it takes to reach freezing temperature. Because of this, it is very difficult to give an exact temperature to which crops can tolerate frost. The information in this section is to be used as a guide only.
- Plant cells contain not only water but also many substances such as proteins, sugars, amino acids and other solutes that can lower the freezing temperature and protect the cells against intracellular ice formation (similar to antifreeze).
  - Even though water freezes at 0 C, a plant cell may need temperatures down to -4 C or lower before the cells freeze and damage will occur.
  - Levels of "anti freeze" compounds depend on different plant parts, stages of plant development and plant type.
- Spring frosts can damage germinating seedlings and the extent of the damage will depend on the location of the growing point and the level of "antifreeze" compounds in the plant.
  - Exposure to cooler temperatures over time can harden off plants so that they are more tolerant to frost.
  - A gradual change in temperature has a smaller effect than a dramatic change.
  - Environmental conditions also play a role; dry soil conditions, high wind with high evaporation potential aggravate frost injury. Moist or heavy dews can reduce the injury.
- Evaluating frost damage is difficult and should be done 24 to 48 hours after the frost for initial symptoms and up to seven to 10 days later for full extent of damage.

General Hail

- Hail damage and recovery is stage and crop dependent. Crops with growing points below ground will likely regrow but maturity will be delayed.
- Give the crop a few days before assessing whether or not reseeding is necessary as plants may recover.
- The open wounds from hail can be an access point for bacterial infection as many bacterial pathogens need open wounds to invade plants.
  - Fungal infections do not increase with hail injury as fungi do not require open wounds to infect plants and research has shown no difference in fungal disease presence with or without hail injury.
  - Increases in fungal disease activity after hail events are more likely due to a humid environment conducive to fungal growth and rain/hail splash of pathogen infected soil onto plant surfaces.

General Moisture

**Information courtesy of Manitoba Agriculture- Managing Crops for Excess Water Stress*

- Wet soils cause an oxygen deficiency in the soil, reducing the ability for the plant to uptake nutrients.
- Crop tolerance to waterlogging depends on a few factors: soil type, plant species and growth stage, temperature, day length and duration of the stress. Plant roots and shoots can adapt to short term reductions in oxygen levels by lowering respiration rates and slowing growth of shoots. Prolonged exposure to excess water creates symptoms similar to those experienced by crops under dry conditions.
- In terms of relative crop tolerance (this will still depend on the above factors):
  - Cereals: oats > wheat > barley
  - Pulses: faba beans > soybeans > field beans > peas/lentils
  - Oilseeds: canola > sunflower > flax
  - Forages: grasses > legumes
    - Reed canarygrass > timothy > orchardgrass = perennial ryegrass
    - Birdsfoot trefoil/red clover > alsike clover > sweet clover > alfalfa

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General Heat and Wind

**Information courtesy of Canola Council of Canada's Canola Encyclopedia and Saskatchewan Pulse Growers- Environmental Damage to Pulses Factsheet*

- Wind can blow seed and seedlings out of the ground or create a sandblasting effect causing plants to tip over or break at the point of injury.
  - » This is more common under dry conditions and in lighter (sandier) textured soils.
  - » It can also be worse on hilltops and side slopes facing into the wind.

Oilseeds

Frost

- Newly emerged canola at the cotyledon stage can be very susceptible to spring frosts as the growing point is above ground.
- Plants at the three to four leaf stage are much more tolerant and can withstand a couple more degrees of frost.
  - » Typically, canola can tolerate temperatures down to -4 C. Plants hardened off by cooler temperature prior to a frost can tolerate temperatures as low as -7 C.
- A light frost that burns the leaves may not injure the growing point. If there is regrowth or green material at the growing point, then the plants may recover (Figure 6.1).
- It will take a few days (three to seven) before damage can really be assessed. Within the field, there can be damaged and undamaged plants close together.
  - » To determine the viability, check to see if the growing point is green (green regrowth should be visible after four to 10 days) and that the stems are still healthy. Severely damaged plants will pinch off at the top of the stem and the whole seedling will brown off.

Figure 6.1 Frost damage on canola

Courtesy of: Saskatchewan Crop Insurance Corporation (SCIC)

- Mustard seedlings are more tolerant to late spring frosts than canola and flax seedlings.
- Fall frost in canola and mustard will freeze the pods and flowers before the leaves. The leaves can tolerate -3 to -4 C while the flowers and developing pods can be affected by -2 to -3 C. Immature seed that contains 50 to 60 per cent moisture can be severely damaged by -3 C, while those that are close to swathing stage (35 per cent moisture) may escape damage. To escape most frost damage, the moisture content should be at least 20 per cent or lower.
    - » Swathing at least 24 hours prior to a frost, and preferably 48 to 72 hours prior, can reduce the green seed count even at early stages such as zero to five per cent colour change.
    - » At 30 to 40 per cent seed colour change, temperatures of -3 C for one hour will have no effect on chlorophyll content. As temperatures reach -7 C, the effect on chlorophyll content will be much greater. Swathing the crop 48 hours prior to -7 C will reduce the chlorophyll content compared to leaving the crop standing.
    - » Once frost occurs, it is important to assess the extent of the damage. Assess the field (damage vs undamaged seed) two to three days after the frost or later. If the majority of the seed is damaged, then swath the crop immediately. If not, then leave to proper swathing stage. If the crop has frozen and the pods begin to turn white, then the crop should be swathed as quickly as possible as the pods will start to shatter.
- Flax is quite sensitive to frost when it is coming out of the ground. Temperatures of -2 C or cooler can injure flax up to the two leaf stage.
- As flax grows, it becomes more tolerant to frost. After the two leaf stage, flax can withstand temperatures down to -7 C and even slightly lower if the plants have been hardened off.
- Frost canker occurs when plants become girdled at or near the soil line and topple over. Damage is most severe in thin stands on light soils and in low spots during early stages of growth.
- Fall frost temperatures of 0 C to -4 C can kill immature seeds in flax depending on the length of the exposure.
    - » After flax seed reaches the dough stage it is more resistant to frost. Frost will cause the bolls to become soft and the developing kernels start to leak moisture. The immature kernels will shrivel up and the bolls turn brown prematurely.
    - » Flax has been known to recover from frost damage.

Figure 6.2 Frost damage on flax

Hail

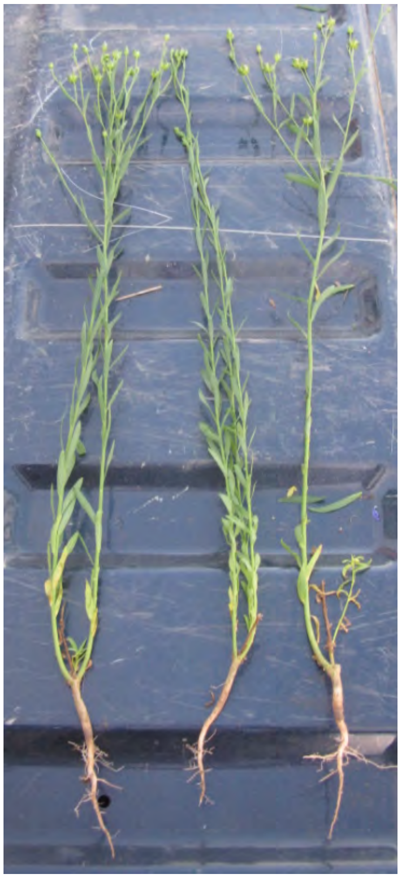
**Information courtesy of Canola Council of Canada's Canola Watch*

- Early season hail rarely has an impact on canola yield potential. Hailed seedlings usually can recover relatively well.
  - » If hail breaks off both cotyledons or snaps the stem, these plants usually do not survive.
- The crop can recover its yield potential as the remaining seedlings take advantage of the reduced competition for light, moisture and nutrients. As a result, plants grow larger, produce more branches, and develop more pods and seeds per pod, compensating for the lost plants.
- Fewer plants can result in delayed and uneven maturity of the crop throughout the field.
  - » This can present challenges for fungicide timing for sclerotinia stem rot and harvest timing, for example.
- Hail that occurs on plants later (four to six leaf stage) has a higher chance of yield loss, given that the plants have less time to recover.
  - » Plants at the six-leaf stage that lose most of the leaf area on the main stem can still live, but these leaves will not regrow.
  - » The plant will be delayed, and more of the yield potential will come more from side branches.
- Crops hailed at the four to six leaf stage or earlier can be more susceptible to blackleg.
  - » If the field was already at high risk for blackleg, hail damage increases that risk.
  - » Hail can cause seeds inside pods to bruise and can increase premature pod shatter.

Figure 6.3 Hail damage on canola

Figure 6.4 Hail damage on canola

Figure 6.5 Hail damage on flax



Courtesy of: Saskatchewan Crop Insurance Corporation

Figure 6.6 Hail damage on flax

Courtesy of: Saskatchewan Crop Insurance Corporation

Figure 6.7 Hail damage on flax

Courtesy of: Saskatchewan Crop Insurance Corporation

Figure 6.8 Hail damage on flax one week after storm

Courtesy of: Saskatchewan Crop Insurance Corporation

Table 6.1 Approximate per cent yield reduction from the indicated per cent total leaf area destroyed at several stages of sunflower plant development

	Percent Leaf Area Destroyed																			
Stage[1]	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
	Approximate per cent yield loss																			
VE to V3 (6-26 days)	0	0	0	1	1	1	2	2	2	3	3	3	4	4	5	7	8	10	12	15
V4 to V5 (27-29 days)	0	0	0	1	2	2	2	2	3	4	4	4	5	5	7	9	12	14	17	21
V6 to V8 (30-34 days)	0	0	0	1	2	2	2	2	3	4	4	5	6	6	8	10	14	16	19	22
V9 to V11 (35-39 days)	0	0	1	2	3	3	4	4	4	5	5	5	5	7	9	11	14	17	21	24
V12 to V(N) (40-43 days)	0	1	2	3	4	4	5	5	5	6	7	7	9	12	15	18	22	26	31	35
R1 (44-51 days)	0	2	3	4	5	6	6	6	7	7	8	9	13	16	20	24	29	34	40	47
R2 (52-58 days)	0	2	3	4	6	8	9	10	11	12	13	14	16	18	23	30	37	45	55	65
R3 (59-67 days)	0	2	5	8	10	15	17	19	21	24	28	32	38	44	51	59	68	78	88	99
R4 (68-75 days)	0	2	4	5	7	10	12	12	15	18	22	27	34	39	45	53	61	72	85	99
R5 (76-84 days)	0	1	2	3	5	7	8	10	13	16	20	25	32	37	43	49	55	67	78	90
R6 (85-92 days)	0	0	1	1	3	3	4	8	11	15	19	24	29	35	41	46	53	63	72	80
R7 (93-102 days)	0	0	1	1	1	3	5	7	8	10	11	13	14	16	17	18	19	20	21	22
R8 (103-110 days)	0	0	1	1	1	2	2	3	4	5	6	7	7	8	9	9	10	10	10	11
R9 (111-maturity)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[1]Number of days after planting for development to a specific stage will vary significantly depending on environmental conditions and the hybrid. Interpolating percent of loss between stages may be necessary.

Courtesy of: North Dakota State University

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Table 6.2 Approximate per cent yield reduction from the indicated per cent stand reduction at several stages of sunflower plant development

	Percent Leaf Area Destroyed																			
Stage[1]	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
	Approximate per cent yield loss																			
VE to V3 (6-26 days)	0	1	2	3	4	8	10	11	12	12	13	14	16	18	24	32	43	58	77	100
V4 to V5 (27-29 days)	0	1	2	3	4	8	10	11	12	12	13	14	16	18	24	32	43	58	77	100
V6 to V8 (30-34 days)	0	1	2	3	4	8	10	11	12	12	13	14	16	18	24	33	43	58	77	100
V9 to V11 (35-39 days)	0	1	2	3	4	8	10	11	12	12	13	14	16	19	25	33	44	59	77	100
V12 to V(N) (40-43 days)	0	1	2	3	4	8	10	12	12	13	14	15	17	21	27	35	46	60	78	100
R1 (44-51 days)	1	2	5	9	12	14	15	16	17	18	19	21	25	29	35	43	53	66	81	100
R2 (52-58 days)	2	3	7	9	13	17	19	21	23	24	26	28	31	35	40	47	57	68	83	100
R3 (59-67 days)	4	7	11	13	15	17	21	24	27	29	31	34	37	41	46	53	61	72	84	100
R4 (68-75 days)	5	10	14	18	20	22	25	27	29	32	35	38	42	47	53	60	68	77	88	100
R5 (76-84 days)	5	10	14	19	20	24	28	31	35	39	42	45	49	54	60	66	73	81	90	100
R6 (85-92 days)	5	10	15	19	22	26	31	34	39	44	48	52	56	62	68	73	79	85	93	100

[1]Number of days after planting for development to a specific stage will vary significantly depending on environmental conditions and hybrid. It may be necessary to interpolate percent of loss between stages.

Courtesy of: North Dakota State University

Table 6.3 Approximate per cent yield reduction from the indicated per cent total leaf area destroyed at several stages of sunflower plant development

	Percent Leaf Area Destroyed																			
Stage[1]	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**100**
	Approximate per cent yield loss																			
VE to V3 (6-26 days)	0	0	0	1	1	1	2	2	2	3	3	3	4	4	5	7	8	10	12	15
V4 to V5 (27-29 days)	0	0	0	1	2	2	2	2	3	4	4	4	5	5	7	9	12	14	17	21
V6 to V8 (30-34 days)	0	0	0	1	2	2	2	2	3	4	4	5	6	6	8	10	14	16	19	22
V9 to V11 (35-39 days)	0	0	1	2	3	3	4	4	4	5	5	5	5	7	9	11	14	17	21	24
V12 to V(N) (40-43 days)	0	1	2	3	4	4	5	5	5	6	7	7	9	12	15	18	22	26	31	35
R1 (44-51 days)	0	2	3	4	5	6	6	6	7	7	8	9	13	16	20	24	29	34	40	47
R2 (52-58 days)	0	2	3	4	6	8	9	10	11	12	13	14	16	18	23	30	37	45	55	65
R3 (59-67 days)	0	2	5	8	10	15	17	19	21	24	28	32	38	44	51	59	68	78	88	99
R4 (68-75 days)	0	2	4	5	7	10	12	12	15	18	22	27	34	39	45	53	61	72	85	99
R5 (76-84 days)	0	1	2	3	5	7	8	10	13	16	20	25	32	37	43	49	55	67	78	90
R6 (85-92 days)	0	0	1	1	3	3	4	8	11	15	19	24	29	35	41	46	53	63	72	80
R7 (93-102 days)	0	0	1	1	1	3	5	7	8	10	11	13	14	16	17	18	19	20	21	22
R8 (103-110 days)	0	0	1	1	1	2	2	3	4	5	6	7	7	8	9	9	10	10	10	11
R9 (111-maturity)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Moisture Stress

Information courtesy of Canola Council of Canada's Canola Watch

- Lack of moisture during reproductive stages in canola can cause a hormone imbalance that disrupts pod formation and seed set.
- During times of low moisture, canola plants will progressively drop flowers at the top of the main raceme and on branches, and put energy into preserving the pods already formed.
- Late season lack of moisture during pod fill, can result in seeds that do form or may germinate in the pod due to the hormone imbalance.
- If moisture returns, plants can start producing flowers again, resulting in a stem with pods at the bottom and top but nothing in the middle.
- Additional symptoms of moisture stress include:
  » Leaf wilting;
  » Flowers with smaller petals that may be off-colour (pale or yellowish-orange); and
  » Flower buds that die before fully opening.

Figure 6.9 Canola floret blasting

Figure 6.10 Moisture stress (heat) damage to canola

Courtesy of: Saskatchewan Crop Insurance Corporation

Figure 6.11 Blasting in canola due to extreme dry conditions

Figure 6.12 Heat stress on canola field

Figure 6.13 Moisture stress (heat) damage to flax

Wind Stress

**Information courtesy of Canola Council of Canada's Canola Encyclopedia and Saskatchewan Pulse Growers- Environmental Damage to Pulses Factsheet*

- Wind can blow canola seed and seedlings out of the ground or create a sandblasting effect causing plants to tip over or break at the point of injury.
  - This is more common under dry conditions and in lighter textured soils.
  - It can also be worse on hilltops and side slopes facing into the wind.

Forage Crops

Frost

- Older alfalfa plants are more susceptible to damage than young stands.
- Symptoms of frost in alfalfa may include:
  - » Wilting within 24 hours at temperatures down to -3 C.
  - » Yellowish or brownish discoloration may appear three-to-four days later.
  - » Top stems bending in the shape of "shepherd's hook"
- Plants will generally recover, but development may be delayed and yield reduced.
- At temperatures lower than -4 C for more than four hours, stems will die and growing points may be damaged.
- Plants will survive in most cases, but the stand can be weakened if it is cut before root reserves have had time to replenish.

Moisture Stress

**Forage information courtesy of the Alberta Forage Manual*

- Most forage crops are tolerant of at least some flooding during spring break-up. Those with low tolerance of excess soil moisture in the root zone are also among the least tolerant of spring flooding.
- Alfalfa:
  - » Excellent tolerance to a lack of moisture. Deep roots make it capable of avoiding the effects of moisture stress for up to a year, and it will survive longer by going dormant.
  - » Poor tolerance to flooding or waterlogging, but will withstand short-term flooding before growth begins in the spring.
- Before planting a forage, consider the site where it will be seeded. Consult a forage manual to ensure the species and variety to be planted will be suitable for the area.

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Cereals

**Corn information in this section courtesy of Manitoba Corn Growers Association- Field Corn Production in Manitoba*

Frost

- The growing point of spring wheat, barley and oats remain below ground until around the five leaf or jointing stage.
- Plants may lose above ground leaf matter but will regrow from below ground.
- Partial injury can be visible when the tips of leaves or leaf edges become damaged and yellow, then turn brown and become brittle.
- Cereals have good frost tolerance and will tolerate temperatures down to -4 C; if hardened, they can withstand -6 C.
- When it comes to fall frost, wheat is typically more tolerant than barley, and barley is more tolerant than oats. Cereal plants exposed at the late dough stage sustain less injury than plants exposed at earlier stages.
  - » Plants in the late boot to flowering stage are most susceptible to frost as this is the stage when reproductive tissue is developing. Barley is more susceptible to frost injury than wheat during the boot stage because it flowers while still in the boot.
  - » In the milk stage, temperatures below 0 C can result in shriveled kernels. After mid-dough stage, temperatures down to -4 C can result in bran frost, kernel shrinkage and possibly a reduction in germination.
  - » Frost damage at the milk and early dough stages first appears as soft, watery kernels that ooze water upon squeezing within a couple of days of the frost.
- Early season frost in corn will often kill leaves, but not the whole plant since the growing point remains below the soil surface until the V6 growth stage. Maturity may be delayed causing an impact on yield.
- Fall frost in corn, before physiological maturity (black layer or R6), can have a negative impact on both grain yield and quality. A killing frost (at least -2 C) any time prior to R6 will kill the entire plant, which will stop kernel development.
- If the frost is not a killing frost, and the leaves/stalks and husks are still green two to five days later, grain filling will continue until maturity (the crop will still need necessary heat units to fully mature following the delay).

**Winter wheat info courtesy of Manitoba Agriculture- Spring Frost Damage Bulletin*

- Winter wheat is at a more advanced stage than other crops in the spring. Although winter wheat survives the cold all winter, once it is green and growing it is susceptible to frost.
  - » Winter wheat is quite tolerant at tillering, tolerating -11 C for up to two hours. Tolerance decreases at stem elongation, handling -4 C for up to two hours.
  - » It is most sensitive at boot stage, tolerating -2 C for up to two hours.

Figure 6.14 Frost damage on rye heads

Figure 6.15 Fall rye with sterile spikelets (white) due to frost

Courtesy of: Saskatchewan Crop Insurance Corporation

Figure 6.16 Cold injury on cereals

Hail

- Hail injury to wheat results from stem breakage.
  - » Greatest yield losses occur when the stems are broken at the milk stage.
  - » Yield losses may not be as great if the injury occurs at the boot stage.
  - » Yield loss at the hard dough stage can be highly variable and may not be as severe as the injury occurring at the milk stage.
- Hail damage in corn is easy to recognize as leaves will be shredded and/or stalks bruised.
  - » Early season hail occurring when the growing point is still below the soil surface will result in very little yield loss.
  - » If hail occurs later, yield loss may be significant.
  - » Delay assessment seven to 10 days following a hail event so that living and dead plant tissue are more easily distinguished.

Figure 6.17 Hail damage to wheat field

Figure 6.18 Hail damage to wheat in boot stage

Figure 6.19 Hail damage to wheat

Figure 6.20 Hail damage in corn

Figure 6.21 Hail damage in corn

Figure 6.22 Hail damage in fall rye field

Courtesy of: Saskatchewan Crop Insurance Corporation

Figure 6.23 Hail damage in fall rye

Courtesy of: Saskatchewan Crop Insurance Corporation

Moisture Stress

Figure 6.24 Moisture stress damage to oats with heat blasting

Courtesy of: Saskatchewan Crop Insurance Corporation

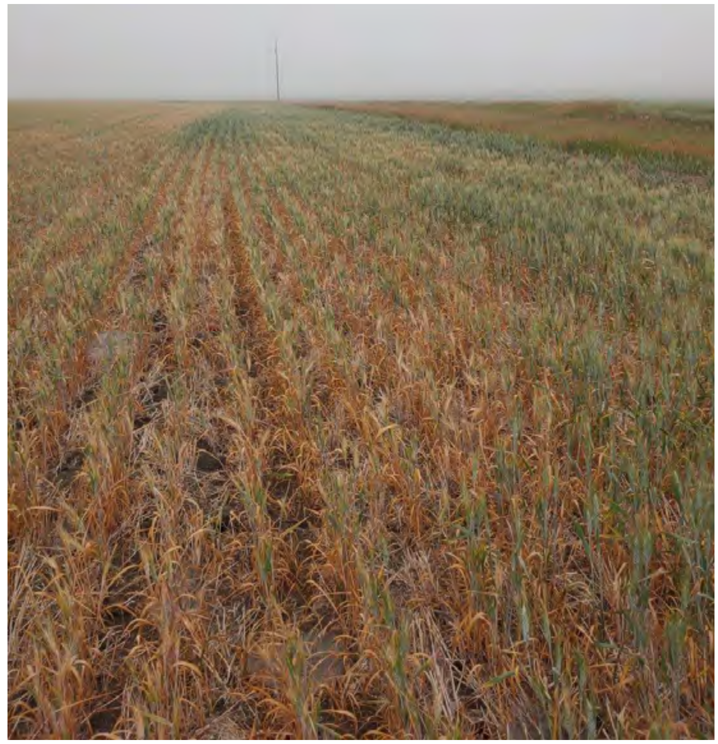
- In corn, dry conditions will cause leaves to roll and turn a dull greyish green. In older plants, nitrogen deficiency symptoms may develop. Severe stunting and irregular brown patches of dead leaf tissue may occur.
- In corn, symptoms caused by a lack of moisture that disappear as the temperature drops are caused by high temperatures. These conditions are most common early in the growing season when root development is inadequate. Permanent bleaching and scalding of leaf tissue is uncommon; however, high temperature and drought during pollination can cause sterility and barren ears.
- Low temperatures (5-10 C) can cause "cold banding" on young corn plants. The most common symptom is the appearance of yellow bands across one or more leaves.
- Waterlogging will cause young plants to turn yellow and eventually die. Older plants can stand water-logged conditions for a longer period, but they will also become yellow, weak, and susceptible to disease after a week.
- High temperatures and moisture stress in oats at the time of panicle differentiation can result in empty seed pods.
  - » Tillers are usually affected more often than the main stems (culms).
- In wheat, as moisture stress develops into the later tillering stage, yield recovery becomes poorer because kernels per spikelet and filling upon recovery are reduced.
  - » Established tillers may be lost if drought stress intensifies as the plant develops further.
- Moisture stress can reduce the size of the spikes that develop.
- Dry soil around the crown reduces the plant's ability to develop adventitious roots which are the primary roots for accessing water and nutrients as the plant develops beyond the seedling stage.

Heat Stress

- High temperatures in wheat reduce grain yield and yield components. Reduced number of kernels per spike can be an indicator of moisture or heat stress.

Figure 6.25 Sun-scalded wheat field

Figure 6.26 Durum field damaged by extreme dry conditions



Courtesy of: Saskatchewan Crop Insurance Corporation

Figure 6.27 Wheat field damaged by extreme dry conditions

Courtesy of: Saskatchewan Crop Insurance Corporation

Wind Stress

- Blowing soil particles can cause damage on leaves and stems of corn and can uproot or break off young plants.
- Dead or damaged tissue will turn brown and dry up. Shredding of young leaves is frequent.
- Strong winds following a period of rapid growth may snap off corn plants at the lower nodes, which is known as "green snap". If the plant is severed, yield will be reduced. Strong winds during grain fill may result in root and stalk lodging.

Pulses

Frost

- Lentils and peas have good frost tolerance as growing points remain below ground during early development.
- The above-ground material may be severely injured by frost, but new growth will resume from the affected nodes within a week to 10 days following a frost.
- Fall frosts of -2 to -3 C will affect flowering pulses, in the podding stage they are a bit more tolerant but will be damaged at -3 to -4 C.
  - » Frost damaged seeds will be water soaked and no longer firm as they start to "leak".
  - » Heavily damaged pods will have a rubbery, wilted appearance.
  - » As pulses mature from the bottom of the plant toward the top, frost injury may be much greater on plant tops. Seeds near the ground may have no frost damage and care should be taken to focus harvest efforts on those seeds.

**Spring frost in soybean information courtesy of Manitoba Agriculture- Spring Frost Damage Bulletin*

- The smaller the soybean plant, the more tolerant they are to frost. Soybean plants that are just cracking through the soil and up to the cotyledon stage can tolerate -2.8 C for a few hours.
- Soybeans exposed to frost at the cotyledon stage may leaf out again. Wait three to five days before going out to look for signs of new growth.
- At the cotyledon stage, soybeans have three potential growing points consisting of the main shoot and two axillary buds that are located at the base of the cotyledons.
- Under normal conditions, the axillary buds never grow, but if the main growing point is killed by frost, the two axillary buds will start to grow within a week of the frost event.
- Under cool, cloudy conditions, you may need to wait up to a week before any sign of recovery occurs. During the summer, one of the axillary branches will become dominant and be the main stem of the soybean plant.

**Fall frost in soybean information courtesy of Manitoba Pulse Growers- Impact of Fall Frost on Soybean Factsheet*

- Fall frosts will impact soybean yield if the soybeans have not reached physiological maturity.
  - » A light frost (0 to -1 C) may kill top leaf growth but should not affect pods and seeds.
  - » Temperatures below -1 C for an extended time period will cause damage to green stems, pods and seeds, reducing yield and quality.
  - » Maximum yield loss would occur if soybeans are in the reproductive stage.

Figure 6.28 Frost on fall soybeans

Figure 6.29 Frost damage on lentils

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Figure 6.30 Frost damaged peas

Figure 6.31 Frost damaged peas

Hail

**Pulse information courtesy of Saskatchewan Pulse Growers- Environmental Damage to Pulses Factsheet*

- Early-season hail damage to peas, lentils, faba beans and chickpeas has an impact similar to frost damage.
  - » The plants will continue to develop from dormant buds within one or two weeks, so reseeding assessment should be delayed to see how the crop recovers.
- Hail damage to the growing point of dry beans in early stages will severely limit recovery.
- Hail damage to the growing point of soybean in early stages will severely limit recovery.
  - » Damage occurring at the vegetative stage can tolerate a fair amount of leaf loss without significant yield loss.

Figure 6.32 Hail damage on pea plant

Courtesy of: Saskatchewan Crop Insurance Corporation

Figure 6.33 Hail damage on pea field

Figure 6.34 Hail damage on pea field

Courtesy of: Saskatchewan Crop Insurance Corporation

Figure 6.35 Hail damage on soybean

Courtesy of: Saskatchewan Crop Insurance Corporation

Figure 6.36 Hail damage on soybean. Newly formed pods since hail (left). Pods formed from flowers not destroyed by same hail incident (middle). Damage to pods at R3 at time of hail (right)

Courtesy of: Saskatchewan Crop Insurance Corporation

Figure 6.37 Hail damage on soybean field one month after hail

Courtesy of: Saskatchewan Crop Insurance Corporation

Moisture Stress

Figure 6.38 Waterlogged peas

- Moisture stress during the vegetative stage of dry beans will result in delayed maturity.
- A decrease in the number of pods/plants and the number of seeds/pod will also occur.
- Indeterminate genotypes with a longer flowering period in dry beans, usually produce more pods under intermittent moisture stress than determinate types with short flowering periods.
- Root growth is also vulnerable to moisture stress. Unlike shoot growth, root growth is less responsive to re-watering after moisture stress.
- Chickpeas are relatively tolerant to moisture stress as its long taproot (often greater than one metre in depth) can access water from a greater depth than other pulse crops.
- Stages that chickpeas are most sensitive to moisture stress include flowering, pod production and seed set.
- Peas and lentils are sensitive to waterlogging or excessive moisture. This results in:
    - » Poor growth, decreased leaf area, faster leaf senescence or necrosis, decreased transpiration and water uptake, and flower drop.
- Excess moisture in peas and lentils may lead to root rot development. See the disease section for more information.

Heat Stress

- Heat stress in soybean can result in a copper discoloration to leaves (Figure 6.38).

Figure 6.39 Heat (sunburn) damage on soybean leaf

Courtesy of Saskatchewan Crop Insurance Corporation

Figure 6.40 Drought damage on soybean

Figure 6.41 Peas damaged by extreme dry conditions

Figure 6.42 Peas damaged by extreme dry conditions

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Section 7: Harvest

Pre-Harvest Information

What are desiccants?

Desiccants are contact herbicides designed to dry down the crop quickly. Desiccants interfere with photosynthesis, causing plant cells to rapidly break down and release their liquid contents so they can dry down more rapidly. Glyphosate is not a desiccant and is intended for weed control prior to harvest only. It is a systemic herbicide which must be absorbed and translocated to growing points to kill plants, and therefore takes longer to dry the crop. True desiccants are contact herbicides and rely heavily on penetration and canopy coverage. So higher water volumes and nozzles that provide good coverage maximize their performance.

When and why to apply desiccants

When applying desiccants, timing is important. Incorrect timing of pre-harvest herbicides can negatively affect crop maturity. Desiccants applied too early can interfere with the process of seed filling, resulting in yield loss. This application should only be applied once the grain moisture is less than 30 per cent in the least ripe part of the field.

Chemical pre-harvest desiccation may reduce the time from maturity to threshing readiness and reduce shatter loss. Desiccation may also result in improved quality if the crop is harvested before being exposed to wet weather, compared to a crop left to mature on its own and being subjected to wet weather. The benefit of chemical desiccation is the opportunity to have the crop harvested sooner, reduced risk of exposure to wet weather, and eliminating the risk of swath movement from wind. Standing desiccated crops will also dry more rapidly after a rain, compared to a crop in swath. Using a desiccant can help minimize late disease development and harvest problems caused by late weed growth, uneven ripening of crops and crop lodging. Individual circumstances will determine if desiccation provides financial and operational benefits.

When timing the application, make sure the crop stage is right, use recommended product rates and surfactants, if required, and respect water volumes. Be ready to combine as soon as the dry down is complete to maximize yield and quality.

Choosing the right product

Select your pre-harvest product based on your intentions for the field. Glyphosate is not a desiccant and is intended for weed control prior to harvest only. Products such as Carfentrazone, diquat, Glufosinate, Heat Brands, and Valtera can act as harvest aids or desiccants to dry down the crop for harvest. If you are intending to use the crop for seed, glyphosate and glufosinate should not be applied pre-harvest. Additionally, buyers will not accept lentils treated with glufosinate this year.

Below is a table out of the Guide to Crop Protection showing what products can be used for desiccation.

Table 7.1 Herbicides for use as harvest aid or desiccant before crop harvest

Herbicide	Alfalfa	Barley	Canola	Chickpea	Dry bean	Faba bean	Forage	Field pea	Flax	Lentil	Oat	Potato	Soybean	Sunflower	Wheat
Beloukha		X									X	X			X
Carfentrazone[3,4]		X		X	X	X		X			X	X	X		X
CleanStart[6]		X		X	X			X			X				X
Diquat[3,5]			X	X	X	X	X	X	X	X		X	X	X	
Glyphosate[1,2,6]		X	X	X	X	X	X	X	X	X	X		X		X
Heat Brands[3,4]		X[8]	X	X	X	X		X		X[7]			X	X	X[8]
Glufosinate 150SN	X									X[6]		X[6]			
Valtera[3]				X	X			X		X					X

[1]Rates of application vary among brands. Consult glyphosate page for specific application rates. [2]For pre-harvest prennial weed control and may provide harvest management benefits. [3]For rapid plant tissue dry down to facilitate harvest. [4]Should be tank mixed with glyphosate when used prior to harvest. Not for crops grown for seed when glyphosate used. [5]Refer to product page for surfactant requirements. [6]Not for crops grown for seed. [7]Red lentil only. [8]Heat LQ only.

Courtesy of: The Guide to Crop Protection

Staging Pre-Harvest Applications of Herbicides

Appropriate application stage is when the crop is at physiological maturity (30 per cent seed moisture or less). Pesticide products can lead to higher residues in the seed and reduced yields when applied too early. Know the proper staging for harvest aid products and ensure the entire area being sprayed is at the recommended stage.

Lentils

The lentil field should have an 80 per cent colour change of tan, brown. Pods on bottom third are brown with hard seeds detached from pod that rattle when shaken. Pods in middle third have seeds that are full size and firm showing 100 per cent colour change from light green to tan-brown. Top third of plant will show 50-75 per cent colour change and may have slight green colour, but seeds are fully formed and firm.

Figure 7.1 Pre-harvest glyphosate application

Grain moisture is 40%. **Wait!** It's too early for pre-harvest glyphosate. All the normal pods on nodes 10–13 of the main branch completely fill the pod cavity and field remains green.

Grain moisture is 30%.* 80% of the plant is yellow to brown. Seeds from the top third of the plant are fully-formed and firm; seeds from the bottom third are hard and tan-brown; pods rattle when shaken.

***All plants in the field must reach this stage before applying pre-harvest glyphosate.**

Grain moisture is 20%. 90% of the pods on the plant are tan-brown.

Courtesy of: Keep It Clean Canada

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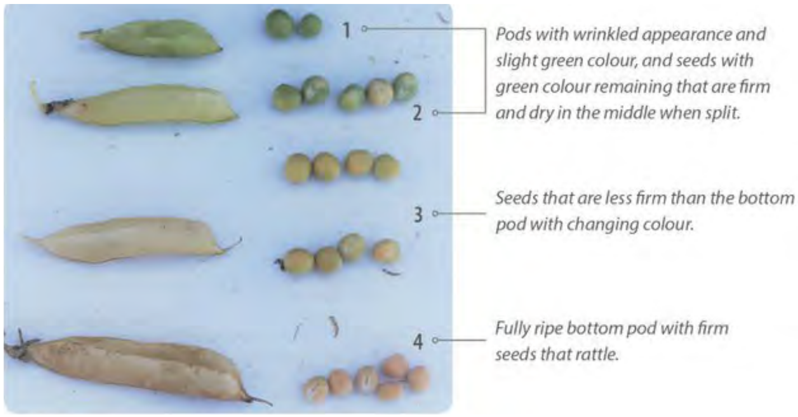
Field Peas

You want to ensure the field has turned to a yellow brown colour and there are minimal green patches. Eighty per cent of plant is yellow to brown in colour. Bottom pods are ripe and dry with seeds detached from the pods making a rattling sound when moved. The middle third of the pea plant the seeds are yellow, full sized, firm, and seeds split when squished. Top pods wrinkled and seed firm. Top of plant may have slight green colour.

Figure 7.2 Field Peas



Courtesy of: Saskatchewan Pulse Growers

Figure 7.3 Pea field

Courtesy of: Saskatchewan Pulse Growers

Figure 7.4 Chickpeas

Courtesy of: Saskatchewan Pulse Growers

Chickpeas

Plants have yellowed, the pods have matured, and seeds have changed colour and detached themselves from the pods (pod rattle stage).

Dry Beans

Crop has lost 80-90 per cent of leaves and 80 per cent of pods are yellow. Seeds have lost their green colour when split.

Figure 7.5 Dry beans

Courtesy of: Saskatchewan Pulse Growers

Faba Beans

Plants are fairly mature with leaves drying down and stems green to brown in colour, pods are filled, and lower 80 per cent of bottom pods are tan or black in colour.

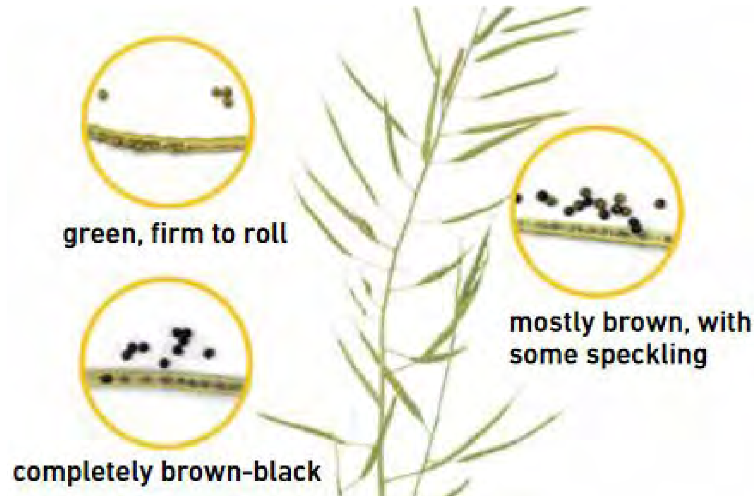
Soybeans

Crop has lost 80-90 per cent of leaves and 80 per cent of pods are yellow.

Canola

Canola must be desiccated at the correct stage to avoid locking in green seed. If fields have variable stages, the stage that will contribute most to total yield should be determined. Canola seeds mature in the bottom pods first, while seeds in the top pods mature last. When using diquat brands, application timing is after 90 per cent of the seed on the entire plant has turned brown. Heat Brands have a labelled application rate of 60-75 per cent brown seed, but recent recommendation is 80 per cent brown seed. Applying desiccants earlier than recommended may result in higher green seed and reduced yields. If harvest is delayed following desiccation of canola, both pod drop and pod shatter may increase. So be prepared to combine as soon as seed moisture has reached suitable levels, which can happen anywhere between four to 14 days post application.

Figure 7.6 Eighty per cent seed colour on a canola plant



Courtesy of: Keep It Clean Canada

To the right is a photo of what 80 per cent seed colour change looks like on a canola plant. The bottom third of the plant is completely black/ brown. The middle third is brown, with some speckling. The top third can be green but must be firm when rolled. When scouting for seed colour change you must step into the field and open pods up. Pods may look green but could have brown-black seeds inside.

Wheat

The easiest way to determine if a wheat crop is ready for a pre-harvest application is the thumbnail test. Put a reasonable amount of pressure from your thumbnail into the kernel and if it leaves a dent without splitting it is ready. This is known as the hard dough stage and must be present throughout multiple areas of the field. After application, harvest is typically seven to 14 days away.

Figure 7.7 Thumbnail test for wheat

Courtesy of: Keep It Clean Canada

What is the Preharvest Interval (PHI)?

Pesticide labels refer to the pre-harvest interval or PHI. This is the minimum number of days that you must let pass from applying a product until the crop is swathed or straight-cut. It may also be referred to as the Spray to Swath Interval. If you disregard the PHI, unacceptable levels of residues can be present on the harvested crop. The PHI applies not only to field crops but forages as well. PHIs have been established for fungicides, insecticides, and herbicides. By following the established PHI, you are protecting the marketability of your crop and in the case of forages, the animals which ingest the crop.

To help time applications, or choose a product that fits a timeline, canola and pulse growers can use the interactive Keep it Clean Spray to Swath Interval Calculator found at ***spraytoswath.ca***.

Maximum Residue Limits (MRLs)

A Maximum Residue Limit (MRL) is the maximum amount of pesticide residue that may remain on food after a pesticide is applied as per label directions and which can safely be consumed.

There are many ways to help ensure that the quality and reputation of Canadian crops helps keep the markets open for all:

1. Only apply pesticides that are registered for use on your crop in Canada and will not create any trade concerns. Always talk to your buyer to ensure the products you are using are acceptable for both domestic and export customers.
2. In addition, always read and follow the label for application rate, timing and pre-harvest intervals (PHI). Always read and follow the label for application rate, timing and PHI. Applying pesticides or desiccants off-label is illegal and may result in unacceptable residues.
3. Manage disease pressures by developing an integrated disease management plan. Diseases such as blackleg and fusarium head blight can create a market risk so make sure to grow disease resistant varieties when available, consider applying an appropriately timed fungicide when disease risk is high, plan rotations to manage disease, plant clean seed and use seed treatments under high-risk conditions, control volunteer plants, weeds and other susceptible disease hosts and use integrated approaches to manage disease.
4. Properly store your crop to maintain quality and keep it free of harmful cross-contaminants such as animal protein like blood meal and bone meal. Use only approved bin treatments and never use malathion to treat bins that will be used to store canola in the current growing season. Make sure to condition crops to moisture and temperature levels safe for long-term storage, in addition to keeping bins cool, clean, dry and well-ventilated. Check bins often to prevent problems later.
5. Deliver what you declare and ensure that you review any updated Declarations of Eligibility before delivering grain. When you sign a mandatory Declaration of Eligibility affidavit at the elevator, you are making a legal assertion that your crop is in the variety and/or class you have designated and that it was not treated with crop input products specified in the declaration. Any incorrect information, intentional or unintentional, can be traced back to the farm and individuals can be held liable for any costs associated with contamination of a bin or shipment. In addition, always make sure to grow only registered varieties.

Adapted from Keep It Clean! Resources to Grow Market-Ready Crops

url: www.keepitclean.ca

Moisture Content

Moisture content is the percentage of water content in the grain. The moisture content of grain at harvest is important for future quality and safe storage. When a grain sample is within acceptable moisture limits it is considered straight grade. As moisture content increases, it is considered as tough, damp, moist, or wet.

The Canadian Grain Commission determines moisture content using a Unified Grain Moisture Algorithm (UGMA) moisture metre. They provide calibrations for a 919/3.5", or equivalent, moisture metre model. Additional information, conversion tables, and calculators can be found on the Canadian Grain Commission's website.

The following table shows the tough and damp moisture content of common crops. Moisture levels below the lowest tough percentage are considered straight grade and within acceptable moisture limits. Grain samples should be free of dockage for an accurate moisture measure.

Table 7.2 Tough and damp moisture content in common crops

	Moisture Ranges	
Grain	**Tough (%)**	**Damp (%)**
Wheat (all classes)	14.6-17.0	> 17.0
Oats	13.6-17.0	> 17.0
Barley, malting (covered and hulless)	13.6-17.0	> 17.0
Barley, food (covered (>52 kg/hl))	13.6-17.0	> 17.0
Barley, food (hulless)	14.1-17.0	> 17.0
Barley, general purpose (covered (>52 kg/hl) and hulless)	14.9-17.0	> 17.0
Rye	14.1-17.0	> 17.0
Triticale	14.1-17.0	> 17.0
Corn	15.6-17.5	17.6-21.0
Canola and Rapeseed	10.1-12.5	> 12.5
Flaxseed	10.1-13.5	> 13.5
Mustard (all classes)	9.6-12.5	> 12.5
Peas (green and yellow)	16.1-18.0	> 18.0
Chickpeas	14.1-16.0	> 16.0
Lentils (red)	13.1-16.0	>16.0
Lentils (green)	14.1-16.0	> 16.0
Faba beans	16.1-18.0	> 18.0
Soybeans	14.1-16.0	16.1-18.0
Sunflower	9.6-13.5	13.6-17.0
Canary seed	13.1-17.0	> 17.0

Adapted from: Canadian Grain Commission-https://grainscanada.gc.ca/en/grain-quality/grain-grading/grading-factors/moisture-content/tough-damp-ranges.html

Table 7.3 Maximum moisture content levels for straight grade seeds*

Grain	Maximum Moisture Content (%)
Barley	14.8
Canary Seed	13.0
Canola/Rapeseed	10.0
Chickpeas	14.0
Corn/maize	15.5
Domestic buckwheat	16.0
Domestic mustard seed	9.5
Faba beans	16.0
Feed Barley	14.8
Flaxseed and solin	10.0
Green Lentils	14.0
Lentils	14.0
Malt Barley	13.5
Mustard	9.5
Oats	13.5
Peas	16.0
Red Lentils	13.0
Rye	14.0
Safflower	9.5
Soybean	14.0
Sunflower	9.5
Triticale	14.0
Wheat	14.5

** Percentage wet weight basis. Courtesy of: Canadian Grain Commission 2005*

Swathing

There are several key points to consider when deciding to swath or straight cut. Swathing may be an option in scenarios where there is uneven maturity in the field due to variable plant emergence, field topography, soil type and soil moisture. It hastens dry-down if there are proper drying conditions in the swath. Producers may not want to risk losses due to shattering while waiting for later maturing areas of the field to dry down. Swathing also helps to reduce shatter losses during harvest, particularly for crops with a higher tendency to shatter, such as six-row barley. It also offers a strategy to deal with lodging and terminates under-story growth such as late flushes of tillers, volunteers, and weeds. Weather conditions also need to be considered if swathing is the best harvest method. If swaths are exposed to heavy rain or dew, this can affect grain quality due to sprouting, staining, and disease build-up compared to a standing crop. High winds can also cause losses.

All considerations should be weighed, and fields should be assessed just before the optimal swath timing for the given crop.

Table 7.4 Optimal swath timing

Crop	Stage
Wheat	Kernel moisture content is 35% or less
Barley (Malting)	Kernel moisture content is below 30%
Canola	An average of 60% seed colour change on the main stem
Flax	75% of bolls or capsules have turned brown
Lentils	The bottom third of the pods turn yellow to brown and rattle when shaken
Peas	The bottom 30% of pods are ripe, the middle 40% of pods and vines are yellow-coloured, and the upper 30% of pods are turning yellow
Chickpeas	Can be swathed as early as 30% seed moisture, but is usually left until the majority of pods are straw yellow

Adapted from: Canola Council of Canada-https://www.canolacouncil.org/download/157/canola-encyclopedia/4900/canola_swathing_guide

Drying Down Tough Grain for Future Use

If you are planning on drying grain during the fall or winter that you intend to use for seed next spring, it is crucial that the grain temperature is kept at or below the maximum safe temperature as shown in Table 7.4. Grain that reaches temperatures above this can have detrimental effects on the germination of the seed and overall viability. If temperatures have exceeded the safe temperature or heating has occurred in the bin, then it is important to determine what per cent is damaged and alter the seeding rate accordingly to accommodate for these damaged seeds. This can be done by testing seed for germination and vigour rates. If the damage is too high, other seed source options should be considered.

Table 7.5 Maximum safe drying temperatures (C) for grain to be used as seed

Crop	Temperature
Wheat	60
Oats	50
Barley	45
Rye	45
Corn	45
Flax	45
Rapeseed	45
Peas	45
Mustard	45
Sunflowers	45
Buckwheat	45

Friesen, O.H., 1980 Heated-Air Grain Dryers. Agriculture and Agri-Food Canada. Pub. 1700.

More information on the safe temperatures and moisture contents of grains can be found on the Canadian Grain Commission website. If your grain is at risk of spoilage, then conditioning using a grain dryer can be important to helping reduce the risk of spoilage. It is important to keep drying temperature in mind if planning on using harvested grain as seed the following year.

Preventing Spoilage

Temperature and moisture content of the grain have a large impact on the ability to store grain long-term over the winter months following harvest. Grain that is taken off with a higher moisture content or considered tough has a risk of spoilage during storage. There is also potential for hot spots to develop in storage bins from things such as moulds, fungi, insects, plant material, and oxidation. These hot spots can cause areas of heated seeds that will lower the germination as well. Different temperature and moisture conditions will enhance insect infestations, a drop in germination and/or fungal heating.

How to use the charts:

- Measure the moisture content and temperature of your crop as it goes into storage.
- Plot this initial moisture content and initial temperature on the chart. If the result falls in the no spoilage zone, then your crop should store safely for up to five months, six months in the case of wheat. If it falls in the spoilage zone, spoilage will occur.
- Cool or dry the crop in storage until the temperature or moisture content puts it in the no spoilage zone.
- The center zone cuts off a one per cent safety margin although spoilage may occur under these conditions.
- Be aware that the moisture content and temperature of a bulk may change during storage due to convection currents, leading to localized spoilage. Monitor the top-center of the bulk crop regularly throughout storage or use aeration.

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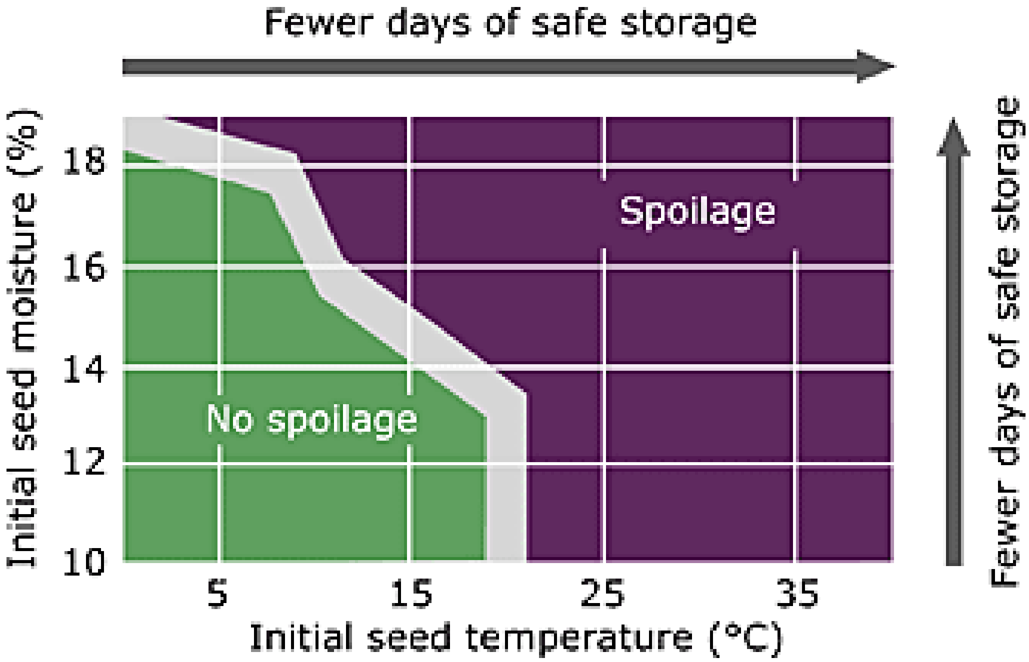
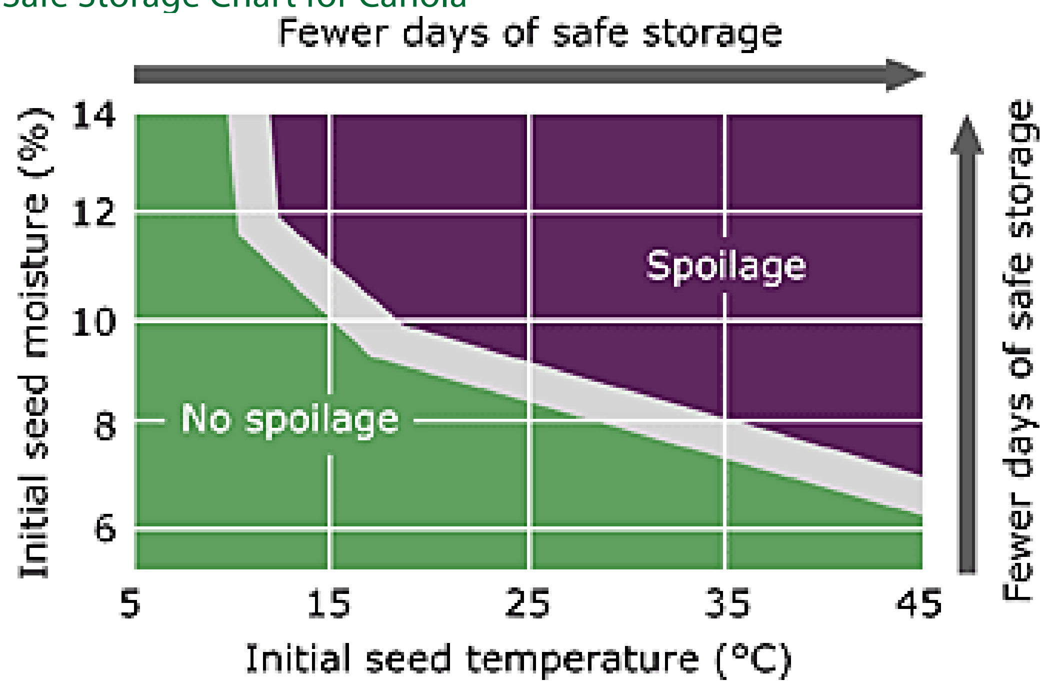
Safe Storage Chart for Barley



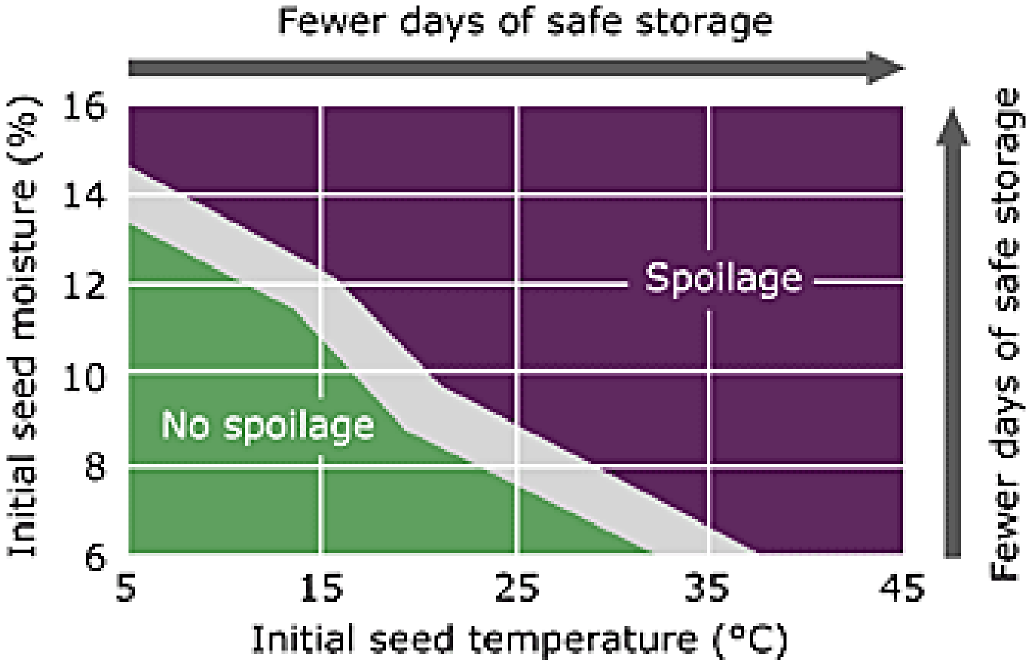
Barley: spoilage occurs when initial temperature ranges from 5 C to 20 C with respective moisture from 18 per cent to 10 per cent moisture content.

Safe Storage Chart for Canola



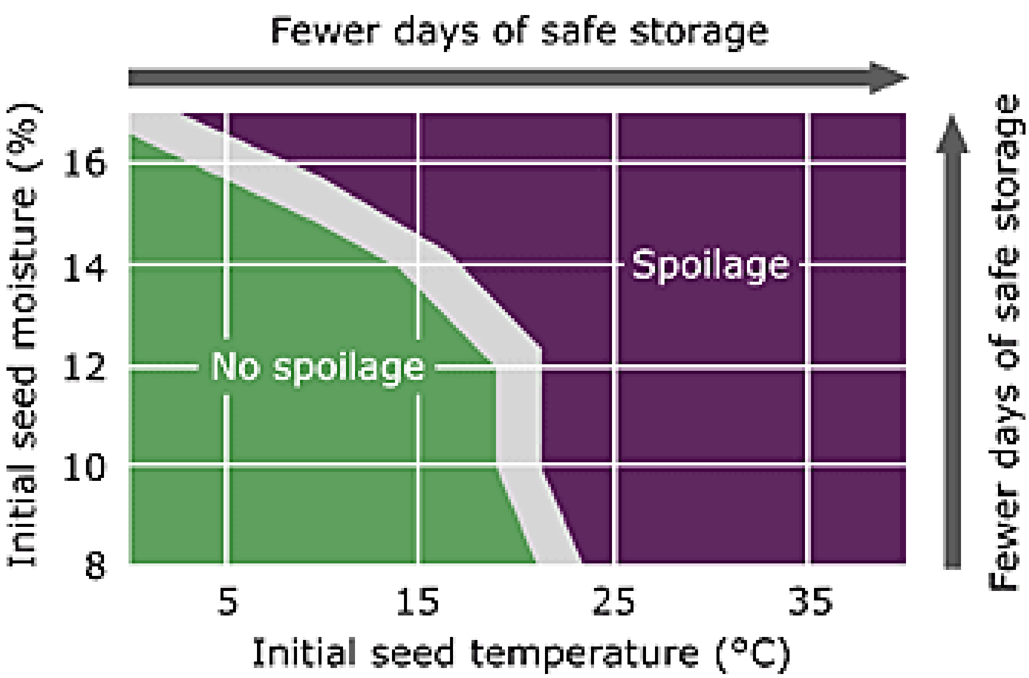
Canola: spoilage occurs when initial temperature ranges from 10 C to 50 C with respective moisture from 12 per cent to seven per cent moisture content.

Safe Storage Chart for Flax



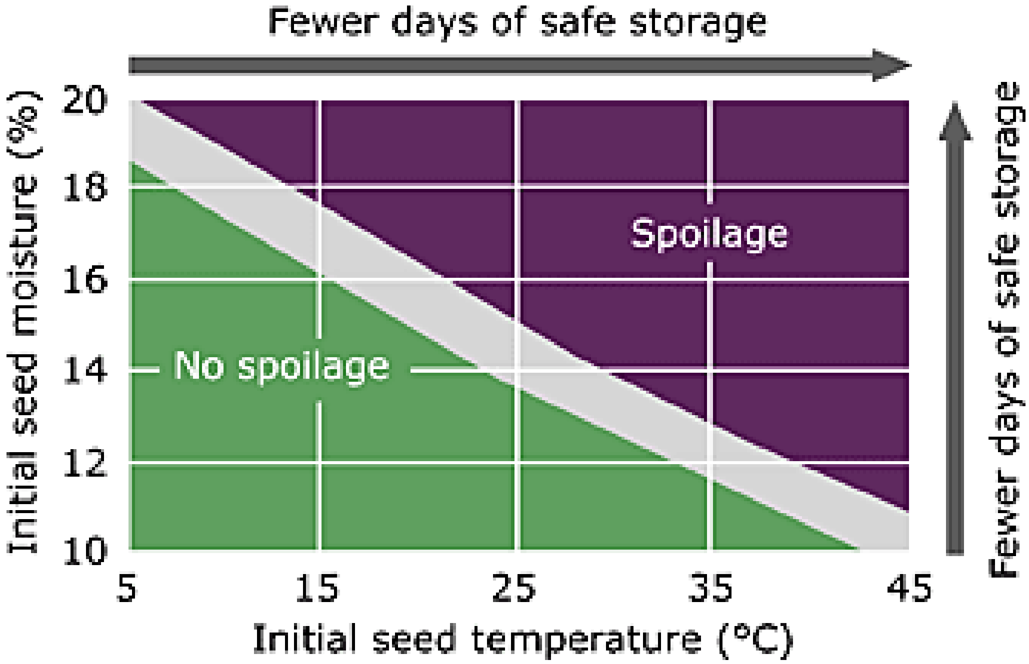
Flax: spoilage occurs when initial temperature ranges from 5 C to 32 C with respective moisture from 13 per cent to six per cent moisture content.

Safe Storage Chart for Oats



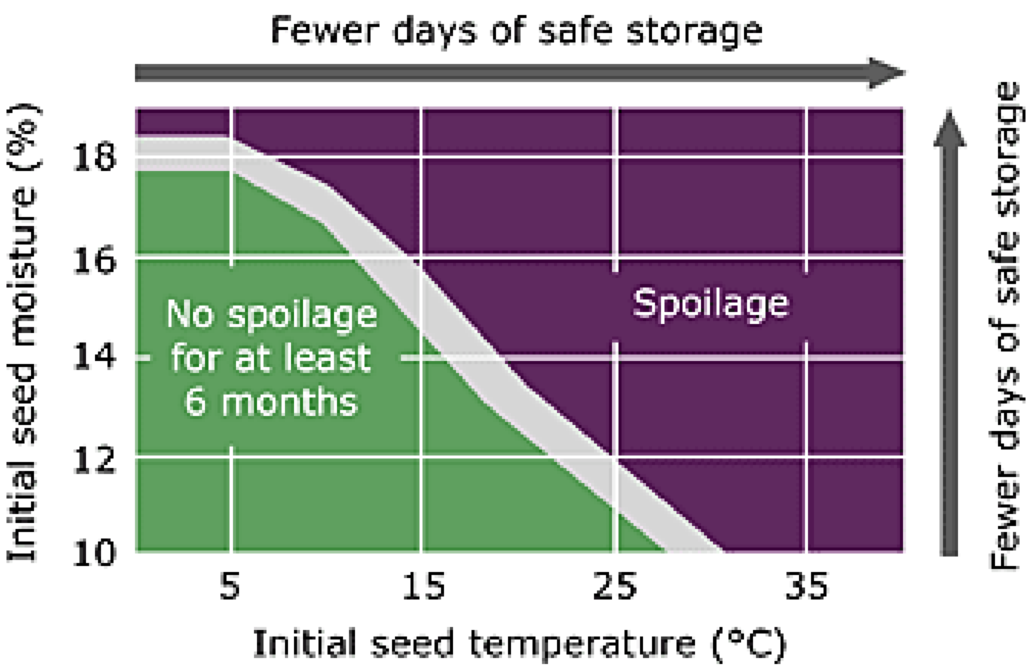
Oats: spoilage occurs when initial temperature ranges from 0 C to 21 C with respective moisture from 17 per cent to eight per cent moisture content.

Safe Storage Chart for Peas



Peas: spoilage occurs when initial temperature ranges from 5 C to 42 C with respective moisture from 19 per cent to 10 per cent moisture content.

Safe Storage Chart for Wheat



Wheat: spoilage occurs when initial temperature ranges from 0 C to 28 C with respective moisture from 18 per cent to 10 per cent moisture content.

Charts reproduced courtesy of: Dr. Noel White, Agriculture and Agri-Food Canada, Cereal Research Centre

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List of Additional Resources

Scan the QR Codes below to download Ministry of Agriculture publications

Guide to Crop Protection **Crop Planning Guide** **Soil Fertility and Crop Rotation Planning Guide**

Additional Agronomic Tools and Publications

Canola Encyclopedia: www.canolacouncil.org/canola-encyclopedia/

Cutworm Pests of Crops on the Canadian Prairies: https://prairiepest.ca/wp-content/uploads/2019/05/Cutworm-booklet-Final-EN-May1-2017.pdf

Digging into Canadian Soils An Introduction to Soil Science: https://openpress.usask.ca/soilscience/

Diseases of Field Crops in Canada: http://phytopath.ca/publications/5479-2/

Durum Production Manual: https://saskwheat.ca/durum-production-manual

Feekes Growth Scale: www.soilcropandmore.info/crops/Wheat/production/whtmang.htm

Field Scouting Guide-Manitoba Agriculture: https://www.gov.mb.ca/agriculture/crops/guides-and-publications/#fsg

Growing Flax-Flax Council of Canada: www.flaxcouncil.ca/growing-flax/introduction

Insect Pest of the Prairies: Available through numerous book sellers

Manage Resistance Now: www.manageresistancenow.ca

Mustard Production Manual: https://saskmustard.com/production-manual/index.html

Prairie Pest Monitoring Network Blog: http://prairiepestmonitoring.blogspot.com/

Pulse Crop Production-Sask Pulse Growers: https://saskpulse.com/growing-pulses/

Saskatchewan Sunflower Committee: http://sksunflowers.com/

Soil Orders in Saskatchewan: soilsofsask.ca

Sprayer Application Technology: http://sprayers101.com/

Weeds of the Prairies-Alberta Agriculture and Rural Development: alberta.ca/agriculture-and-irrigation.aspx

Weeds of the West: Available through numerous book sellers

Winter Cereal Survival Model Research Tool: https://norstar.usask.ca/survivalmodel/

Wireworm Guide-Agriculture and Agri-Food Canada: https://publications.gc.ca/collections/collection_2021/aac-aafc/A42-125-2021-eng.pdf

Zadoks Scale for Crop Staging: www.fao.org/docrep/006/x8234e/x8234e05.htm

Conversion Tables

Table 1: Units of area

Square Feet	Acres
1	0.0000229568
43,560	1
10.764	0.0002471
107,639	2.4710
Square miles	**Hectares**
0.0015625	0.404686
1	258.999
0.00386102	1

Table 2: Domestic and metric weights and measures commonly used for agricultural commodities

Metric Unit	Metric to Imperial	Imperial Unit	Imperial to Metric	Metric Unit
Linear centimetre (cm)	 x 0.39	Linear inch	 x 2.54	Linear centimetre (cm)
Area square metre (m^2) hectare (ha)	 x 1.2 x 2.5	Area square yard acres	 x 0.84 x 0.4	Area square metre (m^2) hectare (ha)
Volume litre (L)	 x 0.22	Volume gallon	 x 4.55	Volume litre (L)
Pressure kilopascals (kPa)	 x 0.14	Pressure psi	 x 6.9	Pressure kilopascals (kPa)
Weight gram(g) kilogram (kg)	 x 0.04 x 2.2	Weight ounce (oz) pound (lb)	 x 28.35 x 0.454	Weight gram(g) kilogram (kg)
Agricultural litres per hectare (L/ha) litres per hectare (L/ha) litres per hectare (L/ha) mililitres per hectare (mL/ha) kilograms per hectare (kg/ha) grams per hectare (g/ha)	 x 0.089 x 0.357 x 0.71 x 0.014 x 0.89 x 0.014	Agricultural gallons/acre quarts/acre pints/acre fluid ounces (fl. oz)/acre pounds (lb)/acre ounces (oz)/acre	 x 11.23 x 2.81 x 1.41 x 70.22 x 1.12 x 70	Agricultural litres per hectare (L/ha) litres per hectare (L/ha) litres per hectare (L/ha) mililitres per hectare (mL/ha) kilograms per hectare (kg/ha) grams per hectare (g/ha)

*Example-To convert centimetres to inches, multiply by 0.39; conversely, to convert inches to centimetres, multiply by 2.54. Caution-Herbicide labels are in metric units only. Conversion between the Metric and Imperial system may result in confusion. It is recommended to use metric units only.

Table 4: Metric units for farm sprayers tank capacity

Imperial gallons	Litres (L)	US gallons	Litres (L)
100	454.6	100	378.54
250	1,136.5	250	946.35
500	2,273	500	1,892.7
800	3,637	800	3,028
1,000	4,546	1,000	3,785.4
1,200	5,455	1,200	4,542

Table 3: For 60 pound bushel weight grains (i.e. wheat, dry peas, lentils, dry beans)

Unit	Equivalent weight	Weight	Equivalent unit
1 bushel	0.026786 long tonne	1 long tonne	37.33 bushels
1 bushel	0.027216 metric tonne	1 metric tonne	36.74 bushels
1 bushel	27.216 kilogram	1 kilogram	0.03674 bushel

Table 5: Crop Bushel Weights and Bushel Equivalents Per Tonne

Crop	lbs/Bushel	Bushels/tonne
Wheat	60	36.744
Oats	34	64.842
Barley	48	45.930
Rye	56	39.368
Flaxseed	56	39.368
Canola/Rapeseed	50	44.092
Corn	56	39.368
Soybeans	60	36.744
Peas	60	36.744
Lentils	60	36.744
Chick Peas	60	36.744
Sorghum	56	39.368
Buckwheat	48	45.930
Mustard	50	44.092
Sunflower	30	73.478
Canary Seed	50	44.092
Faba Beans	60	36.744
Triticale	52	42.396

Courtesy of Canadian Grain Commission

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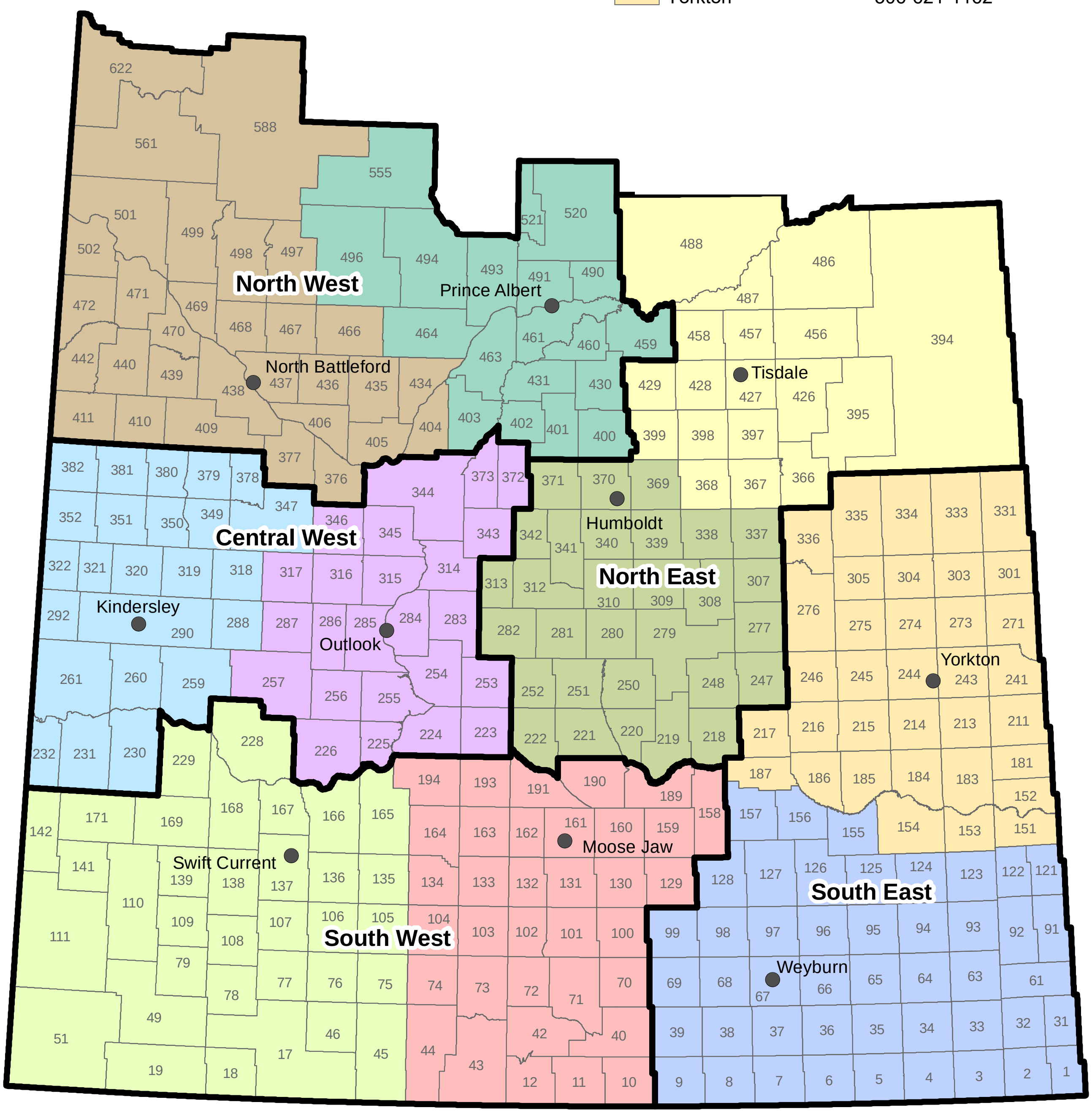
Saskatchewan Ministry of Agriculture's crops extension specialist team works each year to write, edit and update the Crop Diagnostic School Handbook. We have a team spread across 10 regional offices in the province. You can reach out to your local crops extension specialist for unbiased agronomic information on crop management and for the latest updates on extension meetings in your area.

Crops Extension Specialists (CES) Area Boundaries

Humboldt	306-682-6707
Kindersley	1-866-457-2377
North Battleford	306-446-7475
Moose Jaw	306-694-3714
Outlook	306-867-7322
Prince Albert	306-960-2051
Swift Current	306-778-8291
Tisdale	306-878-8807
Weyburn	306-848-2856
Yorkton	306-621-1162



Pest Surveys

To understand the risks and potential damage associated with these pests, the Ministry of Agriculture and its partners monitor the presence, abundance and impact of important crop pests in Saskatchewan. We use this information to build forecast maps, make recommendations for control and for research purposes. This information is freely available and can be used by growers to make informed seed purchase and pest management decisions. The Ministry of Agriculture is adopting a permission-based survey system. This means that we need the help of growers by granting us permission to access land to complete this important work. Find out more on pest surveys and how to sign up by scanning the QR code or by visiting *saskatchewan.ca/agriculture*.

Crop Protection Lab

The Crop Protection Lab provides diagnostic services to help growers identify and deal with pests that affect production. We offer diagnostic services in the areas of: plant health, insects, weed control and herbicide resistance screening. The lab is open year-round to diagnose problems and recommend solutions using up-to-date technology and expertise. The accuracy of our laboratory's diagnosis of your sample is dependent on the quality of the sample submitted and the inclusion of relevant information. Below are some tips on how to collect, package and submit specimens:

- Never add water to the samples or the packaging as this will result in rotting or saprophytic growth. (The only exception is for disease samples where viral causal agents are suspected. For specimens of this nature the sample needs to be maintained in as fresh a state as possible. For above-ground parts showing symptoms, wrap individual parts between lightly moistened paper towels and ship to the lab as quickly as possible.)
- If possible avoid sending in fresh specimens over the weekend to prevent decay in shipping.
- A sample cannot be too large but it can be too small. See forms for sample size information. The information about the sample may be as significant as the sample itself so provide as much information as possible.
- Remember to complete and include the correct sample form available on this website. Samples cannot be tested without a completed form. Both form and sample should be submitted together.

Find out more about the Crop Protection Lab by scanning the QR code or by visiting *saskatchewan.ca/agriculture*.

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For More Information

Contact your nearest Saskatchewan Agriculture regional office:

Kindersley 306-463-5513	Outlook 306-867-5500	Swift Current 306-778-8285	Humboldt 306-682-6701
Moose Jaw 1-866-457-2377	Prince Albert 306-953-2363	Tisdale 306-878-8842	Weyburn 306-848-2857
North Battleford 306-446-7962			Yorkton 306-786-1531

Agriculture Knowledge Centre (Toll Free): 1-866-457-2377

Farm Stress Line: 1-800-667-4442

saskatchewan.ca/agriculture

Saskatchewan