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# SOYBEAN PRODUCTION GUIDE

## Steps to a successful soybean crop.
## Get ready to grow.

This agronomy guide provides growers and agronomists with the knowledge required to grow soybeans in Western Canada. From pre-seed decisions to harvest management, this comprehensive manual covers all the specifics. Prepare to gain a better understanding of the key growth stages and discover the recommended practices for a successful crop. You will also learn about effective integrated management strategies for weeds, disease and insects. Finally, with tips for the most efficient harvest, your soybeans will be on the path to a successful season.

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# Chapter 1 – Introduction to soybean.

## History of soybean production.

*Glycine max*, commonly known as the soybean in North America, was originally domesticated in Northern China in approximately 1100 B.C., and subsequently spread to other nearby Asian countries.[1] Because soybeans are high in both protein and oil, they became a nutritious staple in many Asian diets. Soybeans initially gained attention from the Western World through the trading of soy sauce, which became a desired food item. Soybeans appear to have first arrived in North America in 1765 when they were planted in Georgia, U.S. Over the next 155 years, they were grown almost exclusively as a forage crop.[2]

Soybeans first arrived in Canada in the mid 1800s. Several years later, the Ontario Agricultural College began to evaluate varieties through growth trials, first recorded in 1893.[2] Until the mid 1970s, Canadian soybeans were grown only in Southern Ontario due to its preferable climate. Advanced plant-breeding efforts, leading to the development of early maturing varieties, allowed for the expansion of geographic boundaries where soybeans could prosper. As a result, they have now become an important crop in Quebec, Manitoba, Southeast Saskatchewan, Southern Alberta as well as parts of the Maritimes.[3] Today, soybeans are the third largest Canadian field crop in terms of farm cash receipts and fourth in terms of acreage.[3]

Soybeans were first introduced into Manitoba in the 1990s, reaching recordable acres in 2001. In Saskatchewan, soybeans were found in pockets in the early 2000s and became recordable in 2013. The industry estimates that approximately 10,000 to 12,000 acres of soybeans are grown in Alberta each year; however, Statistics Canada does not yet record them.[4] Since the introduction of soybeans into Western Canada, their acres have increased rapidly, with record acreage seeded each year.

Soybeans were one of the first bioengineered crops to achieve commercial success due, in large part, to the decreased cost associated with growing herbicide-tolerant varieties. In 1996, glyphosate-resistant soybeans were introduced to the international market, overhauling farm-level weed management.[5]

Despite the popularity of bioengineered crops among farmers, global public opinion has led to challenges pertaining to end-use options, marketing and international trade.[6] Still, most soybeans grown in Canada today are herbicide-tolerant. There is, however, a subset of acres of conventional and identity preserved (IP) soybeans that are not bioengineered. These beans are grown to exact customer specifications and are more carefully monitored from seed to export.[3]

**Current global production.**

Soybeans are an important crop in many parts of the world. According to the Food and Agriculture Organization of the United Nations (FAO), soybeans accounted for 35% of the global harvested area of annual and perennial oil crops in 2004. The top four soybean-producing countries (the U.S., Brazil, Argentina and China) account for approximately 90% of global production. Canada is ranked as the seventh largest soybean-producing country, with 1.3% of global production.

| Country | Soybean Production (metric tons) |
|---|---|
| 1. United States | 115,802,000 |
| 2. Brazil | 107,000,000 |
| 3. Argentina | 57,000,000 |
| 4. China | 13,800,000 |
| 5. India | 11,500,000 |
| 6. Paraguay | 9,400,000 |
| 7. Canada | 8,400,000 |
| 8. Ukraine | 4,600,000 |
| 9. Russia | 3,300,000 |
| 10a. Uruguay | 3,000,000 |
| 10b. Bolivia | |

**Table 1.1.** Top 10 countries by soybean production.
Source: FAOSTAT, 2016.

Since the leading soybean producer is geographically close by, Canadian soybean farmers and agronomists have the advantage of being able to learn from the U.S. farming practices and their soybean value chain. Soybeans are the dominant oilseed crop in the U.S., accounting for 90% of oilseed production. Large-scale production did not begin until the 1900s; however, the country has experienced rapid expansion. Today, soybeans are the second most popular planted field crop in the U.S., following corn.[6] Figure 1.1 illustrates the location of soybeans grown across the U.S.

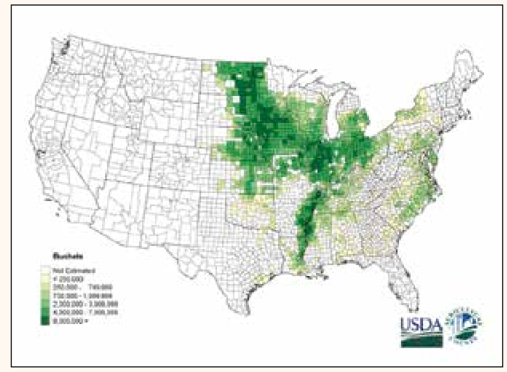


**Figure 1.1.** Soybean production in the U.S.
Source: United States Department of Agriculture (USDA), 2016.

Canadian environmental conditions are favourable for agriculture because of the climate, productive farmland and access to water. Canadian farmers are also known to adopt and invest in advanced equipment and technology.[3] Soybeans certainly created an economic opportunity for Canadian farmers.[7] Seed varieties, fertilizer and pesticide applications, and management practices continued to improve over time, leading to rising yields and rapidly expanding acres.[6] Table 1.2 shows the consistently high soybean yields since 2007. In 2016, the average Canadian soybean yield was 44.6 bushels/acre.[3]

| Crop Year Ending* | Kg/Hectare | Kg/Acre | Bu/Acre |
|---|---|---|---|
| 2017 | 2,600 | 1,052 | 39 |
| 2016 | 3,000 | 1,214 | 45 |
| 2015 | 2,900 | 1,174 | 43 |
| 2014 | 2,700 | 1,093 | 40 |
| 2013 | 2,900 | 1,174 | 43 |
| 2012 | 3,000 | 1,214 | 45 |
| 2011 | 2,900 | 1,174 | 43 |
| 2010 | 3,000 | 1,214 | 45 |
| 2009 | 2,500 | 1,012 | 37 |
| 2008 | 2,800 | 1,133 | 42 |
| 2007 | 2,300 | 931 | 34 |

**Table 1.2.** Average Canadian soybean yields from 2007-2017.
Source: Soy Canada.
*Crop year for soybeans is September to August.

In 2017, total Canadian seeded acres rose to a record high of 7.3 million acres, up 33.2% from 2016.[8] Early maturing varieties specifically allowed for significant Canadian growth. Recall that, until the 1970s, Canadian soybeans were only grown in Southern Ontario due to environmental restrictions.[3] Today, most Canadian soybeans are still grown in Ontario[4]; however, they have become an important crop in Western Canada. Manitoba and Saskatchewan growing conditions are well suited for early-maturing soybean varieties, and farmers have also taken advantage of large crushing and processing facilities south of the border. Overall, the four largest soybean-producing provinces (Ontario, Manitoba, Quebec and Saskatchewan) account for 99% of all seeded acres.[8]

**Demand and market use.**

Approximately two thirds of Canadian soybeans are exported, mainly to the following five countries: China (36.9%), the U.S. (11%), Japan (7%), the Netherlands (6.7%) and Italy (4.1%). Despite significant export, Canada also imports lower value soybeans from the U.S. to be domestically crushed or fed to livestock. Different varieties of soybeans serve different purposes including as human foods, animal rations and several industrial uses (Figure 1.2).[2] Although a small global player, Canada is known for a specialized segment of high quality food-grade beans with specialized traits important for food items like edamame, tofu and miso that captures a premium in domestic and foreign markets.[2] Canadian food-grade soybeans must meet very strict quality standards for cleanliness, size, colour and weight. Food-grade soybeans are primarily grown in Ontario and Quebec due to the optimum growing conditions surrounding the Great Lakes.[3] Canada's domestic industry continues to serve this premium market, while rapidly increasing commodity soybean production for soy protein, vegetable oil, animal feed and industrial products.[9] Between 2008 and 2014 alone, Canadian acreage devoted to commodity soybeans increased by 80%.[3]

| Crop Year Ending* | CANADA TOTAL | Ontario | Quebec | Maritimes | Manitoba | Saskatchewan |
|---|---|---|---|---|---|---|
| 2017 | 7,716,600 | 3,796,600 | 1,115,000 | 80,700 | 2,245,300 | 479,000 |
| 2016 | 6,462,700 | 3,374,700 | 1,040,000 | 76,500 | 1,769,000 | 202,500 |
| 2015 | 6,235,000 | 3,592,500 | 1,000,000 | 72,200 | 1,390,700 | 179,600 |
| 2014 | 6,048,600 | 3,791,100 | 898,000 | 88,500 | 1,107,700 | 163,300 |
| 2013 | 5,358,900 | 3,238,600 | 847,000 | 86,700 | 1,068,200 | 118,400 |
| 2012 | 5,086,400 | 3,401,900 | 843,000 | 71,300 | 770,200 | — |
| 2011 | 4,466,500 | 3,189,700 | 800,000 | 63,100 | 413,700 | — |
| 2010 | 4,444,600 | 3,129,800 | 823,000 | 56,400 | 435,400 | — |
| 2009 | 3,581,600 | 2,694,300 | 530,000 | 36,200 | 321,100 | |
| 2008 | 3,335,900 | 2,476,600 | 600,000 | 17,100 | 242,200 | |
| 2007 | 2,686,200 | 2,000,300 | 472,000 | 11,100 | 202,800 | |
| 2006 | 3,465,500 | 2,667,100 | 535,000 | 11,100 | 252,300 | |
| 2005 | 3,155,600 | 2,585,500 | 505,000 | 9,300 | 55,800 | |
| 2004 | 3,043,900 | 2,476,600 | 520,000 | 6,500 | 40,800 | |
| 2003 | 2,273,300 | 1,728,200 | 390,000 | 5,400 | 149,700 | |
| 2002 | 2,335,700 | 1,905,100 | 315,000 | 6,700 | 108,900 | |
| 2001 | 1,635,200 | 1,279,100 | 315,000 | 4,400 | 36,700 | |

**Table 1.3.** Canadian soybean production (metric tons) by region, from 2001-2017. *Crop year for soybeans is September to August.
Source: Soy Canada.

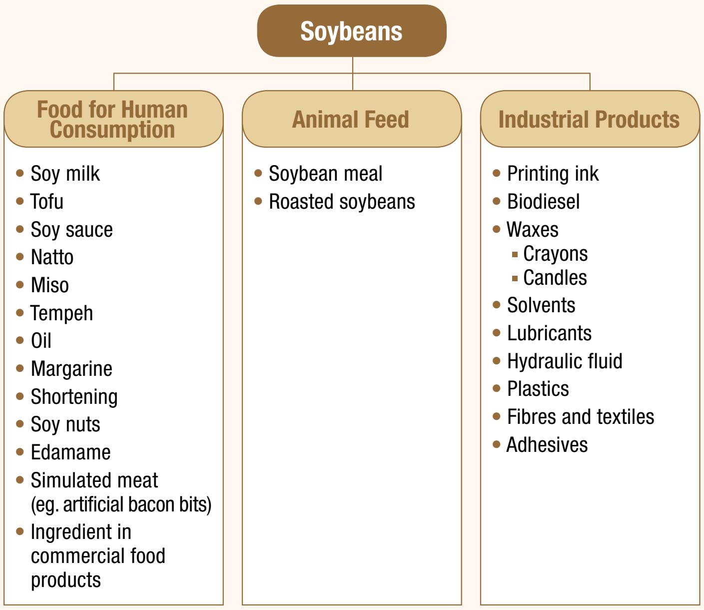



**Figure 1.2.** Soybean uses.
Source: Statistics Canada, Census of Agriculture, 2017.

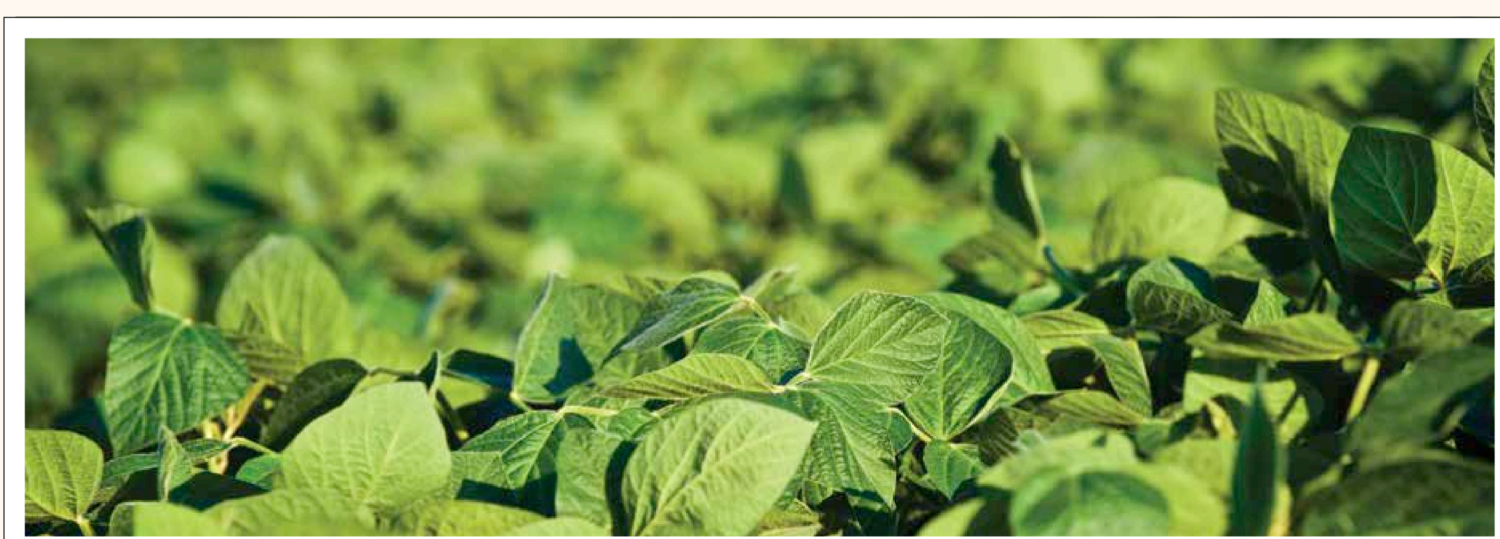
| | |
|---|---|
| **Whole Soybean** | Food – soy beverage, tofu, miso |
| | Industrial – seed |
| **Oil Component** | Food – margarine, shortening, cooking/salad oil |
| | Industrial – biodiesel, paints, resins and plastics |
| **Protein Component** | Food – flour, protein isolate, protein concentrate |
| | Feed – livestock and poultry, pets |
| | Industrial – personal care products, resins and coatings |

**Table 1.4.** End uses of the various parts of the soybean.
Source: Soy Canada.

Soybeans are often processed prior to use. Processing plants separate the oil and meal components for various respective uses (Table 1.4). In Canada, soybean processing plants are located primarily in Ontario and Quebec, so Western Canadian soybeans are often exported south for processing in the U.S.

Aside from water, soybeans are composed primarily of protein (32% to 56% by dry weight) and fats/oil (18% by dry weight). They are also a good source of several vitamins and minerals including: molybdenum, vitamin K1, folate, copper, manganese, phosphorous and thiamin. They also contain antioxidants and phytonutrients. Health benefits associated with the consumption of soybeans include: prevention of some types of breast cancer, alleviation of menopausal symptoms and a decreased risk of osteoporosis.[10]

Based on the nutritional information above, it should come as no surprise that soybeans are often used in livestock feed rations. In fact, soybean meal is the most popular protein additive in livestock feeds. Soybean meal has the highest protein content and digestibility among all plant-based protein sources, which results in it being relatively expensive. So much so that livestock farmers across the Canadian Prairies often choose canola meal, field peas and dried distiller's grains with solubles (DDGS) for their animal rations.[4] Unlike some less expensive protein feed additives, soybeans must be roasted or processed prior to use.[2]



**Future expectations.**

Soybeans are not only an important crop for human consumption, animal feed and industrial products, they are also important for crop rotation and sustainable agriculture in Western Canada. Their ability to produce their own nitrogen within a growing season, as well as some residual nitrogen for subsequent crops, may lead to a reduced carbon footprint especially when soybeans are followed by crops like canola or wheat. Canadian farmers can take advantage of the growing global demand for soybeans all the while improving soil fertility for subsequent crops.

Like other crops, future demand and subsequent development is dependent on advancing genetics, environmental conditions, global markets and resulting on-farm margins.[7] At present time, soybeans are an attractive crop for Canadian farmers because input costs are relatively low and no large equipment investments are necessary to incorporate soybeans into rotation.[11,12] Increased yields are caused by improved varieties, plant protection products and cultural practices, all of which also encourage growth in soybean acres.[6] Rapid adoption of soybeans in Manitoba and Saskatchewan demonstrates that soybeans can even thrive in dry land crop rotations. Future research and development may encourage further spread and allow Alberta to become a more suitable location for substantial acreage.[4]

In Canada, millions of dollars are spent each year to research soybeans. Public funding programs exist at both the federal and provincial levels, and both groups work to support industry associations like Manitoba Pulse and Soybean Growers, Saskatchewan Pulse Growers and Western Grain Research Foundation. Conversely, the private sector spent an estimated $9.5 million in 2017 on soybean-specific programs and employs approximately 1,500 individuals. Several private funding sources also contribute financially to publicly funded soybean research where appropriate. Current research and development on Canadian soybeans focuses on topics including: genetics/genomics, plant pests, agronomy and quality.[13]

Overall, Canadian soybean research is well coordinated relative to other crop sectors. However, continued collaboration and effective knowledge transfer must continue between the research sectors (both private and public), farmers and extension staff in order to produce innovative solutions for a successful soybean crop. Interaction with farmers is critical in guiding future research efforts. Strong research and development efforts should also position Canada to share its best practices with global soybean growers.

# Chapter 2 – Growth stages.

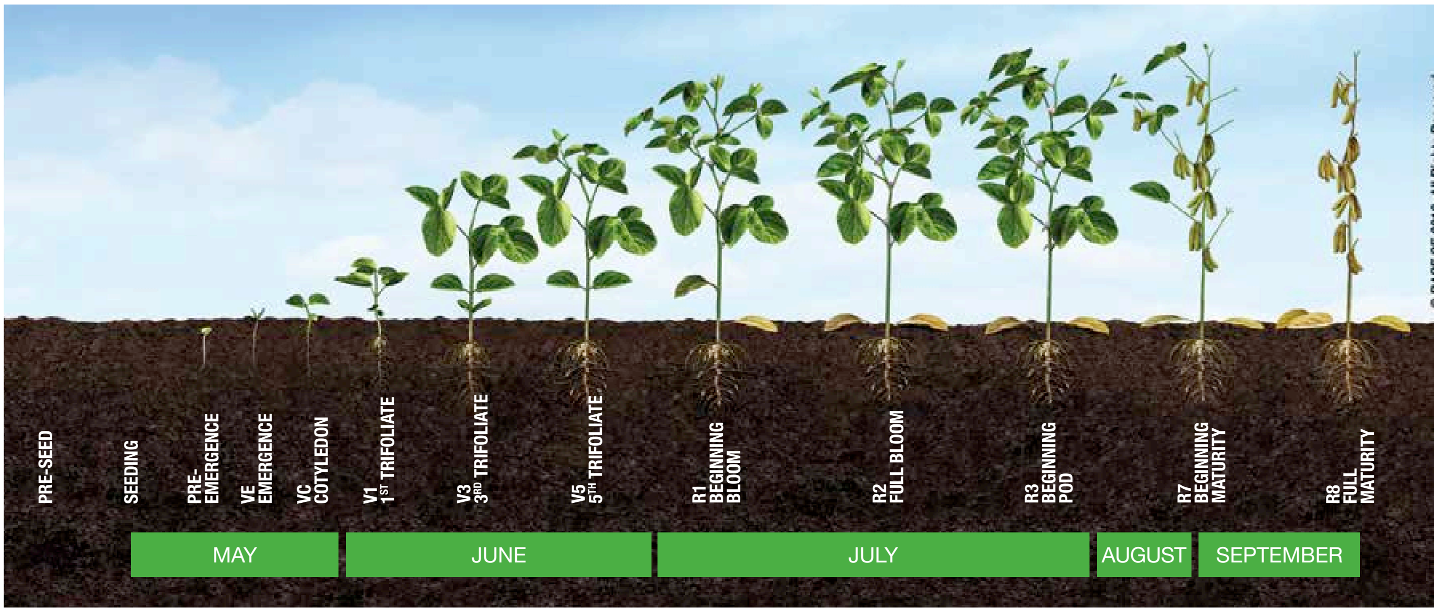



**Figure 2.1.** Soybean stages of growth.

Soybean growth begins with germination and emergence then progresses to vegetative (V) and reproductive (R) development. The emergence (VE) and the cotyledon growth stages (VC) are the most unique.[1] The V stages coincide with the number of soybean trifoliates, whereas the reproductive stages are based on flower, pod and seed production. The V stage associated with the onset of the R stages varies based on soybean growth, habitat type, planting date and soybean maturity group. V stages and R stages overlap since vegetative growth continues until R5.

Understanding soybean stages of growth (Figure 2.1) is critical to making timely pesticide applications. Labels often describe application timing based on growth stage and proper timing is essential to increase efficacy while decreasing crop injury. Equally important, reductions in soybean yield potential, whether by limited soil moisture, disease, weed infestation or insect damage, are strongly affected by the growth stage in which they occur. For example, growers should strive to keep the soybean field weed free between VE to V3. In general, stresses that occur in the soybean V stages are less damaging to the final soybean yield than those that occur in the R stages.[1]

### Germination and emergence.

Soybean seed germination requires moisture and adequate soil temperatures. Warm soil temperatures activate the enzymes necessary to initiate the process, which includes releasing food sources from the cotyledon and the beginning of radicle (young root) elongation. The temperature threshold is 10°C; however, germination and emergence are more efficient with warmer soil temperatures closer to 25°C. As such, the time between planting and emergence decreases as soil temperature increases.

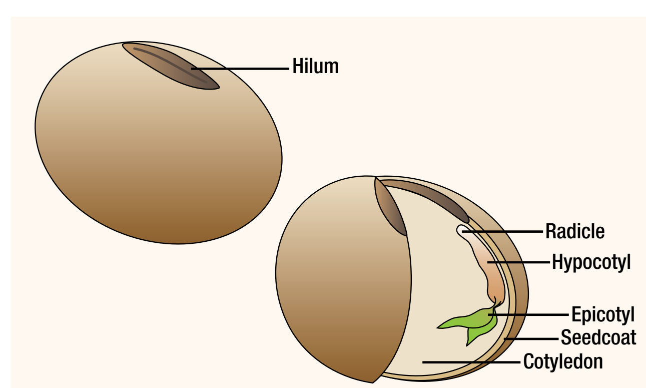



**Figure 2.2.** The parts of the soybean seed.
Source: BASF USA, 2015, Soybean Production Training Module.

When the radicle emerges, the process of hypocotyl (stem) elongation begins and the large cotyledons are pulled through the soil. Hypocotyl elongation ceases when the plant senses sunlight, at which time it resembles a hook. The cotyledons continue moving, straightening out the soybean seedling.

**Figure 2.3.** Soybean seed germination.
Source: BASF USA, 2015, Soybean Production Training Module.

Emergence is difficult under adverse conditions, the worst of which is soil crusting. This is caused by short-duration heavy rains that disperse soil particles, followed by rapid drying. This condition is particularly stressful to the plant during VE. If the hypocotyls have emerged, they may also swell and the seed may lack the energy to pull the cotyledon out of the ground. In the worst cases, crusting before hypocotyl emergence may even prevent the first stage of emergence. If soybeans eventually emerge under adverse conditions, they may have also used excessive food energy and thereby display smaller or absent cotyledons. These plants are immediately under stress and may show grain yield losses compared to quickly emerging soybeans.[1]

**Figure 2.4.** Soybean seed emergence.
Source: BASF USA, 2015, Soybean Production Training Module.

**VE – emergence.**

As previously mentioned, soybean emergence (Figure 2.6) requires moisture and adequate soil temperatures. Soil temperatures at the seeding depth need to be at least 10°C. Cotyledons provide energy for the newly emerged plants and become the first photosynthetic organ of the plant. The cotyledons continue to move, eventually straightening out the soybean seedling, and providing energy to the plant for approximately one week post emergence.[1]

**VC – cotyledon/full unifoliate.**

The cotyledons and unifoliate leaves are both fully expanded at the VC stage (Figure 2.7). Cotyledons still provide the energy for newly emerged plants through VC, and continue to do so until V1. Quickly emerged plants with fleshy cotyledons have the most energy. During VC, the cotyledons lose approximately 70% of their dry weight. Loss of one cotyledon provides little threat to yield; however, two absent or greatly diminished cotyledons could result in yield reductions of 8% to 10% overall.[1]

In the VC stage, the first true leaves (unifoliate leaves) are produced with opposite arrangement around the stem on short petioles; the leaf margins of the unifoliates do not touch.

**Figure 2.5.** Soybean early growth development stages.
From left: seed, hook stage, VE stage, VC stage, V1 stage, V2 stage.
Source: BASF USA, 2015, Soybean Production Training Module.

**Figure 2.6.** VE stage of soybean.
Source: Paul Vassalotti, BASF USA, 2015.

**Figure 2.7.** VC stage of soybean.
Source: Paul Vassalotti, BASF USA, 2015.

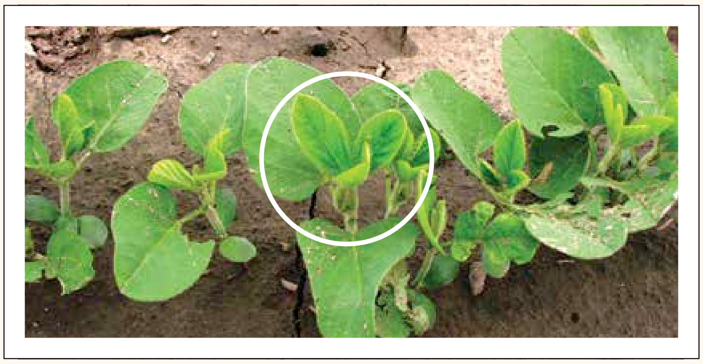


**Figure 2.8.** V1 stage of soybean.
Circled area shows first set of trifoliate leaves.
Source: Paul Vassalotti, BASF USA, 2015.

**Figure 2.9.** Soybean plant at V4 stage. The newly forming trifoliate leaves are curled and unfurling, but their edges are no longer touching.
Source: BASF USA, 2015, Soybean Production Training Module.

Lateral root formation also begins at this stage. The first axillary nodes are found above the cotyledon. Therefore, soybean plants cut down below the cotyledon have no chance for further vegetation growth and will die. Moving forward, a healthy, undamaged soybean plant progresses to a new V stage approximately every three to 10 days from VC to V5.[1]

**V1 – first node stage/first trifoliate.**

At the V1 stage, one set of fully developed trifoliate leaves appears at the unifoliate node (Figure 2.8). A fully developed leaf is one that has unfolded leaflets. At this stage, photosynthesis kicks in and begins to take over for diminishing cotyledon-supplied energy. This new energy source is adequate to sustain the plant.[1] It is critical to prevent weed competition during V1. This is also the stage when plant roots become infected with rhizobia.[1]

**V2 – second trifoliate.**

In the second trifoliate stage, two sets of trifoliate leaves are fully developed. Trifoliate leaves are alternately arranged and the leaflet margins do not touch. Recall, new trifoliates appear every three to 10 days depending on growing conditions. Between V2 and V5, roots grow exponentially within the top six inches of the soil. Roots infected by *Bradyrhizobium japonicum* now begin actively fixing nitrogen through the nodules. Nodule formation continues to increase until V5; after that it rapidly decreases.[1]

**V3 – Vn.**

The V stages denote the number of fully developed trifoliate leaves. For example, a V3 plant has three emerged trifoliates and a V4 plant has four (Figure 2.9). During vegetative growth stages, axillary buds may produce secondary branching, especially with low-density plant populations or 30-inch rows. At this stage, if the growing point of the plant is injured, axillary buds will continue to grow. The final number of nodes is determined by approximately V5. By V6, the primary root and several major lateral roots will have rapidly grown across inter-row spaces and can reach a depth of 2.5 to 3.25 feet.[14] The cotyledons and unifoliate leaves are mature at this point and may begin senescence.

**Transition to R stages.**

Since Canadian soybean varieties are indeterminate, the later vegetative and early reproductive stages overlap, meaning that growth continues as the soybean initiates development of seed. Whereas for determinate soybeans the onset of reproductive growth would terminate the vegetative growth. Photoperiod determines the transition from strictly vegetative growth to reproductive development. The time elapsed since planting, as well as environmental conditions, determines soybean growth prior to R1. Alternatively, the amount of growth following R1 is dependent on soybean type.[1] The R stages begin with the first flower and continue until the plant reaches full maturity.[1]

**R1 stage – beginning flower.**

The R1 stage is designated by the first open flower on any main stem node (Figure 2.10). Flowering begins between the third and sixth nodes of the main stem and progresses both upward and downward. Branches begin to flower a few days after the main stem. Flower petals are white or purple and are self pollinated. At R1, vertical root growth also increases dramatically and secondary roots and root hairs proliferate.[1]

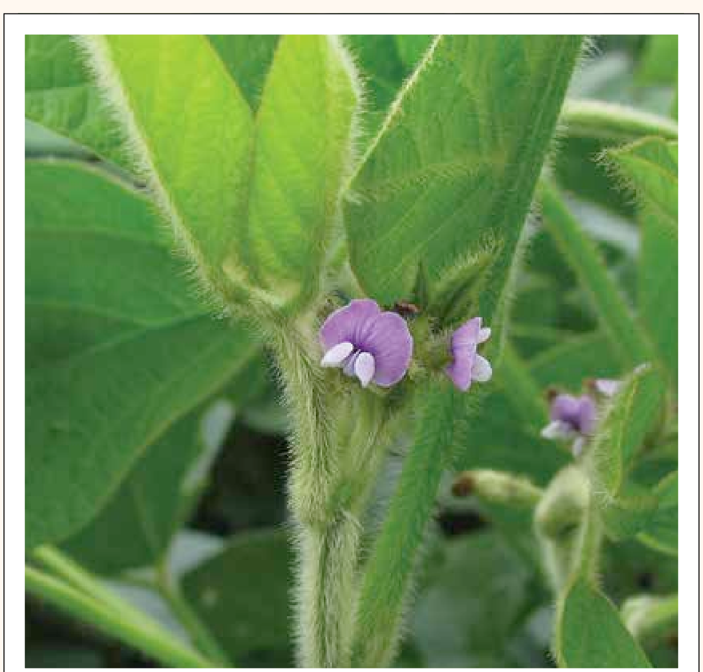


**Figure 2.10.** R1 stage of soybean.
Source: BASF USA, 2015, Soybean Production Training Module.

The onset of subsequent R stages and the number of flowers is dependent on the environment (photoperiod response), orientation and variety of the plant.[1] The flowering period generally begins six to eight weeks after seedling emergence; however, it may begin earlier if soybeans were planted late since development accelerates with warmer temperatures. Generally, yield increases as the length of time between R1 and maturity increases.

**R2 stage – full bloom.**

In the R2 stage, an open flower is found on one of the top two stem nodes. The soybean plant is now growing rapidly, accumulating both dry weight and nutrients in the vegetative plant structures. Approximately 50% of total nodes are formed. Flowering continues and extends through to R5. It is estimated that 60% to 70% of flowers will naturally abort and, therefore, never contribute to yield.

Flower abortion, often caused by drop, increases under hot and dry conditions. Within the soil, peak nitrogen fixation occurs at R2. At this stage, roots completely cross the inter-row field space and the growth of several lateral roots turn downward. Both the lateral roots and the taproot continue to elongate deep into the soil until late in the R6 stage.

**R3 – pod development.**

A 3/16-inch-long pod at one of the four upper main stem nodes indicates the R3 stage (Figure 2.11). At this stage, it is common to see overlapping development stages including: developing pods, withering flowers, open flowers and flower buds. This allows the soybean plant to compensate for stress-induced losses. At this stage, pods may spontaneously abort; however, this occurs less often than flower abortion.[1] The number of pods per plant, number of seeds per pod and the weight per seed determine soybean yield potential. Genetics determine the maximum number of seeds per pod and seed size. That said, these two components still fluctuate with environmental conditions.

**Figure 2.11.** R3 stage of soybean.
Source: BASF USA, 2015, Soybean Production Training Module.

### R4 – full pod.

The R4 stage is signified by a 3/4-inch pod at one of the four upper nodes (Figures 2.12, 2.13). Plants have lots of pods, although pods are not full. This is also the stage when final yield begins to be determined. Recall, the number of pods, number of seeds and the seed weight determine yield potential. Once the number of pods is determined, pod fill determines the rest of the yield equation. Plant stressors between R4 and R6 reduce yield more than the same stress at any other period of development since yield compensation is now limited to the number and size of beans per pod. Also, flowering soon stops, highlighting the critical importance of retaining developed pods.[1]

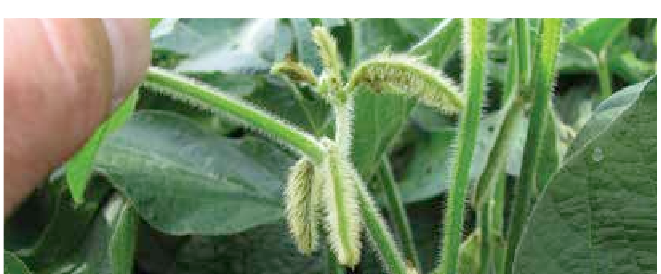


**Figure 2.12.** R4 stage showing beginning pod of soybean.
Source: Paul Vassalotti, BASF USA, 2015.

**Figure 2.13.** R4 stage showing full pod of soybean.
Source: Paul Vassalotti, BASF USA, 2015.

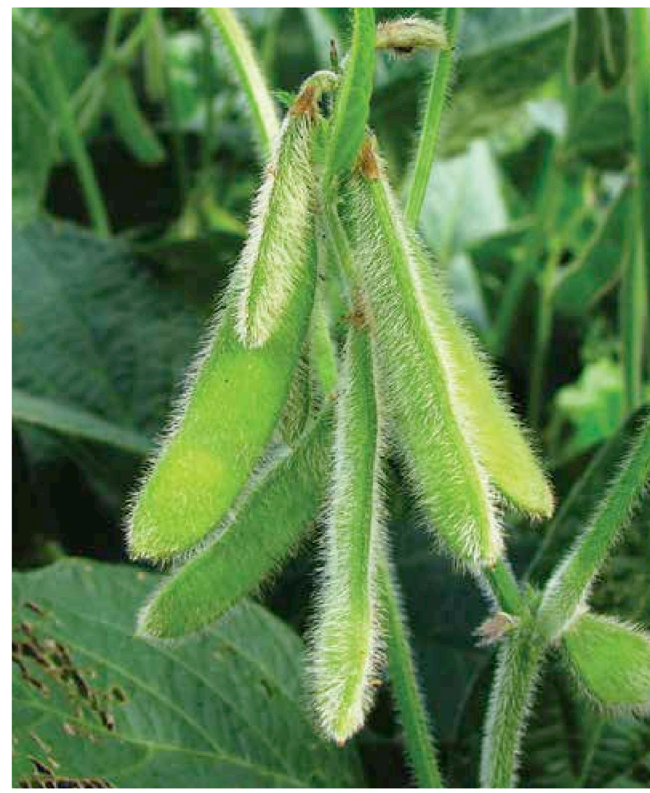


**Figure 2.14.** R5 stage showing beginning seed of soybean.
Source: BASF USA, 2015, Soybean Production Training Module.

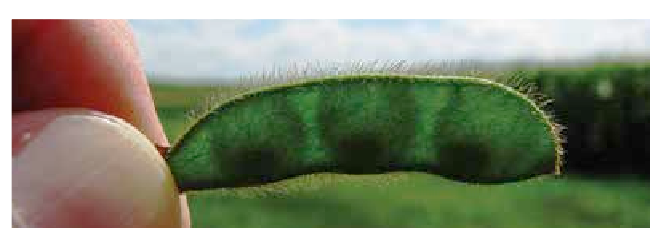


**Figure 2.15.** Soybean pod at R5 stage.
Source: Paul Vassalotti, BASF USA, 2015.

| Growth Stage | Yield Loss Following a Frost Event |
|---|---|
| **Beginning Seed (R5)**<br>Seed is 1/8 of an inch inside the pod located on the main stem at one of the four upper most nodes. | 65% |
| **Full Seed (R6)**<br>A green seed fills the pod cavity on one of the top four nodes on the main stem. | 37% |
| **Beginning Maturity (R7)**<br>One pod on the plant has reached its mature colour. | 11% |
| **Full Maturity (R8)**<br>Mature colour is reached by 95% of the pods. | 0% |

**Table 2.1.** Soybean growth stages and predicted yield loss after a frost. Source: BASF USA, 2015, Soybean Production Training Module.

### R5 – seed development.

The R5 stage is designated by a 1/8-inch seed in one of the pods at the four uppermost nodes (Figures 2.14, 2.15). Rapid seed fill occurs, meaning dry weight and nutrients from the leaves, petioles and stems are redistributing to seed production. During the seed-filling period, demand for water and nutrients is immense. In fact, moisture is critical for nutrient availability to the plant. Halfway through the R5 stage, the plant attains its maximum height, node number and leaf area but dry weight accumulation continues. Early frost now becomes a major risk as seen in Table 2.1.

### R6 – full seed.

R6 is the final growth stage prior to maturation. It is indicated by a pod containing a green seed at one of the four uppermost nodes (Figures 2.16, 2.17). Finally, the rapid rate of whole plant nutrient and dry weight accumulation begins to slow.

Three to six trifoliate leaves may have already fallen from the lowest nodes before rapid yellowing begins. Root growth terminates in the middle of R6. Senescence, leaf yellowing and death begin at the end of R6. The potential for yield reduction is still high as the soybean plant concludes development. Stress causes yield loss, mostly by reduction of seed size; however, pods and seeds are still susceptible to dropping.[1]

**Figure 2.16.** R6 stage showing full seed of soybean. Source: BASF USA, 2015, Soybean Production Training Module.

**Figure 2.17.** Full soybean seed at R6 stage. Source: Paul Vassalotti, BASF USA, 2015.

**Figure 2.18.** R7 stage showing full seed of soybean. Source: Paul Vassalotti, BASF USA, 2015.

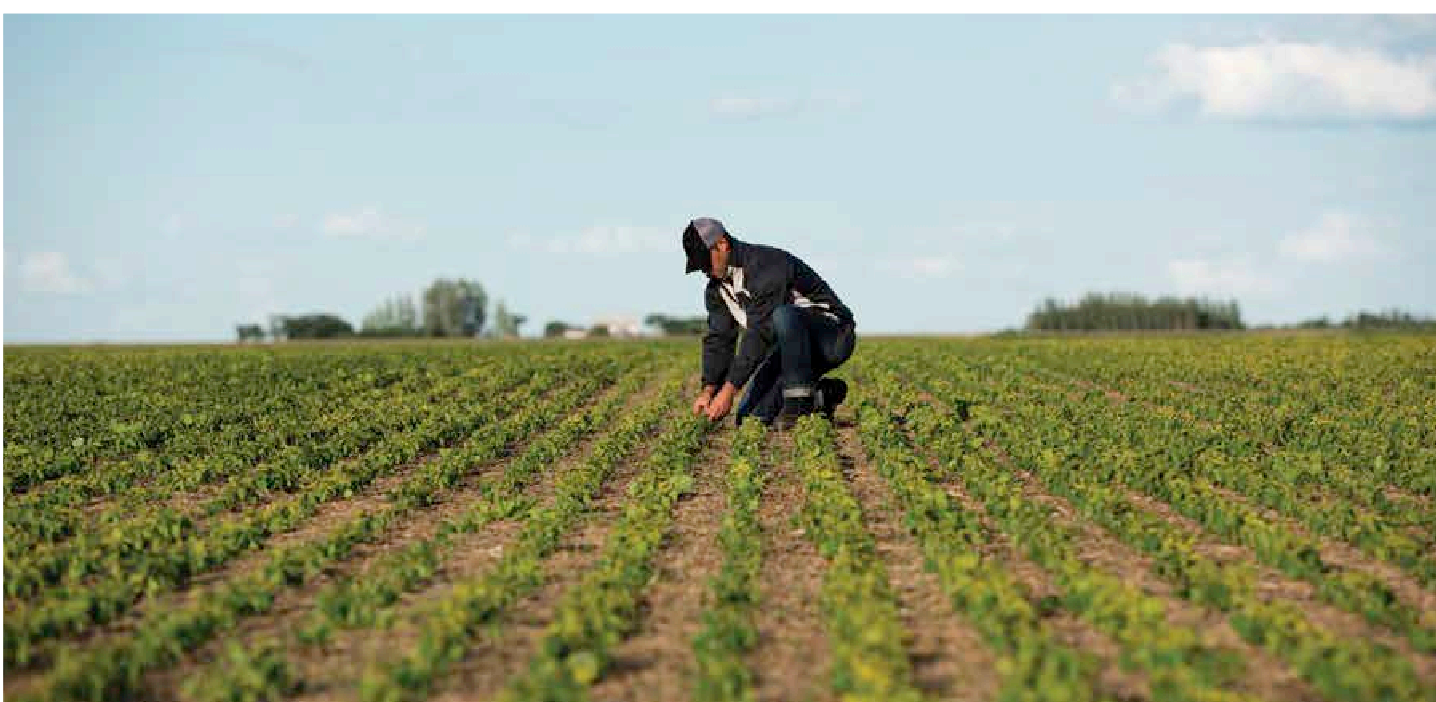
**Figure 2.19.** R8 stage showing full maturity of soybean.
Source: Paul Vassalotti, BASF USA, 2015.

### R7 – beginning of maturity.

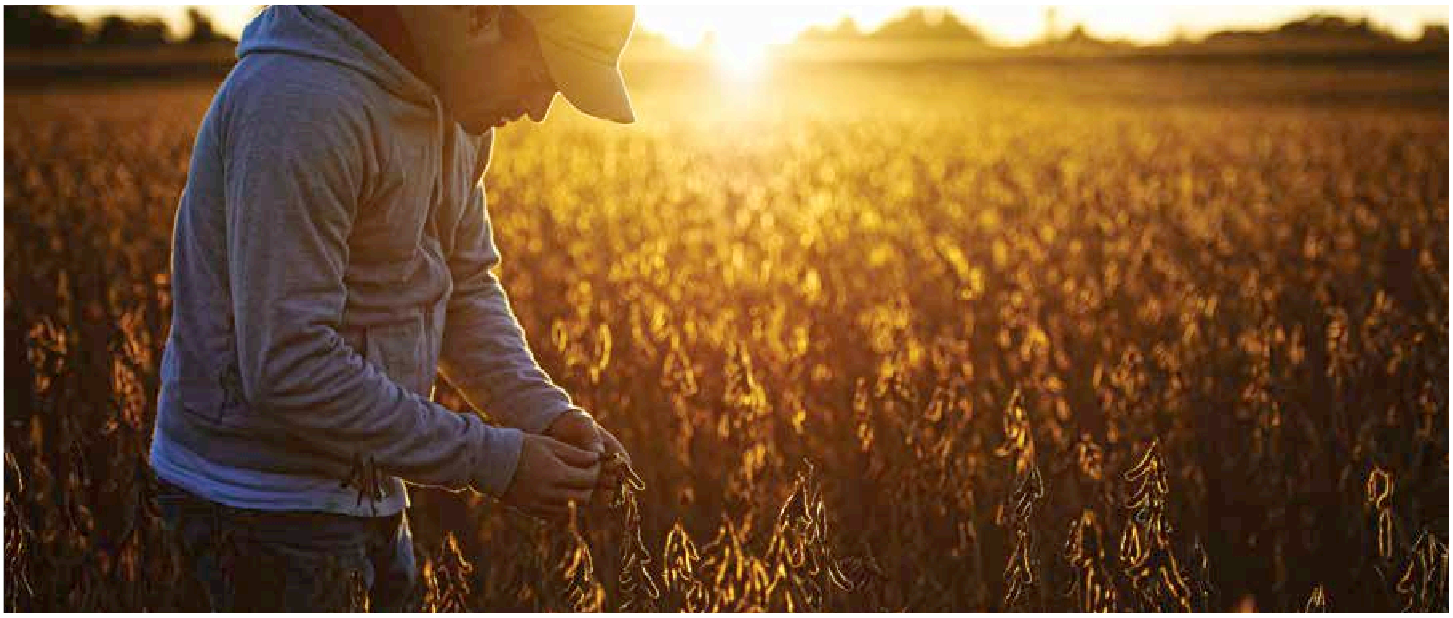
A main stem pod reaches its mature size in the R7 stage. Not all pods are mature, but very little additional pod growth occurs as accumulation of seed dry weight slows and eventually ceases. At this stage (Figure 2.18), seeds are usually yellow, physiologically mature and have approximately 60% moisture. Stress can still alter seed size and final yields; however, they are less susceptible because as pods mature they become less prone to drop.[1]

### R8 – full maturity.

At R8, 95% of pods reach their mature colour (Figure 2.19). However, this is deceiving since soybeans are still not ready for harvesting until they attain their harvest shape and desired moisture content. Leaves senesce but are of no value for increasing yield since seed growth is complete. Now, only pod splitting or excising pods affects grain yield. Soybean moisture should drop to between 14% to 20% prior to harvest, which should occur five to 10 days after R8. It is important to ensure the crop reaches physiological maturity before the typical frost date.[7]



# Chapter 3 – Seed selection.



Shortly following fall harvest, growers evaluate their soybean varieties and begin planning their next crop. Selecting the seed is one of the most important managerial decisions. Farmers should always choose their seed system with their on-farm practices, local conditions and production goals in mind.

**Key soybean systems.**

Soybean production in Western Canada consists of conventional, herbicide-tolerant (HT) (including Roundup Ready (RR), dicamba-tolerant (DT) and LibertyLink (LL) soybeans) and bin-run/other varieties. In 2017, total Western Canadian soybean production consisted of 87% HT, 11% bin-run, and 2% conventional varieties.[15] Provincially, soybeans in Manitoba are 98% RR and 2% conventional and soybeans in Saskatchewan and Alberta are approximately 99.5% RR.[16] It's important to understand the different varieties when selecting seed.

*Conventional.*

- They have not been genetically modified (GM)
- A small percentage of Canadian grown soybeans, and even smaller portion of Western Canadian soybeans
- They have a premium per bushel
- The shift towards herbicide-tolerant soybean varieties is motivated by challenging on-farm weeds

*Identity preserved (IP).*

- Are a specific subset of conventional soybeans
- Are contracted and sold for an additional premium
- Contracts signed in the fall for the following growing season indicate specific end uses for the beans
- Each step of production is controlled to ensure they meet customer specifications
- The seeds are certified
- Farmers must carefully clean all equipment prior to seeding and harvest to prevent any contamination
- Meticulous records must be kept throughout the season
- IP beans must be stored separately and are thoroughly inspected at the elevator
- Third-party testing and analysis is also conducted.[3] Despite rigorous process, customers still have right of refusal.
- Approximately 99% of non-GM soybeans are exported into the specialty foods market[13]

There is scientific consensus that GM crops pose no risk to human health; however, the public does not always perceive GM crops as safe. This results in demand for IP soybeans and a premium sale price. Legal and regulatory status of GM crops varies by country.

*Roundup Ready (RR).*

- Globally, glyphosate use has risen approximately 15-fold since glyphosate-tolerant crops were introduced[17]
- Today herbicide-tolerant crops account for 56% of global glyphosate use[17]
- They were introduced to the Canadian market in 1995
- RR varieties make it relatively inexpensive to have clean fields
- RR soybeans typically require additional technology to control weeds because of glyphosate-tolerant weeds and crop volunteers

*Dicamba-tolerant (DT).*

- DT varieties are increasing in popularity (5% of soybeans in Western Canada are currently DT[15])
- They are a good fit where glyphosate-resistant weeds have become problematic for growers
- Incorporating DT-soybean varieties on-farm does not mean growers must spray dicamba herbicide, but rather that growers have an additional mode of action available to control weeds, if needed
- Non-DT crops are highly sensitive to dicamba

- Unique application instructions are mandated with dicamba including strict limitations on boom height, sprayer speed, nozzle type, buffer zones and strict tank mix instructions
- Off-target movement is also of concern on farms[18]

**TIP**
Learn more about our stewardship guidelines at **agsolutions.ca/applicationstewardship**.

*LibertyLink (LL).*

- Group 10-resistant soybean variety
- Good choice for growers that want to rotate their non-selective herbicides to manage weed resistance
- Contains a unique trait making it the only non-selective alternative to glyphosate-tolerant systems

*The future.*

Research and development into new biotech seed options are underway. Enlist™ soybeans are expected to come to the Canadian market in the future. These will be tolerant to glyphosate and 2,4-D, another systemic herbicide. Shortly after the introduction of Enlist, Monsanto is expected to add the Liberty® gene to their seeds, which are already tolerant to dicamba and glyphosate (Roundup Ready 2Xtend® soybeans). This will allow the use of an additional mode of action that can be used to kill one of the most problematic weeds in Western Canada, volunteer canola.

**Additional variety considerations.**

*Growth type.*

Soybean growth type and the geographic location of a crop both significantly impact harvest results. Varieties are classified as having semi-determinant, indeterminant or determinant growth. Indeterminant plants continue to grow indefinitely for as long as conditions allow. Determinant plants stop growing at a genetically pre-determined growth stage. Determinant soybeans are most common in the southern states and they typically stop growth at or soon after flowering. Indeterminant soybeans are regularly chosen in Canada because the cold nights signal growth to stop without the need for any genetic trigger.[1]


**Figure 3.1.** Soybean growing areas in Canada.
Source: Soy Canada.

*Maturity.*

Western Canada is the northern most site of soybean production in North America thanks to the development of early maturing varieties (Figure 3.1).[3] It is expected that acres in the Prairies will continue to increase as additional varieties are bred to thrive in shorter-season climates. Recall, that soybeans respond to photoperiod and, to a lesser extent, temperature. In fact, they are often referred to as short-day plants because the plants flower in response to shorter day length. Therefore, local growing conditions greatly affect maturity. Each variety is signaled into flowering based on a different amount of daylight and, therefore, has an optimum north-south geographic range of approximately 150 to 250 kilometres. Since latitude affects day length, geography plays an important role in variety selection and subsequent soybean production.

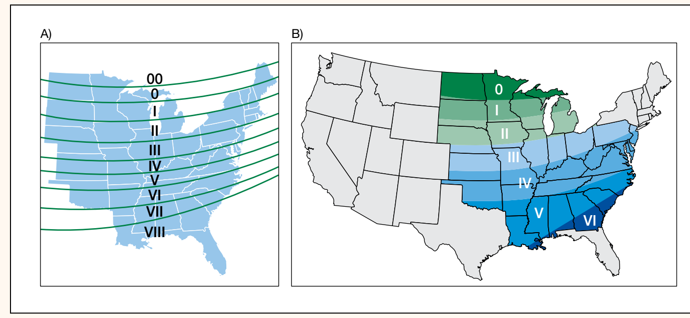



**Figure 3.2.** MG regions in the U.S. and Southern Canada.
Source: A) Scott and Aldrich, University of Illinois, 1970. B) Zhang et. al, 2007

Temperature may also influence soybean flowers and maturity, but to a much lesser extent.[1]

The maturity group (MG) rating system (Figure 3.2) classifies soybean varieties accordingly. Each MG region covers one to two degrees of latitude, and subgroupings with a zero to nine decimal number represent more slight increases in maturity. In Western Canada, most varieties are either MG 00 (roughly requires 2400 to 2550 Corn Heat Units (CHU)) or MG 000 (requires less than 2400 CHU).[19] Each soybean variety will indicate recommended heat units. A map of heat units can be seen in Figure 3.3.

If a variety is grown too far south, it will flower and mature early, which leads to decreased yield. Alternatively, if a variety is grown too far north, it will flower and mature late, risking a frost prior to harvest.[11] Further, soybean physiological differences may be heightened when conditions are less than favourable. Maturity is often delayed when growing conditions are cool and wet. Conversely, when conditions are warm and dry, maturity may be shortened.[19]

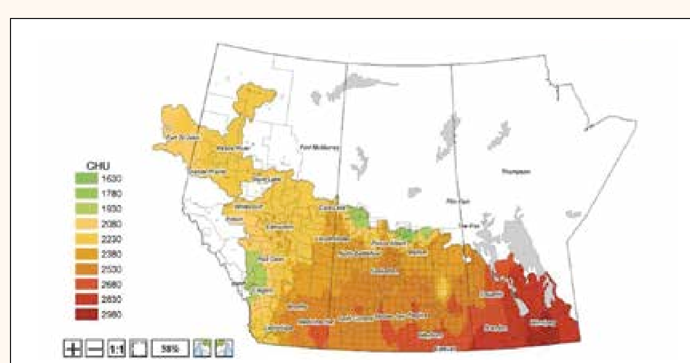



**Figure 3.3.** Map of accumulated CHU across the Prairies.
Source: WeatherFarm, 2015.

Based on distinct geographical differences, soybean cultivars are adapted to each geography to allow maximum yield potential in each area. Planting several different maturities can help to spread workload at planting and harvest, while also reducing the risk associated with variable weather conditions.[1]

*Yield.*

Since grain is the product heading to market, yield is a very important attribute of a soybean variety. To best select a variety for use in a specific area, growers should consider yield. It is recommended that several years of local yield data in addition to environmental conditions be taken into consideration when making seed decisions. Growers should consider yield stability, not just the average yield. It is also important to look at how consistent varieties performed across a range of weather conditions and soils.[1] Keep in mind, not all varieties are tested in third-party trials; however, other growers in the area may provide valuable feedback on varieties as well.

*Iron deficiency chlorosis.*

Iron deficiency chlorosis (IDC) is a challenge for soybean production that growers have faced in Western Canada. What causes this problem is when soybeans can't access iron (Fe) in the soil. Wet soils tend to aggravate IDC as they can bring up salts or carbonates which interfere with the plants ability to access iron. If a grower suspects he has a field with IDC, testing the soil carbonate and salt levels will help plan the variety selection. If IDC is a concern, selecting a variety with a high IDC tolerance is critical.

| | Organization / Company | Breeding Program |
|---|---|---|
| **Public** | Agriculture and Agri-Food Canada | Non-GM |
| | Centre de recherche sur les grains inc. (CÉROM) | Non-GM |
| | University of Guelph | Non-GM |
| **Private** | DEKALB (Monsanto) | GM |
| | Dow AgroSciences | Both |
| | La Co-op Fédérée | Both |
| | Pioneer (DuPont) | GM |
| | Pride Seeds | GM |
| | Sevita International | Non-GM |
| | Semence Prograin Inc. | Both |
| | Syngenta | Both |

**Table 3.1.** Soybean breeders in Canada.
Source: Soy Canada.

*Disease resistance and pest management.*

Additionally, growers should evaluate disease resistance when selecting soybean varieties for their farms.[1] Several diseases and pests are best managed through variety selection. Therefore, growers must choose varieties with traits that address pertinent issues.

*Ongoing research.*

Canada is considered a world leader in plant breeding. Seed development is made possible by its research sector, which is made up of both private and publicly funded breeders. These breeders (Table 3.1) have provided Canadian soybean farmers with approximately 200 registered varieties.[3]

Seed development and breeding efforts also strive to alleviate other soybean stresses that challenge farmers. Overall, soybean research is often focused on issues such as disease, shattering, lodging and drought resistance.[1] Specific to Canada, research is focused on reducing the risk of cold damage specifically via maturity, seeding date, residue management and better understanding plant response.[20]

With an increasing number of varieties to choose from, it is critical growers select an appropriate variety for their specific farm. Seed companies offer a range of unique plant characteristics including maturity class, yield potential, disease resistance, standability, emergence and vigour. Growers must prioritize what is important for production success on their farms when selecting soybean seed. In Western Canada, maturity is one of the most important factors.[19]

*Hilum.*

Where the pod attaches to the seed is called the hilum. The hilum can be of different colours depending on the variety including yellow, brown and black amongst others. However, yellow hilum beans are usually preferred in the export market.[21]

*Other considerations.*

Many soybean seed companies also rate their varieties for emergence, vigour, resistance to lodging and adaptation to no-till. Soybean varieties must fit with a grower's cultural practices because varieties may perform differently with distinct tillage, plant populations, spacing and fertility.[22] Grain composition as it relates to protein content or other health-related parameters may also influence soybean value in the future.[1]

**Seed handling.**

*Bin-run seed.*

Bin-run, or farm-saved seed, refers to soybeans that have been stored from a previous harvest for planting in a subsequent year. One of the biggest concerns is using patent protected seed and the legality issues affiliated with this practice. Saving seed for future planting comes with stiff penalties, due in large part to patent protection on the trait in the seed. There are also quality issues that prevent growers from saving seed. Using saved seed is not recommended because it is often not cleaned or germination tested and can provide growers with many issues during the season that negate the cost savings they receive. Low germination percentage, reduced emergence and low seedling vigour are all likely results of using bin-run seed.[1]

*Mechanical seed damage.*

Every time soybean seed is handled, from harvest to planting, there is an increased likelihood of damage to the seed. Care must be taken at every step to minimize seed damage that will hurt germination, vigour, susceptibility to diseases and, eventually, stand counts. Poor seed quality can greatly affect the stand counts and disease susceptibility of soybeans. Seed damage prior to planting will limit the yield potential through these indirect effects. Soybeans with visibly damaged seed coats (cracked, etc.) showed a 15% reduction in field germination compared to seed with no visible damage. Use of air or belt conveyers versus augers, for example, will often reduce seed damage. Handling of seed in cold temperatures can increase damage in comparison with warmer conditions.[1] It is important to harvest seed within 14% to 20% moisture content as lower moisture can also increase the risk of seed damage.

*Trial results.*

Soybeans are categorized based on maturity groups; however, different breeders may offer slight variations. Growers and agronomists must evaluate such variations through performance trials in their regions, to select the best seed option for each farm.[19] Numerous public and private soybean trials are conducted across Canada.[1] Annual public trial results are summarized and published to provide independent information on performance and agronomic characteristics. As of 2017, Saskatchewan Pulse Growers coordinate Saskatchewan trials and Manitoba Pulse and Soybean Growers and Manitoba Agriculture coordinate Manitoba trials. Test sites are located across the Prairies in: Hamiota, Boissevain, Roblin and Carberry, Manitoba; Saskatoon, Floral, Rosthern, Yorkton, Redvers and Outlook, Saskatchewan; and Brooks and Bow Island, Alberta.[19]

# Chapter 4 – Pre-seed decisions.

**Fertility.**

It is critical for both short- and long-term success that growers have a comprehensive understanding of their soil because soil fertility is an integral part of establishing healthy and profitable crops.[1] Soil fertility is especially important in growing soybeans as they require fewer inputs when compared to other crops.[7] Soil testing annually or bi-annually is recommended as it allows growers to understand fertility needs, both in terms of cost and environmental factors. In general, soybean fields require low nitrogen, but high phosphorus and potassium.[7]

**TIP**[22]

One bushel of soybeans requires:

| | |
|---|---|
| 5.2 lbs nitrogen (N) | 1 lb phosphate ($P_2O_5$) |
| 4.4 lbs potassium ($K_2O$) | 0.34 lbs sulphur (S) |
| 2.0 lbs calcium (Ca) | 0.69 lbs magnesium (Mg) |

Soybeans require 16 essential elements. $CO_2$ and water supply carbon, hydrogen and oxygen. The soil or fertilizers supply the other 13 essential elements. The interaction of several variables determine plant nutrient availability. These variables include: rooting depth, soil-water content, soil temperature and soil pH.[1] Soybean roots will not extend where dry; therefore, moisture is necessary to move nutrients within the soil.[1] Soybeans also perform best at a pH range of 6.0 to 7.0. Problems may occur in fields where the pH is outside of this range. The native fertility of the soil is determined by the soil parent material, which also influences soil texture, pH and organic matter.[1] In general, high-fertility, medium-textured soils grow large soybeans, whereas clay soils tend to grow shorter soybeans with a more open canopy. Lighter soils also struggle to retain moisture.

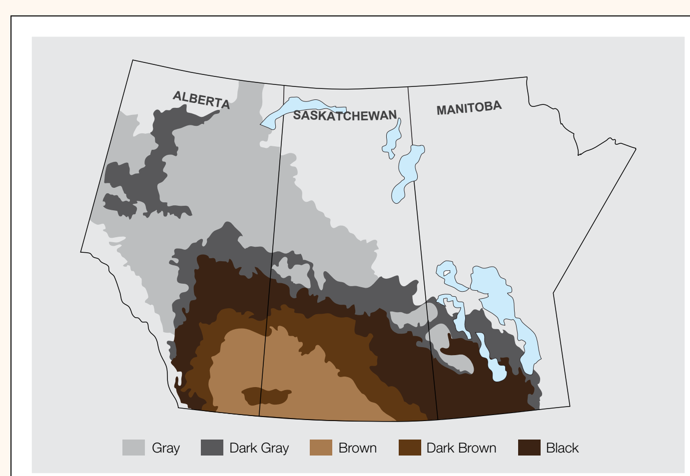



**Figure 4.1.** Western Canadian soil zones.
Source: Yan, W., Fetch, J.M., Fregean-Reid, J., Rossnagel, B., and Ames, N. 2011. Genotype x location interaction patterns and testing strategies for oat in the Canadian Prairies. Crop Science Society of America. 51(5): 1903-1914.

**Macronutrients.**

*Nitrogen (N).*

### Required for

Chlorophyll (photosynthesis), amino acids (protein) and nucleic acids (DNA).[23] Soybeans utilize soil N until fixation begins, at which point it becomes the main source of the nutrient.

### Soil mobility

Very mobile in the soil and prone to leaching. Leaching is more prone in sandy soils.[24]

### Fertilization needs

If fertility tests show inadequate soil N, growers should apply a starter fertilizer. However, it is important that there is never more than 50 pounds of N available within the top 24 inches of soil because this can result in delayed nodulation and reduced N fixation overall.

### Symptoms if the nutrient is deficient

The lower leaves become chlorotic or pale green (Figure 4.2). This occurs because any available N goes towards new plant growth.[25]

### Nitrogen fixation

N is readily available in the atmosphere, primarily in an unusable form to plants. N fixation, facilitated by rhizobia bacteria, is the process that converts unusable N gas ($N_2$) to useable ammonia ($NH_3$). In soybeans, these bacteria live in root nodules. Typically, the symbiotic process of N fixation begins shortly after crop emergence and becomes the main source of N for plants within two subsequent weeks.[1] The plant continues to supply nutrients, energy and housing to the rhizobia bacteria and the bacteria in turn fix N into its usable form within the soybean plant. An average of 50 to 60% of soybean N requirements are fixed by the crop.[26] Nodules turn pink or red inside when N fixation occurs, whereas non-fixing nodules are white or brown inside.[1] N fixation may be negatively impacted by extreme heat or cold, excessive soil moisture that depletes oxygen, salinity or compacted soils.[1] Using N from the soil requires less plant energy; therefore, soybeans prefer to obtain N in this manner.

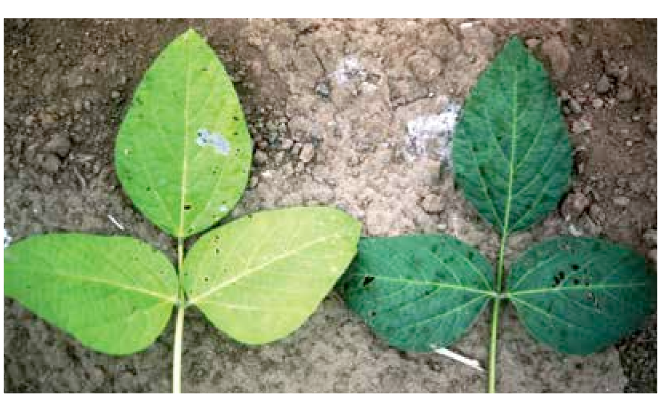


**Figure 4.2.** Nitrogen deficiency in soybeans. The N deficient leaf is on the left.
Source: International Plant Nutrition Institute. 1997. A closer look at deficiency symptoms in major crops. Better Crops, 81(3), 8-15.

**TIP**

If N is too high in the soil, the field becomes a poor candidate for a soybean crop because soybeans will not maximize nodulation. When soybean plants are properly inoculated, crops do not require an in-season fertilizer.

*Phosphorous (P).*

### Required for

Plant development, nodule formation and N fixation. It is needed most during pod formation through to seed maturity.[1]

### Soil mobility

Limited mobility in the soil and availability is further affected by pH, specifically outside the 6.0 to 7.0 range.

### Fertilization needs

Soybeans readily utilize P although research has shown that they rarely respond to in-season phosphorus fertilization.[27] Still, maintenance within the soil is important.[7] It's recommended that P is either added to meet crop needs as a banded application in soybeans or that soybean P needs are addressed throughout the rest of the crop rotation.

### Symptoms if the nutrient is deficient

The leaves turn dark green to bluish green and plants may have small lesions and appear stunted overall (Figure 4.3).[1]

**Figure 4.3.** (left) Phosphorous deficient soybean plants and (right) healthy soybean plants.
Source: (left) International Plant Nutrition Institute. 1997. A closer look at deficiency symptoms in major crops. Better Crops, 81(3), 8-15.

*Potassium (K).*

### Required for

Photosynthesis, tolerance to drought and pod filling.[28]

### Soil mobility

More mobile in the soil than P, but it still moves less than other nutrients. Most soils across the prairies have adequate levels of K although it may be required in light textured soils.

### Fertilization needs

Pre-season fertilizers, used to supplement K, are salts and should not directly contact the seed. Instead, it is ideal to add fertilizer 1.5 to 2 inches from the seed.[1]

### Symptoms if the nutrient is deficient

If soybeans are K deficient, older leaves begin to yellow or are affected by chlorosis, starting at the tip and moving down the leaf margin as the plant translocates K from older tissue to new growth as seen in Figures 4.4 and 4.5.[29]

**Figure 4.4.** Potassium deficiency showing chlorosis of the lower leaves.
Source: Dave Mengel, Kansas State University, 2014.

**Figure 4.5.** Potassium deficient soybean plants.
Source: BASF USA, 2015, Soybean Production Training Module.

*Calcium and magnesium (Ca and Mg).*

Deficiencies of Ca and Mg are rare, especially in the West because of the Ca and Mg rich parent material. Although some discussion of Ca/Mg balance exists in the scientific literature, there is little proof that addressing this concern is warranted.[1]

*Sulfur (S).*

S bonds with N to form proteins. S deficiencies are rare; however, they have become more common with improved air quality standards and purer fertilizers. Deficiencies are most common in sandy, excessively drained soils.[1]

| Pounds of Actual Macronutrients per Bushel of Soybean | | |
|---|---|---|
| | Uptake | Removal |
| Nitrogen | 5.2 | 3.8 |
| Phosphate | 1.0 | 0.8 |
| Potassium | 4.4 | 0.8 |
| Sulfur | 0.4 | 0.1 |
| Calcium | 2.0 | 0.1 |
| Magnesium | 0.7 | 0.2 |

**Table 4.1.** Soybean nutrient uptake and removal (lb/bu).
Source: Manitoba Agriculture, 2007, Manitoba Soil Fertility Guide.

## Micronutrients.

Most soybean fields provide adequate micronutrient supply. Micronutrient deficiencies are rare but can occur in highly weathered soils, organic soils or high pH soils. Deficiencies of iron (Fe), manganese (Mn), boron (B) and zinc (Zn) have all been documented, mostly in high pH soils. Mn deficiencies occur in high organic matter high pH soils. Since Mn deficiencies are associated with soil immobilization, foliar spring applications of Mn are the best solution if levels are inadequate. B deficiencies can occur in low organic matter, sandy soils that receive excessive rainfall, due to mobility of the ion.[1]

Iron deficiency chlorosis (IDC) is common in soybeans grown in the West. Fe may be present in soils at adequate levels but is unavailable to the crop because of interactions with carbonates and other soluble salts. This risk of IDC increases as carbonates and soluble salt content increases and is common in high pH soils. Interveinal chlorosis of the leaves and leaf veins which remain dark green during V1 to V3 is the most common symptom of IDC in soybeans. Iron is a key building block in several enzymes involved in the formation of chlorophyll. Severe IDC or IDC that extends beyond V3 can impact yield. To avoid Fe deficiencies, select varieties with tolerance and avoid fields at high risk of IDC. In-furrow and foliar applications of iron chelate to soybeans grown on susceptible soils is used elsewhere but has not been proven in Canada.

**Figure 4.6.** Iron deficiency chlorosis.
Source: Daren Mueller, Iowa State University, Bugwood.org

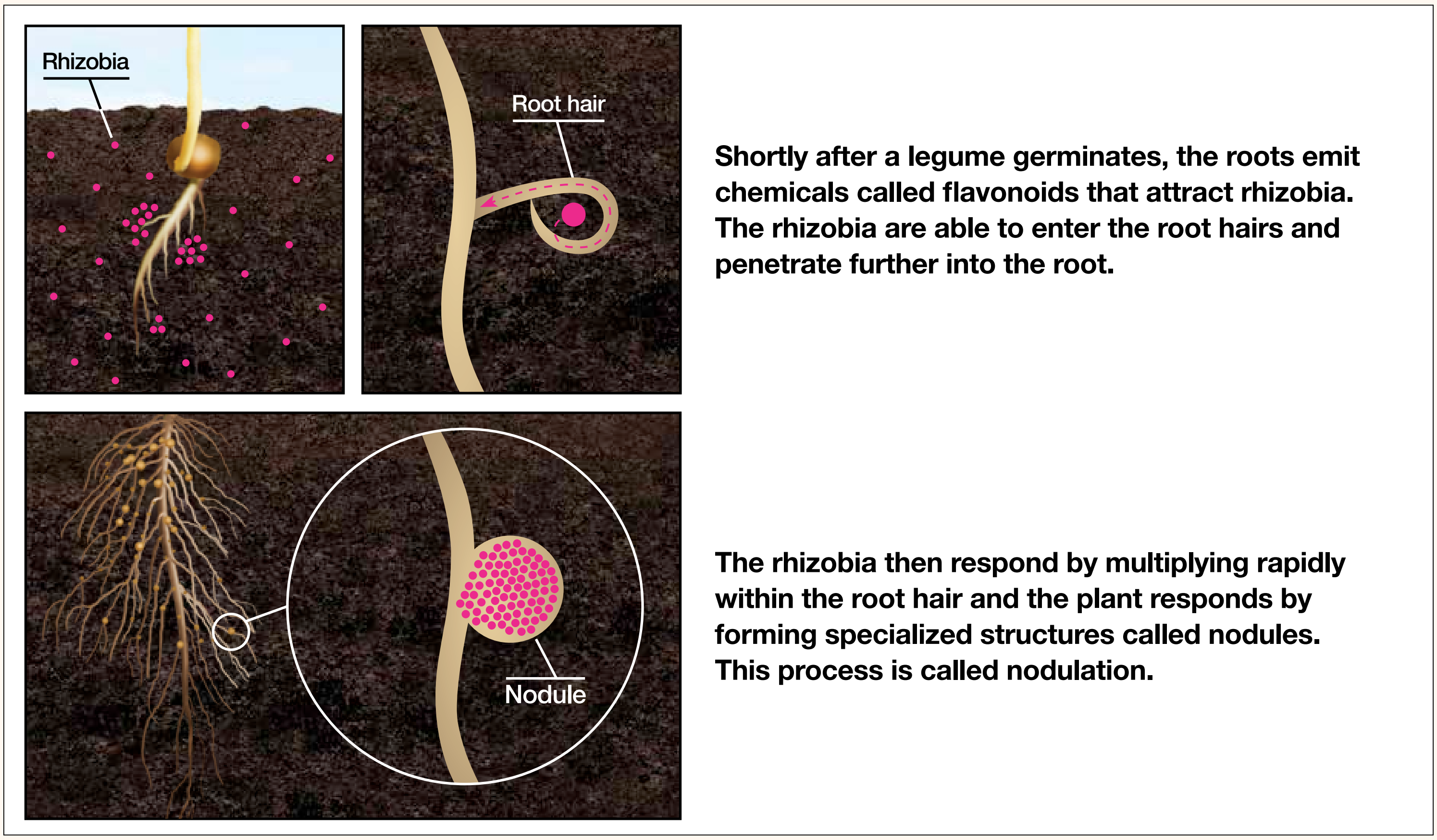



**Figure 4.7.** Rhizobia infection pathway.

**Inoculants.**

Inoculants are one of the most important inputs for soybean production. Use is a vital part of any integrated management strategy for the successful establishment and maximized yield potential of soybean crops. Inoculants enhance the unique and mutually beneficial relationship between soybeans and N-fixing bacteria called rhizobia. The legume plant works together with the rhizobia to make N available for the plant to use. Rhizobia are located in nodules on the plant's roots and convert atmospheric N into ammonia, a form that can be readily taken up by the crop. In return, the plant provides the rhizobia with energy, water and nutrients. Soybeans add approximately one pound of N per soybean bushel produced, which helps follow up-crops.[12]

*Bradyrhizobium japonicum* (*B. japonicum*) is the specific strain of rhizobia bacteria, critical for soybeans. *B. japonicum* is not native to Western Canadian soils. Therefore, without proper inoculation, N fixation will not be optimal. Recall that the majority of N comes from N fixation. This means rhizobia management is very important. In the past, agronomists only recommended inoculation at planting for first-time soybean fields. Today, we understand that environmental stresses negatively impact rhizobia populations. As a result, the recommendation is that growers inoculate soybean fields each year. Agronomists also encourage growers to double inoculate (on seed and in furrow) soybean fields.

When the soybean germinates, its roots emit chemical flavonoids to attract the rhizobia. The rhizobia secrete nodulation factors that stimulate root hair elongation of the soybean plant. When rhizobia enter the plant, this infection causes cell division within the root and eventually forms a nodule. Nodules become visible on soybean roots around the V1 stage and become fully functional by V3. Growers may see a yellow flash when the plant switches over from soil-acquired N to N fixation.

Nodulation is not always effective so agronomists recommend growers check soybean roots from several areas of the field. Approximately 40 days post-emergence, carefully dig up plants and wash the roots. Plants should each have at least 10 healthy nodules.

**Figure 4.8.** Soybean roots with healthy nodules.
Source: BASF USA, 2015, Soybean Production Training Module.

**Figure 4.9.** Root nodule formation.

*Choosing the right inoculant.*

Not all inoculants available on the market are equal in terms of efficacy so it's important to choose one from a reliable manufacturer who guarantees a minimum rhizobial count. Over time rhizobia die off so it's key to start with the highest possible rhizobial levels. All inoculant manufacturers should provide detailed information on their product labels. Levels of rhizobia are represented in scientific notation. Look for a high power of 10 (i.e. $2x10^8$ is the minimum required by CFIA).

**TIP**
Nodules form on the primary root near the crown if the grower used an on-seed inoculant, and on secondary roots if they applied an inoculant in-furrow. In addition, the inside of nodules should appear pink or red to indicate they are actively fixing N. See Figures 4.7-4.10.

**Figure 4.10.** Healthy nodule, actively fixing nitrogen.
Source: Jennifer Dean, Penn State.

**Figure 4.11.** Comparison of soybeans with good and poor nodulation. The soybeans in the left part of the field have good nodulation. The soybeans on the right have poor nodulation and exhibit nitrogen deficiency symptoms.
Source: Tom Maxwell, Kansas State University Research and Extension, 2017.

Since inoculants are living organisms, they can't be produced as far in advance as crop protection products. Growers must order inoculants early to give manufacturers the opportunity to accurately plan for market demand and distribution. Farmers buy seed from the seed company and then any custom treatment and inoculation is usually done at the dealer in the weeks prior to planting. Therefore, accurate forecasts are also critical for dealers to meet on-farm needs.[1]

Inoculant choice is farm specific and depends on equipment, field conditions and crop rotation history. They are available in several different formulations including: liquid, peat, granular and solid core granular. They all work effectively but there are some limitations with certain formulations. They are listed here in order of increasing stability.

a) Liquid inoculants are applied directly on seed or in furrow and are relatively inexpensive; however, performance can be limited on virgin or very dry soils
b) Peat inoculants are applied directly on seed, are most commonly used, inexpensive and contain a sticking agent that restricts use with certain seed treatments
c) Granular inoculant (primarily peat) is applied in furrow and needs its own tank on the seeder
d) Solid core granular inoculant (primarily clay granular) has a very uniform size that provides more even application with less dusting off

*Handling.*

All the above-mentioned inoculant formulations must be handled and stored differently than pesticides because they are living organisms and viability is of primary concern. Since seeds are not treated with inoculants very far in advance, on-farm storage is short lived. Due to the Canadian Food Inspection Agency's (CFIA) minimum rhizobial load standards, all inoculants have a designated shelf life and precise handling requirements.

Each product has individual recommendations; however, in general, inoculants should be :

- Stored in a cool, dry place, out of direct sunlight and drying winds (not frozen)
- It is also important not to stack granular inoculants to prevent clumping
- In addition, seed applied liquid and peat inoculants need to be planted within the stated window otherwise the seed must be re-inoculated


**Figure 4.12.** Tank-mix application.

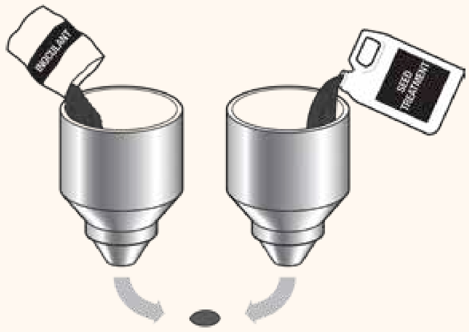



**Figure 4.13.** Wet-sequential application.

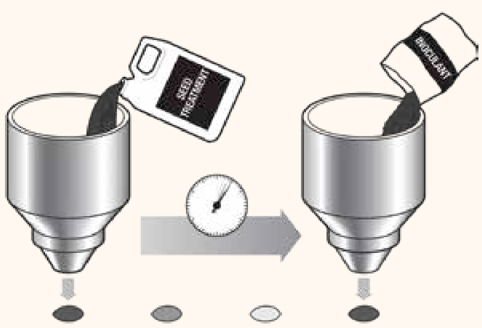



**Figure 4.14.** Dry-sequential application.

Growers must also consider inoculant compatibility with additional soybean inputs. Seed treatments are not always compatible and can negatively impact rhizobia on-seed survivability. Each supplier has compatibility information, which must be carefully followed. Inoculants are also sensitive to granular fertilizer since the rhizobia need adequate space and time to initiate N fixation.[1]

*Application.*

Producers should apply inoculants shortly before seeding to ensure optimum rhizobia survivability. It's important to check compatibility charts (available through the inoculant manufacturer) for on-seed survival times to confirm re-inoculation is not required if seeding is delayed.

In-furrow inoculant applications require a separate tank on the equipment for the inoculant. Growers should regularly inspect hoses and fittings for cracks and broken parts. It is also important to reference the manufacturer label and calibrate equipment accordingly. The inoculant tank should never be more than half full and the auger should run at 50% capacity or less. Do not leave the mixture in the tank overnight.

There are three methods of on-seed application of inoculants:

1) Tank mix – mix products at the same time and apply on seed together.
2) Wet sequential (simultaneous) – don't mix products, but apply to seed at the same time.
3) Dry sequential – apply seed treatment, allow to dry, apply inoculant.

**Seed treatments.**

A seed treatment is a chemical formulation, typically a fungicide, insecticide, biological and/or nematicide, applied to the seed prior to planting to protect the seed and seedling in the soil. Polymers bind the active ingredient to the seed and pigment is used to distinguish treated from untreated seed. Seed treatment works to strengthen a crop during emergence, preventing it from early attacks by insects and diseases, as well as supporting growth and field establishment. Top-performing seed treatment products provide additional positive effects including improved germination, better stress tolerance and increased vigour.[1]

It is important for growers to thoroughly analyze early-season conditions and to make seed treatment selections that best align with the specific risk factors. The primary factor growers should consider when choosing a seed treatment is seed- and soil-borne diseases of concern. Insecticide seed treatments are also available when insects are of concern. Ease of use is another important factor for farmers who apply seed treatments on farm.

As is the case with inoculants, growers should follow best practices while handling seed treatments. They should always carefully read the label to ensure they apply proper rates. The seed treatment manufacturer provides tank-mix guidelines, inoculant/insecticide compatibility and seed-treater calibrations to ensure proper application and thorough coverage. Seed treatments should always be stored above freezing, ideally between 0 and 30°C, to maintain proper viscosity. In addition, at the time of application, the seed temperature must not be below -9°C as this can prevent the seed treatment from adhering. Dusting-off occurs with all seed treatments, but ensuring the seed is clean and has been stored properly helps avoid this.

**TIP**

When picking a field for your soybeans, make sure there are no rotational cropping restrictions from the herbicides you used the previous season.

**Seeding.**

As soybean acres expand in Western Canada, both public and private research focuses on providing the best agronomic advice to local growers. Growers understand that seeding is a critically important time to maximize crop yields. When seeding soybeans, growers should consider a variety of information including rotation, planting date, water requirements, equipment, seeding rate, row spacing, seed depth and cropping system.

| Stage | Result of Low Soil-water Content |
|---|---|
| Germination | Delayed or terminated emergence |
| Early V stages | Little effect on final yield |
| R1-R3 | Blooms and small pods drop off plant |
| R4-R6 | Reduced seed size and yield |

**Table 4.2.** Effects of low soil-water content during soybean growth stages.
Source: BASF USA, 2015, Soybean Production Training Module.

*When to seed.*

Soybean planting dates are determined using several criteria including:

- Soil temperature
- Soybean maturity group
- The remaining frost-free season

There are benefits to planting early including a higher yield potential and the potential for an earlier harvest. There are also risks including slow germination, seedling diseases, frost injury and insect feeding. Delayed planting also negatively impacts yield potential, as a two- to three-day delay in planting results in approximately a one-day delay in maturity.[1]

Soil temperature is one of the most important factors to consider at seeding.[30] Farmers should seed soybeans after peas, cereals and canola when soil temperatures are warmer and there is no longer risk of frost.[7] The top two inches of soil should reach a minimum of 10°C when seeding soybeans. In ideal conditions this soil temperature would reach 25°C; however, this is rarely the case between the typical planting window of May 10 to 25.[19] When possible,

**Figure 4.15.** Air disk drill.
Source: Kristen MacMillan, University of Manitoba.

**TIP**

During the summer solstice (June 21) plants change their focus from vegetative to reproductive growth. Therefore, the more growth that is achieved before then, the better for potential yield.

do not seed soybeans when the soil is cold and wet, conditions more common in no-till cropping.[1] Research on soil temperature is ongoing and researchers hope to better understand how soybeans respond to cold temperatures to establish management practices to reduce cold damage.[19]

Soybeans require between 450 to 700 mm (18 to 28 inches) of water per season, sourced via available water within the soil or in-season precipitation. If water is in short supply, the soybean plant will exhibit varied symptoms depending on the current growth stage (Table 4.2). It is most critical that soybeans have access to water during flowering and pod-fill.[1]

Although soybeans require a water supply, they do not thrive if there is too much. Excessive water prevents the plant from accessing soil oxygen by creating a barrier to prevent gas exchange between soils and the atmosphere. Seedling diseases are also more likely to develop in wet soils. Finally, saturated soils reduce rhizobia populations necessary for nodulation.[1] If a fall season is very wet, saturated soils can occur and increase the levels of soluble salts that are elevated from the water table. The saturation-depleted soil oxygen causes inoculum built up in the soil to die. If the following spring is very dry, the remaining soluble salts in the soil can slow soybean inoculation speed and negatively affect growers.

*Equipment.*

Soybeans can be seeded using a planter, grain drill or an air seeder.[4] The debate is ongoing to determine whether a planter or air drill is best as results show growers can get a good soybean yield with either. Planters allow for a lower (more economical) seeding rate because they result in an improved plant stand across growing conditions. However, buying an expensive planter to only use on one crop is often economically unrealistic, especially when the alternative is only the cost of additional seed for the air drill.

*Seeding rate.*

Appropriate seeding rate is specific to each farm based on equipment type, seed quality, seedbed and the environment.[7] There are advantages and disadvantages to both higher and lower plant populations so consider all aspects to achieve maximum yields in each field.

*Seeding Rate (lbs/ac)*

$$\frac{\textbf{Desired plant population per ft}^2 \times \textbf{(1,000 kernel weight)}}{\textbf{(\% Expected seed survival} \times \textbf{10)}}$$

*Example:*

*a) Desired plant population per ft²:*
*target seeding rate/ac divided by ft²/ac therefore ex.*
***175,000 plants/ac / 43,560 ft²/ac = 4***

*b) 1,000 Kernel weight: ex. variety 23-10RY soybean have 2,600 seeds/lb therefore*
***1,000 seeds = approximately 174 g***

*c) % Expected seed survival: 85%*

***Seeding rate (lbs/ac) = (a x b) / (c x 10)***
***Seeding rate (lbs/ac) = (4 x 174 g) / (85% x 10)***
***Seeding rate (lbs/ac) = 82***

**Figure 4.16.** Example equation to calculate seeding rate.
Source: Saskatchewan Pulse Growers, 2018, http://saskpulse.com/growing/soybeans/seeding/.

*Seeding Rate (seeds/ac)*

$$\frac{\textbf{Desired plant population}}{\textbf{\% Germination} \times \textbf{\% Pure seed} \times \textbf{\% Live seed emergence}}$$

*Example:*

*a) Desired plant population: 175,000 plants/ac*
*b) % Germination: 93% (usually found on the seed tag)*
*c) % Pure seed: 99% (usually found on the seed tag)*
*d) % Live seed emergence: 85%*

***Seeding rate (seeds/ac) = a / (b x c x d)***
***Seeding rate (seeds/ac) = 175,000 / (0.93 x 0.99 x 0.85)***
***Seeding rate (seeds/ac) = 223,615***

**Figure 4.17.** Example equation to calculate seeding rate.
Source: Andrew P. Robinson and Shawn P. Conley, Purdue University.

Advantages of high-plant populations include quick canopy closure, greater light interception and lower weed competition. As the number of plants per acre increases, individual plants capture less light, limiting each plant's growth. High-plant populations also increase competition for nutrients and water, may promote lodging and add to seed costs. Higher seeding rates were justified years ago to develop a dense canopy structure to overcome erratic planting and emergence and to out compete weeds. Weed control and plant technologies are vastly improved today, taking away the need for yesteryear's higher seeding rates. Alternatively, when plant populations are low, individual soybean plants increase their leaf area so each plant captures more sunlight, yields more branches and produces more pods.[1]

When using a row crop planter, growers should target 160,000 to 190,000 seeds per acre, whereas a seeding rate of 180,000 to 230,000 seeds per acre is most appropriate when using an air seeder. Growers should target a seeding rate to achieve a live-plant population between 140,000 and 160,000 plants per acre. This plant population creates an optimum canopy, which is especially important under high-disease pressure.

A general rule of thumb is to expect a stand of 80% seed emergence with good quality seed, a good seedbed, proper planting depth, a well calibrated planter and moderate planting speed. If one of these attributes is missing, emergence may decrease to 70%. For example, crusting-prone soils reduce emergence by approximately 10%. With this logic in mind, it is common for growers to plant 10% to 15% more soybean seeds than what is recommended based on germination rate, since seed companies test germination under ideal conditions that are often challenging to replicate.[1] As mentioned above, plant population also varies based on the seeding equipment used. Seeding with an air drill results in approximately 74% seed survival, whereas a planter results in approximately 82% survival.

*Row spacing.*

Seeding rate combined with row spacing begins to define the geometry of the soybean canopy.[1] Row spacing is a function of the equipment used; in the West, about 70% of soybeans are seeded on narrow rows (less than 15 inches) and 30% planted on wide rows (15 inches and greater). Growers should strive to have bare soil completely covered by the soybean canopy at flowering. This maximizes light utilization during reproductive growth stages, minimizes weed competition, decreases the soil temperature and decreases moisture loss.[1]

Overall, narrow row spacing usually produces higher yielding soybeans. Years of research indicate that 30-inch row soybeans yield on average 7% less than either 7.5- or 15-inch row soybeans. The greatest positive response to narrower rows occurs in regions like Western Canada where a shorter growing season puts a premium on quicker canopy closure.[1] Growers who still choose wide rows may do so because of equipment limitations, or they find it provides more uniform seed placement, emergence and decreases overall seeding rates.

*Seeding depth.*

Growers should typically plant soybean seeds between 0.75 and 1.5 inches deep, depending on soil type, conditions and tillage. They can plant seeds shallower in heavy soils, such as high-clay soils, or in wet and cold conditions. Uniform seed placement promotes uniform emergence, which is better than staggered emergence as it often results in plant-to-plant competition. Always properly calibrate both planters and drills.[1]

*Tillage and cropping system.*

Tillage systems are defined by both the type of tillage/planter used and the amount of residue left on the soil surface.

- No-tillage: soil is left undisturbed and seed is direct seeded in the opened slot
- Reduced or conservation tillage: greater than 30% residue remaining on the surface
- Conventional tillage: soil residue is incorporated into the soil with little residue left on the soil surface

The development of Roundup Ready soybeans greatly enhanced reduced tillage in soybean production systems. Prior to that, weed control challenges prevented widespread adoption of no-till. Tillage is needed the earlier, and further north, planting occurs and with darker, poorly drained soils. Additionally, there is less chance for crop residue to breakdown in northern soils if it is not incorporated into the soil.[1]

Stand establishment also depends on rotation, variety, field selection and fertility. Crop rotations are important for diversity and lead to improved yield due to better weed, disease and insect control. See Figure 4.18 for common soybean rotations in Canada. In a study conducted by the University of Guelph Ridgetown College, continuous soybeans yielded 43 bu/ac, while in the winter wheat-soybean rotation soybeans yielded 48 bu/ac.[21] Furthermore, short rotations with other crops such as canola, lentils, peas and dry beans can lead to an increase of white mold. Make sure to have a longer rotation between these crops or to select resistant varieties to reduce the susceptibility of sclerotinia stem rot (white mold) in the soybean crop. In the case of phytophthora root rot, it can be found in dry beans and potatoes.[31] If winter wheat will follow the soybean crop, consider selecting an earlier-maturing variety and planting the soybeans earlier to allow timely planting of the winter wheat.[21]

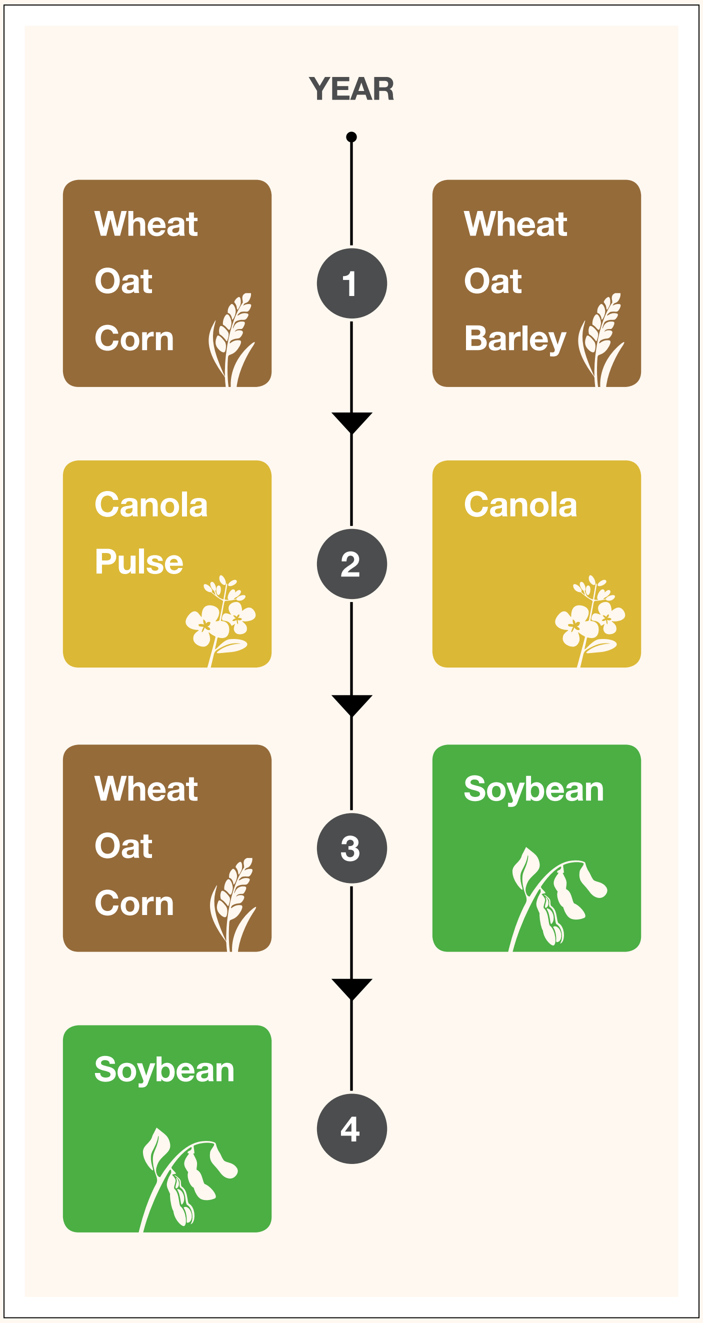



**Figure 4.18.** Common soybean rotations.
Source: Adapted from Kristen Podolsky, Manitoba Pulse & Soybean Growers. "Soybeans: production knowledge for Western Canada." CropSphere, 13 January 2016, Saskatoon, SK.

*Rolling.*

If planting conditions are poor, growers may decide to roll their soybean fields to improve seed-to-soil contact. A smoother field surface and improved seedbed with fewer rocks improves harvest efficiency and allows the cutter bar to get closer to the base of the plants to preserve yield. Ideally, rolling occurs prior to soybean emergence and when conditions are dry. Rolling should be avoided when soybeans are just emerging because it can cause breakage. However, growers can roll soybeans once they emerge, preferably on warmer days as the slight wilting makes plants more flexible and less prone to breakage. Soybeans can even be rolled up to, not including, the third trifoliate stage and a positive yield response has been shown when soybeans are rolled at the 1st trifoliate stage.[32] Avoid rolling immediately after any stress to the plants, such as a frost event or herbicide application. Instead, allow a couple of days for recovery before proceeding. If possible, also avoid rolling in damp conditions as it can sometimes increase compaction and the spread of seedling diseases throughout the field. Despite popularity, growers should analyze field conditions annually and only roll when necessary. Generally, if planting conditions are favourable, and growers are using good farm equipment, rolling is not recommended.

*Counting your plant stand.*

There are two ways to achieve a plant stand count. It is recommended to use the first method when the row width is greater than 15 inches and the second one for rows narrower than 15 inches or when the soybeans are solid seeded. However, both methods can be used for any row spacing as long as you have the conversion factor.

1. **Row length:** Refer to the chart below and find the row spacing that you used when planting your soybeans. Measure the row length that matches up with it and count how many plants there are in one row which will give you the stand for 1/1000th of an acre. Multiply the number of plants by 1,000 and you will have the number of plants per acre. If using hectares, multiply the number of plants counted by 2.47.

| Row Width | Row Length for 1/1,000 Acre |
|---|---|
| 18 cm (7 in.) | 22.8 m (74 ft 8 in.) |
| 38 cm (15 in.) | 10.62 m (34 ft 10 in.) |
| 51 cm (20 in.) | 7.97 m (26 ft 2 in.) |
| 56 cm (22 in.) | 7.24 m (23 ft 9 in.) |
| 71 cm (28 in.) | 5.69 m (18 ft 8 in.) |
| 76 cm (30 in.) | 5.31 m (17 ft 5 in.) |
| 91 cm (36 in.) | 4.43 m (14 ft 6 in.) |

**Table 4.3.** Row length for a partial acre.
Source: OMAFRA.

2. **Hula hoop method:** Throw the hula hoop at random and count the plants that are inside the hoop. Refer to the table below for the multiplication factor to use depending on the diameter of the hoop.

Make sure to repeat the method chosen multiple times across the field to get an accurate estimate.

| Diameter of the Hoop | Area | Factor by which to multiply the number of plants within the hoop to equal: | |
|---|---|---|---|
| | | Plants per Hectare | Plants per Acre |
| 91 cm (36 in.) | 0.66 $m^2$ (7.1 $ft^2$) | 15,228 | 6,162 |
| 84 cm (33 in.) | 0.55 $m^2$ (5.9 $ft^2$) | 18,122 | 7,334 |
| 76 cm (30 in.) | 0.46 $m^2$ (4.9 $ft^2$) | 21,928 | 8,874 |
| 71.8 cm (28.25 in.) | 0.37 $m^2$ (4.36 $ft^2$) | 24,711 | 10,000 |
| 61 cm (24 in.) | 0.29 $m^2$ (3.1 $ft^2$) | 34,263 | 13,866 |

**Table 4.4.** Hula hoop method for determining plant and pest populations. Source: OMAFRA.

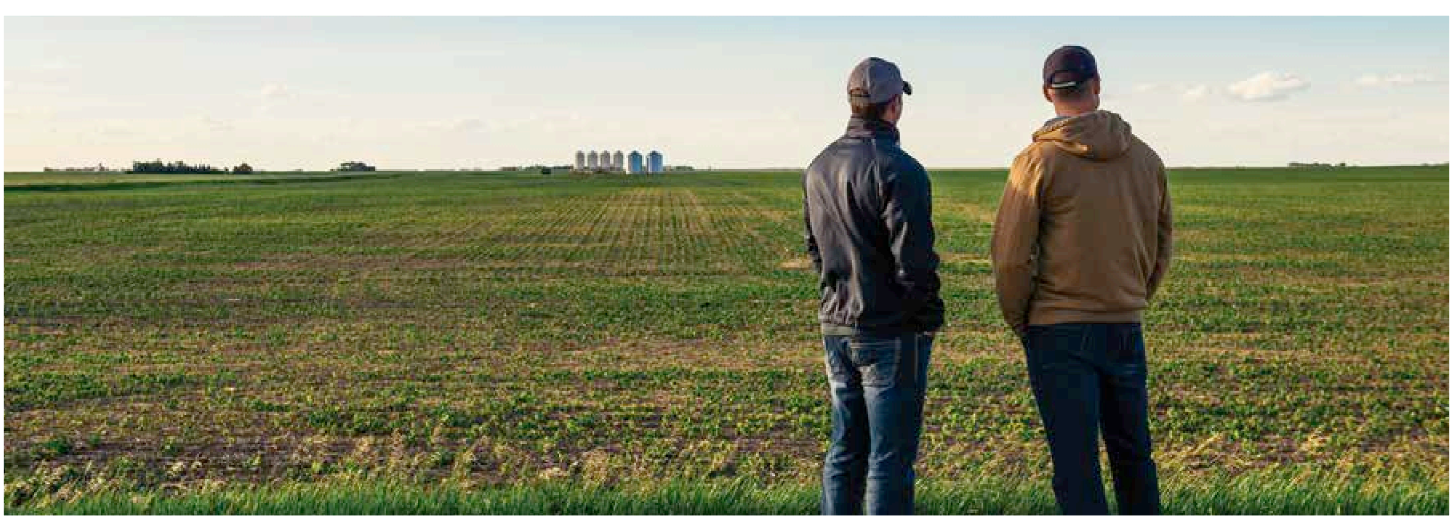
*Replanting.*

Unfortunately, not every crop will be successful and sometimes one must decide if they will replant the soybean field. This can be a difficult decision especially if the plant stand isn't uniform throughout the field. In most cases, if the plant stand is reduced by 50% uniformly across the field and is healthy, the field does not need to be replanted.[21]

Remember, replanting does not always lead to a perfect stand and keeping the 50% stand might be more profitable.[21] Soybeans can easily compensate for the gaps in thin stands. A soybean plant can fill up a 12-inch space either between plants within a row or between 2 rows when there is no weed competition.[21] Before deciding to replant consider these factors:[21]

a) The current health, uniformity and population of the stand
b) What caused the reduced plant stand?
c) The cost of replanting
d) The current yield potential compared to the possible yield potential
e) The date; yield potential declines as the month of June progresses

Sometimes, patching the stand can be done, however, it does not usually improve the yield potential unless the current stand is extremely low.[21] Furthermore, it can make it hard to time some field operations such as weed control and harvest since not all plants in the field will be at the same maturity.[21] However, if you do decide to proceed, make sure the same soybean variety is available and do not destroy the current stand.[21]



# Chapter 5 – Weed management.

Weeds are a significant threat to crop production globally. In order to effectively control weeds, growers must consider their field history and past challenges in addition to careful monitoring of fields in season to manage any new potential problems. It is recommended growers scout fields two to three weeks after planting and after herbicide applications.[1] To get a good idea of the weed pressure and type of weeds present in the field, scout the entire field in a W pattern (Figure 5.1), taking weed counts at a minimum of 20 points throughout. Being aware of any new or herbicide-resistant weeds present in the field helps growers make effective management decisions before problems escalate. Constructing a field map can be useful to monitor success of control methods and the spread of weeds; it also provides a reference point for future years. While scouting, also pay attention to the specific time of year and note any recent weather events as both impact the severity of weeds.

### Key weeds.

Prior to considering strategies for weed control, it is valuable to understand weed biology. Weed species typically exhibit rapid germination, abundant seed production and widespread seed dispersal. They also produce seeds that can lie dormant and survive harsh winters. Weeds interfere with crop production through aggressive competition for resources including moisture, nutrients and sunlight; through reducing harvest efficiency; by hosting plant diseases and insects and by risking contamination.[1] Weeds are classified according to their lifecycle and may grow on an annual, biennial or perennial basis. Annual weeds complete one lifecycle per season and are either summer or winter varieties. Biennials complete one lifecycle over two years. Perennials regrow every season for at least three years. The competitiveness of a specific weed is determined by its particular growth habits, time of emergence and size. Many weed identification guides are available and always recommended to use for proper weed identification.[1]

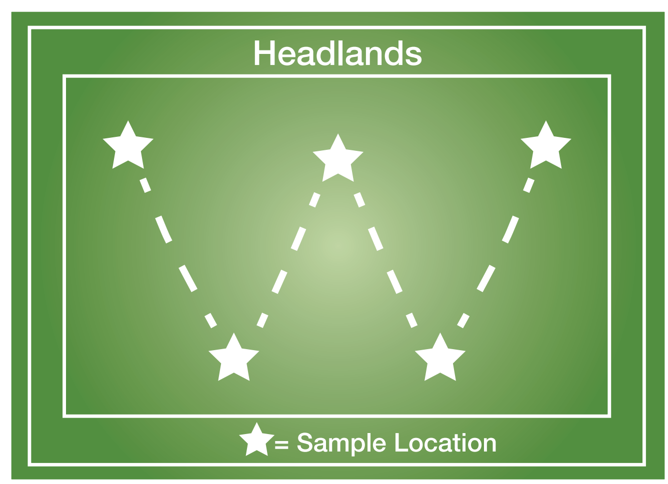



**Figure 5.1.** The recommended W pattern for scouting fields.

**Broadleaf weeds.**

***Biennial wormwood*** *(Artemisia biennis Willd.)*

### Growth Habit

Biennial wormwood emerges from spring into fall and, despite its name, behaves more like an annual. Biennial wormwood prefers moist conditions and is most common in Manitoba.[33]

### Identification

This weed can grow up to three metres tall and produces more than 400,000 seeds per plant. It is often misidentified as common ragweed. Identification becomes more challenging as the plant matures.[33]

### Scouting

To scout, growers should take a minimum of 20 weed counts across the field.

### Additional Information

If biennial wormwood is identified, it is best to control with pre-emergent and post-emergent herbicides.[33] This weed becomes more difficult to control as the season progresses and has adapted to all tillage systems. It also shows tolerance to some soil-applied and post-emergent herbicides such as Group 2's.

***Canada thistle*** *(Cirsium arvense (L.) Scop.)*

### Growth Habit

Canada thistle is a perennial weed that reproduces via seed (approximately 700 per plant) and sprouting of rhizomes.

**Figure 5.2.** Biennial wormwood.
Source: Pamela B. Trewatha.

**Figure 5.3.** Canada thistle.

It is a strong competitor and causes the most crop losses when compared to other broadleaf weeds found in Western Canada. Canada thistle also slows crop harvest and the green matter increases drying costs for growers.[34]

### Identification

Canada thistle reaches anywhere from 30 to 150 cm in height and has some branches on the stem. It has narrow leaves that alternate and have a spiny margin. There are multiple flower heads that have a purple tinge and the flowers are quite small (0.5 to 1.5 cm in width). The plant can flower from June into the fall.[34,35]

### Scouting

To scout, growers should take a minimum of 20 weed counts across the field and pay particular attention to edges, as large patches are often found there.[34]

### Additional Information

To control Canada thistle, a multi-year plan is necessary. It should include tillage, patch mowing, crop rotation and herbicides. Currently this weed has not established herbicide resistance.[34]

***Chickweed*** *(Stellaria media (L.) Vill.)*

### Growth Habit

Chickweed is an annual or winter annual weed that reproduces by seeds and stolons. It is known to be a high-volume seed producer. Chickweed prefers moist soils that are high in nitrogen and a temperature range of 12 to 20°C. Although it is shade tolerant, it is very drought sensitive. This symptomatic weed has two main flushes, the first in early spring and the second in late fall.[36]

**Figure 5.4.** Chickweed.

### Identification

The plant is bright green in colour with stems that have many branches and can be prostrate or erect. A key feature of chickweed is the single line of white hairs that are found on the stem and that alternate sides between each node. There are two opposite leaves on each node which are oval with a pointed tip and may have a few hairs. The plant produces small (>0.5 cm) white flowers which have five two-lobed petals. Flowers occur throughout the growing season.[36,37]

### Scouting

Growers should scout by taking a minimum of 20 weed counts throughout the field, paying particular attention to low lying moist areas.[36]

### Additional Information

Chickweed competes with soybean crops, which may delay drying and cause tangles during harvest. Its seeds may also result in the accumulation of toxic levels of nitrogen. Currently, populations of Western Canadian chickweed are resistant to Group 2 herbicides; however, other herbicide options are available for control.[36,38]

## ***Cleavers*** *(Galium aparine L.)*

### Growth Habit

Cleavers are annual or winter annual weeds that reproduce by seed when environmental conditions are wet. They are very competitive with soybeans and may lead to significant yield losses as they become more common throughout the West. Cleavers can also negatively affect harvest.[39]

### Identification

Cleavers have weak and limp stems, square cross-sections with strongly ribbed corners and very short curved bristles. There are three to eight linear leaves arranged in a whorl. A key identifying feature of cleavers is that they stick together or to clothing, animal fur, etc. The flowers are very small and short lived, being replaced by the fruit; a small green sphere. The plant flowers from May to August.[39,40]

**Figure 5.5.** Cleavers.

### Scouting

Growers should scout for cleavers early, taking a minimum of 20 counts in their field.[39]

### Additional Information

Currently, cleavers populations show resistance to Group 2 herbicides across Western Canada and also to Group 4 herbicides in Alberta. If they become problematic, tillage and alternative herbicides are recommended.[38,40]

## ***Dandelion*** *(Taraxacum officinale Weber.)*

### Growth Habit

Dandelions are perennial weeds that reproduce by seeds. Dandelions are one of the most easily identified weeds, both on and off farm. They can be readily found in reduced tillage fields.[41]

### Identification

Dandelions have one deep taproot and long lobed leaves arranged in a rosette. The plant produces a single yellow flower per stem throughout the growing season. The seeds are attached to a white pappus which aids in its dispersal. When cut, the plant produces a white sticky substance.[41,42]

### Scouting

To scout, growers should take a minimum of 20 weed counts across the field, paying particular attention to field edges.[41]

### Additional Information

Tillage is an efficient method of control. It must be done deep enough to cut the taproot at a depth of 10 cm. This can be achieved using a cultivator or deep tiller, however, discers aren't always as successful. Herbicides are another control option.[41]

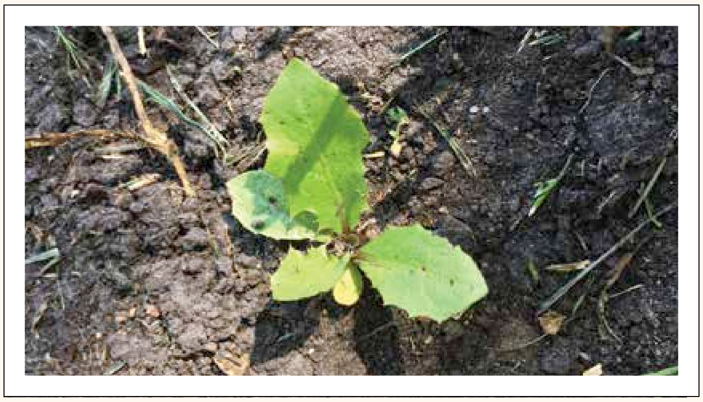


**Figure 5.6.** Dandelion.

***Hairy nightshade*** *(Solanum sarachoides Sendt.)*

### Growth Habit

Hairy nightshade is native to South America and is mostly found on muck and mineral soils. It is an annual that reproduces by seeds.[43]

### Identification

This weed can reach 1 m with branching stems that are either spreading or erect. Alternate leaves are ovate to triangular with some fine hairs and smooth margins. The multiple flowers occur on a raceme and are white or blueish in colour. Flowers occur from July to October followed by a green fruit that will become brown at maturity.[43]

### Scouting

To scout, growers should take a minimum of 20 weed counts across the field.

### Additional Information

Nightshade species may reduce soybean yield and quality due to bean staining from the fruits of the nightshade, while also increasing harvest costs. Currently nightshade

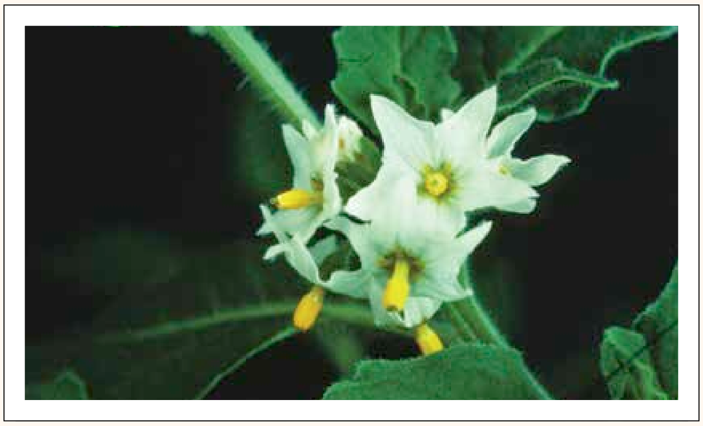


**Figure 5.7.** Hairy nightshade.
Source: Charles T. Bryson, USDA Agricultural Research Service, Bugwood.org

weeds are mostly found in Manitoba; however, growers should still scout their fields across Western Canada. If control is necessary growers may opt to cultivate and/or utilize herbicides.[44]

***Hemp-nettle*** *(Galeopsis tetrahit L.)*

### Growth Habit

Hemp-nettle is an annual weed that reproduces by seed. Seeds may remain dormant in the soil for long periods of time. As a result, hemp-nettle is very hard to manage once introduced.[45]

### Identification

Hemp-nettle has square stems that reach approximately 30 to 75 cm in height. They are covered in hairs and swollen at the nodes. The opposite leaves are elliptic with an apex and round-toothed margins. The flowers are found in the upper leaf axils and have a purple tinge.[45]

**Figure 5.8.** Hemp-nettle.

### Scouting

Growers should scout early, taking a minimum of 20 weed counts per field and pay particular attention to low spots.[45]

### Additional Information

There are some herbicide control options which should be applied early when the weed is still small for the best efficacy.[45] Hemp-nettle has developed resistant biotypes to both Group 2 and 4 herbicides in Alberta and Group 2 in Manitoba.[38]

***Kochia*** *(Bassia scoparia (L.) Roth.)*

### Growth Habit

Kochia is a summer annual, which reproduces by seed and spreads quickly in saline soil. It thrives in drier years. Seeds are short lived and only survive for a few years in the soil. Still, kochia is very competitive and difficult to manage once populations are established. Kochia usually germinates early in the spring; however, it can also germinate throughout the growing season.[46,47]

### Identification

This bushy plant can grow anywhere from 15 to 180 cm in height but usually reaches 90 to 120 cm. During the seedling stage, the underside of the cotyledon is pink. Kochia has many branches and the stems have a red tinge. The plant has many alternate leaves that are pale green and hairy with pointed tips. The leaves can turn purple or red in the fall. The plant also has green flowers that are found either in the leaf axils or on spikes. It spreads its seeds by tumbling at the end of the season.[47]

**Figure 5.9.** (Left) Kochia. (Right) Glyphosate resistant kochia treated with glyphosate.

### Scouting

To scout, growers should take a minimum of 20 weed counts across the field.

### Additional Information

Several herbicides are registered for control if growers identify kochia. It is important to spray early as kochia germinates early and might be further along in terms of growth stages than other weeds.[47] Resistance to Group 2 herbicides is widespread in Western Canada (99+% of kochia). In addition, resistance to Group 4 and/or 9 has been identified in kochia populations across the Prairies.[38] Tillage before planting can also be used to reduce kochia densities, however, a study has shown that zero tillage practices reduced kochia more than conventional tillage practices.[47]

***Lamb's quarters*** *(Chenopodium album L.)*

### Growth Habit

Lamb's quarters is an annual weed that reproduces by seed. It germinates early and then again late in the season and prefers to grow in soil with high organic matter.[48]

### Identification

Lamb's quarter can grow 60 to 90 cm in height and is erect. The stem has some grooves on it and sometimes green or red stripes. The leaves can have many shapes such as lance-shaped or triangular; however, they are alternate and have coarse-toothed margins. There are white 'speckles' (salt accumulation) mostly on the underside of the leaves that can have a red tinge during the early growth stages. The small flowers are green and located in the top leaf axils.[48,49]

### Scouting

To scout, growers should take a minimum of 20 weed counts across the field.[48]

### Additional Information

If growers are looking for control options, they must keep in mind that lamb's quarters is resistant to Group 2 herbicides in Saskatchewan, however, multiple herbicide options are available.[38,48]

**Figure 5.10.** Lamb's quarters.

### ***Night-flowering catchfly*** *(Silene noctiflora L.)*

#### Growth Habit

Night-flowering catchfly is an annual or winter annual, which reproduces by seed.[50]

#### Identification

Night-flowering catchfly is similar to white cockle at the seedling stage. The mature plant however, is erect with some branches and can reach up to 1 m. Both the stems and opposite leaves have sticky hair. There are 5 flower petals which are white to pink.[50]

#### Scouting

To scout, growers should take a minimum of 20 weed counts across the field.[50]

#### Additional Information

There are effective pre-seed/pre-emergent and post-emergent herbicides to manage night-flowering catchfly. They are somewhat tolerant to Group 4.[50] It's important for growers to know if they are dealing with an over-wintering or a spring population to determine ideal management timing.

**Figure 5.11.** Night-flowering catchfly.
Source: Pamela B. Trewatha.

### ***Redroot pigweed*** *(Amaranthus retroflexus L.)*

#### Growth Habit

Redroot pigweed is an annual weed that reproduces by seeds that are viable for up to five years in the soil. It prefers rich soil and high temperatures for germination. It can germinate throughout the growing season when moisture is available. Redroot pigweed can cause yield losses and is also a preferred insect host.[51]

#### Identification

Redroot pigweed has a long red or pink taproot and light green, rough stems that can reach 60 to 90 cm. The leaves are alternate, dark green and ovate in shape. The plant has multiple green flowers found either in the leaf axils or in a spike at the top of the plant.[51]

**Figure 5.12.** Redroot pigweed.

#### Scouting

To scout, growers should take a minimum of 20 weed counts across the field, especially when conditions are warm as this leads to rapid growth of the weed.[51]

#### Additional Information

When crops are established before the warm weather sets in, they can compete with redroot pigweed. There are many herbicides available, however, redroot pigweed can grow fast under warm conditions and therefore become bigger than the recommended stage.[51] To control redroot pigweed with herbicides, growers must keep in mind that populations have developed Group 2 herbicide resistance in Manitoba and Saskatchewan.[38]

**Figure 5.13.** Shepherd's purse.
Source: (left) James Atland.

***Shepherd's purse*** *(Capsella bursa-pastoris (L.) Medic.)*

### Growth Habit

Shepherd's purse is an annual or winter annual weed that reproduces by seed. It can produce 33,000 seeds per plant. At this time, it is thought to have little effect on crop quality.[52]

### Identification

This plant, with an erect or branching stem that is covered in grey hairs, can reach 10 to 60 cm in height. It forms a rosette with lobed, alternate leaves. Shepherd's purse produces white flowers throughout the growing season that form triangular seed pods that have a notch at the top making them resemble the shape of a heart. This weed can be recognized by the star-shaped hairs found on the leaves.[52,53]

### Scouting

To scout, take a minimum of 20 weed counts across the field.[53]

**Figure 5.14.** Smartweed species.

### Additional Information

If growers find shepherd's purse, they may choose to control it through cultivation or a herbicide application.[53] To date, populations of shepherd's purse have developed Group 2 herbicide resistance across the Prairies.[38]

***Smartweed species*** *(Polygonum spp.)*

### Growth Habit

Smartweed species are annual weeds that reproduce by seed. They prefer very moist conditions and often grow close to ponds and sloughs.[54]

### Identification

Smartweeds have branched, hairless stems reaching up to 80 cm in height. The leaves are elongated and taper at both ends. Some leaves can have red or black spots on them towards the center of the leaf. They have ocreas at the nodes. Flowers are clustered at the end of the stem or on stalks emerging from the axils of the upper leaves and can be green, white or pink.[54]

### Scouting

To scout, take a minimum of 20 weed counts across the field, paying attention to low moist areas.[54]

### Additional Information

If population counts are high, smartweeds may cause soybean yield reduction. Herbicides are available to control them in soybeans. If management is necessary, keep in mind that Group 2 resistant smartweed biotypes have developed in Manitoba and Alberta.[38,54]

***Sow-thistles*** *(Sonchus spp.)*

### Growth Habit

Sow-thistles are perennial or annual weeds depending on the species, that reproduce through seeds (annual and perennial) and underground roots (perennial only).[55] They are often confused amongst each other and with dandelions. They are widespread and grow in agricultural fields, meadows, roadsides and moist areas in the case of annual sow-thistles.[55,56,57]

### Identification

This erect weed can measure between 60 and 120 cm. Perennial sow-thistles have a smooth stem at the bottom while it is hairy and branched at the top. The stem also produces a milky sap. Annual sow-thistles have hallow and glabrous stems while the leaf veins can be purple. Sow-thistles have alternating leaves about 15 to 30 cm long that have toothed or lobed margins. The weed produces multiple yellow flowers that resemble those of dandelions. The seeds are attached to white hairs allowing them to be carried by the wind.[55,58] Annual sow-thistle can be differentiated from perennial sow-thistle due to the deeper lobes of the leaves. Perennial sow-thistle has more spines and a larger flower head. Lastly, the most effective distinguishing characteristic is that annual sow-thistles have short taproots compared to their counterparts with long rhizome-like roots.[55,58]

**Figure 5.15.** Annual sow-thistle rosette.
Source: James Atland.

### Scouting

Take 20 weed counts across the field. Perennial sow-thistles usually occur in patches while annual sow-thistles usually occur in the low-lying areas.[55,57]

### Additional Information

Perennial sow-thistle can lead to a slower harvest as well as increase the amount of green matter found in the grain while annual sow-thistles can host nematodes, aphids and viruses. Control of perennial sow-thistle requires a multi-year plan. Tillage, mowing, herbicides both in crop and pre/post-harvest as well as crop rotation need to be part of the plan. Tillage can be tricky as it can move the weed to other parts of the field.[55] As for annual sow-thistle control, tillage is recommended to reduce the seed bank, as well as pre- and post-emergence herbicides.[55,57] To date, spiny annual sow-thistle has developed resistance to Group 2 herbicides in Alberta.[38]

## ***Stinkweed*** *(Thlaspi arvense L.)*

### Growth Habit

Stinkweed is an annual or winter annual weed that reproduces by seed. Generally, seeds remain viable in the soil for up to six years; however, if buried by tillage they may survive up to 20 years. Stinkweed that has overwintered can grow quickly the following spring.[59]

### Identification

Stinkweed has smooth, erect stems that are 5 to 60 cm tall with some branching occurring. The bottom leaves can be in a rosette while the upper leaves are alternate on the stem and clasp it. It produces small white flowers. The seeds are oval and flat except for the middle part that is thicker. A key identifying feature of stinkweed is the odour it emits when the leaves are crushed.[59,60]

### Scouting

To scout, growers should take a minimum of 20 weed counts across the field.[59]

### Additional Information

Since stinkweed plants that germinate at the end of summer or the beginning of fall are harder to control in the spring, growers should plan to control them with tillage or a herbicide application in the fall.[59] Growers planning to control it with herbicides should keep in mind that stinkweed populations have developed Group 2 resistance across Western Canada.

**Figure 5.16.** Stinkweed.

***Volunteer canola*** *(Brassica napus L.)*

### Growth Habit

Volunteer canola is an annual weed that reproduces by seed. Volunteer canola competes aggressively with soybeans.[61]

### Identification

Volunteer canola grows 1 m tall and has a branched erect stem that is a tinge of blue mixed with green. The leaves are dark green, smooth and hairless. It produces yellow flowers on a raceme. It then produces small green rounded seeds that become dark brown to black at maturity.[61]

### Scouting

To scout, take a minimum of 20 weed counts across the field.[61] The economic threshold of volunteer canola in soybean is two to three plants per square meter.[62]

### Additional Information

Control is complicated as volunteer canola is often herbicide-tolerant depending on the canola variety.[61] Keep good records of the type of resistant canola used in previous years to help decide which herbicide to use. In some cases, hand pulling can be used.[61]

***Wild buckwheat*** *(Polygonum convolvulus L.)*

### Growth Habit

Wild buckwheat is an annual weed that reproduces by seed in moist conditions.[63]

### Identification

Wild buckwheat has angular branching stems that can reach anywhere between 30 and 90 cm in length. The plant grows along the ground or on top of other plants. It has alternate leaves that are heart shaped with a pointed apex. It produces small greenish white flowers that have no petals, either in the leaf axils or at the tip of the branches.[63]

### Scouting

Growers should scout early, looking in the low spots of the field and take a minimum of 20 weed counts across the field.[63]

### Additional Information

To control, growers must apply herbicides early in the season. To date, wild buckwheat populations have developed Group 2 herbicide resistance in Alberta.[38] By climbing on crops, buckwheat can cause lodging and makes harvesting more difficult.[63]

***Wild mustard*** *(Sinapis arvensis L.)*

### Growth Habit

Wild mustard looks very similar to Polish canola and flushes with cool and wet conditions. It will not grow in dry conditions.[64]

**Figure 5.17.** Volunteer canola.

**Figure 5.18.** Wild buckwheat.

**Figure 5.19.** Wild mustard.

### Identification

Wild mustard is erect, 1 m tall and the stem has many short hairs on its lower part and few on the upper part. The plant branches in the upper parts. Purpling can appear on the stems at the nodes as the plant matures. The leaves are attached in an alternate pattern and they are coarsely-toothed. The plant has clusters of yellow flowers and produces small dark brown or black seeds. One way to distinguish wild mustard from canola is to look at the upper leaves: if they clasp the stem, it is canola but if the leaves have stalks it is wild mustard.[64,65]

### Scouting

To scout, growers should take a minimum of 20 weed counts across the field.[64]

### Additional Information

To control wild mustard, a well-timed herbicide application is recommended. To date, populations of wild mustard have developed resistance to Group 2 herbicides across Western Canada and resistance to Group 4 and 5 herbicides in Manitoba.[38]

## Grasses.

***Barnyard grass** (Echinochloa spp.)*

### Growth Habit

Barnyard grass is an annual weed that thrives in warm and wet conditions.[66]

### Identification

The flattened stems usually branch and spread over the ground. The leaves are flat or v-shaped and keeled below and smooth to rough on top. It does not have auricles or a ligule. It produces multiple spikelets on the flowering stems that are purplish green.[66]

### Scouting

To scout, take a minimum of 20 weed counts across the field paying attention to field borders and low spots where there may be built-up moisture.[66]

### Additional Information

In soybeans, barnyard grass can reduce yield and negatively impact harvesting equipment.[66] Light tillage may not control this weed as it can produce roots from its nodes and quickly re-establish itself. There are herbicide options available to control it. Group 2-resistant barnyard grass was found in the most recent herbicide-resistant weed survey in Manitoba.[67]

**Figure 5.20.** Barnyard grass.
Source: Howard F. Schwartz, Colorado State University, Bugwood.org

***Green foxtail** (Setaria viridis (L.) Beauv.)*

### Growth Habit

Green foxtail is an annual weed that reproduces by seed. Seeds are plentiful and may remain viable in the soil for three years. Green foxtail grows rapidly when temperatures are high; however, it is generally a poor competitor. Still, yield losses can be drastic following a hot spring.[68]

### Identification

This erect grass reaches 20 to 60 cm in height. It has a round stem, hairless rough leaves and a ligule but no auricles. It produces cylindrical green seed heads that taper at the top. They are soft and have green bristles.[68,69]

**Figure 5.21.** Green foxtail.

## Scouting

Growers should scout, especially under hot conditions, by taking a minimum of 20 weed counts across the field.[68]

## Additional Information

If herbicides are required for control, growers must be mindful of local resistance. To date, Group 1 and 3 herbicide-resistance has developed across Western Canada and Group 2 resistance has developed in Manitoba.[38] Furthermore, green foxtail can grow quickly under the right conditions and therefore must be monitored to properly time the herbicide application. It is possible to control green foxtail by having strong crop stands through early seeding and adequate fertilization. Reduced and no-till fields can also help control the weed.[68]

### ***Quackgrass*** *(Elymus repens (L.) Gould)*

## Growth Habit

Quackgrass is a difficult-to-control perennial grass that thrives under cool and moist conditions. It reproduces through seed production and, more commonly, through underground rhizomes. These rhizomes secrete toxic substances to supress nearby plant growth and increase its competitiveness. Overall, quackgrass reduces yield.[70]

## Identification

This weed with smooth stems can reach anywhere between 35 and 140 cm in height. The leaves have slight hairs at the base on the upper side of the leaves as well as clasping auricles. The weed produces spikes that have 2 horizontal rows of florets. The seeds are white or yellow.[70]

## Scouting

Scout frequently, with a minimum of 20 weed counts across the field. Quackgrass is usually found in dense patches.[70]

**Figure 5.22.** Quackgrass.

## Additional Information

To control quackgrass, a multi-year integrated strategy is recommended. It should include tillage, patch mowing, crop rotation and herbicide application. Growers must be careful if using tillage as to not spread the rhizomes to other sections of the field. Therefore, quackgrass should be tilled towards the center of the weed patch and equipment should be free of rhizomes before leaving the patch for other sections of the field.[70]

### ***Wild oats*** *(Avena fatua L.)*

## Growth Habit

Wild oats is the most serious grassy weed in the Prairies, causing yield losses, dockage losses, cleaning costs and lowered grade. This annual weed reproduces by seed that can remain viable in the soil for seven to eight years. Wild oats prefer cool and wet conditions.[71]

## Identification

Wild oats seedlings have a counter-clockwise twist, a ligule and no auricles. The mature plant has erect stems that reach 150 cm in height. The head is a panicle with spikelets containing seeds of a wide range of colours (black, brown, yellow and white). The base of the seed is hairy.[71]

**Figure 5.23.** Wild oats.

## Scouting

To scout, growers must properly identify wild oats from both wheat and barley. Wild oats do not have auricles, whereas wheat and barley plants do. Take a minimum of 20 weed counts across the field. Wild oats are usually spread throughout the field but, sometimes they will be concentrated in the low spots. An easy way to spot them is after they have headed and are taller than the crop.[71]

Additional Information

Planting strong crops will help minimize the competition from wild oats. There are many herbicides available, however most are from Group 1, a group to which many wild oats populations are resistant. Therefore, planning a good herbicide rotation is key if you have wild oats.[71] Herbicide resistance is an issue with wild oats as Group 1, 2, 8, 15 and 25 resistance has developed across different parts of Western Canada with some biotypes having multiple resistance to up to four of the groups.[38]

***Yellow foxtail*** *(Setaria glauca (L.) Beauv.)*

Growth Habit

Yellow foxtail is an annual weed that reproduces by seed. Yellow foxtail prefers a warmer climate and therefore currently has restricted growth in the Prairies.[72]

Identification

This erect, tillered weed can reach 5 to 100 cm in height. The leaves are smooth, twisted and have some long wispy hairs at the base. It has a fringe of hairs that make up the ligule. The flowers occur in spikelets on a panicle covered in yellow bristles. The seeds are green to yellow to dark brown.[72]

Scouting

To scout, growers should take a minimum of 20 counts across the field.[72]

Additional Information

Where it has been identified, yield reductions of 15% have been observed.[72] There are many herbicide options available in the market.[72] Yellow foxtail populations in Manitoba have developed resistance to Group 1 and 2 herbicides.[67]

**Figure 5.24.** Yellow foxtail.
Source: Bruce Ackley, The Ohio State University, Bugwood.org

**Figure 5.25.** Volunteer barley.

***Volunteer barley*** *(Hordeum vulgare L.)*

Growth Habit

Volunteer barley is an annual weed that reproduces by seeds. It can be fairly competitive and reduce yields of other crops.[73]

Identification

This weed has many tillers with smooth stems. It has wide and smooth leaf blades and a ligule. The auricles are fairly large and almost white. It produces a spike and white to light yellow seeds.[73]

Scouting

Take 20 weed counts throughout the field. It is important to scout crops that are planted in barley stubble as infestations usually the year after the crop has been grown.[73]

Additional Information

This weed usually only has one flush, therefore delayed seeding paired with a burn-off application can provide adequate control. Otherwise, there are other herbicide options.[73]

***Volunteer wheat*** *(Triticum aestivum L.)*

Growth Habit

Volunteer wheat is an annual weed that reproduces by seeds. The seeds survive for one to three years in the soil. It can be competitive and reduce yields of other crops.[74]

Identification

Volunteer wheat has smooth erect stems that can have multiple tillers. It has a ligule as well as small auricles. The flowers occur on a spike and the lower bract of the floret may or may not have an awn. The weed produces reddish seeds that are oblong.[74]

### Scouting

Take 20 weed counts throughout the field. It is important to scout crops that are planted in wheat stubble.[74]

### Additional Information

There are some chemical control options available.[74]

**Other noteworthy weeds.**

***Canada fleabane*** *(Conyza canadensis (L.) Cronquist)*

Canada fleabane is a winter or summer annual that reproduces by seeds.  It is a strong competitor since it emerges either in August to October and overwinters or from March to May. Plants form a rosette before bolting and slightly branching to reach a height of 10 to 180 cm. The stems are hairy as well as the oval leaves with slightly toothed margins. The plant produces multiple flowers with white ray florets. The seeds have a pappus allowing them to be dispersed quite far.[75] This weed is resistant to Groups 2 and 9 and spreading quickly throughout Ontario. In the West, Canada fleabane is an increasing issue in row crops like soybean although no resistance has yet been documented.[38]

***Field horsetail*** *(Equisetum arvense L.)*

Field horsetail is a perennial weed that is problematic in soybean fields as it is a strong competitor. It reproduces by spores and with underground rhizomes. It is usually found in poorly-drained soils or sands. During the fruiting stage (early in the spring) this weed has ash-coloured stems with no branches or leaves. However, at the top there are brown cones which produce the spores. These stems die down and a second set of stems (vegetative) come up for the rest of the growing season. During the vegetative stage, it has whorls of leafless branches which are green.[76] Unfortunately, field horsetail is difficult to control as it tolerates tillage and most herbicides, including glyphosate.[76]

***Giant ragweed*** *(Ambrosia trifida)*

Giant ragweed is native to North America and the most common cause of hay fever. Plants may grow up to 1.5 m in height and produce up to one billion grains of pollen. Giant ragweed can significantly reduce soybean yields. Growers should scout and take a minimum of 20 weed counts across their field. Giant ragweed has developed glyphosate resistance in Eastern Canada and throughout the U.S.; however, it has not yet developed in Western Canada.[77]

***Northern willowherb*** *(Epilobium ciliatum Raf.)*

Northern willowherb is a perennial weed that is very adaptable and grows in a range of environmental conditions. It is becoming more common across Western Canada and is tolerant to glyphosate.[78] This weed can reach 1.2 to 1.8 m in height. Its leaves are elongated with a sharp apex, up to 15 cm in length and are dark green or reddish with deep veins. It produces pink trumpet-shaped flowers, but they can also be white.[79]

**Figure 5.26.** Volunteer wheat.

**Figure 5.27.** Canada fleabane.

**Figure 5.28.** Field horsetail.


**Figure 5.29.** (left) Giant ragweed. **Figure 5.30.** (right) Northern willowherb. Source: (right) James Atland.

**Figure 5.31.** Waterhemp.

***Waterhemp*** *(Amaranthus tuberculatus)*

Waterhemp is an annual weed that reproduces by seed. This pigweed species competes very aggressively with soybeans, causing major losses throughout the Midwest. To date, waterhemp has been identified in two fields in the Red River Valley of Manitoba. Waterhemp is sometimes confused with pigweed, however, it has smooth hairless stems and long, narrow and glossy leaves compared to pigweed which has hairy stems and egg-shaped leaves with hairs. It can grow between 1.5 to 2.5 m tall.[80] If identified, control is recommended. Waterhemp has developed resistance to Groups 2, 5, 9 and 14 herbicides in Ontario and Groups 2 and 9 in North Dakota; however, although suspected, herbicide resistance has not been documented in Western Canada to date.[38,81]

**Weed management.**

Significant improvements have been made to weed management within the last 15 to 20 years.[1] Growers can control weeds at various crop stages and through both cultural and chemical methods. Integrated weed management is most recommended and involves the combination of both cultural and chemical weed control. Long term use of this strategy helps reduce herbicide use and decrease the development of resistant weeds. Currently, the adoption rates of integrated weed management vary across Canada. It is expected that adoption will increase as economic benefits of cultural control methods are better demonstrated.

Overall, it is most critical that soybean fields are weed free until canopy closure, which usually occurs between the VE and V3/V4 growth stages (based on 15-inch row spaces).[7] Herbicides remain the most important method to ensure fields are clean until this point; however, cultural control methods such as mechanical cultivation, planting narrow rows and a high plant population can also help. Growers can mechanically cultivate via tillage, prior to planting, to disrupt emerged winter annuals or they can row-cultivate in season. Narrow rows and a higher plant population both help with earlier canopy closure, which decreases weed competition.[1]

Chemical weed control entails the application of herbicide via an on-farm sprayer. Depending on the soybean crop, growers can choose to apply herbicides pre-plant, pre-emerge, post emerge or even pre-harvest, if required. Generally, early applications are best, when weeds are less than four inches in height. Herbicides can have contact activity, systemic activity or both. Contact herbicides cause rapid dry down when they come in contact with plant tissue, whereas systemic herbicides are translocated to growing points of the plant where natural senescence occurs. Herbicides in Canada are classified according to The Weed Science Society of America (WSSA) group chemistries. Chemicals are separated by group based on their mode of action (MOA) as shown in Table 5.1. Several herbicides are created through combinations of existing groups.

| Group | Function | Outcome |
|---|---|---|
| 1 | AcetylCoA carboxylase (ACCase) inhibitors | Interferes with fatty acid creation so the plant cannot build new cell membranes needed for growth. Only effective on grasses. |
| 2 | Acetolactate synthase (ALS) and actohydroxyacid synthase (AHAS) inhibitors | Interferes with production of branched-chain amino acids, taking away building blocks needed for protein synthesis and plant growth. |
| 3 | Root growth inhibitors | Binds the tubulin protein, inhibiting cell division and stunting root growth. |
| 4, 19 | Growth regulators | Mimics the plant's natural growth hormones or inhibits their transport causing uncontrolled growth and eventual plant death. |
| 5, 6, 7 | Photosystem II inhibitors | Binds a specific protein in photosystem II, interfering with photosynthesis and plant growth. |
| 8, 15, 16 | Shoot growth inhibitors | Chemistries affect more than one plant process, including the synthesis of fatty acids and lipids, proteins, plant pigments and growth regulators (gibberellins). This prevents cell growth and division. |
| 9 | 5-enolpyruvylshikimate-3-phosphate (EPSP) synthase inhibitor | Glyphosate is the only one in this group. It inhibits the production of aromatic amino acids needed for protein synthesis and growth. |
| 10 | Glutamine synthase inhibitors | Inhibits an enzyme that converts ammonia to glutamine. Ammonia builds up to toxic levels, destroying the plant cell. |
| 12, 13, 27 | Pigment synthesis inhibitors | Inhibits the production of carotenoids needed to mop up reactive chemical compounds, leading to a bleached appearance and cell death. |
| 14, 22 | Cell membrane disrupters | Directly or indirectly causes a build-up of reactive compounds that destroy cell membranes, leading to cell leakage and plant death. |

**Table 5.1.** Herbicides by group, function and outcome.

According to Statistics Canada, herbicides account for 76% (57 million acres) of pesticides used in the Prairies and 93% of Western Canadian oilseed crops receive at least one herbicide application.[82] Despite widespread use of herbicides, considerations should be taken prior to and during herbicide application. It is important growers properly identify the weed species present in their soybean field and choose the correct product(s) that is most effective against them (Table 5.2). Further, the growth stage of the weeds is important and should influence the timing of the application to optimize efficacy. Chemicals must always be applied at the appropriate rate for the field and soil type. Remember, all herbicide products have different instructions, which are found on the label, for application timing and limitations based on soil type, moisture, pH and organic matter amount. Finally, the field history of herbicide use is important to consider since residue may build up and can affect which crops may be grown in future rotations. Consult government crop protection guides and product labels before applying any herbicide.

**Economic threshold of an application.**

The presence of weeds impacts growers economically by reducing soybean yield and decreasing crop quality. Growers must also consider the additional cost of controlling weeds via chemical treatment.[83] The economic threshold is the level at which the financial cost from yield loss, due to weed infestation, is greater than the cost of herbicide application. Whenever the economic threshold is exceeded, spraying is the most favourable option from a cost perspective. While some producers may consider this to be a decision-making formula, it is important to consider it more as a guideline. This is because the yield loss from weeds may not appear to make spraying worth it, but dockage and downgrading from weed seeds and other plant material may also impact the crop return. Applying a herbicide may be more financially favourable, at a lower economic threshold, than calculated solely from yield loss from weed competition.

| Herbicides | Resistance Group | Broadleaf Weeds | | | | | | | | | | | | | | | | | | Grassy Weeds | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Buckwheat, Wild | Canada Thistle | Chickweed | Cleavers | Cocklebur | Dandelion | Hemp-nettle | Kochia | Lamb's Quarters | Mustard, Wild | Nightshade, Hairy | Perennial Sow-thistle | Pigweed, Redroot | Russian Thistle | Shepherd's Purse | Smartweed, Annual | Stinkweed | Volunteer Canola | Barnyard Grass | Foxtail, Green | Foxtail, Yellow | Quackgrass | Volunteer Barley | Volunteer Wheat | Wild Oat |
| Authority® | 14 | • | | | S | | | | • | • | | | | • | | | | | | | | | | | | |
| Authority Supreme | 14&15 | • | | | • | | | | • | • | | | | • | | | | • | | • | • | • | | | | S |
| Basagran® Forté | 6 | | • | • | • | • | | | | • | • | • | | S | S | • | • | • | • | | | | | | | |
| Blackhawk® | 4&14 | S | | | •[12] | • | •[18] | | •[14] | •[19] | S | | | •[19] | • | • | | • | •[20] | | | | | | | |
| Clethodim | 1 | | | | | | | | | | | | | | | | | | | • | • | • | | • | • | • |
| Dicamba[10,11] | 4 | • | TG | | • | | | | | • | • | | TG | • | | | • | | | | | | | | | |
| Dual II Magnum® | 15 | | | | | | | | | | | | | •[6] | | | | | | •[6] | •[6] | •[6] | | | | |
| Edge® Granular | 3 | • | | • | S | | | S | • | • | | | | • | S | | S | | | • | • | • | | S | S | S |
| Engenia®[10] | 4 | • | TG | | • | | | | • | • | • | | TG | • | | | | | | | | | | | | |
| Fierce® | 14&15 | • | | • | | | • | | • | • | • | • | | • | | | • | | S | | • | | | | | |
| Flexstar™ GT[1,2] | 9&14 | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • | • |
| Focus® | 14&15 | | | | •[6] | | | | | S[6] | | | | •[6] | | | | •[6] | • | •[6] | •[6] | •[6] | | | | S[6] |
| Glyphosate[2,3] | 9 | • | • | • | • | • | • | • | • | • | • | | • | • | • | • | • | • | •[9] | • | • | • | • | • | • | • |
| Heat®/Heat LQ | 14 | • | | | • | | •[13] | | •[14] | • | • | | TG | • | | • | | • | •[15] | | | | | | | |
| Heat Complete | 14&15 | •[16] | | | •[16] | | •[13] | | •[14,16] | •[16] | •[16] | | TG | •[16] | | • | | •[16] | •[15,16] | | S[17] | S[17] | | | | S[17] |
| Liberty 200SN®[8] | 10 | • | S | • | | • | | | | • | • | | • | • | | • | • | • | | • | • | • | S | | | • |
| Linuron | 7 | • | | • | | | | | | | | | | • | | • | • | • | | S | S | S | | | | |
| Metribuzin + Treflan™ EC (PPI) | 5 | • | | • | | | | • | | • | • | | | • | • | • | • | • | • | • | • | • | | | | • |
| Odyssey® NXT | 2 | • | | • | • | | | • | | S | • | | | • | • | • | • | • | •[4] | • | • | | | • | •[4] | • |
| Odyssey Ultra NXT | 1&2 | • | | • | • | | | • | | S | • | | | • | • | • | • | • | •[4] | • | • | • | S | • | • | • |
| Pinnacle® | 2 | | | | | | | | | • | • | | | • | | | • | | | | | | | | | |
| Poast® Ultra | 1 | | | | | | | | | | | | | | | | | | | • | • | • | • | • | • | • |
| Pursuit® | 2 | S | | | | | | • | | | | • | | • | | | • | • | •[4] | | | | | | | S |
| Quizalofop | 1 | | | | | | | | | | | | | | | | | | | • | • | • | • | • | • | • |
| Reflex® + Basagran[1] | 6&14 | | | | | • | | | | • | • | | | S | | • | • | • | • | | | | | | | |
| Roundup Xtend®[10] | 4&9 | • | • | • | • | • | • | • | •[12] | • | • | | • | • | • | • | • | • | •[9] | • | • | • | • | • | • | • |
| Solo® ADV | 2 | S | | | S | | | | | • | • | | | • | • | • | | • | •[4] | • | • | • | | • | •[4] | • |
| Solo Ultra | 1&2 | S | | | S | | | | | • | • | | | • | • | • | | • | •[4] | • | • | • | S | • | • | •[22] |
| Trifluralin (broadleaf & grassy weeds) | 3 | •[6] | | •[6] | | | | | | •[6] | | | | •[6] | •[6] | | | | | •[6] | •[6] | •[6] | | | | •[6] |
| Ultra Blazer® | 14 | | S | | | • | | | | • | • | | | • | | | • | | | | | | | | | |
| Valtera™[5] | 14 | | | | | | | | | • | | • | | • | | | | | S | | S | | | | | |
| Viper® ADV | 2&6 | S | | | • | | | S | S | • | • | | S[21] | • | • | • | | • | • | | • | • | | • | •[4] | • |
| Zidua® SC | 15 | | | | | | | | S[23] | S[23] | | | | •[23,24] | | | | | | •[23] | •[23,24] | •[23,24] | | | | S[23] |

**Table 5.2.** Weed control in soybeans.
Source: Adapted from Saskatchewan Ministry of Agriculture, 2018, Guide to Crop Protection.

• Control. S – Suppression. TG – Top growth control.

**ALWAYS CONSULT THE HERBICIDE LABEL BEFORE APPLYING ANY HERBICIDE.**

[1] For use in the Red River Valley of Manitoba only. [2] For use on glyphosate tolerant varieties only. [3] Not all glyphosate products are registered for use on glyphosate tolerant soybeans. [4] Will not control **Clearfield**® varieties. [5] Apply in fall or spring prior to seeding of or up to 3 days after seeding. [6] Control of the following weeds emerging from seed (not controlled if emerged at application). [7] For in season activity only. [8] For use in Liberty tolerant soybeans only. [9] Will not control glyphosate tolerant varieties. [10] For use on RR Xtend soybean varieties only. [11] Not all dicamba products are registered for use on RR Xtend soybeans. [12] Including glyphosate resistant biotypes. [13] Top growth burndown control only of perennial plants, control of spring germinating plants. [14] Includes group 2-resistant and glyphosate-resistant biotypes. [15] All herbicide-tolerant canola systems including glyphosate-tolerant canola. [16] Residual suppression (may be rate dependent). [17] Residual suppression only. [18] Spring seedlings and season long suppression. [19] Including group 2 & 5 resistant biotypes. [20] Including glyphosate, glufosinte ammonium, and imidazolinone-resistant biotypes. [21] Top growth suppression only. [22] Including Group 1 resistant biotypes and Group 2 resistant biotypes. Solo Ultra will not control biotypes that are multiple-resistant. [23] Early-season residual suppression at 50 to 95 ml/ac (120 to 240 mL/ha). [24] Controlled at 101 to 200 ml/ac (250 to 493 mL/ha).

**Crop injury prevention and diagnosis.**

When the decision is made to apply a herbicide, proper application is critical to prevent crop injury. Crop response following an application is not uncommon; however, nobody wants to see their soybean crop looking overly stressed post-application. In general, pre-seed herbicide applications are recognized as a more ideal option compared to in-crop/post-emergent applications. If a post-emergent application is necessary, take a look at the following tips to reduce the likelihood of crop injury:

- Always check variety tolerances
- Avoid applying herbicides to dry soils
- Apply only at the recommended plant stage
- Do not spray when crop is stressed
- Try to spray in the evening as temperatures tend to be lower than mid-day or morning
- Use the recommended water volume or an increased water volume
- Ensure tank is well cleaned before filling with herbicide
- Follow wind speed recommendations to help prevent drift

Symptoms of herbicide injury are often confused with other issues including poor nodulation or nutrient deficiency (Figure 5.32).

**Management – avoiding resistance.**

Herbicide resistance is defined as the inherited ability of a plant to survive and reproduce following application of a normally lethal herbicide.[83] The original, common form of the weed that is susceptible to the herbicide is known as the wild type. Alternatively, the herbicide-resistant form of the weed is known as the resistant biotype.[1]

The risk of resistance is dependent on the selection pressure intensity, influenced mainly by two factors: the weed genetics and the herbicide selection pressure. Weed genetics factors that increase the selection pressure intensity include intense seed production, effective seed dispersal, wide genetic diversity, dense populations and annual growth. Herbicide selection pressure factors include efficacy, frequency of application and soil persistence.[84]

**Figure 5.32.** Soybean crop injury due to stress caused by improper herbicide application.
Source: Kristen MacMillan, University of Manitoba.

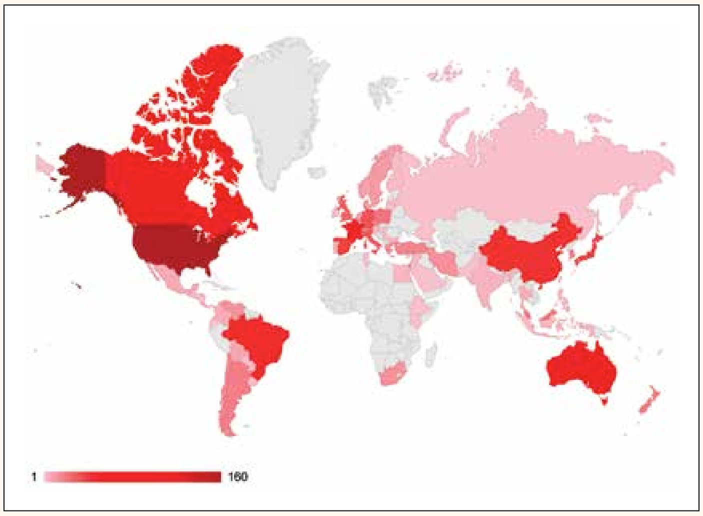



**Figure 5.33.** Canada has the third highest number of resistant weeds in the world.
Source: Heap, I., 2017. The International Survey of Herbicide Resistant Weeds, WeedScience.org

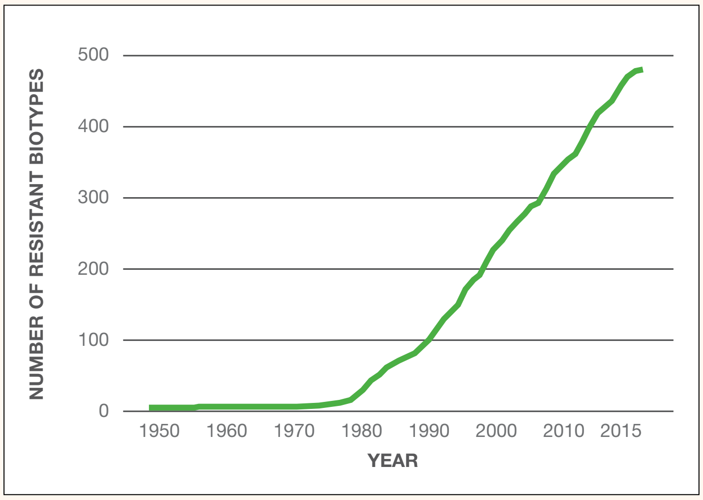



**Figure 5.34.** Increase of resistant weeds globally.
Source: Heap.I., 2017. Chronological increase in resistant weeds globally, WeedScience.org.

An integrated weed management approach is always recommended. Rotation of crops and seed systems is key to delay and manage resistance. When considering herbicide application on a field, it is recommended to delay the development of resistance by implementing a one-in-three-year herbicide rotation. Remember that if herbicide applications are avoided in a particular season, it provides a greater variety of active ingredients to choose from the following season. However, deciding not to spray because weed pressure is low only increases the severity of the problem the next year. This is because the weeds present are able to set and disperse seed, essentially multiplying the potential number of weeds for the following season.

**Integrate this into your approach.**

With more resistant biotypes appearing every year, an effective management strategy integrates herbicidal control with different agronomic practices to help your crop outcompete the weeds. By using several different techniques, weeds are less likely to adapt and grow beyond our control.

*Outcompete the weeds.*

Seed at higher rates and in narrow rows to help shade out the weeds. Faster canopy closure may mean just one herbicide pass, rather than two. Use an effective burndown to start with clean fields.

*Vary seeding dates.*

Seeding early helps outcompete weeds that benefit from more growing degree days, such as green foxtail, lamb's quarters and kochia. But cool-season weeds, such as wild oats and stinkweed may require delayed seeding for more effective herbicidal control.[85]

*Use clean equipment.*

This will help prevent the transfer of resistant weeds from one field to the next.

| Resistant Weed | Herbicide Group |
|---|---|
| Ball mustard | 2 |
| Barnyard grass | 2 |
| Chickweed | 2 |
| Cleavers | 2<br>Combinations of 2 & 4 |
| Cow cockle | 2 |
| Green foxtail | 1<br>2<br>3<br>Combinations of 1 & 2<br>Combinations of 1 & 3 |
| Hemp-nettle | 2<br>4 |
| Kochia | 2<br>Combinations of 2 & 9<br>Combinations of 2 & 4<br>Combinations of 2,4 & 9 |
| Lamb's quarters | 2 |
| Narrow-leaved hawk's beard | 2 |
| Persian darnel | 1 |
| Powell amaranth | 2 |
| Redroot pigweed | 2 |
| Russian thistle | 2 |
| Shepherd's purse | 2 |
| Smartweed | 2 |
| Spiny annual sowthistle | 2 |
| Stinkweed | 2 |
| Wild buckwheat | 2 |
| Wild mustard | 2<br>4<br>5 |
| Wild oat | 1<br>2<br>8<br>Combinations of 1, 2 & 8<br>Combinations of 1, 2 & 25<br>Combinations of 1, 2, 8 & 25<br>Combinations of 1, 2, 8 & 15 |
| Yellow foxtail | 1<br>2<br>Combinations of 1 & 2 |

**Table 5.3.** Herbicide-resistant weeds in Western Canada.
Source: Heap, I., 2018. Status of herbicide resistance in Canada. WeedScience.org.

*Fertility.*

Compared to broadcast, banded nitrogen fertilizer is less available to weed seedlings.[85] Ensure adequate levels of essential nutrients to encourage a competitive stand (see pg. 21 for more).

*Insect and disease management.*

Seed treatments can help reduce the impact of insects, as well as seed- and soil-borne diseases.

*Rotate crop types with modes of action.*

Include a variety of different crop types, such as cereals, pulses and forage crops to switch up your herbicide chemistry and the weeds controlled.

*Apply at full label rates.*

A common pitfall, applying herbicides at reduced rates increases the chances of weeds survival and in turn, increases the risk of resistance. Apply at correct timings and with correct water volumes.

*Use multiple modes of action (MOA) and rotate them.*

Rotate into different MOA both within and between seasons. Rotating within a season helps control weeds that escaped burndown and manage them before they set seed. Use active ingredients with overlapping activity to avoid placing selection pressure on a single chemistry.

Not all herbicides are suitable for all crops. The more resistance develops, the fewer options we have for cropping and weed control. If resistance isn't kept in check, our need for multiple chemistries will only grow and potentially lead to higher costs.

*Scout and keep records.*

It is also important to properly scout for weeds both pre- and post-herbicide application. This allows for response time to changing weed populations and management options prior to weed seed set. Finally, keep sound records of weeds identified and all herbicides used.

Once present, herbicide-resistant weeds are hard to control, so it is important to have a management plan. If you suspect the development of herbicide-resistant weeds, please reference the checklist below.

Checklist for growers who suspect they have resistant weeds:

- [ ] Herbicide controlled other weeds on the label
- [ ] Discreet patches of weed in question
- [ ] Dead plants next to live ones of the same species
- [ ] Same MOA used at this site for greater than five years
- [ ] This weed was effectively controlled in the past with this chemical
- [ ] Same herbicide, or same MOA, failed in the same area the previous year

**Submission facilities for samples of weeds, diseased plant tissue or insects.**

**Ag Quest**

210 South Railway Street, Minto, MB  R0K 1M0
Telephone: 204-776-2087

Elm Creek Co-op
43 Church Avenue, Elm Creek, MB  R0G 0N0
Telephone: 204-436-3080

Highway 14, Saskatoon, SK  S7K 3J5
Telephone: 306-384-1117

5809 54th Avenue, Taber, AB  T1G 1X4
Telephone: 403-223-4626

Website: https://agquest.com/services

**Pest Surveillance Initiative (PSI)**

Offers a PCR genetic test for glyphosate-resistant kochia. This lab also delivers in-season results.
5A-1325 Markham Road, Winnipeg, MB  R3T 4J6
Telephone: 204-813-2171
Email: info@mbpestlab.ca
Website: www.mbpestlab.ca/

**Saskatchewan – Provincial Lab**

Crop Protection Laboratory
346 McDonald Street, Regina, SK  S4N 6P6
Telephone: 306-787-8130
Website: http://www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/programs-and-services/crops-programs/crop-protection-laboratory-services

**Others**

University of Guelph, Pest Diagnostic Clinic
95 Stone Road West, Guelph, ON  N1H8J7
Telephone: 519-767-6299
Email: aflinfo@uoguelph.ca
Website: www.guelphlabservices.com

Pest samples should be sent to the University of Guelph when growers suspect they have found a suspected resistant weed known to exist in Ontario. (Ex. common ragweed, giant ragweed, Canada fleabane and waterhemp). Such submissions can be submitted through Manitoba Agriculture and/or the University of Manitoba.

# Chapter 6 – Disease identification and management.

## What is a disease?

Plant diseases are one of the major causes of crop losses around the world, resulting in billions of dollars in losses annually. This makes it vital for growers to control economically important plant diseases. A plant disease is defined as abnormal growth and/or dysfunction of a plant, resulting from a disturbance in normal life processes. Pathogens are living organisms like fungi, bacteria and viruses that cause disease. Plant diseases are identified based on the symptoms of the disease or the response of the host plant to the pathogen. Symptoms include lesions, necrosis or dead plant tissue, blocked nutrient and water transport vessels, mutated reproductive structures and chlorosis or yellowing of the plant. When diagnosing a disease, growers can also look for the presence of the pathogen in the form of fungal vegetative structures called mycelium and hyphae or spores and bacterial ooze.

A complete disease triangle is required for disease to develop. This includes: a susceptible host (soybean plant), a pathogen (disease) and favourable environmental conditions as shown in Figure 6.1.

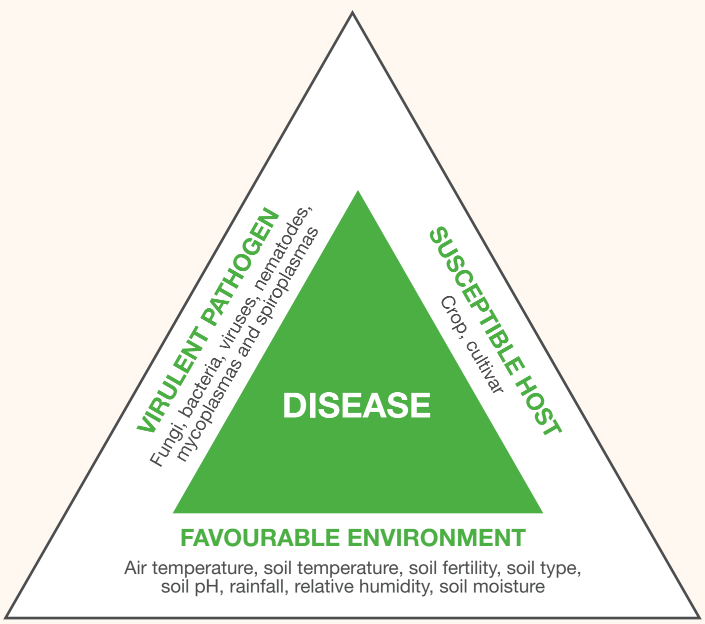



**Figure 6.1.** Plant disease triangle.
Source: Krupinsky, J.M., Bailey, K.L., McMullen, M.P., Gossen, B.D., and Turkington, T.K. 2002. Managing plant disease risk in diversified cropping systems. Agronomy Journal, VOL. 94.

Growers can predict disease potential by evaluating field history (cropping and diseases), soil moisture, organic matter and plant genetics.[1] Environmental stressors, such as extreme temperatures, excess moisture, hail/wind damage, fertility issues and pests, also make soybeans more susceptible to disease infection.

**Key diseases – root and stem.**

***Fusarium root rot*** *(Fusarium spp.)*

Current spread in Western Canada

- All provinces[86]

Conditions it thrives in

- Warm and dry

Infection symptoms

- Poor or delayed emergence and pre- or post-emergent damping off.[87] If severe, upper plant leaves may wilt, whereas lower and middle leaves may yellow. Roots of an infected plant will be stunted and appear purple and/or brown.[88]

**Figure 6.2.** Impact of fusarium root rot on crop.
Source: Daren Mueller, Iowa State University, Bugwood.org

When to look for it

- Emergence to R6, paying attention to soybean roots[88]

Management solutions

- Seed treatments[87]

***Rhizoctonia root rot*** *(Rhizoctonia spp.)*

Current spread in Western Canada

- All provinces[86]

Conditions it thrives in

- Wet periods followed by warm and dry conditions[89]

**Figure 6.3.** Young plants killed by *Rhizoctonia solani*.
Source: Dean Malvick, University of Minnesota.

Infection symptoms

- Pre- or post-emergent damping off and plants have reddish-brown, dry stem lesions.[88] The infection may affect single plants or patches of the field. Although rhizoctonia requires wet soil for infection, symptoms may become more apparent in dry soil conditions.

When to look for it

- Emergence to R1, paying attention to areas of the field with poor emergence

Management solutions

- Seed treatments[87]

***Pythium root rot*** *(Pythium spp.)*

Current spread in Western Canada

- All provinces[86]

Conditions it thrives in

- Cool and moist[88]

Infection symptoms

- Infected seeds appear rotten, whereas seedlings have pre- and post- emergent blight and damping off.[87] Older seedlings may yellow and wilt.[88] Pythium may infect single soybean plants or be found in patches. Diagnosis is often challenging, and growers may need to send samples to a lab for confirmation.[87]

**Figure 6.4.** Pythium infected soybean seedlings.
Source: Martin Chilvers, Michigan State University.

### When to look for it

- Emergence to V2, especially in low areas of the field[88]

### Management solutions

- Growers should plant early and use seed treatments containing metalaxyl[87]

***Phytophthora root and stem rot*** *(Phytophthora sojae)*

### Current spread in Western Canada

- Manitoba[86]

### Conditions it thrives in

- Warm, wet and in compacted soils[88]

### Infection symptoms

- Pre- or post-emergent damping off.[88] Stems may appear water soaked, with characteristic brown lesions extending up the outer stem from the soil surface that may cause girdling. Inner stems may or may not appear brown in colour. Eventually, if infection is severe, plants wilt and may die.[87]

**Figure 6.5.** Soybeans infected with phytophthora.
Source: Daren Mueller, Iowa State University, Bugwood.org

### When to look for it

- Emergence to R6, especially following a heavy rainfall.[88] Phytophthora can infect a soybean plant at any growth stage.[87]

### Management solutions

- Plant a tolerant cultivar, rotate crops, and reduce soil compaction.[90] Use of a seed treatment can prevent early infection.[87]

**Key diseases – stem and pod.**

***Stem and pod blight*** *(Diaporthe phaseolorum)*

### Current spread in Western Canada

- Manitoba[86, 87]

### Conditions it thrives in

- Warm, wet and humid[86, 87]

**Figure 6.6.** (top left) Linear rows of pycnidia on soybean stem indicative of pod and stem blight. Source: Daren Mueller, Iowa State University.
**Figure 6.7.** (top right) Pycnidia on soybean pods indicate infection by the pod and stem blight fungus. Source: Alison Robertson, Iowa State University.
**Figure 6.8.** (bottom left) White chalky mold on soybean seeds may indicate Phomopsis seed decay. Source: Albert Tenuta, OMAFRA.
**Figure 6.9.** (bottom right) Stems affected by pod and stem blight showing visible black streaks or lines. Source: Daren Mueller, Iowa State University.

### Infection symptoms

- Disease complex that includes stem cankers as well as pod and stem blight. Infection may occur early and can be asymptomatic or it can cause delayed or reduced germination.[88] Soybean plants eventually develop linear rows of black pycnidia along the stem.[87] Seed decay is also possible but not common in Western Canada. Infected seeds may appear normal or develop cracks and turn white.[88] Due to the range of visible symptoms, laboratory diagnosis may be required.[87]

### When to look for it

- R1 to R7 (extensive infection will occur as seeds mature)[91]

### Management solutions

- Stem and pod blight may overwinter on seeds, residue and soil.[87] Use clean, high-quality seed.

**_White mold/Sclerotinia stem rot_** *(Sclerotinia sclerotiorum)*

### Current spread in Western Canada

- All provinces[86]

### Conditions it thrives in

- Cool, wet and humid

### Infection symptoms

- Symptoms begin with apothecia, which are small, mushroom-like growths in the soil. They produce spores that, in turn, infect the flowers of soybean plants.[87] Infected seeds are small, light in colour and may have visible white fungal growth.[87] The white fluffy growth and black overwintering structures known as sclerotia help distinguish sclerotinia from other diseases.

### When to look for it

- At canopy closure usually in July and August[89]

### Management solutions

- Crop rotation is not an effective management option because sclerotinia affects a range of broadleaf crops including canola, dry beans, lentils and sunflowers. Growers should manage it through properly timed (R1.5 to R3) foliar fungicides.[87]

**Figure 6.10.** (left) Soybean plants infected with white mold.
**Figure 6.11.** (right) Apothecia causing sclerotinia stem rot.
Source: (right) Canola Council of Canada.

### Factors that affect the risk of white mold

Multiple factors can affect the risk of white mold and should also be considered when deciding how to control it. Wider rows can reduce white mold incidence; maximize distance between plants when considering row spacing. Sclerotia left on the surface deteriorate much faster than if they are buried in the soil. Conventional tillage systems incorporate sclerotia deeper into the soil, aiding survival for two to three years. This increases the chance of white mold when compared to no-till systems. Manure and over-fertilizing lead to dense canopies which further creates conditions conducive for infection.

**_Anthracnose_** *(Collectotrichtum truncatum)*

### Current spread in Western Canada

- Uncommon in Western Canada[86,87]

### Conditions it thrives in

- Warm and moist

### Infection symptoms

- Anthracnose symptoms occur on leaves, stems and pods. Infected leaves develop reddish veins, rolling and defoliation. Stems and pods develop brown lesions. As the plant matures, black spots develop.[88] Unlike stem and pod blight, the black spots along the stem caused by anthracnose are not arranged in linear rows but occur randomly. Infected seeds may or may not show symptoms.

### When to look for it

- Early in the season as it may only impact yield if infection occurs at the beginning of the season[86,87]

**Figure 6.12.** (left) Anthracnose-infected soybean stem. Source: Clemson University – USDA Cooperative Extension Slide Series, Bugwood.org
**Figure 6.13.** (right) Soybean plants lodging due to anthracnose infection. Source: Daren Mueller, Iowa State University, Bugwood.org

### Management solutions

- Rotate crops, use tillage and apply registered foliar fungicides preventatively[87]

**Key diseases – leaf.**

***Bacterial blight*** *(Pseudomonas savastonoi)*

### Current spread in Western Canada

- All provinces[86]

### Conditions it thrives in

- Cool and wet and will not grow if temperatures are high[88]

### Infection symptoms

- Bacterial blight is often the first disease to develop; however, early season symptoms are difficult to distinguish.[87] It is often first observed in the upper canopy where leaves develop lesions with reddish-brown centres and yellow halos.[88] These angular lesions eventually grow together and dead tissue may fall out. Eventually, symptoms may also occur on the stems, petioles and pods.[87] Although bacterial blight is common, it rarely causes yield loss.

**Figure 6.14.** Bacterial blight lesions on soybean leaves.
Source: Dean Malvick, University of Minnesota.

### When to look for it

- Soybeans may become infected any time after VE.[89] However, symptoms may not become apparent until V2 through to V6.[88]

### Management solutions

- The pathogen survives on residue on seed. Crop rotation and tillage practices should be used to manage it. Avoid in-crop operations when foliage is wet.

***Septoria brown spot*** *(Septoria glycines)*

### Current spread in Western Canada

- All provinces[87]

### Conditions it thrives in

- Warm and wet

### Infection symptoms

- The infection develops soon after planting and throughout the growing season. During the vegetative growth stages, the symptoms of septoria brown spot are typically mild and may progress up the canopy during pod fill. Symptoms include small, purple or brown lesions on the unifoliate leaves of young plants. These lesions may grow together, resulting in large blotches. Leaves infected by septoria quickly turn yellow and drop.

### When to look for it

- When the trifoliate leaves appear[89]

### Management solutions

- Septoria brown spot does not generally cause yield reduction in Western Canada. The fungus survives on residue and inoculum spreads to healthy plants by wind and rain. Crop rotation and conservation tillage practices should be used to manage it.

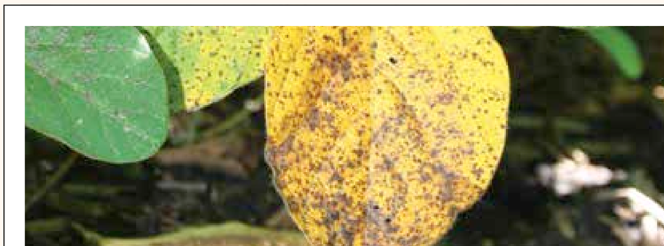


**Figure 6.15.** Septoria brown spot.
Source: Daren Mueller, Iowa State University, Bugwood.org

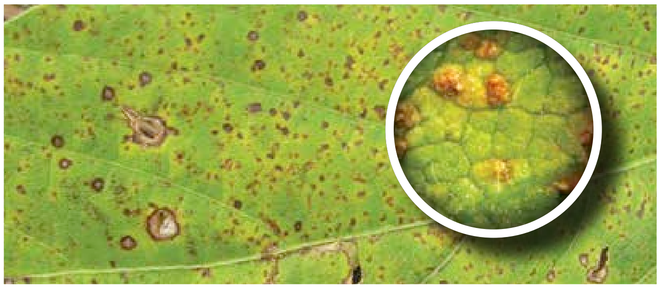


**Figure 6.16.** Asian soybean rust. Close-up of Asian soybean rust (inset).
Source: Dean Malvick, University of Minnesota.

***Asian soybean rust*** *(Phakopsora pachyrhizi)*

Current spread in Western Canada

- Has not been identified to date in Western Canada[86,87]

Conditions it thrives in

- Cool and moist[7]

Infection symptoms

- Symptomatic lesions first appear in the lower canopy and are small, tan or brown and are located on the underside of leaves.[88] Yield loss is most severe if infection occurs during pod formation since it can negatively affect both pod number and seed size.

When to look for it

- At any stage of development[87]

Management solutions

- If management is required, foliar fungicides can control the disease[87]

***Cercospora leaf spot*** *(Cercospora kikuchii).*

Current spread in Western Canada

- Uncommon in Western Canada[86,87]

Conditions it thrives in

- Warm and wet[88]

Infection symptoms

- While cercospora infects soybean fields early, there are no symptoms until seed set.[87] Foliar symptoms first appear at the top of the canopy with purple discolouration and bronze highlights.[88] Eventually, if the infection becomes severe, soybean plants may lose their leaves entirely.[87]

**Figure 6.17.** Soybean plant exhibiting symptoms of cercospora leaf spot.
Source: Daren Mueller, Iowa State University, Bugwood.org

When to look for it

- R3 to R6[88]

Management solutions

- Foliar fungicides are available to manage it.[87] It is best to apply fungicides preventatively since control is limited once disease symptoms are already visible.

***Downy mildew*** *(Peronospora manshurica)*

Current spread in Western Canada

- All provinces[86,87]

Conditions it thrives in

- Warm and humid

Infection symptoms

- Downy mildew is often widespread throughout the field. Leaves develop light green or yellow lesions on the upper surfaces and grey fungal growth on the lower surfaces.[88] Infected pods are asymptomatic; however, seeds may be covered in fungal mycelium.[87] It rarely results in soybean yield loss but, if severe, can cause seed quality loss.[86,87]

**Figure 6.18.** Downy mildew on leaf surface.
Source: Daren Mueller, Iowa State University, Bugwood.org

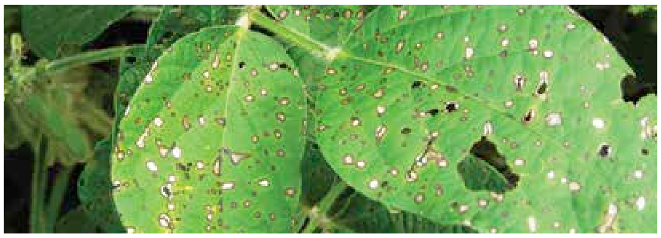


**Figure 6.19.** Frogeye leaf spot.
Source: BASF USA, 2015, Soybean Production Training Module.

### When to look for it

- R3 to R6[88]

### Management solutions

- Use crop rotation and tillage[87]

***Frogeye leaf spot*** *(Cercospora sojina)*

### Current spread in Western Canada

- Uncommon in Western Canada but is becoming more prevalent[86]

### Conditions it thrives in

- Warm and wet[88]

### Infection symptoms

- Lesions appear small, round and grey with brown-purple halos that first appear on upper plant leaves. If infections are severe, lesions also appear on stems and pods.[87] Soybean plants are most susceptible when very young or maturing.

### When to look for it

- R1 to R6, especially following heavy rain[87,88]

### Management solutions

- Use crop rotation, tillage and foliar fungicides.[87] It's best to apply fungicides preventatively since control is limited once disease symptoms are already visible.

**Key diseases – other.**

***Soybean cyst nematode (SCN)*** *(Heterodera glycines)*

### Current spread in Western Canada

- Present in Ontario and at the northern border of North Dakota but has not yet been identified in Western Canada.[86] As a result, the University of Manitoba conducts annual surveys to monitor spread.

### Conditions it thrives in

- Dry and in lighter soils[89]

### Infection symptoms

- Plant symptoms may not appear for several years following initial infestation. Initial symptoms, once they occur, may include uneven plant growth, delayed canopy closure and early maturing plants.[87] If infection is severe, plants may be yellow and stunted. It often infects high-yielding fields because the same conditions that favour soybean growth also favour soybean cyst nematode.[88]

### When to look for it

- Six weeks after planting until harvest time, looking specifically for white females on the roots[88]

### Management solutions

- Once present, plant resistant cultivars and use seed treatments to protect seedlings early in the season[87]

**Figure 6.20.** Soybean cyst nematode infestation on soybean roots. The cysts are much smaller than nodules but still visible to the unaided eye. Source: Penn State Department of Plant Pathology & Environmental Microbiology Archives, Penn State University, Bugwood.org.

**Figure 6.21.** Soybeans infected with sudden death syndrome.
Source: Daren Mueller, Iowa State University.

## FUNGICIDE APPLICATION EVALUATION FACTORS.

Inspect at least 10 locations in your soybean crop at R1.

### Disease Potential

- Frequency of host crops in rotation
- Presence of host crop residue
- Disease incidence in the previous growing season
- Single or multiple infection periods
- Proximity to other host crops or weeds
- Dense, early row closure
- Part of plant affected by the disease (i.e. stem diseases causing lodging, foliar diseases reducing photosynthetic potential, flower diseases affecting yield and quality)

### Weather Potential

- Frequency of rain during the last 10 to 14 days
- Potential for rainfall in next 10 to 14 days
- Heavy dews
- High humidity
- Moisture inside the canopy
- Wind
- Moderate temperatures

### Yield Potential

- Soybeans with potential of 30 bu/ac or more
- Varieties with commodity prices
- Susceptible or tolerant varieties

**Figure 6.22.** Evaluation factors for applying a fungicide.

***Sudden death syndrome (SDS)*** *(Fusarium solani)*

Current spread in Western Canada

- Not yet found in Western Canada[86]

Conditions it thrives in

- Cool, wet and compact soils. It is often found in fields with soybean cyst nematode.[88]

Infection symptoms

- After flowering, leaves develop yellow spots in between green veins, eventually leading to defoliation. Stems may also appear brown.[88] Once introduced, the pathogen may survive on crop residue or in the soil for several years.[87]

When to look for it

- R1 to R6, looking for patches within the field

Management solutions

- Plant a tolerant cultivar, improve drainage in affected area and delay planting[89]

**Disease control.**

Making informed disease management decisions is important to prevent yield loss. Disease management does not always involve crop protection products. Management should also include the use of resistant soybean varieties, high quality seed, residue management and comprehensive scouting[1] as well as crop rotation with non-host crops. When chemicals are required, see Figure 6.22 to determine if a fungicide application is economically beneficial. It is also recommended that growers consult an agronomic professional when making disease management decisions.

**Registered fungicides.**

Soybean diseases may be controlled using fungicides, including seed treatments or foliar applications.[1] Seed treatments are recommended when soybeans are planted early and conditions are conducive to disease, when there is lots of crop residue, if the field history is unknown, if the seeds are poor quality or if humidity is high.[1] There are many seed treatments and foliar treatment products available for growers as listed in Tables 6.1 and 6.2.

The most commonly used fungicide Groups to control disease in soybeans in Western Canada are Groups 3, 7, and 11.[92] Each Group uses a different mode of action to control targeted diseases. Group 3 fungicides are also known as demethylation inhibitors (DMI-fungicides) and make use of the triazole, imidazole and pyrimidine chemical groups that target sterol biosynthesis, an integral membrane constituent in fungi. Group 7 fungicides are better known as succinate dehydrogenase inhibitors (SDHIs) that target Complex II in the cellular respiration of fungi using carboxamides. Group 11 fungicides, or quinone outside inhibitors (QoI-fungicides), target Complex III in the cellular respiration of fungi at its outer binding site using a number of different chemical groups.[93]

Though fungicides work best as a preventative measure, some Group 3 fungicides are labelled as curative. Despite their name, curative fungicides will not cure a plant of the disease and are not effective against advanced disease cycles. A curative fungicide stops early growth of the pathogen after infection has occurred. These fungicides are also effective when employed as a preventative measure. Preventative fungicides work by protecting the potential sites of infection on the plant from initial infection from the pathogen. Preventative applications can also be used post-infection to control further pathogen infection of the plant.[94]

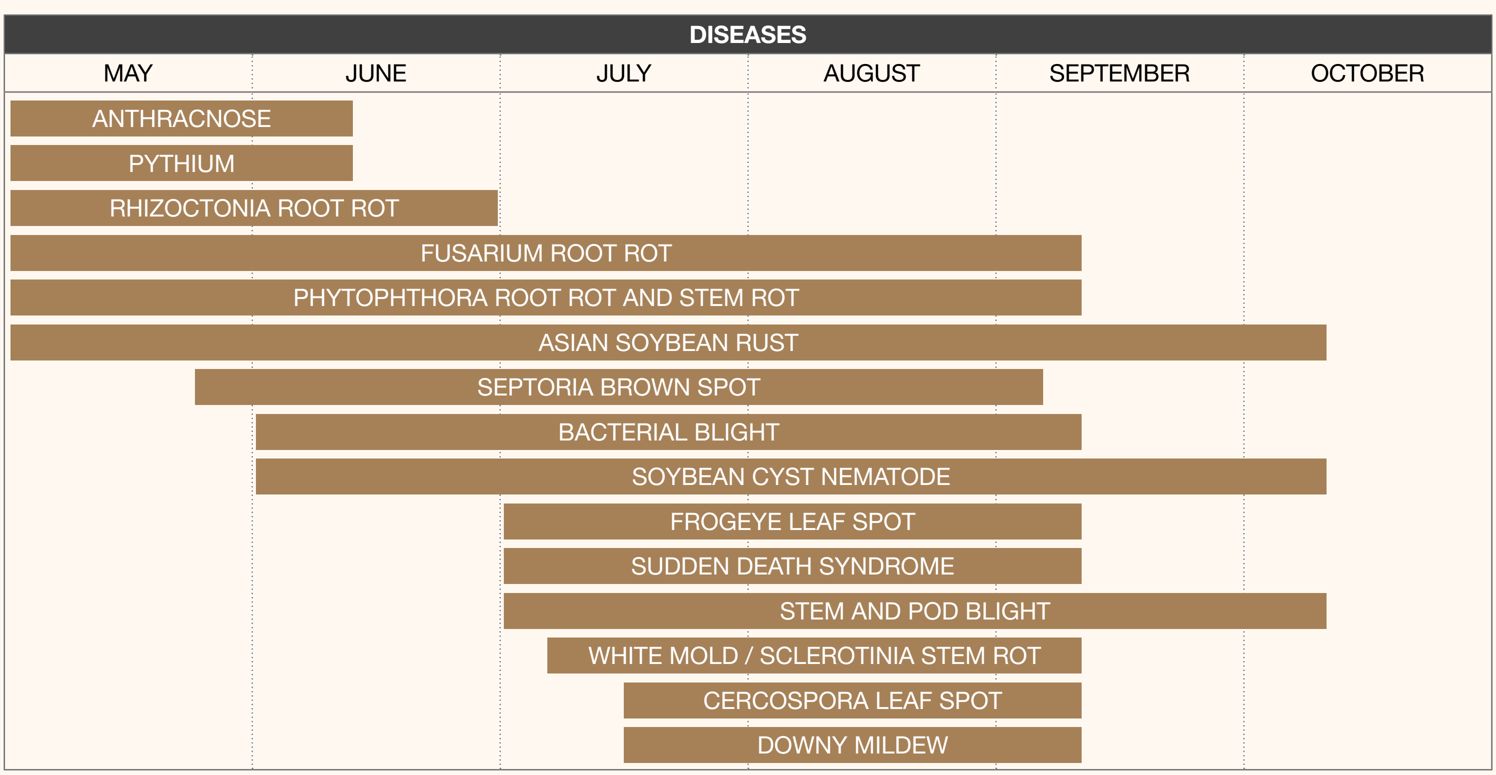



**Figure 6.23.** Soybean diseases scouting calendar for the Prairies.
Source: Adapted from Manitoba Pulse & Soybean Growers.

| Seed Treatments | Group | Diseases | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | General Seed/Root/Seedling Rots/Blights | Ascochyta blight (*Ascochyta* spp.) | *Botrytis* spp. (seed- and/or soil-borne) | *Fusarium* spp. (seed- and/or soil-borne) | *Phomopsis* spp. (seed- or soil-borne) | *Phytophthora* spp. (soil-borne) | *Pythium* spp. (soil-borne) | *Rhizoctonia solani* (soil-borne) | White mold (*Sclerotinia sclerotiorum*) |
| Agrox® FL | M4 | •[1] | | | | | | | | |
| Allegiance™ FL | 4 | | | | | | • | • | | |
| Belmont™ 2.7 FS | 4 | | | | | | • | • | | |
| Cruiser® 5FS | 4 | | | | | | | | | |
| Cruiser Maxx® Vibrance® Beans | 4, 7, 12 | | | | • | • | • | • | • | |
| EverGol® Energy | 3, 4, 7 | | | • | • | • | | • | • | |
| Heads Up® Plant Protectant | N/A | | | | | | | | • | • |
| Insure® Pulse | 4, 7, 11 | | • | •[2] | • | | | • | • | |
| INTEGO™ Solo Fungicide | 22 | | | | | | •[2] | • | | |
| Thiram 75WP | M3 | •[1] | | | | | | | | |
| Trilex® AL | 4, 11 | | | | • | • | | • | • | |
| Vibrance 500FS | 7 | | | | | | | | • | |
| Vibrance Maxx RFC/RTA | 4, 7, 12 | | | | • | • | • | • | • | |
| Vibrance Maxx RFC with INTEGO Seed Treatment | 4, 7, 12, 22 | | | | • | • | • | • | • | |
| Vitaflo® Brands | 7, M3 | | | | • | • | | | • | |

**Table 6.1.** Seed treatment products for soybeans.

**ALWAYS CONSULT THE SEED TREATMENT LABEL BEFORE APPLYING ANY SEED TREATMENT.**

Source: Adapted from Manitoba Agriculture, 2018, Guide to Field Crop Protection.

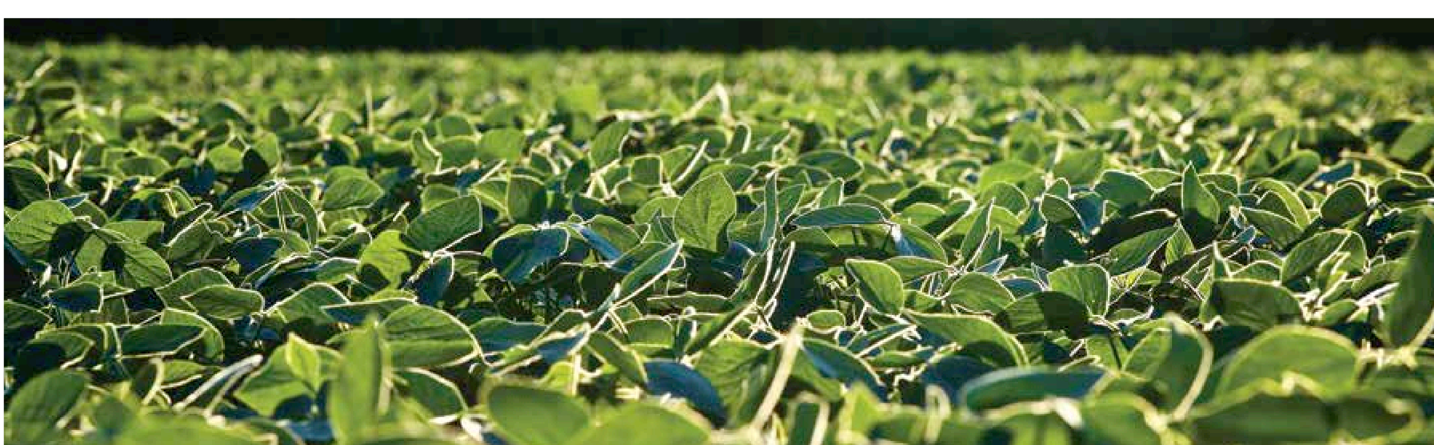
[1] Product does not specify causal pathogen.
[2] Suppression only.
[3] Multiple modes of action.

| Fungicides | Group | Diseases | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Stem and pod blight (*Diaporthe* spp./*Phomopsis*) | Anthracnose (*Colletotrichum truncatum*) | Septoria Brown Spot (*Septoria glycines*) | Cercospora Leaf Spot (*Cercospora kikuchii*) | Powdery Mildew (*Microsphaera diffusa*) | White mold (*Sclerotinia sclerotiorum*) | Frogeye leaf spot (*Cercospora sojina*) |
| Acapela® | 11 | | | • | | | •[2] | • |
| Allegro® 500F | 29 | | | | | | • | |
| Azoshy 250 SC | 11 | | • | | • | • | | |
| Cotegra® | 3,7[3] | | | •[2] | | | •[2] | • |
| Cueva® | M1 | | | | | • | | |
| Delaro® | 3,11[3] | • | | • | | | •[2] | • |
| Double Nickel™ LC/Double Nickel 55 | 44 | | | | | | •[2] | |
| Elatus™ | 7,11[3] | • | | • | | • | | • |
| Fullback™ 125SC | 3 | | | • | • | | | • |
| Priaxor® | 7,11[3] | | | • | | | •[2] | |
| Propel® | 3 | | | | • | • | | • |
| Propi Super 25 EC | 3 | | | | • | • | | • |
| Quadris® | 11 | | • | | • | •[2] | | |
| Quilt® | 3,11[3] | | • | | | •[2] | | • |
| Serenade® CPB | 44 | | | •[2] | | | •[2] | •[2] |
| Serenade OPTI | 44 | | | •[2] | | | •[2] | •[2] |
| Stratego PRO® | 3,11[3] | • | | • | | | •[2] | • |
| Tilt® 250E | 3 | | | | • | • | | • |
| Trivapro™ | 3,7,11[3] | •[2] | • | • | | • | •[2] | • |
| Vertisan® | 7 | | | • | •[2] | | | •[2] |

**Table 6.2.** Foliar fungicides for disease control in soybeans.

**ALWAYS CONSULT THE FUNGICIDE LABEL BEFORE APPLYING ANY FUNGICIDE.**

Source: Adapted from Manitoba Agriculture, 2018, Guide to Field Crop Protection.



**Fungicide application.**

When conditions for disease are present, a preventative fungicide application is the best option. Growers should then monitor for diseases that occur later in the season, including white mold. There are some tips growers can use to make their fungicide applications more effective:

1. Using higher water volumes (minimum of 10-20 gallons per acre [gpa]) is recommended for ground application for foliar diseases. For aerial application, a minimum of 5 gpa of water is recommended. For diseases that impact the lower parts of the plant and are not easily visible from the tip of the canopy, higher water volumes are recommended (15-20 gpa) to increase the likelihood of the fungicide reaching the lower canopy. High water volumes have the greatest impact on fungicide efficacy, over both droplet size and application pressure.

2. In ideal spraying conditions, nozzles with fine droplets provide the best coverage, especially in dense canopies. Fine droplets can be generated with either high pressure or fine nozzle tips and are good for foliar diseases. However, finer droplets easily drift in the wind and can evaporate quickly. Research from North Dakota State University shows that a fine to medium spray quality is best for white mold in soybeans, allowing for both adequate coverage and canopy penetration to reach the flowers along the stem.[90] In less than ideal conditions, medium to coarse droplets at high water volumes can provide good coverage, especially since leaves can catch a range of droplet sizes.

3. Slower application speeds of around 10 miles per hour (mph) are also advantageous for application, if possible.

**Resistance management and stewardship.**

Fungicide resistance occurs when a fungal population shows decreased or limited sensitivity to a fungicide. In other words, the fungicide has little to no effect on a resistant population at the same concentration that would inhibit a sensitive population. Resistant characteristics occur naturally at very low frequencies in fungi. However, these characteristics in fungal populations can be selected for through repeated use of the same products or products with the same mode of action. It is the repeated use of the same fungicide or the same mode of action that increases the frequency of these resistant characteristics and leads to the development of resistance.

It is important to remember that fungicides don't create resistant fungus; they select for the fungus with resistant characteristics. This change occurs via two types of resistance:

1. The first occurs when low levels of fungicide resistance are naturally present in the population without any noticeable loss of fungicide efficacy. This is sometimes referred to as shifting resistance where the population is shifting toward resistance, but not all individuals are resistant yet.

2. The second type of resistance is called practical resistance. This occurs over time as the resistant populations become dominant. A rapid loss of efficacy is observed due to significant changes in the population dynamics, ultimately leading to economic damage.

Resistance is a reality for all target site-specific fungicides, some of which are at greater risk than others. Site-specific fungicides comprise the vast majority of the products on the market and include, but are not limited to, Group 3 (triazoles), Group 7 (SDHI) and Group 11 (strobilurins). Even though most fungicides are site-specific, generally there is only resistance to Group 11 fungicides and no resistant biotypes have been found in soybeans in Canada. For successful resistance management, it is necessary to reduce fungicidal pressure on the disease.

Growers have several strategies they can use to mitigate the risk of resistance:

1. Fungicide management strategies.
   - Rotate fungicides with different modes of effective action or use tank mixes combining multiple modes of effective action on the target disease
   - Apply fungicides only when necessary
   - Ensure applications are timed properly
   - Apply preventatively so disease pressure remains low
   - Always apply the labelled rate of fungicide
   - Maximize spray coverage by adjusting application methods

2. Cultural management strategies.
   - Plant disease-resistant varieties
   - Use clean seed and seed treatments to manage seed- and soil-borne diseases
   - Rotate to non-host crops
   - Avoid over-fertilization – extremely lush canopies can encourage disease development

3. Resistance monitoring.

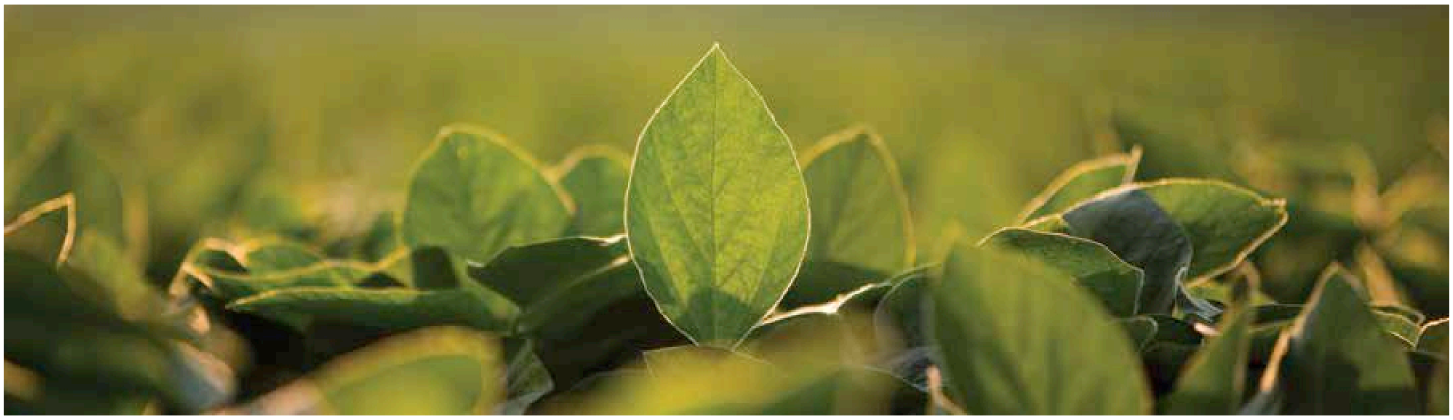
As part of product stewardship and risk management, monitoring for resistance is necessary to:

- Determine the sensitivity of pathogen populations to fungicides
- Monitor fungicide performance after introduction
- Evaluate the effectiveness of resistance strategies and provide information for the development of new ones
- Test isolate sensitivity in cases of reduced performance and take to an accredited lab or Ag Canada facility where resistance isolate monitoring can be completed. Consult a Provincial Specialist or an agronomist on the best methods to collect and store samples
- Confirm the development of practical resistance

Growers, agronomists and anyone else involved should:

- Report suspected cases of resistance
- Send samples to the appropriate testing facility

More information regarding fungicide resistance is available online at **agsolutions.ca/fungicideresistance**



# Chapter 7 – Insect management.

In Western Canada, growing seasons are relatively short and winters are cold, both of which help to limit insects. Still, insect pests have the ability to cause yield loss when conditions are favourable, and populations are unmanaged. Field crops are excellent insect feeding grounds and various insects attack any part of the plant, at any growth stage.

Control of insects requires proper identification of pests, thorough understanding of their life cycles and economic thresholds.

### Cycling through the stages.

There are several different stages of development insects go through to get from egg to adult. This process is known as 'metamorphosis', and there are two types:

*Incomplete metamorphosis.*

Insects that undergo incomplete metamorphosis go through three developmental stages: eggs, nymphs and adults. Nymphs share the same body parts and body structure as adults, but they are smaller in size. They also lack functional wings and reproductive appendages.

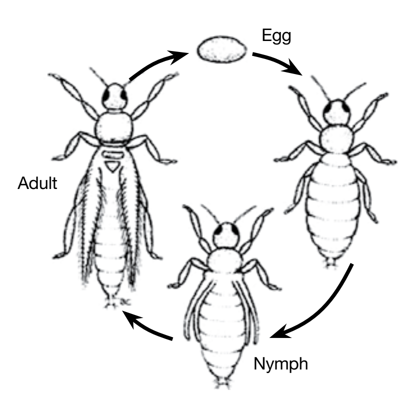



**Figure 7.1.** Stages of development for insects; incomplete metamorphosis. Source: Australian Centre for International Agricultural Research.

*Complete metamorphosis.*

Insects that undergo complete metamorphosis go through four stages of development including eggs, larvae, pupae and adults. Larva feed on different hosts than adults. They go through four to five moulting stages known as instars, before they transform into pupae. Pupae are either covered by a protective case called a cocoon or exposed, and they're typically hidden within or near the host plant.

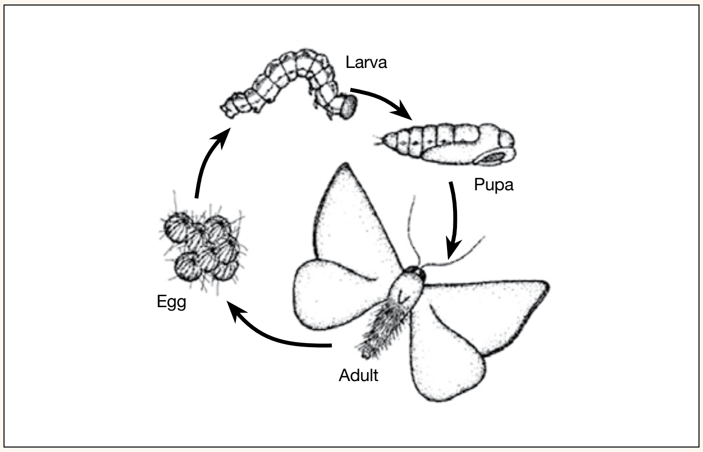



**Figure 7.2.** Stages of development for insects; complete metamorphosis. Source: Australian Centre for International Agricultural Research.

You can find many different insects in your soybeans; some that are beneficial and some that are a nuisance. To manage unwanted ones, you will need to be able to recognize them. Furthermore, you will need to know if they have reached their economic threshold. This is the amount of crop damage or the number of insects in a given area that marks the point when the yield benefits of applying an insecticide will balance the cost of an application.[95]

**Insect pests – belowground and surface feeders.**

***Wireworms** (Ctenicera spp., Agriotes spp. and others)*

### Identification

- **Larvae (mature):** 2-40 mm long; elongated, cylindrical, hardened body with a distinct flat head. Three pairs of legs near the front of the body.[96]
- **Adults:** Known as click beetles, 8-12 mm long; adults will make an audible clicking sound when they try to right themselves when placed on their backs[96]

**Figure 7.3.** (left) Wireworms, (right) Click beetle (adult wireworm). Source: (left) John Gavloski, Manitoba Agriculture, (right) John Obermeyer, Purdue Extension Entomology.

- The larval stage typically lasts three to six years. In Canada, 30 economically important species of wireworms have been identified; they prefer a wide range of environmental conditions.[97]

### Damage

- **Larvae:** Feed on germinating seeds and on the underground parts of stems of young seedlings. Damage is often blamed on poor quality or dry soil and occurs only in the spring.
- **Adults:** Feed on pollen of flowering weeds and ornamentals

### Economic threshold

- One wireworm per bait trap indicates the need for an insecticide seed treatment or soil-applied insecticide[21]

### Scouting

- Establish two bait stations per high-risk area (such as sandy silty knolls, grass weed patches), dig a hole approximately 6 inches deep and bury your bait trap
- Bait traps can be various mixtures such as; 1 cup of flour or 1 cup of untreated corn, wheat and/or bean seed soaked overnight. Mark traps with a flag.
- Examine the bait traps 1-2 weeks later by digging them up and determining the presence of wireworms[21]

### Control

- Seed treatments can help reduce damage
- Foliar sprays are not effective[96]

***Seedcorn maggot** (Delia platura)*

### Identification

- **Larvae (mature):** Approximately 8 mm long, white with two dark spots on a legless abdomen
- **Adults:** 6 mm long, gray flies, wings that overlap[96]
- Overwinters as a reddish-brown pupa in the soil of harvested crops[96]
- Females can lay an average of 250-300 eggs throughout a season in freshly tilled soils high in moisture and organic matter[96]

**Figure 7.4.** Seedcorn maggot.
Source: John Gavloski, Manitoba Agriculture.

### Damage

- **Larvae:** The maggots feed on germinating seeds and as secondary feeders on damaged tap roots. Damage is more severe under cool temperatures and wet soil conditions.[96]
- **Adults:** None

### Economic threshold

- None established

### Scouting

- Growers should scout between VE and stand establishment. Look for signs of injury as soon as the crop emerges. Scout for adults starting in mid May using yellow sticky card traps.

### Control

- If seed corn maggots are a known problem for that field, utilize seed treatments to help manage them. There are no rescue treatments available.[88]

## ***Cutworms** (Euxoa messoria and Peridroma saucia)*

### Identification

- **Larvae (mature):** Length can vary by species, but fall within a range of 35-40 mm long. Skin is fleshy and gray in colour. They have different colours of stripes depending on the species. Cutworms usually curl up when you disturb them.[96]
- **Adults:** Moths are generally 20-50 mm long with various patterns on their wings depending on species[96]
- Common species in Western Canada include darksided and variegated cutworms. However, there are many other species that can attack many crops.

**Figure 7.5.** (left) Army cutworm, (middle) variegated cutworm, (right) variegated cutworm moth. Source: (left) Frank Peairs, Colorado State University, Bugwood.org, (middle & right) Jack Foreman.

### Damage

- **Larvae:** Darksided cutworms hide during the day and come out at night to feed on leaves and stems of young plants causing areas of bare soil shortly after crop emergence. Variegated cutworms will climb up plants at night to feed on foliage, flowers and buds.[96]
- **Adults:** Feed on nectar of flowers

### Economic threshold

- 2-6 larvae per square metre for the darksided cutworm and 2-4 worms per square metre for the variegated cutworm[96]

### Scouting

- Growers should scout between VE and R4 and treat fields if defoliation occurs before the R1 growth stage[88]
- Scout seedlings every 3-4 days; noting any bare patches, holes and notches in the leaves and plants that are wilted, cut or falling over
- At night a sweep net can be used to capture variegated cutworms and darksided ones can be observed feeding[96]
- During the day, both species can be found hiding in the soil near plants or in debris[96]
- Pheromone traps are available to detect adults only[96]

### Control

- Apply insecticides in the late evening or at night as cutworms are nocturnal
- Infested fields should be sprayed before reseeding

## ***Slugs** (Agriolimax reticulatus)*

### Identification

- **Juveniles and adults:** 1-3 cm but can sometimes reach 10 cm. They are soft-bodied, grey brown with a shiny slime covering their bodies. They have no legs, but the head has two tentacles.[21]

### Damage

- **Juveniles:** This is the life stage that is the most damaging. They can feed above and below ground and make holes on the lower leaves of the plant that resemble hail damage. When populations are high, they can eat seeds before germination.[21]
- **Adults:** Due to two populations of slugs, spring maturing and fall maturing, damage can be seen on small plants in both those growing seasons. The fall population can overwinter and feed in the field the following spring. Their eating habits are like the juveniles.[21]

### Economic threshold

- There is no threshold number for slugs, however, if slugs are frequently found below the boards as described below, your field is at risk of slug damage the following spring[21]

### Scouting

- Slugs are nocturnal and therefore scouting should take place at night or early in the morning. Looking under debris can also be helpful.[21]
- Slugs can create small holes in leaf tissue and reduce plant stand. However, the best way to know is by looking for a slime trail, which is silver coloured and can be found on the plants or the soil.[21]
- Scouting can be done by placing multiple pieces of wood (a few feet long) or roofing shingles across the field. Monitor the boards/shingles every 5 days for about 1 month to determine if slugs shelter below them.[21]

### Control

- There are no economical sprays available for the control of slugs. Baits are available for control of slugs, however, their cost is prohibited to using them on large sections of field. Some cultural methods can help with reducing the impact of slugs.[21]

***Japanese Beetle** (Popillia japonica)*

### Identification

- **Larvae:** Small white grubs found in the ground. They overwinter just below the frost line.

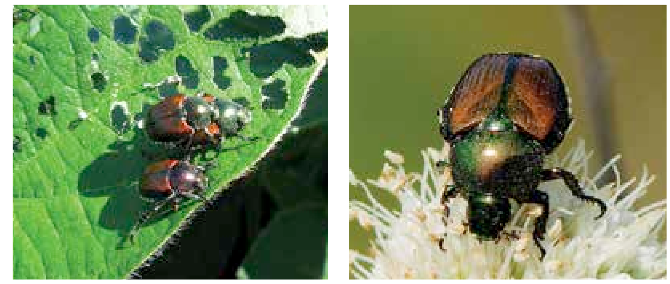


**Figure 7.6.** (left) Japanese beetle feeding on soybean leaf, (right) close-up of a Japanese beetle.
Source: (left) BASF USA, 2015, Soybean Production Training Module, (right) Jack Foreman.

- **Adults:** 13 mm in length and can be easily identified by their metallic green and bronze coloured wing covers. They also have white tufts of hair on the abdomen.[21]
- Uncommon in Western Canada

### Damage

- **Larvae:** Feed on plant roots until mid-late June
- **Adults:** Adults emerge in July and feed on soybean leaves. They feed primarily on the upper canopy.

### Economic threshold

- 40% defoliation when the soybeans are between the V1 and V6 stage. 15% defoliation between stages R1-R5. At R6 the threshold is 25% defoliation.

### Scouting

- Monitor for Japanese beetles between July and September

### Control

- If management is required, foliar insecticide treatments are available

**Insect pests – sap and fluid feeders.**

***Soybean Aphid** (Aphis glycines)*

### Identification

- **Nymphs (mature):** Smaller version of a wingless adult
- **Adults:** Pinhead-size, pale yellow aphid with black cornicles. They can be winged or wingless. The winged version has a shiny black head and dark green body.
- Eggs overwinter on the buds and branches of buckthorn species and migrate to soybean fields in the spring. They are not known to overwinter in the Western provinces but blow in from the US.

### Damage

- **Nymphs and adults:** The piercing-sucking mouth parts suck the juices and nutrients from the plant. Populations in high numbers (especially in dry years) can cause the plants to abort flowers, become stunted, and reduce pod/seed production and quality. Aphids also excrete a sticky substance called honeydew, which can act as a substrate for grey sooty mould.[21]

### Economic threshold

- 250 aphids per soybean plant in at least 80% of the field, with aphid populations increasing. Aphid numbers that remain constant or decrease indicate predation by beneficial insects and an insecticide application is not usually necessary.[21]

### Scouting

- Aphids can do the most damage between the R1 and R5 stage, therefore start scouting at R1. Aphids prefer newly emerging leaves; early in the season this will be the top of the plant. As the soybeans mature, aphids are most likely found in the middle of the canopy. Monitor fields every 7-10 days, or every 3-4 days if aphid populations approach threshold.

### Control

- There are various insecticides available to control soybean aphids

***Potato leafhopper** (Empoasca fabae)*

### Identification

- **Nymphs (mature):** 6 mm long, pale yellow-green body that is wedge-shaped. Leafhoppers can be identified by their lateral walking pattern.[96]
- **Adults:** Adults are similar in size, colour and shape to the nymphs. One way of recognizing them is that they hop or fly away when you disturb them.[96]

### Damage

- **Nymphs and adults:** They pierce leaf tissue to suck the sap. Their saliva is toxic to the plant. In soybeans, yellow patches will appear on the leaves along with some crinkling and cupping of the leaves. Plant growth can be stunted and later planted soybeans face a greater risk. The symptoms can sometimes be confused for herbicide injury.[96]

**Figure 7.7.** Soybean aphid.

**Figure 7.8.** Potato leafhopper.
Source: Bill Keim.

### Economic threshold

| Soybean Stage | Threshold Number of Leafhoppers per Plant |
|---|---|
| V1 | 1.4 – 3.6 |
| V2 | 3.0 – 7.8 |
| V3 | 4.7 – 12.2 |
| V4 | 6.5 – 16.7 |
| R4 | 9.0 |
| R7 | 18.0 |

Source: Field crop and forage pests and their natural enemies in Western Canada: identification and management, 2018, Agriculture and Agri-Food Canada.

### Scouting

- Scout by walking the field and counting the leafhoppers present on a plant in multiple areas[96]

### Control

- There are no chemical options registered in Canada and most predatory enemies of the potato leafhopper do not contribute significantly to its control. However, planting soybean varieties with hair can help reduce the impact of feeding compared to hairless varieties.[96]

### ***Lygus bug*** *(Lygus spp.)*

#### Identification

- **Nymphs:** Smaller than the adults but the "V" is not visible. They have five black dots on the thorax and the abdomen and beginning wing growth is visible.[96]
- **Adults:** 6 mm long and pale green to reddish-brown in colour. They have a yellow V-shape on their back.[96]

#### Damage

- **Larvae and adults:** Both feed by piercing tissues and sucking the sap of new plant growth and reproductive parts of the plant causing these parts to fall thus decreasing yield potential[96]

#### Economic threshold

- The economic threshold for soybeans has not been established

#### Scouting

- Use a sweep net for scouting[96]

#### Control

- There are many predatory species that attack the lygus bug. There are also chemical options to control the lygus bug.[96]

**Figure 7.9.** Lygus bug.
Source: Kathy Keatley Garvey

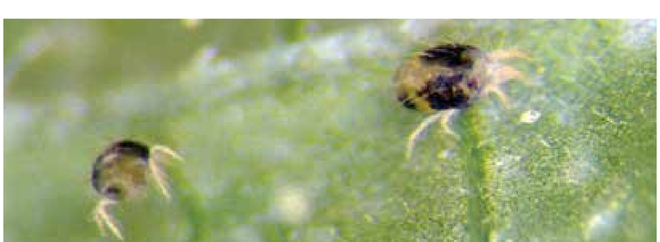


**Figure 7.10.** Two-spotted spider mites.
Source: Frank Peairs, Colorado State University, Bugwood.org.

### ***Two-spotted spider mite*** *(Tetranychus urticae Koch)*

#### Identification

- **Larvae:** Have only 3 pairs of legs
- **Nymphs:** Smaller versions of adults with 4 pairs of legs
- **Adults:** Barely visible to the naked eye (0.5-1 mm in length), rounded and yellowish brown with two dark spots on the sides of the abdomen. Overwintering females are orange/red.
- There can be up to 7 generations per year. They overwinter as adult females in plant debris or red clover.

#### Damage

- **Nymphs and adults:** Two-spotted spider mites are uncommon in Western Canada; however, risk increases in hot, dry years.[98] Mites create webbing on the undersides of leaves where they puncture cells to feed. This causes stippling, yellowing or browning of the leaves.[96]

#### Economic threshold

- Four or more mites per leaflet, or one severely damaged leaf per plant prior to pod fill indicates control is necessary[21]

#### Scouting

- Scout between stages R1 and R5 on a weekly basis. Start at the edges of the field, as infestations usually move in from the edge of the field as hot spots. Check for feeding injury and characteristic webbing on the undersides of leaves. Pull these leaves and shake onto a white piece of paper to see the actual mites moving. A 10X hand lens is handy to have to properly identify the mites.[21]

#### Control

- 1-2 insecticide sprays may be necessary if mites are numerous. Border sprays or spot sprays may also be all that is needed. Choose your insecticide carefully as not all insecticides effectively control this pest.[88]

**Figure 7.11.** Grasshopper.
Source: Adam Sisson, Iowa State University, Bugwood.org.

## Insect pests – defoliators

### ***Grasshoppers*** *(Family Acrididae)*

#### Identification

- **Nymphs:** First instars are pale green to yellow-brown with various stripes or markings depending on the species of grasshopper
- **Adults:** There are four main species of grasshopper; packard, clearwinged, migratory and two-striped, all various shapes of green, yellow, tan or brown with their own distinct markings
- Grasshoppers overwinter as eggs in pods (8-150 eggs/pod) laid in soil and hatch in the spring. There is only one generation per year.[96]

#### Damage

- **Nymphs:** Grasshopper nymphs can consume entire seedlings, but incidence varies year to year and soybeans are not a common host crop
- **Adults:** Feed on foliage and pods leaving small holes. Damage is often more significant in weedy fields or around field edges.

#### Economic threshold

- If more than eight grasshoppers are found during a sweep, or 40% of foliage is affected before R1, treatment should be considered

#### Scouting

- Scout between R1 and R5, especially in dry years. Start with the outside edges of the field or weedy areas.

#### Control

- There are products available as sprays and baits. Younger instars should be targeted in order to use lowest recommended rates. Once grasshoppers reach adult stage insecticides are much less effective.

### ***Green cloverworm*** *(Plathypena scabra)*

#### Identification

- **Larvae (mature):** 25-30 mm long, pale green caterpillars with a white stripe down each side and three paler white lines down the back[96]
- **Adults:** 14 mm long moths that form a triangle shape when at rest. The forewings are charcoal grey with patches of brown and silver. The head looks like a snout.[96]
- Green cloverworm is not common in Western Canada

#### Damage

- **Larvae:** Feed on leaves, occasionally defoliating plants. They can also attack seed pods.
- **Adults:** Feed on nectar from flowers

**Figure 7.12.** Green cloverworm.
Source: Adam Sisson, Iowa State University, Bugwood.org.

**Figure 7.13.** Green cloverworm moth.
Source: Nicholas Block.

### Economic threshold

- 22 green cloverworms per metre of soybean row. If conditions are very dry, the threshold is 10 per metre of soybeans.

### Scouting

- Scout for cloverworms between V5 and R5

### Control

- There are currently no chemicals registered in Canada for controlling cloverworms. However, many parasites, predatory insects and fungi can attack cloverworms at early life stages.[96]

**_Bean leaf beetle_** *(Certoma trifurcata)*

### Identification

- **Larvae:** Up to 10 mm long and white with a brown head and three pairs of legs. The larvae are very difficult to find and rarely seen.[21]
- **Adults:** 5 mm long and most often have four black parallelogram shaped spots on their wing covers. The beetles can vary in colour in different shades of yellow, green, tan or red. The most distinguishing feature is a small black triangle at the point where their wings are attached.
- There is one generation of bean leaf beetle per year. The beetle overwinters in the adult stage in woodlots, grassy edges of fields and leaf litter.

### Damage

- **Larvae:** Feed on soybean roots and nodules but are usually not of economic concern
- **Adults:** Feeding injury by bean leaf beetle adults is generally not serious unless it is to young soybean plants (V1-V2). Cotyledons and seedlings can be clipped off by heavier beetle populations. Late season pod feeding can also be a concern. They leave lesions, which make the pods more susceptible to secondary diseases. Pods can also be clipped off the plant.[21]

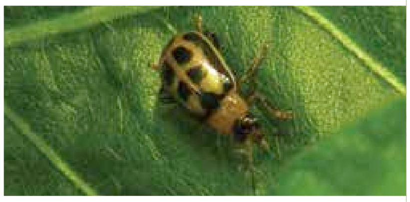



**Figure 7.14.** (left) Bean leaf beetle, (right) larvae.
Source: (left) Jessica Louque, Smithers Viscient, Bugwood.org, (right) Jeffrey Bradshaw, University of Nebraska-Lincoln.

### Economic threshold

- VE-V2 stage: 52 adult beetles per metre of row
- R5-R6 stage for food grade and seed fields: 10% of the pods on the plants have feeding injury and the beetles are still active in the field. If the damage is only on the leaves this does not apply.[21]

### Scouting

- Scout between VE and V3, then again between R4 and R5

### Control

- For control of early feeding from overwintering adults seed treatments are the best option
- Well-timed foliar insecticides are warranted only when defoliation or pod-feeding thresholds are reached[21]

**_Thistle caterpillar/painted lady butterfly_** *(Vanessa cardui)*

### Identification

- **Larvae (mature):** 40-45 mm long, 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.[96]
- **Adults:** Butterflies with pointed wings spanning 42-66 mm and salmon-pink in colour with black markings
- The butterflies are occasionally blown up from the southern US in vast numbers that settle on weed hosts. Usually one generation per year, possibly two if temperatures are favourable.[96]

**Figure 7.15.** Thistle caterpillar.
Source: John Gavloski, Manitoba Agricutlure.

### Damage

- **Larvae:** Feed in groups together in leaf nests created near the terminals of host plants
- **Adults:** Feed on nectar of flowers

### Economic threshold

- Thistle caterpillar is rarely of economic concern however, damage is very noticeable and therefore often emotional for growers
- Vegetative stage is 40% defoliation, pod-fill stage is 20% defoliation and pod-fill to harvest stage is 35% defoliation[96]

### Scouting

- Monitor fields between V3 and V4 and then again between R1 and R5. Checking the field edges first and any areas where there are thistles.

### Control

- There are no insecticides registered in Canada for the control of thistle caterpillar. They are highly subject to bacterial disease and have many predators (rodents, birds, wasps, etc.).

***Alfalfa caterpillar*** *(Colias eurytheme Boisduval)*

### Identification

- **Larvae (mature):** Caterpillars are green with a white stripe on each side of their body. They can reach up to 30 mm in length.[96]
- **Adults:** Butterflies have a wingspan of 50 mm and can be yellow, orange or white with the underside of the wings being yellow or white. On the top side, they have black margins around the outside edge of the wings but not on the underside.[96]

### Damage

- **Larvae:** No damage of economic importance has been recorded in Western Canada. However, sometimes they will eat whole leaves from small host plants.[96]
- **Adults:** They are nectivores[96]

### Economic threshold

- There is currently no economic threshold[96]

**Figure 7.16.** Painted lady butterfly.

**Figure 7.17.** Alfalfa caterpillar.
Source: John Capinera, University of Florida, Bugwood.org

### Scouting

- No methods of scouting have been developed[96]

### Control

- Cultural methods as well as predatory insects can help manage the pest. If there is noticeable defoliation and predatory insects don't seem to be present, then a chemical spray may be warranted.[96]

**Beneficial insects.**

Beneficial insects feed on insect pests and keep populations low. Recognizing beneficial insects in a soybean field may impact a grower's decision to treat insect pests as they do not want to kill beneficial insect populations. Figures 7.18-7.24 show common beneficial insects for soybeans. We have added which insect pest featured in this book they prey on.

**Figure 7.18.** Lady beetle. Preys on mites and aphids.[96]
Source: Daren Mueller, Iowa State University, Bugwood.org.

**Figure 7.19.** Damsel bug. Preys on aphids, caterpillars, mites, lygus bugs and leafhoppers.[96]
Source: Whitney Cranshaw, Colorado State University, Bugwood.org.

**Figure 7.20.** Green lacewing. Preys on aphids, motile mites and eggs, small caterpillars and leafhopper nymphs.[96]
Source: Johnny N. Dell, Bugwood.org.

**Figure 7.21.** Hoverfly larvae. Preys on aphids and caterpillars.[99]
Source: Clemson University – USDA Cooperative Extension Slide Series, Bugwood.org.

**Figure 7.22.** Minute pirate bugs. Preys on aphids, two-spotted spider mites and moths.[96]
Source: Bradley Higbee, Paramount Farming, Bugwood.org.

**Figure 7.23.** Aphid midge larvae. Preys on aphids and mites.[96]
Source: Whitney Cranshaw, Colorado State University, Bugwood.org.

**Figure 7.24.** Parasitic wasp, seen here forming aphid mummies which are remains of parasitized aphids (right). Preys on aphids and caterpillars.[100]
Source: Michael J. Raupp, University of Maryland.

**Soybean insect management.**

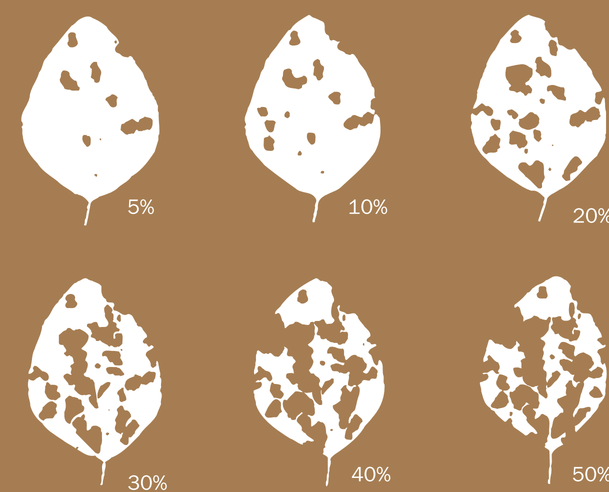
Growers must evaluate insect pests in order to effectively manage them. To do that, growers should consider recent weather and scout their fields. Overall, scouting is one of the most important management strategies for insect control because it allows for proper identification, evaluation of prevalence and severity and determination of thresholds for each pest. The proper time to scout is dependent on the insect type as shown in Figure 7.25.

Once growers reach spray thresholds, there are numerous strategies to manage populations and ensure a healthy crop. Growers can rely on biological control and use cultural practices and chemical options. Monitor spray threshold levels with sweep nets, sticky traps or simply walking the fields.

If growers find an insect pest they can not identify, or a pest they believe is new in their region, they should submit it to their Provincial Entomologist or to one of the labs listed in Chapter 5.

**TIP**

Refer to this chart to determine defoliation percentage due to leaf-feeding insects in soybeans.




Defoliation chart for soybean leaf-feeding insects.
Source: Adapted from Agronomy Guide for Field Crops – Publication 811, OMAFRA.

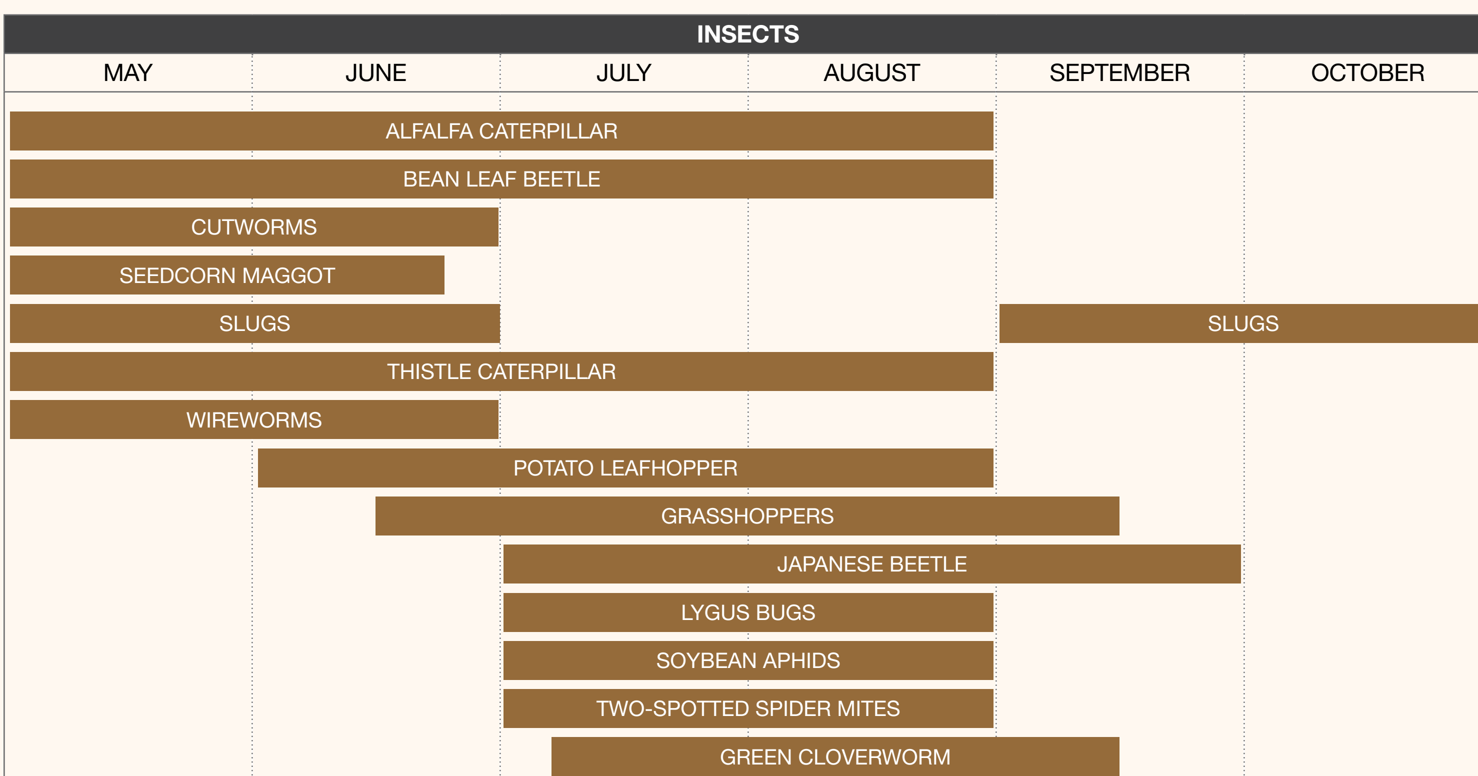



**Figure 7.25.** Insect scouting calendar for Canada. Source: Adapted from Manitoba Pulse & Soybean Growers.

**Cultural practices.**

There are many ways to reduce pest populations without the use of insecticides. Some of these methods include cultural practices but not all cultural practices work for each insect pest. These practices include[96]:

- Rotating crops to non-host crops
- Planting resistant cultivars
- Increasing seeding rates
- Seeding as early as possible or delaying seeding by 1 to 2 weeks when the pest is hatching
- Using seeds that will produce vigorous seedlings
- Controlling weeds
- Tillage
- Maintaining beneficial/predatory insect populations

**Choosing an insecticide.**

Early-season protection is attained via seed treatment, often in combination with a fungicide seed treatment.[1] Seed treatments help control pests early in the season including: soybean aphid (early populations), bean leaf beetle, seedcorn maggot and wireworm. Table 7.1 lists insecticides registered for use on soybeans.

| | | Insects | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Products | Group | Armyworms | Corn earworm | Cutworms | Grasshoppers | Leafhoppers | Lygus bugs | Seedcorn maggot | Soybean aphid | Spider mites | Wireworms |
| Seed Treatments | | | | | | | | | | | |
| Cruiser Maxx Vibrance | 4A | | | | | | | • | | | • |
| Cruiser 5F | 4A | | | | | | | • | | | • |
| Stress Shield® 600 (Alias®, Sombrero™) | 4A | | | | | | | • | | | • |
| Foliar Treatments | | | | | | | | | | | |
| Concept® | 3+4 | | | | | | | | • | | |
| Coragen® | 28 | • | • | • | • | | | | | | |
| Cygon®/Lagon® | 1B | | | | | • | • | | • | • | |
| Delegate™ | 5 | • | | | | | | | | | |
| Matador®/Silencer® | 3 | | | • | • | | • | | • | | |
| Movento® | 23 | | | | | | | | • | | |
| Sefina™ | 9D | | | | | | | | • | | |
| Voliam Xpress® | 3+28 | | • | | | | | | • | | |

**Table 7.1.** Soybean insect management chart.

**ALWAYS CONSULT THE INSECTICIDE LABEL BEFORE APPLYING ANY INSECTICIDE.**

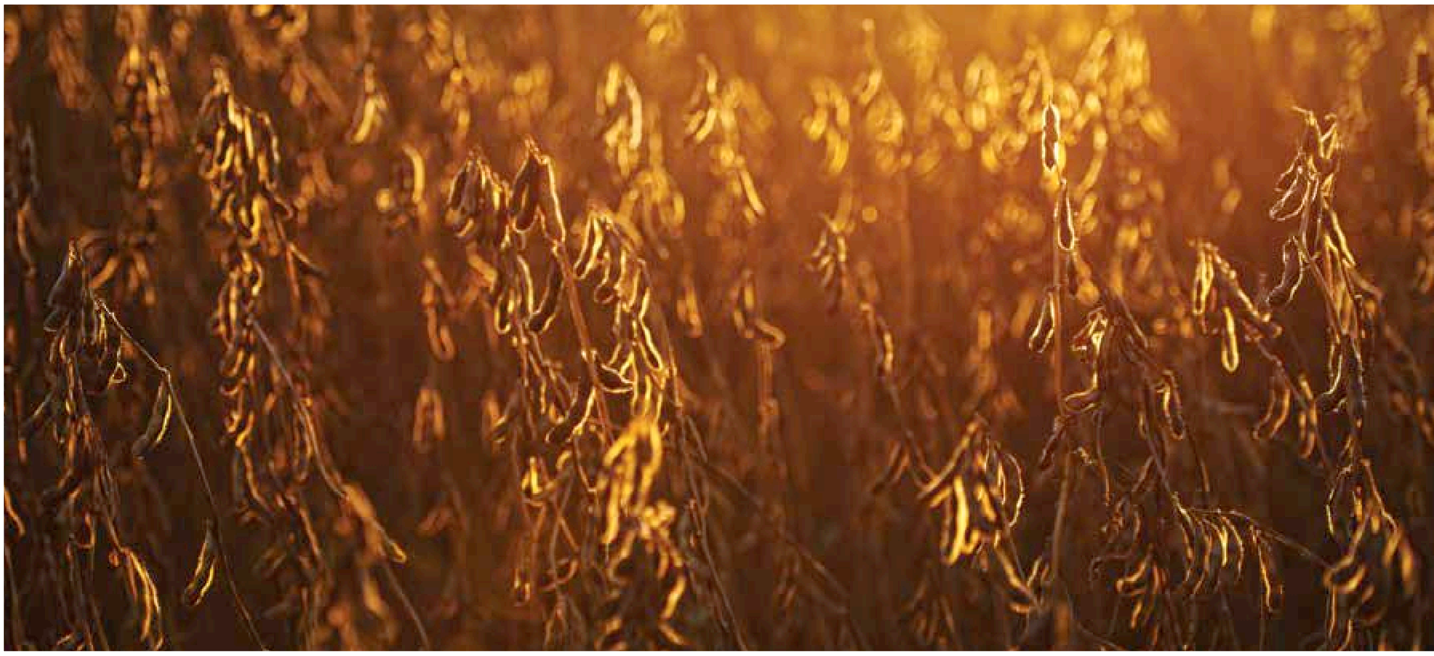
**Best practices for application and resistance management.**

Like any pesticide, there are several best practices that can improve efficacy and stewardship when using insecticide products. These include the following:

- Ensure spraying is timed accurately when pest is most vulnerable
- Use action thresholds, when available to determine the need and timing for control. Consider 'dynamic' action thresholds that account for beneficial insects when possible.
- Use only recommended insecticide rate, mix properly and apply carefully
- Do not tank mix with other insecticides with the same mode of action
- Avoid repeated use of the same mode of action within same crop season or sequential years
- Rotate chemicals for each generation of the insect
- Best to spray at dawn or dusk when honeybees are not foraging
  - Provide beekeepers 48 hours' notice before applying an insecticide close to where honeybees are kept. This can be done through the BeeConnected app at **http://croplife.ca/beeconnected-app**.
- Applying an insecticide to the border edges of a field for grasshoppers is often effective
  - They prefer more open canopies and will likely remain in those areas rather than moving into the field if the crop is dense
  - This may also be used for spider mites depending on their distribution in a field
- It is often advantageous to plant a strip of trap plants
  - Trap plants are planted earlier or have an earlier maturity, so they reach the ideal insect-target timing before the real crop emerges
  - Trap the insects to lessen the damage
  - The trap also prevents resistant insects from reproducing and being maintained in the population
- Use various control strategies, not just synthetic insecticides to assist with maintaining effectiveness
  - Use cultural practices including rotation to crops targeting different insects, beneficial insects, weed control (host for insects) and biological insecticides when available
- If only one insecticide is fully effective, use less effective ones when pressure is low, so the better product can be used when pressure is high and the need for efficacy is more important
- Where soil erosion is not a concern, tillage is recommended to bury crop residues
  - Removes food source for both susceptible and resistant insects
  - Prevents insect overwintering

When it comes to insect management there are many factors that need to be taken into consideration. Identifying which insects are beneficial and which are pests is very important. Consistent scouting helps with identification and monitoring populations. Once the insect has been recognised, selecting the proper insecticide and maintaining best practices for application and resistance management increases efficacy.

# Chapter 8 – Harvest.



## Optimum harvest timing – signs of maturity.

Soybeans have been grown in Eastern Canada for over a century; therefore, growers have had time to optimize their production practices. As previously mentioned, the introduction of soybeans to Western Canada has been relatively recent and acreage is rapidly increasing. As a result, the opportunity exists for many Western Canadian growers to further refine their on-farm soybean practices to realize additional crop benefits.[13]

Yield is determined by several factors and there have been significant improvements due to variety development, plant protection products and beneficial cultural practices.[1] Correctly timed soybean harvest is an example of a cultural practice that provides an opportunity to significantly impact production results. To properly time harvest, it is recommended growers scout their fields and do not make rushed timing judgements while driving by their crop. Soybeans begin maturing at the R7 growth phase (Figures 8.1 and 8.2). At R7, very little additional plant growth occurs and the pods formed on the main stem reach maturity. Moisture is still too high to harvest (~60% in seeds) and seeds are often yellow. Soybeans reach full maturity during R8. At R8 (Figures 8.3 and 8.4), 95% of pods have reached mature colour and moisture levels will be optimum for harvest in an additional five to 10 days with good weather conditions.[1] Harvest should take place any time between 14% and 20% moisture, these moisture levels may require additional drying.[101,102] If moisture falls below 12% prior to harvest, seeds may crack and split, whereas below 11% moisture, pods may shatter leaving beans in the field.[103] Soybeans are direct-combined usually with a floating flexible cutterbar using automatic header height control[21], as swathing causes significant loss due to shattering pods.

## Potential challenges.

Harvesting soybeans becomes more complicated when the crop has been damaged by frost, or if the field has a lot of weeds. Frost-damaged soybeans are wet and often difficult to properly thresh. Frost-damaged soybeans also often have green or immature beans, especially if they were planted late. This can cause oxidation of the refined oil and decrease shelf life. Therefore, they must be removed prior to use, but at an additional cost to the processor. As a result, both green and immature beans contribute to the total damage factor.[104] Overall, to avoid significant harvest delays, growers need to harvest frost-damaged soybeans with higher moisture content and then dry them to an appropriate moisture level for storage.[104] Weeds create a problem too because they are moist and difficult to combine. If a soybean field has a significant number of weeds, growers often desiccate prior to harvest. Further, weed seeds mixed in with soybeans negatively affect the price earned if the beans are conventional. Mature green seeds can be a problem.[21] These beans are still green even though they have reached maturity and a humidity level of 13% or less.[21] These can result when conditions are dry in July and August and in soils with poor water-holding capacity.[21] Due to minimal enzyme activity in the beans, the green colour will not go away with time.[21] There is nothing to be done at this point and it is hard to prevent the occurrence of mature green beans since they are weather dependent.[21]

**TIP**

To optimize yield, it is important to understand yield potential. It is estimated that if all flowers, on all plants, produced pods with maximum seeds, soybean yields could approach 250 bushels per acre.[1] This figure is of course significantly higher than any recorded soybean yield to date; however, it may act to motivate improved on-farm practices.

**Preventing harvest losses.**

Decreasing yield loss at harvest is a very effective way to improve soybean profitability. When four beans are lost in an area of 4 square feet ($ft^2$), this represents a loss of 1 bu/ac.[21] It is estimated that 10 to 15% of yield is lost during harvest and yet, with more careful practices and equipment use, losses can decrease to 1 to 3%.[105] Overall, harvest losses are categorized into three groups including: pre-harvest shatter, gathering losses and machine losses.

Pre-harvest shatter is influenced by weather and harvest timing, both previously discussed. To avoid shatter, growers should consider planting shatter-resistant varieties and strive to properly time their soybean harvest. As was previously mentioned, it is recommended growers plant varieties with different maturities, so they can appropriately spread their workload during planting and harvesting times. This should allow growers to accurately time and execute harvest. The next two categories of harvest losses are

| Stage | R7 | R8 |
|---|---|---|
| Moisture in Seeds | ~60% | 14 – 20% |
| Colour | • Seeds and stems are yellow<br>• Pods are yellow/brown | • Stems and 95% of pods are brown |
| Maturity | • Pods on main stem reach maturity<br>• Too early for harvest | • Soybeans at full maturity<br>• Optimal timing for harvest |

**Figure 8.1.** Soybean plants at R7 stage, stems are yellow and pods are a combination of yellow and brown.
Source: Kristen MacMillan, University of Manitoba.

**Figure 8.2.** Soybean field at R7 stage, stems are yellow and pods are a combination of yellow and brown.
Source: Kristen MacMillan, University of Manitoba.

both dependent on equipment. Gathering losses account for those soybeans that don't make it into the combine (80 to 85% of total harvest loss), whereas machine losses describe those beans that remain in pods or pass through the combine.[1]

**Combine tips.**

Overall, caring for your combine can have big impacts on crop yield.[106] Since approximately 80% of harvest losses occur while cutting and gathering soybeans, growers should regularly consider equipment maintenance and slight modifications to mitigate loss.[106] Recommended modifications include the use of add-ons:

- Flex headers
- Pickup reels
- Lovebars
- Row crop headers on the combine

Figure 8.3. Soybean plants at R8 stage, stems and mature pods are brown. Source: Kristen MacMillan, University of Manitoba.

**Figure 8.4.** Soybean field at R8 stage, stems and mature pods are brown. Source: Kristen MacMillan, University of Manitoba.

All of which have been shown to further reduce harvest losses.[12] Seasonal combine maintenance should include inspection and repair of the header knives, which must be sharp and tight for optimum harvest. Growers should check the cutter bar for wear, flex and appropriate height to harvest more beans. All cylinders, belts and chains should be maintained with adequate tension.[106] Growers must minimize seed damage, often caused by impact, pinching and sheering. Such damage can occur within the equipment or during threshing, but most often is caused by the cylinder or rotor speed. Damage is more severe at very low moisture content (<10%) or very high moisture content (>14%).[107]

A recent Prairie Agriculture Machinery Institute (PAMI) study indicated two combining changes that can significantly increase yield including decreased combine speed and the investment in an air reel.[108] The study compared combining at two, three, four and five miles per hour and found that when the combine reached five miles per hour losses increased from 1.36 bushels per acre to 2.18 bushels per acre. The study also focused on losses at the combine header, which are estimated to account for 80% of total harvest loss. They found that an auger head with an air reel was twice as efficient at picking up the crop, thereby significantly reducing losses at the header.[108]

To ensure harvest is as successful as possible, it is also recommended that the combine operator be well-informed and patient. A study from the University of Arkansas demonstrated a yield bump at harvest because of a more skilled combine operator. Like the PAMI study, they recommended the combine move slowly at three miles per hour or less, although they also indicated speeds could increase with the addition of a draper head.[109]

**Drying and storage.**

Growers need more than a concrete pad with a corrugated steel bin to properly store their commodities. Growers who are used to relying on an elevator tend to forget that the risk of storing grain now falls back on them once they have their own storage facilities.[102] For IP soybeans, cleaning the combine to exact specifications, which are usually laid out in the grower's contract[102], is important. Having a clean storage bin is also important in order to prevent cross-contamination of the load and any possible monetary losses from the loss of premiums.[110]

Beyond harvest, growers must consider proper drying and storage of soybeans. Knowing when to aerate the bin, when to inspect for insect pests and to monitor the moisture are part of the routine maintenance of stored grains.[102] Two key components of storing soybeans requiring the utmost attention are the temperature of heated air and relative humidity levels. Drying is recommended when beans are harvested at increased moisture levels due to uncooperative weather.[12] Keep in mind that with IP soybeans, many varieties cannot be dried artificially.[102]

Soybeans can lose or gain moisture due to ambient conditions. If using heated air for drying soybeans, the relative humidity of the air must be maintained above 40% to prevent splitting of seed coats.[21] All drying methods are suitable; however, temperatures should not exceed 55 to 60°C otherwise seed coats begin cracking and/or splitting. In optimum weather conditions, it may be necessary to lower those temperatures.[102] Remember, if temperatures are too high, it is possible to cause 100% cracking in soybeans in as little as five minutes. Caution is also required when stirring or re-circulating loads, particularly when the moisture content of the soybeans falls to 12% or lower.[102] A properly stored crop includes no weed seeds and minimum split beans. Ideal storage temperatures for soybeans is 2 to 5°C in the winter and 5 to 15°C in the summer.[111] It is also important to maintain ideal moisture, which is 13 to 14% for one year of storage and between 11 to 12.5% for longer term storage. Keep air cold to prevent fungal growth. Given the state of commodity prices and the price of land, fuel, seed costs, fertilizers and chemical products, farmers with on-farm storage should monitor and maintain the quality of the grain inside the bins. There needs to be that level of commitment, since tolerances relating to bugs and quality parameters are stringent, regardless of the commodity.[1] The Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) offers several suggestions about storage such as determining airflow, equilibrium moisture content and measuring the relative humidity in their Agronomy Field Guide for Crops.[21]

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