2. Soybeans

Soybeans have become the largest row crop by acreage in the province. Over 1.0 million ha (2.47 million acres) of soybeans are grown annually in Ontario. The year 2014 was the first time that acreage reached 1.21 million ha (3.0 million acres). The development of early maturing varieties, adaptability to no-till production, a wide selection of herbicides and the relative low cost of production have contributed to the widespread adoption of soybeans.

Glyphosate-tolerant varieties make up about 75% of the crop, while the remainder is non-GMO (genetically modified organism). The demand for specialty soybeans with identity preservation (e.g., food grade, non-GMO, organic, etc.) has created marketing opportunities for Ontario beyond the traditional end-use of soybeans for oil production and livestock feed. Ontario is recognized worldwide for its identity preserved (IP) soybean industry. Soybeans are Ontario's largest agricultural export commodity.

Tillage Options

Soybeans will grow well under a wide variety of tillage systems, particularly no-till and minimum tillage. Approximately two-thirds of the soybean crop is grown with reduced tillage and no-till systems. In recent years there has been an increased use of conventional tillage and vertical tillage, especially in northern counties. The management specific to each tillage system used is as important as the actual system selected.

No-Till and Minimum Tillage

Field experience and Ontario research trials have shown similar yields between tillage systems; that no-till soybean yields were similar to the fall mouldboard plow in row widths of 56 cm (22.5 in.) or less and in twin rows. See Table 2–1, *Soybean yield response under various tillage systems*. Although the yields were comparable between the two tillage systems, no-till input costs were lower and profit was higher. Where single 76 cm (30 in.) rows were used, mouldboard plowing produced the highest yields. When soybeans were planted in twin rows, soybean yields improved over single 76 cm (30 in.) rows for all tillage systems. In this study, zone tillage showed no significant yield improvement over no-till. Other Ontario research trials have averaged a small yield gain — about 0.13 t/ha (2 bu/acre) for conventional tillage over no-till. In extreme years or unique situations this yield difference can be greater. In general, there is a greater immediate response to tillage in fields with

Table 2–1. Soybean yield response under various tillage systems

A difference of less than 0.16 t/ha (2.4 bu/acre) is statistically insignificant.

LEGEND: – = no data available

Tillage[1]	Row Width				
	Single 76 cm row (30 in.)	**Twin 76 cm row (30 in.)**	**56 cm row (22.5 in.)**	**38 cm row (15 in.)**	**19 cm row (7.5 in.)**
No-till	2.72 t/ha (40.4 bu/acre)	3.04 t/ha (45.3 bu/acre)	2.93 t/ha (43.6 bu/acre)	3.06 t/ha (45.5 bu/acre)	3.06 t/ha (45.5 bu/acre)
Fall mouldboard	2.94 t/ha (43.8 bu/acre)	3.02 t/ha (44.9 bu/acre)	2.93 t/ha (43.6 bu/acre)	3.12 t/ha (46.4 bu/acre)	3.21 t/ha (47.7 bu/acre)
Fall zone-till	2.78 t/ha (41.3 bu/acre)	2.93 t/ha (43.6 bu/acre)	–	–	–
Spring zone-till[2]	2.71 t/ha (40.3 bu/acre)	3.02 t/ha (45.0 bu/acre)	–	–	–

[1] Trials were conducted on clay loam, silty-clay loam, silt loam and Guelph loam soil types.
[2] Spring zone-tillage conducted approximately 1 day prior to planting.

a poor crop rotation compared to a rotation with fewer soybeans. However, over the long term, no-till soybeans yield higher than tilled soybeans, especially in crop rotations with many years of soybeans. A decrease in soil structure, organic matter and overall soil health associated with many soybeans in the rotation would be a contributing factor. Soybeans often benefit from some form of tillage in poorly drained fields, heavy soil types or compacted soils. No-till soybeans often yield higher than those grown in conventional tillage, especially in dry years or on lighter soil types. No-till systems can be a critical component for producers trying to aggressively manage fields with a severe history of white mould.

The keys to successful no-till production include minimizing compaction, managing residue and planting only when soil conditions are fit. The adoption of no-till on heavy textured soil types (e.g., clay, silty clay loam or silty clay) can be more challenging than on lighter soils. This is especially true in cooler growing areas. Heavy corn residue from the previous crop can also be a challenge for no-till drills to penetrate, often resulting in reduced plant stands.

Planting soybeans into no-till fields is sometimes done later than in conventionally tilled fields due to wetter and cooler soil conditions. Some producers mitigate this problem with springtime vertical tillage (shallow minimal tillage leaving much of the crop residue on the surface). Vertical tillage with a one-pass coulter implement has shown a small yield benefit over straight no-till. Coulters operated at the time of planting have also shown a marginal benefit if run at a depth of 9 cm (3.5 in.). Coulters operated at a depth of 3.8 cm (1.5 in.) showed no yield gain in the research summarized in Table 2–2, *Soybean yield response to spring minimal tillage*. When operating vertical tillage implements it is important to wait for subsurface conditions to be dry enough to avoid compaction. Soybeans are highly sensitive to soil compaction. Even though the top 5 cm (2 in.) of the soil may be dry enough to conduct vertical tillage, subsurface compaction may still occur if subsurface conditions are too wet, resulting in lower yields.

Managing Crop Residue

When soybeans follow a cereal crop, pay special attention to the management of cereal residue — beginning at harvest — to avoid problems with soybean establishment. The best action is to remove the straw and spread the chaff evenly. Wheat straw removal improves seedbed conditions, stand establishment, growth and yield of no-till soybeans. The results are shown in Table 2–3, *Effect of tillage and wheat residue management on soybean yields*. Cereal residue can form a mat that slows soil warming and drying in the spring. This can delay soybean planting, reduce soybean emergence and early growth, and lead to increased damage from slugs.

Table 2–2. Soybean yield response to spring minimal tillage

LEGEND: – = no data available

Treatment[1]	Depth	Average Yield
No-till drill[2]	–	3.03 t/ha (45.1 bu/acre)
No-till drill with coulters[2]	3.8 cm (1.5 in.)	3.05 t/ha (45.4 bu/acre)
No-till drill with coulters[2]	9 cm (3.5 in.)	3.09 t/ha (46.0 bu/acre)
Vertical tillage operated 1–3 days prior to seeding	9 cm (3.5 in.)	3.15 t/ha (46.9 bu/acre)

[1] Values based on 40 trials seeded with a JD 1560 no-till drill. Coulters run at seeding time in the row (2 cm (0.75 in.) wide coulters) were added to the JD drill on a separate tool bar. Vertical tillage implement operated 1–3 days before seeding at a depth of 9 cm (4.5 cm (1.75 in.) wide coulters).
[2] No statistical difference between no-till drill and no-till drill with coulters.

> Minimum tillage in the fall or spring improves seedbed conditions, without the need for secondary tillage, and creates looser, finer soil to improve early soybean growth, while maintaining adequate residue to reduce erosion.

Photo 2–1. Variable emergence in no-till soybeans.

Table 2–3. Effect of tillage and wheat residue management on soybean yields

Based on research at Centralia and Wyoming. Stubble heights were approximately 20–30 cm (10–12 in.) except for plots where stubble was cut and removed.

Soil types — Centralia: loam, clay loam, Wyoming: silty clay, silty clay–loam.

Soybeans were seeded with a JD 700 conservation planter equipped with a single 3.2 cm (1.25 in.) coulter. The no-till planter was equipped with tine row cleaners.

Tillage (and Straw Management)	Soybean Yield
Fall mouldboard/straw baled	3.29 t/ha 48.9 bu/acre
Fall chisel/straw baled	3.30 t/ha 49.1 bu/acre
Fall disk/straw baled	3.21 t/ha 47.7 bu/acre
Fall zone-till/straw baled	3.19 t/ha 47.5 bu/acre
No-till/all straw and stubble remain	2.27 t/ha 33.8 bu/acre
No-till/straw baled but stubble remains	3.00 t/ha 44.7 bu/acre
No-till/straw baled and stubble removed	3.28 t/ha 48.8 bu/acre

Higher corn yields and greener corn stalks at harvest have increased the amount of corn residue that soybean producers must manage. Large amounts of corn residue will lead to similar problems as cereal residue, including poor stands, slow growth and slug feeding, etc. A row unit planter with 38 cm (15 in.) spacing will perform better than a no-till drill in heavy corn residue. Vertical tillage or some form of minimal tillage can also be used to reduce the amount of corn residue that a drill must penetrate. Increasing seeding rates by 10% in narrow rows is an option for no-till to help establish an acceptable plant stand.

It is best to avoid tillage along highly erodible knolls and slopes. In these situations, it may be sensible to use tillage only where the soil routinely remains cooler or wetter in the spring.

Crop Rotation Considerations

Soybeans are very responsive to crop rotation. Table 2–4, *Soybean yield response to tillage and rotation*, summarizes the results of long-term rotation studies conducted at Ridgetown Campus, University of Guelph. A rotation of soybeans, winter wheat and corn, or a rotation of soybeans and winter wheat provided the greatest soybean yield in this study. Growing soybeans continuously had the lowest yield, especially using conventional tillage. A short rotation leads to a build-up of disease and other long-term problems, including:

- Rapidly increasing soybean cyst nematode (SCN) populations.
- Incidence of white mould; where maintaining a 3–4-year rotation with other non-host crops will reduce the incidence of white mould.
- The severity and number of races of phytophthora root rot, in fields with a history of this disease the spread of Group 2-resistant weeds due to the repeated use of Group 2 Herbicides-ALS inhibitors.

Table 2–4. Soybean yield response to tillage and rotation

Average soybean yield response under long-term (established in 1995) no-till and conventional tillage systems across crop rotations on a Brookston clay loam at Ridgetown, Ontario, 2009–2014.

A difference of less than 0.27 t/ha (4 bu/acre) is statistically insignifiant.

LEGEND: rc = underseeded red clover

Crop Rotation	Tillage System		Across Tillage Systems
	Conventional	**No-Till**	
Continuous soybean	3.74 t/ha (55.6 bu/acre)	4.06 t/ha (60.3 bu/acre)	3.90 t/ha (58.0 bu/acre)
Corn-soybean	3.87 t/ha (57.6 bu/acre)	4.14 t/ha (61.5 bu/acre)	4.01 t/ha (59.6 bu/acre)
Winter wheat-soybean	4.35 t/ha (64.7 bu/acre)	4.55 t/ha (67.6 bu/acre)	4.45 t/ha (66.2 bu/acre)
Winter wheat (rc)-soybean	4.49 t/ha (66.8 bu/acre)	4.34 t/ha (64.6 bu/acre)	4.42 t/ha (65.7 bu/acre)
Winter wheat-soybean-corn	4.37 t/ha (65.0 bu/acre)	4.42 t/ha (65.7 bu/acre)	4.40 t/ha (65.4 bu/acre)
Winter wheat (rc)-soybean-corn	4.51 t/ha (67.0 bu/acre)	4.31 t/ha (64.1 bu/acre)	4.41 t/ha (65.6 bu/acre)
Average across crop rotation	**4.22 t/ha (62.8 bu/acre)**	**4.30 t/ha (64.0 bu/acre)**	**4.26 t/ha (63.4 bu/acre)**

Winter Wheat Following Soybeans

In Ontario, winter wheat often follows soybean harvest. The dilemma is always between balancing a high-yielding soybean variety, with a variety that has a relatively early harvest date, allowing for timely planting of winter wheat. If winter wheat is to be grown following soybeans:

- Select a variety that is 0.5–1.0 MG (Maturity Group) less than the target MG for your area. Research from Ridgetown Campus, University of Guelph indicated that selecting a variety that is 0.5 MG less than an adapted variety, advanced the maturity by an average of 5 days (range: 3–7 days). A variety that is 1.0 MG less advanced the maturity 9 days compared to an adapted variety. See Table 2–5, *Soybean physiological maturity dates and days to maturity.*
- Plant the soybean crop early, as late planting will delay wheat planting. If soybean planting can be achieved by early May, choosing a shorter season (lower MG) variety is less important.
- The wheat planting date can be calculated using the soybean planting date and the days to maturity of the soybean variety.

Refer to the winter wheat planting dates in Chapter 4, *Cereals*.

Table 2–5. Soybean physiological maturity dates and days to maturity

Harvest would occur 3–10 days after these dates.

Year	Planting Date	Maturity Groups (MG)		
		1.6 MG	**2.1 MG**	**2.6 MG**
1990	May 28	Sept. 20 115 days	Sept. 25 120 days	Sept. 30 125 days
1991	May 11	Sept. 8 120 days	Sept. 13 125 days	Sept. 20 132 days
1992	May 15	Sept. 25 133 days	Sept. 27 135 days	Oct. 2 140 days
1993	May 20	Sept. 21 124 days	Sept. 26 129 days	Oct. 1 134 days
1994	May 27	Sept. 14 109 days	Sept. 16 111 days	Sept. 21 116 days
1995	May 23	Sept. 16 115 days	Sept. 18 117 days	Sept. 21 120 days
1997	May 23	Sept. 17 116 days	Sept. 21 120 days	Sept. 27 126 days
1998	May 21	Sept. 14 115 days	Sept. 17 118 days	Sept. 23 124 days
1999	May 12	Sept. 10 121 days	Sept. 13 124 days	Sept. 19 130 days

Variety Selection

There are over 250 soybean varieties grown in Ontario and their turnover in the marketplace is rapid. Aside from maturity and yield, variety selection should be based on resistance or tolerance to disease, aphids, plant standability and SCN resistance.

Maturity Group (MG)

Soybean development is affected by genetics, temperature and hours of sunshine. Disease, moisture stress and other stresses can lengthen or shorten the actual days to maturity, depending on when the stress occurs.

Relative maturity is a system where new cultivars are compared over years to established cultivars and maturity ratings. There are 13 maturity groups (MG) recognized in the Americas, ranging from the earliest MG 000, to the latest MG X. In Canada, maturity groups range from MG 000 to MG III. With the use of decimals, each decimal unit is approximately equivalent to one day of maturity, that is, a cultivar rated MG 1.5 is about 5 days later maturing than a cultivar rated MG 1.0 in its region of adaptation.

Select a variety that corresponds to the MG for the area using Figure 2–1, *Ontario Soybean Relative Maturity Map*. These varieties are adapted to mature in early fall, given a normal planting date.

Selecting adapted varieties will offer the opportunity to maximize yield by making use of the full growing season. When growing specialty soybeans, such as the white hilum types, selection of a shorter-season variety (lower MG) will help ensure quality at harvest.

Hilum Colour

The hilum is the point at which the soybean seed attaches to the pod. Varieties differ in hilum colour and can be yellow (Y), imperfect yellow (IY), grey (GR), buff (BF), brown (BR), black (BL) or imperfect black (IBL). Yellow hilum soybeans are generally the preferred type for the export market. Hilum discolouration may occur on the imperfect yellow (IY) varieties. Affected beans may not be acceptable for export markets.

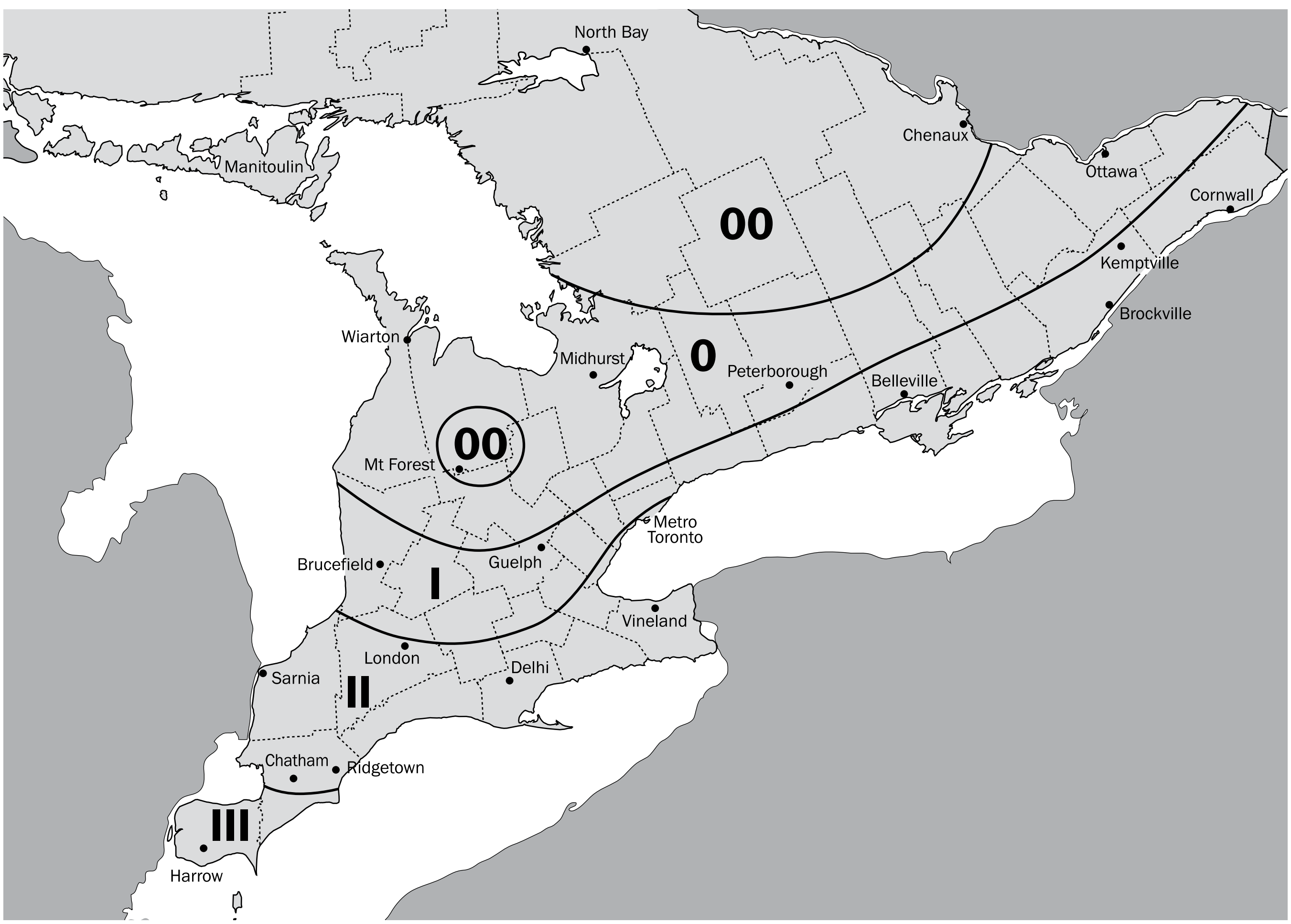


Figure 2–1. Ontario soybean relative maturity map.

Choosing Superior Varieties

In addition to maturity rating, other important factors for choosing varieties are:

- yield potential
- herbicide resistance traits
- standability
- insect and disease resistance

In selecting superior varieties, three main sources of information exist:

- performance trial data
- on-farm strip trial data
- company information on variety characteristics

The Ontario Soybean and Canola Committee co-ordinates annual performance trials at various locations across the province. Results are published each fall in the brochure *Ontario Soybean Variety Trials*. This brochure is available on the internet at www.gosoy.ca and is valuable for comparing the yield potential of varieties. It also provides ratings for maturity, plant height, lodging and other characteristics, such as resistance to phytopthora root rot at locations with heavy textured soils, or resistance to SCN.

Seed companies will provide detailed information on a number of growth characteristics of varieties to aid in selection. When evaluating variety performance, take into account that variety trials conducted under conventional tillage have also proven to be a reliable indicator of a variety's performance under no-till conditions.

If the soybeans are intended for on-farm livestock feed, choose a variety with a high protein index.

Plant lodging can be a significant yield-reducing problem in Ontario. Varieties with good standability ratings or lodging scores should be chosen for production on medium-to-light-textured soils, fields that have regular manure application, fields with high residual nitrogen levels and fields with a history of lodging. Lowering seeding rates will also reduce lodging.

> Soybean variety selection is one of the most important management decisions for improving yields on any farm. A minimum of three different varieties should be grown each year to evaluate the performance of newer higher-yielding varieties.

Individual varieties may perform differently depending on growing conditions. Growing more than one variety will help reduce the risk of crop failure. Plant the majority of the acreage to proven varieties while testing new varieties on a smaller scale.

Identity-Preserved (IP) Varieties

Identity preservation is the segregation of a variety from planting through to delivery to an end user. It is not a new concept, but IP varieties have existed in a number of markets, including seed production and the production of food-grade soybeans. The introduction of GMO crop varieties has resulted in consumer demand for identity-preserved, non-GMO soybeans. The market offers various levels of premiums and contracts to the producer to grow IP soybeans.

The premiums offered for producing IP varieties must be weighed against their yield potential, increased costs, time and management. Acreage planted should be limited to a size that can be harvested in a timely fashion. Performance information for some specialty-trait varieties may not be available or may only be available from the company selling the seed and/or agreeing to take delivery of the crop after harvest. The agronomic qualities of an IP variety, such as yield, disease resistance and maturity should be evaluated to determine whether or not the premium offered upon sale is adequate. Performance trials of many food-grade soybeans are conducted by the Ontario Soybean and Canola Committee (OSACC). This information is available on the OSACC website at www.gosoy.ca. For crop insurance purposes, Agricorp provides a yield adjustment factor for a number of specialty types since specific varieties may yield less.

Biotechnology

Varieties carrying special traits, such as resistance to certain herbicides, are available in Ontario. Over 75% of soybean varieties have GMO-resistance to herbicides such as glyphosate. These may have value for producers trying to address specific or difficult to control weed issues. They can also be useful in certain tillage systems where burndown treatments or herbicide applications can be applied without killing the GMO resistant soybean variety. These varieties or the pesticides used on them may not be accepted in all soybean markets.

Planting and Crop Development

Seed Quality

It is important to know the quality of the seed being planted. Certified seed is a guarantee of purity and germination standards. The quality of "farm-saved" bin run seed or common seed is not known unless the germination is tested at an accredited seed lab prior to planting. See Appendix F, *Ontario Laboratories Offering Custom Seed Germination Testing*.

Viability and Deterioration

Germination is the major quality consideration used in grading seedlots. It is the ability of a seedlot to produce normal seedlings under favourable conditions of 95%–100% humidity and 25°C. Stress conditions in the field following planting often reduce field emergence compared to the lab.

A better measure of the ability of seed to emerge rapidly and uniformly under a wide range of conditions is the vigour rating of the seed, called the vigour test, or more appropriately referred to as a stress test. Certified seed standards require that seed be tested for germination, however, in addition to germination, some seed distributors routinely test and report seed vigour.

Figure 2–2, *The relationship between seed vigour, viability and deterioration*, illustrates the relationship between germination and vigour. As seed deterioration increases, germination drops slowly, whereas vigour drops very rapidly.

With Lot A, deterioration is minimal and germination and vigour are similar. On the other hand, Lot B has excellent germination but low vigour.

A number of factors can contribute to loss of seed vigour, including genetics, disease, mechanical seed damage and deterioration in storage and weather conditions prior to harvest. The most important factor affecting vigour appears to be environmental. Time-of-harvest studies conducted by the University of Guelph suggest that vigour is lost if there is a delay between physiological maturity and harvest. Timely harvest is important when soybeans are being grown for seed.

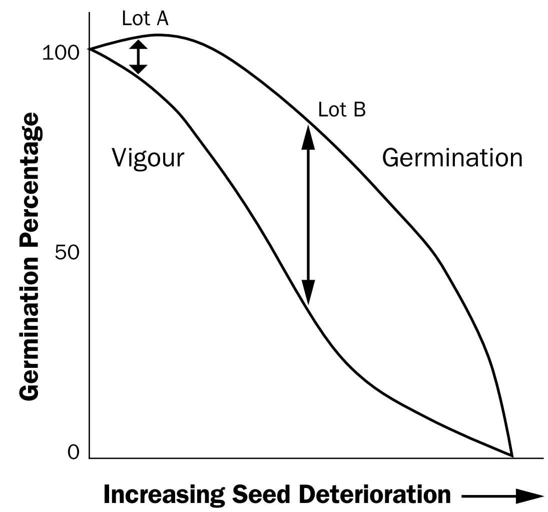


Figure 2–2. The relationship between seed vigour, viability and deterioration.

Source: Delouche and Caldwell, 1960.

Inoculation

Biological N fixation converts gaseous nitrogen in the air (N_2) to a form of nitrogen the plant can use, namely ammonium (NH_4+). In legumes, symbiotic nitrogen fixation occurs when rhizobia bacteria invade the root hair and form a nodule. The process of adding soybean rhizobia (*Bradyrhizobium japonicum*) to the soil is called "inoculation." The rhizobia receive a protected growing environment, carbohydrates, and minerals from the plant and in turn provide the plant with nitrogen. A 3.4 t/ha (50 bu/acre) crop of soybeans will remove over 200 kg/ha (180 lb/acre) of N. Some of this N comes from residual nitrogen in the soil, but 40%–75% will come from biological N fixation. The amount that comes from the soil depends on how much soil N is available and environmental conditions.

Inoculants can be applied "on farm" at planting time or as "pre-inoculants." Pre-inoculants are formulated to allow the bacteria to survive on the seed, making it possible to inoculate the seed well before planting. These products are applied as a commercial seed treatment and are compatible with many fungicide and insecticide seed treatments. Pre-inoculants show similar efficacy to inoculants applied at planting time.

The majority of products now available use a sterile peat-based carrier or a liquid formulation. Sterile-carrier inoculants use a powdered peat base that is sterilized prior to the addition of the inoculant strain. These inoculants carry much higher numbers of rhizobia than the older, non-sterile powdered peat. Non-sterile powdered peat often contains microbial contaminants, which may compete with the rhizobia.

> On first time soybean fields, the use of two different inoculants is suggested to avoid a nodulation failure.

When soybeans are grown on land for the first time, inoculation with soybean rhizobia is essential for high yields. Establishing a healthy number of root nodules on first-time fields can be challenging. The use of two different products, or at least two different lots of the same product, will improve the chances of good nodulation. When soil temperatures are unusually cool, nodulation failures are common. Soybean nodulation and N fixation are vulnerable to cool soil temperatures. Soybeans are a subtropical species and for optimal symbiotic activity the soil temperature should be above 25°C. A root zone temperature of at least 15°C–17°C is critical for soybean nodulation and N fixation to occur normally. Nodulation may not occur at all if soil temperature is below 10°C. Under extremely cool conditions nodulation can be delayed until August or there may be a complete nodulation failure. Nodules can only form on new root hairs and root hairs are only present on new root growth. At times roots grow past where the inoculant was initially placed in the soil before nodulation occurs, resulting in an inoculation failure and a nitrogen-deficient crop. By using two products the overall rhizobial population is increased, reducing the chances of a nodulation failure.

Good seed coverage is required for maximum efficacy of any inoculant. When applying "on farm," apply inoculants at the base of a brush auger when loading the planter. Kits that hang on the side of a truck, tote or gravity wagon are available from dealers. Occasionally, some producers have experienced bridging in the planter or build-up in augers from over-application of liquid seed treatments or inoculants. Simultaneous application of a low rate of peat is one option to reduce bridging.

Some seed treatments and liquid fertilizers can negatively impact inoculant performance. When using an inoculant, check the label to confirm how long the inoculant will be viable on the seed if applied with a seed treatment or mixed with a liquid fertilizer.

Inoculants are not essential where a well-nodulated, dark-green soybean crop has been grown in the past. Exceptions are acid soils (pH below 6.0), sandy soils and fields with poor drainage that have been flooded for an extended period of time. Under these conditions, inoculation is suggested for each soybean crop. A producer who is not certain that previous soybean crops were well nodulated should inoculate to avoid the possibility of poor nodulation. In Ontario trials, results indicate a 0.1 t/ha (1.5 bu/acre) yield increase by inoculating soybeans planted into fields that have previously grown well-nodulated soybeans. Even in the absence of a soybean crop, soybean rhizobia will survive in most soils for 7–10 years and in some fields for over 50 years.

Studies have shown little success in attempting to replace existing strains of rhizobia in the soil with newer, more-effective strains. Once a strain of rhizobia has become established in the soil, it will out-compete any new strain that is introduced on the seed.

Manure or commercial nitrogen fertilizer applied to soybean fields supplies a readily available source of nitrogen, which soybeans will use prior to that provided by the rhizobia. In these fields, nodulation may be delayed, but yields are not generally reduced. On first-time soybean fields where manure or commercial N is applied, nodulation may not occur, and unless soil nitrogen is abundant, nitrogen deficiency may be observed late in the season.

Soybean roots normally become infected with *Bradyrhizobium japonicum* shortly after emergence. Nodulation of soybeans may be observed 2–3 weeks after planting. Checking fields at this point will allow time for nitrogen application, should an inoculant failure occur. In first-time fields, nodules will be located on the taproot. In previous soybean fields, nodules will also be found along lateral roots.

> Seven to fourteen nodules per plant at first flower indicates adequate nodulation.

Soybeans often go through a period when leaves are light green or even pale yellow. This is the period just before the nodules start to supply adequate nitrogen to the leaves and is an important phase in the development of a healthy crop. Usually by the third trifoliate stage, the nodules have established and start providing nitrogen, the leaves will turn a dark-green colour. With proper nodulation, sufficient nutrients and adequate moisture, soybeans will remain yellow for only 7–10 days.

Planting Date

Planting date is an important management tool to maximize yield potential. Soybean planting should be initiated based on calendar date, seedbed conditions, and the weather forecast for 48 hours after planting. It is critical to have a good seedbed. If significant rainfall is forecast, wait until conditions improve before planting. A cold rain immediately after seeding can impact emergence. Yield response to planting date will vary depending on the growing season and the MG of the variety. On average the highest yields are obtained from early plantings, generally before the middle of May. If springtime conditions are favourable, planting in late April or early May can result in a yield advantage over planting in the middle of May. Later plantings are likely to incur significant yield reductions yield 0.34 t/ha (5 bu/acre), as shown in Table 2–6, *Effect of planting date on yield*. When planting early, select a variety that is adapted or longer season (0.5 MG) for a given area for maximum yields. A three-year study, which compared planting long-season varieties to varieties adapted for a given area, showed a 0.28 t/ha (4 bu/acre) advantage to planting long-season varieties when seeding early. This is shown in Table 2-7, *Yield of an adapted variety compared to a long-season variety when planted early.*

Table 2–6. Effect of planting date on yield

Planting Date	Yield	Percent of Full Yield (%)
April 15–May 5	4.29 t/ha (63.8 bu/acre)	100%
May 6–20	4.26 t/ha (63.3 bu/acre)	99%
May 21–June 5	3.93 t/ha (58.5 bu/acre)	92%

The data in this table represents the average of 22 trials across Ontario from 2010–2012.

There is concern that planting later-maturing soybean varieties will delay winter wheat seeding after soybean harvest. However, if a long-season variety is seeded before the middle of May, the delay in harvest will be minimal (1–3 days) compared to seeding an adapted variety in late May.

Photo 2–2. Planting date differences. Plot on left planted in May. Plot on right planted in June.

Table 2–7. Yield of an adapted variety compared to a long-season variety when planted early

Average of 22 trials across Ontario from 2010–2012

Planting Date	Variety	Yield
Mid-May (May 6–May 20)	Adapted for the area based on relative maturity map	4.17 t/ha (62.1 bu/acre)
Early planting (April 15–May 5)	Adapted for the area based on relative maturity map	4.23 t/ha (62.9 bu/acre)
Early planting (April 15–May 5)	Long-season variety (0.5–0.8 MG) for the area based on relative maturity map	4.45 t/ha (66.2 bu/acre)

Field studies have shown that planting a short season (low MG) variety early can reduce yields if August conditions are dry. The short season variety will mature too rapidly and will not be able to take advantage of late season rains.

Soybeans are more sensitive to soil temperature than corn. However, if soil temperature and moisture conditions are suitable for planting corn, they are generally also suitable for soybeans. Soybean seed emergence can be negatively impacted by a cold hard rain immediately after planting if crusting occurs.

A hard spring frost can kill early-planted soybeans, since the growing point of the emerged seedling is above the soil surface. However, soybean plants can withstand temperatures as low as -2.8°C for a short period of time, while corn experiences tissue damage at -2°C.

Delayed Planting

When planting is delayed, fewer days are required for the plant to reach maturity. A one-month delay in planting results in a 9-day delay of maturity. Delayed planting will reduce the vegetative growth period. This results in shorter plants with significantly fewer nodes and pods set lower on the plant. Late planting also reduces the number of pods per plant because of the shorter flowering period. Planting date also has an effect on the duration of the pod-filling period.

> A 3-day delay in planting date generally results in a 1-day delay of maturity.

Planting after July 1st, most years, has been unprofitable in Ontario and is not covered by crop insurance. If planting must be delayed beyond July 1st:

- On heavy textured soils, select an adapted variety. Planting a short-day variety late in the season will result in extremely short plants with few pods. An early frost may cause dark hilums to "bleed" into the soybean. Select a light hilum variety if this is a concern.
- On medium or light textured soils choosing a variety that is 0.5–1.0 MG less than adapted will aid in reaching maturity before a killing frost.
- Improve vegetative growth of late plantings by selecting taller varieties and planting in narrow rows. Using wide rows when planting late will lead to reduced yield potential. Increase seeding rates by at least 10%. This will increase the height of the low-set pods as well as the number of pods per acre.

Double Cropping Soybeans

In a warm year, some producers in the southernmost regions of Ontario will attempt to grow soybeans immediately following the harvest of their winter cereal or pea crop. Double cropping soybeans in Ontario can be successful if they are seeded early enough; if there is adequate soil moisture for germination and if the fall season is long with a late killing frost. In southwestern Ontario it is possible to achieve a 2 t/ha (30 bu/acre) crop if planting on or before July 1st and if the weather cooperates. However, the 2 t/ha (30 bu/acre) yield potential drops approximately 67 kg/ha/day (1 bu/acre/day) after July 1st. The chances of success drop dramatically if seeding after July 10th. Areas with more than 3000 CHU have a greater likelihood of success. There is no crop insurance for double cropped soybeans in Ontario.

Producers who have made double cropping work consistently often harvest wheat early, even if some drying is necessary. When it comes to double cropping, every day counts. The following management tips will increase the chances of a successful double crop:

- Do not take out a good red clover stand to double crop. The benefits from the clover stand will outweigh the risk involved in a double crop venture.
- Do not attempt double cropping if soybean cyst nematode is a problem in the field. The soybean crop will reduce the benefits of the non-host (winter cereal) crop and increase cyst populations.
- Wheat stubble may contain many weed seeds. Glyphosate tolerant varieties are generally more suited to double cropping due to more weed control options with limited soil moisture. Volunteer wheat must be controlled.
- Plant immediately after a timely cereal or pea harvest. Double cropping after July 10th is not successful.
- Plant no-till to retain moisture and reduce costs. At harvest, leave approximately 20 cm (8 in.) of cereal stubble to promote soybean stem elongation and higher pod set.
- Plant 1 cm (0.5 in.) into moisture, but do not plant deeper than 7.5 cm (3 in.). If conditions are extremely dry, do not attempt to double crop. Many double crop failures can be attributed to seed being planted into dry conditions.
- Choose tall, small seeded varieties that are 1.0 MG lower than suggested for normal planting dates. Choosing very short day maturities (00 MG) is not a good option. Short season soybeans planted very late will not yield well because the plants will not grow tall enough.
- Plant in narrow rows using high seeding rates. (618,000 seeds/ha or 250,000 seeds/acre).

Row Width and Seeding Equipment

Soybeans grow well under a wide range of row widths, especially in the long-season regions of Ontario. The choice of row width depends on factors such as tillage system, equipment suitability, weed problems, soil conditions, white mould pressure and planting date. Most soybeans grown in Ontario are solid seeded (19 cm or 7.5 in. spacing) or intermediate row widths (38–56 cm or 15–22 in.). There is a trend to plant in wide rows especially in fertile soils that produce large amounts of vegetative growth, or in fields with a regular white mould history. Improved air movement in wider rows will help reduce the severity of white mould.

Wide rows allow inter-row cultivation for organic production and are less affected by soil crusting. In-season weed control is more challenging in wide rows due to late emerging weeds. Wide rows will yield less in cool years or with late planting. Narrow rows allow the crop canopy to fill in more quickly, providing maximum light interception and weed suppression. Table 2–8, *Row spacing vs. days to full canopy (May planting)* shows relative time differences to canopy cover. Rapid canopy development often means narrow rows need one less in-season herbicide application.

Table 2–8. Row spacing vs. days to full canopy (May planting)

	Days to Full Canopy	
Row Spacing	**Planting Before May 15**	**Planting After May 15**
18 cm (7 in.)	30 days	25 days
38 cm (15 in.)	45 days	40 days
51 cm (20 in.)	55 days	50 days
76 cm (30 in.)	70 days	65 days

On heavier soil types such as clay, wider row widths increase the number of seeds per foot of row, which can aid in emergence (Photo 2–3). On clay soils prone to crusting, a minimum row width of 38 cm (15 in.) has shown better emergence than solid seeded beans 19 cm (7.5 in.). Wide rows of 76 cm (30 in.) are not advised on heavy clay soils because the canopy takes too long to fill and yields are lower than with intermediate row widths.

Photo 2–3. Soybean seedlings breaking crust.

Across a range of soil types and growing conditions the yield increase from narrow rows is greatest in short-season areas. The yield advantage decreases in southwestern Ontario. Row widths of 38 cm (15 in.) or less are ideal in short-season areas (less than 2,800 CHUs).

Some producers have excellent yields using wide rows of 76 cm (30 in.). Wide rows are best suited on productive soils where beans grow tall and lush. When planting in wide rows choose bushy varieties, seed early and conduct some form of tillage. These practices will help to fill the canopy as soon as possible, reducing the yield losses associated with wide rows. Planting wide rows late can lead to significant yield reductions.

In southwestern Ontario, there may still be some yield advantage in reducing row widths to less than 53 cm (21 in.), as noted in Table 2–9, *Effect of row width on yield*, although this effect is less consistent than it is further north. Row widths of 38 cm (15 in.) have gained popularity because they allow a reduction in seeding rates compared to 19 cm (7.5 in.) rows but still provide excellent yield potential. For much of Ontario an intermediate row width of 38 cm (15 in.) is a good compromise between the higher yield potential associated with narrow rows and the advantages of more air movement from wide rows. Plant fields prone to white mould in row widths of 38 cm (15 in.) or greater, even in short-season areas.

Table 2–9. Effect of row width on yield

Row Width	Yield[1]
18 cm (7 in.)	3.3 t/ha (49 bu/acre)
36 cm (14 in.)	3.2 t/ha (47 bu/acre)
53 cm (21 in.)	3.0 t/ha (45 bu/acre)
71 cm (28 in.)	2.7 t/ha (40 bu/acre)

[1] Values are based on research on clay loam soils in a 2.8 maturity-group (MG) area. Greatest response would be anticipated in shorter-season regions.

Table 2–10, *Seed drill vs. planter unit yields*, shows the yield impact of drilled, solid-seeded stands versus intermediate rows using a drill or planter units. The planter unit yielded 3.5% (0.12 t/ha or 1.8 bu/acre) more than the drill in 38 cm (15 in.) rows. The planter also yielded more than the 19 cm (7.5 in.) drill by 0.07 t/ha (1.1 bu/acre). The higher yield is often a result of improved seed placement with a row unit resulting in a more uniform plant stand.

Seeding Rates

Soybeans will yield well over a wide range of seeding rates. Plants will compensate considerably for differences in stands, without impacting yield. Too high a seeding rate adds unnecessary seed costs and will increase risk for lodging and disease. Soybeans should be planted based on seeds/ha (seeds/acre) not simply by the kg/ha (lb/acre). For most soil types, there is no significant yield advantage to seeding rates over 494,000 seeds/ha (200,000 seeds/acre) as is shown in Figure 2–3. *Soybean yield response to seeding rates.*

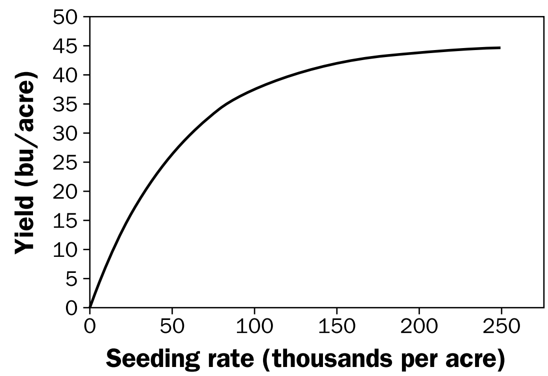


Figure 2–3. Soybean yield response to seeding rates.

Based on results from 45 Ontario trials in 38 cm. (7.5 in.) rows.

Higher seeding rates (10%) are required for maximum yield potential on heavy clay soils or when using poor quality seed. High seeding rates can result in lodging, especially on lighter soil types or in years with excess rainfall (Photo 2–4).

Photo 2–4. High seeding rates can result in lodging. On the left, a high seeding rate of 250,000 seeds/acre. On the right, a population of 200,000 seeds/acre has no lodging.

Table 2–10. Seed drill vs. planter unit yields

A difference of less than 0.27 t/ha (4 bu/acre) is statistically insignificant.

Comparison	Row Spacing: Drill 19 cm (7.5 in.)	Row Spacing: Drill 38 cm (15 in.)	Row Spacing: Planter 38 cm (15 in.)
Yield	3.28 t/ha (48.9 bu/acre)	3.24 t/ha (48.2 bu/acre)	3.36 t/ha (50.0 bu/acre)
Plant stand at 30 days after seeding	72.6%	74.6%	79.8%

Seeding rate guidelines are listed in Table 2–11, *Soybean seeding rate guidelines*. The wider the row width, the lower the seeding rate required. These seeding rates are adequate for both conventional and no-till production. Rates can be reduced by 5% when using precision seeding equipment, compared to a seed drill. Seeding rates may be lowered by an additional 5% if a seed treatment is used. An emergence rate of 75%–80% is considered normal. Full yield potential is achieved in Ontario with final plant stands between 309,000–370,000 plants/ha (125,000–150,000 plants/acre), depending on row width. Heavy clay soils may require more plants/acre, especially in dry years or years with late planting. Seeding rate must be adjusted upward for seed with a lower germination or vigour rating or for soils that tend to crust. Some producers are successful with seeding rates as low as 320,000 seeds/ha (130,000 seeds/acre) in intermediate row widths and even lower rates in 76 cm (30 in.) rows. The goal of seeding is to establish a given number of plants per hectare or acre. With careful management and good soil conditions low seeding rates will establish the minimum necessary plants per hectare or acre. In order to use low seeding rates precise planting equipment, early planting, and excellent seed quality are essential.

Special consideration should be given to fields prone to white mould. Variety selection, wider rows, no-till and lower plant populations are the main tools available to minimize disease damage. Although wider rows and lower seeding rates will give up some yield in years when conditions do not favour white mould development, this strategy can significantly reduce white mould severity during wetter summers. Fields prone to white mould should be planted with a minimum row width of 38 cm (15 in.) at 370,000 seeds/ha (150,000 seeds/acre). In fields with a severe history of white mould, consider using 76 cm (30 in.) rows.

Increase planting rates by 10% with late plantings into mid-June. Varieties respond similarly to changes in seeding rate. The formula for determining seeds needed per foot of row is:

Table 2–11. Soybean seeding rate guidelines

Seeding rates are based on having a germination of 90% and an emergence of 85%–90% (plant stand of 76%–81% of seeding rate).

	Parameters			
Number of seeds	**19 cm (7.5 in.) row** 480,000 seeds/ha (194,000 seeds/acre) 9 seeds/m of row (2.8 seeds/ft of row)	**38 cm (15 in.) row** 437,000 seeds/ha (177,000 seeds/acre) 17 seeds/m of row (5.1 seeds/ft of row)	**56 cm (22 in.) row** 425,000 seeds/ha (172,000 seeds/acre) 24 seeds/m of row (7.2 seeds/ft of row)	**76 cm (30 in.) row** 400,000 seeds/ha (162,000 seeds/acre) 30 seeds/m of row (9.3 seeds/ft of row)
4,400 seeds/kg (2,000 seeds/lb)	109 kg/ha (97 lb/acre)	99 kg/ha (89 lb/acre)	98 kg/ha (86 lb/acre)	91 kg/ha (81 lb/acre)
4,900 seeds/kg (2,200 seeds/lb)	98 kg/ha (88 lb/acre)	89 kg/ha (80 lb/acre)	88 kg/ha (79 lb/acre)	82 kg/ha (74 lb/acre)
5,300 seeds/kg (2,400 seeds/lb)	91 kg/ha (81 lb/acre)	82 kg/ha (74 lb/acre)	82 kg/ha (72 lb/acre)	76 kg/ha (68 lb/acre)
5,700 seeds/kg (2,600 seeds/lb)	84 kg/ha (75 lb/acre)	77 kg/ha (68 lb/acre)	76 kg/ha (66 lb/acre)	70 kg/ha (63 lb/acre)
6,200 seeds/kg (2,800 seeds/lb)	77 kg/ha (69 lb/acre)	70 kg/ha (63 lb/acre)	70 kg/ha (62 lb/acre)	65 kg/ha (58 lb/acre)
6,600 seeds/kg (3,000 seeds/lb)	73 kg/ha (65 lb/acre)	66 kg/ha (59 lb/acre)	65 kg/ha (58 lb/acre)	61 kg/ha (54 lb/acre)
7,100 seeds/kg (3,200 seeds/lb)	68 kg/ha (61 lb/acre)	62 kg/ha (55 lb/acre)	61 kg/ha (54 lb/acre)	57 kg/ha (51 lb/acre)
7,500 seeds/kg (3,400 seeds/lb)	64 kg/ha (57 lb/acre)	58 kg/ha (52 lb/acre)	58 kg/ha (51 lb/acre)	53 kg/ha (48 lb/acre)

$$\text{Seeds needed per m (ft) of row} = \frac{\text{Desired final plant population per m (ft) of row}}{\text{\% germination x \% expected emergence}}$$

Example:

$$\text{Goal 156,000 ppa: } \frac{\text{4.5 seeds/ft row final}}{\text{80\% germination x 80\% emergence}} = \text{7 seeds/ft row required}$$

Example:

$$\text{Goal 385,500 plant/ha: } \frac{\text{15 seeds/m row final}}{\text{80\% germination x 80\% emergence}} = \text{23 seeds/m row required}$$

Seed size differences affect seeding rates. The larger the seed, the higher the volume of seed required for planting. For each variety, seed size and seed quality are influenced by growing and harvest weather of the previous year. There can be as much as 20% variation in the seed size of a variety from one year to the next.

Seed Treatments

Soybean seed treatments have been shown to increase plant stands and improve yields in some situations. They can be an important tool in establishing a uniform plant stand, especially in no-till, in clay soils or in early planted fields. Stand and yield response are dependent on the weather conditions following seeding and the level of disease and insects pressure. Table 2–12, *Soybean plant stand and yield response to seed treatments*, shows average trial results. When conditions were favourable for rapid emergence and little disease or insect pressure was evident, no yield benefit was found to soybean seed treatments. For more details on specific pests and control measures, see OMAFRA Publication 812, *Field Crop Protection Guide*.

Planting Depth

A seeding depth of 3.8 cm (1.5 in.) is generally adequate for soybeans. Seeding depth for early planting into no-till conditions can often be reduced to 2.5 cm (1 in.) if there is sufficient soil moisture. However, due to the high water demand for germination, plant 1 cm (0.5 in.) into moisture, but no deeper than 6.4 cm (2.5 in.) (Photo 2–5). A newly planted soybean seed is completely dependent on its reserve of energy to push through the soil. In general, larger seeds contain more energy and can be planted slightly deeper than small seed. Precise seed placement is difficult to achieve with some seed drills, especially in reduced or no-till fields. Adequate down pressure, ballast and the use of a coulter cart can help achieve proper seeding depth. It is important to have good seed-to-soil contact and a closed seed slot. The key is to plant into adequate soil moisture with a properly adjusted planter or drill. If seeding into moisture with a drill cannot be achieved, consider seeding with the planter, rather than waiting for rain.

Table 2–12. Soybean plant stand and yield response to seed treatments[1]

Response	Control	Fungicide + Insecticide
Population[1]	307,000 plants/ha (124,000 plants/acre)	321,000 plants/ha (130,000 plants/acre)
Yield	3.3 t/ha (49.4 bu/acre)	3.4 t/ha (51.1 bu/acre)

[1] Plant stands taken at 30 days after seeding.

Photo 2–5. Lack of germination or emergence due to shallow planting into dry soil. Left side planted at 4 cm (1.5 in.), right side at 2 cm (0.75 in.).

Varieties differ in their ability to emerge from planting depths greater than 5 cm (2 in.). Seed companies can provide an "emergence score" or hypocotyl length rating, which rates the ability of the seedling to emerge from unusually deep planting.

Rolling

Rolling helps conserve moisture and prepare the field for harvest. Rolling can help level the soil and push rocks into the ground, making it possible to do a better job combining. Some producers roll immediately after planting, while others wait until the soybeans have emerged. Rolling immediately after planting provides improved seed-to-soil contact and reduces the likelihood of plant injury, however, it also increases the risk of soil crusting, which hinders soybean emergence. Soybean fields that are not rolled after the drill often emerge more quickly and uniformly. If rainfall occurs after seeding, rolled fields are more prone to crusting. If conditions are very dry, rolling can improve emergence from moisture conservation. There is no evidence that rolling increases yield by stimulating plant growth or flowering. Any yield gains associated with rolling are most likely a result of better combine header performance.

Rolling soybeans after emergence does not reduce yields if:

- Fields are rolled during the heat of the day to ensure that soybeans are limp. Soybeans are the most turgid (stiff) during the morning hours and rolling during that time will result in more plant injury.
- Soybeans that are just emerging are left to grow until at least the unifoliate stage, since seedlings are vulnerable to being broken off at emergence. Soybeans should not be rolled past the second trifoliate.

Soil Crusting

Crusting of the soil surface following a driving rain or ponding water can inhibit soybean emergence. The crust can break the hypocotyl arch (the portion of the plant that lifts the cotyledons above the soil surface). If soil is prone to crusting and there is a heavy rain, plan to break the crust before the seedlings are attempting to break through. "Crust-busting" is often done too late to actually increase plant stands.

Light tillage with a rotary hoe, harrows, a coulter cart, or even the planter or seed drill can help break the soil crust and aid bean emergence. Typically these operations will cause at least a 10% loss of emerged beans. A higher stand loss can occur when the hypocotyl arch is breaking the surface. "Crust-busting" may not be necessary in uniform thin stands (e.g., 60%) where full yield potential already exists. See Table 2–13, *Expected yield of soybeans in optimum and reduced stands* to determine yield potential.

Table 2–13. Expected yield of soybeans in optimum and reduced stands

% of Full Stand	Row Spacing				Expected Final Yield as % of Optimum
	18 cm row (7 in.)	**36 cm row (14 in.)**	**53 cm row (21 in.)**	**76 cm row (30 in.)**	
100%	553,300 plants/ha (223,900 plants/acre)	402,600 plants/ha (162,900 plants/acre)	392,700 plants/ha (158,900 plants/acre)	405,100 plants/ha (163,900 plants/acre)	100%
80%	442,100 plants/ha (178,900 plants/acre)	323,600 plants/ha (131,000 plants/acre)	313,700 plants/ha (127,000 plants/acre)	323,600 plants/ha (131,000 plants/acre)	100%
60%	331,000 plants/ha (134,000 plants/acre)	242,100 plants/ha (98,000 plants/acre)	237,100 plants/ha (96,000 plants/acre)	244,500 plants/ha (98,900 plants/acre)	100%
40%	222,300 plants/ha (90,000 plants/acre)	160,600 plants/ha (65,000 plants/acre)	158,100 plants/ha (64,000 plants/acre)	163,000 plants/ha (66,000 plants/acre)	87%
20%	111,200 plants/ha (45,000 plants/acre)	81,500 plants/ha (33,000 plants/acre)	79,000 plants/ha (32,000 plants/acre)	81,500 plants/ha (33,000 plants/acre)	62%

Replant Decisions

Soybeans are more prone to poor stand establishment than corn or wheat, because the seedling must pull the cotyledon seed leaves through the ground to emerge. Deciding whether it is worth replanting a poor stand can be difficult. Plant stand reductions are rarely uniform, which makes a decision to replant more challenging. Often it is best to treat parts of a field separately. Do not assess a poor soybean stand too quickly, since more seedlings may still emerge. Fields with a plant reduction of 50% do not need replanting if plant loss is uniform and the stand is healthy. Numerous studies and field experience have demonstrated that keeping an existing stand is often more profitable than replanting. Replanting gives no guarantee of a perfect stand.

Every replant decision is based on factors surrounding the individual field. Information needed to make a replant decision includes:

- Assessing the population and health of existing stand. Normal seeding rates include a margin of safety to ensure emergence of an adequate stand.
- Evaluating the cause of the low plant population. A number of factors can cause reduced soybean stands. These include soil crusting, herbicide injury, frost, hail, insects and diseases. For instance, in a wet year, damping-off is likely to be caused by two fungal classes — *Pythium* and *Phytophthora*. In this situation, if the stand is to be replanted, consider the use of a variety resistant to *Phytophthora* plus a seed treatment.
- Determining the uniformity of the remaining plant stand.
- Comparing the yield potential of the existing stand to the yield potential of the replanted stand. Yield potential begins to decline after the optimum planting date and declines throughout June.
- Estimating the cost of replanting and additional weed control in thin stands.

Compensation and Plant Spacing (Gaps)

Soybean plants have an amazing ability to compensate for thin stands. Soybean plants can fill interplant spaces up to about 30 cm (12 in.) within or between rows without any yield loss, provided weeds do not compete for this space. Ontario research has found that a 33% reduction in the stand, distributed uniformly over the field, will not significantly affect yield.

Plants in very thin stands branch profusely, making them heavy and more prone to lodging. Branched plants tend to bear more of their pods near the ground. Consequently, harvest losses can be higher in these stands. In trials with thin stands, lodging did not become a problem until populations dropped below 60% of a full stand.

Evaluating Stand Reductions

Accurately assess the stand for the population, spacing and health of the remaining plants. To determine plant population, see the hula-hoop method in Appendix K, *Hula-Hoop Method for Determining Plant and Pest Populations*.

Table 2–13, *Expected yield of soybeans in optimum and reduced stands*, provides an estimate of the yield potential compared to a full stand, based on research conducted in Ontario. It is important to note that Table 2–13 is based on the number of healthy plants remaining in a thin stand, spaced uniformly and kept free of weed competition.

> Do not replant a plant stand of more than 222,000 plants/ha (90,000 plants/acre), in 19 cm (7.5 in.) row spacings on most soil types. Very heavy clay soils need a minimum of less than 250,000 plants/ha (110,000 plants/acre) before a replant is worthwhile.

Calculating Returns from Replanting

- Estimate the yield of a full stand with the original planting date.
- Determine the population of the existing stand. See the hula-hoop method described in Appendix K, *Hula-Hoop Method for Determining Plant and Pest Populations*.
- Estimate the yield potential of the reduced stand. See Table 2–13, *Expected yield of soybeans in optimum and reduced stands.*
- Estimate the yield potential of the replanted full stand. The later date will reduce the yield potential. See Table 2–6, *Effect of planting date on yield*.
- Estimate the cost of replanting.
- Compare the value of reduced stand to replanted stand, see Figure 2–4, *Reduced stand in field*.

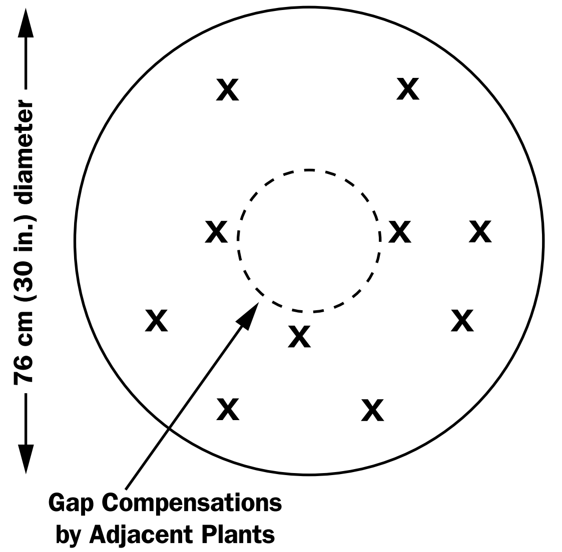


Figure 2–4. Reduced stand in field.

Example:

A field planted on May 12 is estimated to have a yield potential of 3 t/ha (45 bu/acre) if there were a full stand. On June 5, a reduced stand of solid-seeded, 18-cm row spacing (7-in. row) soybeans has an average population of 222,220 plants/ha (90,000 plants/acre). The yield potential of this stand is 87% (2.6 t/ha or 39 bu/acre) of a full stand (Table 2–13, *Expected yield of soybeans in optimum and reduced stands*). Yield expectation from replanting on June 6th would be about 2.8 t/ha (41 bu/acre) due to the later planting date (3t/ha x 92% or 45 bu/ac x 92% — from Table 2–6, *Effect of planting date on yield*). Replanting would not be justified in this situation due to the seed and planting cost, and risk associated with replanting.

Patching or Thickening Thin Stands

In cases of poor stand establishment, replanting alongside the established seedlings to patch up or thicken the existing stand only improves yields when the stand is very poor. The replanted seedlings are so far behind in development that they are unable to compete with even a thin original stand. However, thickening a thin stand may still be the best option to maximize yields and is usually better than removing the original stand of thin soybeans. If patching or thickening is contemplated, use the same variety and do not destroy the original stand. Repair planting can lead to timing difficulties with weed control and harvest date but is manageable, especially with glyphosate-tolerant varieties.

Plant Development

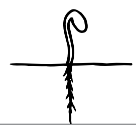
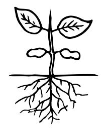
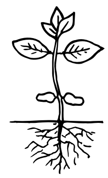
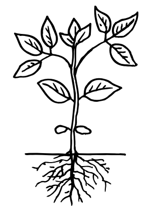
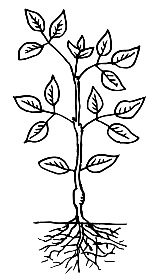
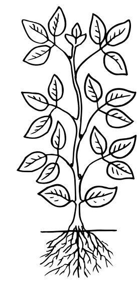
Table 2–14, *Vegetative growth stages of soybeans* shows the growth stages of the soybean plant from emergence to full maturity. Table 2–15, *Reproductive growth stages of soybeans* shows the reproductive growth stages from beginning bloom to full maturity.

The system used to describe soybean growth stages divides plant development into two stages: vegetative (V) — leaves and nodes — and reproductive (R) — flowers, pods and seeds. The V stage refers to the number of nodes on the main stem with fully developed leaves, beginning with the unifoliate node. A leaf is considered fully developed when the leaflets on the next node have unrolled far enough that their edges are not touching. For example, V1 refers to the stage when the unifoliate node has a fully developed leaf, meaning that the leaf above (first trifoliate) is unrolled. This stage is commonly referred to as the "first trifoliate" because the first trifoliate is unrolled. The node is the place on the stem where the leaf is or was attached. Trifoliate leaves on branches are not counted when determining V stages.

The first two leaves of the soybean plant are unifoliates (each is a single leaf) occurring opposite each other at the first node, above the cotyledons. Subsequent leaves are trifoliate (three leaflets per leaf) and are on alternate sides along the stem. When the plant has 2–3 trifoliates, the nodules, which are important for the fixation of atmospheric nitrogen, become visible on the roots.

When planted at the optimal time, soybeans will develop 5–7 trifoliates before flowering begins. Flowering is triggered mainly by day length and temperature changes. Very early-maturing soybeans are nearly insensitive to day length. Instead, flowering is controlled mainly by accumulated heat units. Later-maturing varieties are influenced more by day length. Therefore, late-planted, long-season soybeans take fewer days to mature than those planted early.

Table 2–14. Vegetative growth stages of soybeans

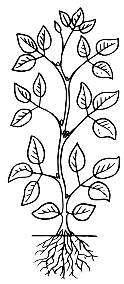
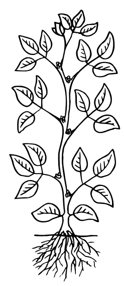
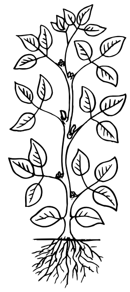
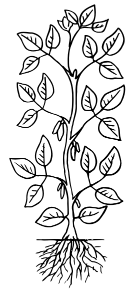
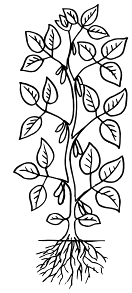
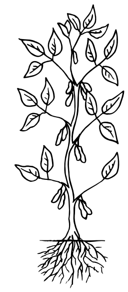
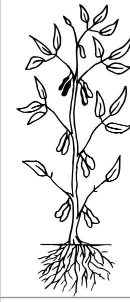
	VE	VC	V1	V3*	V5	Vn
						
Stage Title	emergence	unifoliate	first trifoliate	third trifoliate	fifth trifoliate	nth trifoliate
Days to Achieve Stage[1]	15	5	5	3	3	3 days/trifoliate leaf
Range[2] (Days)	5–22	3–10	3–9	3–9	3–9	(varies)
Description	• seedlings emerge from the soil (crook stage)	• hypocotyl straightens • cotyledons unfold • unifoliate leaves unroll (leaf edges are not touching) • growing point is above soil surface	• first trifoliate emerged and opened • start of critical weed-free period	• 3 trifoliate leaves emerged and opened • end of critical weed-free period • nitrogen fixation has started	• 5 trifoliate leaves emerged and opened • 50% leaf loss has little impact on final yield • early maturity soybeans reach R1 at ~V4	• n = number of nodes on the main stem with fully developed leaves, beginning with the unifoliate node • number of nodes is a function of maturity rating, planting date and climatic conditions

[1] An estimate of the number of days required to move from one stage to the next.

[2] The estimate of days is influenced by the variety maturity rating, planting date, growing region, and climate conditions and can vary within and between seasons.

* V2 and V4 are vegetative growth stages but were not included in the table.

Table 2–15. Reproductive growth stages of soybeans

	R1	R2	R3	R4	R5	R6	R7	R8
								
Stage Title	beginning bloom	full bloom	beginning pod	full pod	beginning seed	full seed	beginning maturity	full maturity
Days to Achieve Stage[1]	3	10	10	11	14	16	11	(varies)
Range[2] (Days)	1–4	8–12	8–12	9–13	12–16	14–18	8–13	(varies)
Notes	• triggered by changing day length and temperature • 1 open flower visible from any node on stem • flowering begins near node 5 (V4) and moves up and down the stem • root growth rates increase • extreme heat can reduce growth, flowering and pod development	• open flower on one of the top 2 nodes on main stem • 50% height and dry weight accumulation • stress does not usually reduce yield • nitrogen fixation increasing rapidly	• short pods visible at top 4 nodes (fully developed leaves) of main stem • flowering peaks • look for 2–3 seeds per pod	• pods 2 cm long at top 4 nodes of main stem • stress occurring between R4–R6 can result in significant yield loss	• seed can be felt through the pod on one of the upper pods (top 4) • flowering generally completed • plant reaches maximum height, nodes and leaf area • N-fixation rates reach maximum and begin to decline • rapid nutrient uptake and redistribution to pods	• seeds in a pod at one of the top 4 nodes fill pod cavity • pods reach full length • root growth slows substantially • above-ground dry weight accumulation slows • rapid leaf yellowing begins • leaves in lower canopy begin to fall	• one major pod has changed to brown colour on the main stem • seed moisture begins to decline (~60%) • physiological maturity and maximum dry weight reached	• 95% of pods have changed to brown colour • harvest moisture reached in 1–2 weeks after R8

[1] An estimate of the number of days required to move from one stage to the next.
[2] The estimate of days is influenced by the variety maturity rating, planting date, growing region, and climate conditions and can vary within and between seasons.

Germination and Emergence

Germination begins with the seed absorbing soil moisture until it reaches a moisture content of about 50%. The first external sign of germination is the emergence of the radicle (primary root), which grows downward and anchors itself in the soil. Shortly after, the hypocotyl (the section of the stem above the radicle) starts growing upwards, pulling the cotyledons (seed leaves) with it. Once emerged, the hook-shaped hypocotyl straightens out, the cotyledons fold down and the growing point is exposed to sunlight. Emergence normally occurs about 5–21 days after planting, depending on soil moisture, soil temperature and planting depth.

Commercial soybean varieties in Ontario are indeterminate, which continue to grow taller and produce new leaves after flowering has commenced. Tall-determinate varieties grow to their full height before flowering begins. The flowering process occurs over a shorter period of time. Tall-determinate varieties characteristically have their lowest pods higher off the ground than indeterminate varieties.

Fertility Management

Nitrogen and Sulphur

Nitrogen fertilizers are not usually required for soybeans, see earlier Chapter 2 section *Inoculation*. Research studying nitrogen fertilizer applied at planting has shown that excess nitrogen can delay nodule formation and N fixation, and promote excessive vegetative growth that increases risk of lodging. Ontario research has not shown a significant yield gain to applying nitrogen fertilizer to a well-nodulated field of soybeans. There is also no evidence that soybeans respond to sulphur application in Ontario.

If nodulation does not occur, and the soybeans are pale green and N-deficient, the suggested remedial measure is to apply 50 kg/ha (45 lb/acre) of N at first flower — as urea or calcium ammonium nitrate — when the foliage is dry.

Phosphate and Potash

Phosphate and potash guidelines for soybeans are given in Tables 2–16 and 2–17, *Phosphate and Potash Guidelines for Soybeans*. These guidelines are based on OMAFRA-accredited soil tests using the sufficiency approach, which applies the most economic rate of nutrients for a given crop year.

Profitable response to applied nutrients occurs when the increase in crop value, from increased yield or quality, is greater than the cost of the applied nutrient.

Where manure is applied, reduce the fertilizer application according to the amount and quality of manure. See Chapter 9, Table 9-10 *Typical amounts of total and available nitrogen, phosphate and potash from various organic nutrient sources and average concentrations.*

Table 2–16. Phosphate (P_2O_5) guidelines for soybeans

Based on OMAFRA-accredited soil tests.

Profitable response to applied nutrients occurs when the increase in crop value, from increased yield or quality, is greater than the cost of the applied nutrient.

Where manure is applied, reduce the fertilizer application according to the amount and quality of manure (Chapter 9, Manure section).

LEGEND: HR = high response, MR = medium response, LR = low response, RR = rare response, NR = no response

Sodium Bicarbonate Phosphorus Soil Test	Phosphate Required
0–3 ppm	80 kg/ha (HR)
4–5 ppm	60 kg/ha (HR)
6–7 ppm	50 kg/ha (HR)
8–9 ppm	40 kg/ha (HR)
10–12 ppm	30 kg/ha (MR)
13–15 ppm	20 kg/ha (MR)
16–30 ppm	0 (LR)
31–60 ppm	0 (RR)
61 ppm +	0 (NR)[1]

100 kg/ha = 90 lb/acre

[1] When the response rating for a nutrient is "NR," application of phosphorus in fertilizer or manure may reduce crop yield or quality. For example, phosphate applications may induce zinc deficiency on soils low in zinc and may increase the risk of water pollution.

Table 2–17. Potash (K_2O) guidelines for soybeans

Based on OMAFRA-accredited soil tests.

Profitable response to applied nutrients occurs when the increase in crop value, from increased yield or quality, is greater than the cost of the applied nutrient.

Where manure is applied, reduce the fertilizer application according to the amount and quality of manure (Chapter 9, Manure section).

LEGEND: HR = high response, MR = medium response, LR = low response, RR = rare response, NR = no response

Ammonium Acetate Potassium Soil Test	Potash Required
0–15 ppm	120 (HR)
16–30 ppm	110 (HR)
31–45 ppm	90 (HR)
46–60 ppm	80 (HR)
61–80 ppm	60 (MR)
81–100 ppm	40 (MR)
101–120 ppm	30 (MR)
121–150 ppm	0 (LR)
151–250 ppm	0 (RR)
251 ppm +	0 (NR)[1]

100 kg/ha = 90 lb/acre

[1] When the response rating for a nutrient is "NR," application of potash in fertilizer or manure may reduce crop yield or quality. For example, potash application on soils low in magnesium may induce magnesium deficiency.

Potassium deficiency will appear in soybeans as yellowing or browning of margins in older leaves, and in severe cases will also be evident on leaves at the top of the plant (Photo 2–6). Soybeans remove a tremendous amount of potassium (approximately 78 kg/ha for a 3.4 t/ha yield (70 lb/acre for a 50 bu/acre crop). Many Ontario soybean fields are deficient in potassium each year. Either fall application or spring application is acceptable for soybeans. Research trials in Ontario have shown little benefit of banding P and K in a 5 cm (2 in.) to the side and 5 cm (2 in.) below the seed, compared to broadcast application. See Table 2–18, *Soybean yield response to spring application of fertilizer in low-testing soils.*

Photo 2–6. Potassium (K) deficiency appears as a yellowing or browning of leaf margins on older leaves.

Table 2–18. Soybean yield response to spring application of fertilizer in low-testing soils

Average of three trials from with a soil test of 11 ppm for P and 92 ppm for K. All fertilizer was applied in the spring. Broadcast treatment was incorporated.

A difference of less than 81 kg/ha (1.2 bu/acre) is statistically insignifcant.

LEGEND: – = no data available

Treatment	Yield	Yield Advantage
Untreated	3.05 t/ha (45.3 bu/acre)	–
25P + 40K (broadcast)	3.33 t/ha (49.5 bu/acre)	0.28 t/ha (4.2 bu/acre)
25P + 40K (2x2 band)	3.35 t/ha (49.8 bu/acre)	0.30 t/ha (4.5 bu/acre)
25P (in furrow)	3.32 t/ha (49.3 bu/acre)	0.27 t/ha (4.0 bu/acre)
2-20-18 + liquid inoculant (liquid in furrow)	3.27 t/ha (48.6 bu/acre)	0.22 t/ha (3.3 bu/acre)

There is no yield response to P and K application if soil test values are adequate. For additional information about soil testing, refer to *Fertilizer Guidelines* in Chapter 9, *Soil Fertility and Nutrient Use.*

Methods of Application

N or K fertilizer should not be placed in contact with soybean seeds, due to the sensitivity to fertilizer salts. Unlike corn, there is no yield advantage to this practice. The fertilizer may be broadcast and worked into the soil either in the fall or spring. A planter with a separate attachment for fertilizer placement may also be used to place the fertilizer 5 cm (2 in.) to the side and 5 cm (2 in.) below the seed. For further information, see Chapter 9, Table 9–22, *Maximum safe rates of nutrients in fertilizer.*

Plant Analysis

The guideline for tissue analysis of soybeans involves sampling the top fully developed leaf (three leaflets plus stem) at first flowering. See Table 2–19, *Interpretation of plant analysis for soybeans.* For sampling at times other than first flower, take samples from both deficient and healthy areas of the field for comparative purposes. Often taking a soil sample from the same area and at the same time as the plant sample will help with diagnostic interpretation.

Table 2–19. Interpretation of plant analysis for soybeans

Values apply to the top fully developed leaf (3 leaflets plus stem) at first flower.

LEGEND: – = no data available

Nutrient	Critical Concentration[1]	Maximum Normal Concentration[2]
Nitrogen (N)	4.0%	6.0%
Phosphorus (P)	0.35%	0.5%
Potassium (K)	2.0%	3.0%
Calcium (Ca)	–	3.0%
Magnesium (Mg)	0.10%	1.0%
Boron (B)	20.0 ppm	55.0 ppm
Copper (Cu)	4.0 ppm	30.0 ppm
Manganese (Mn)	14.0 ppm	100.0 ppm
Molybdenum (Mo)	0.5 ppm	5.0 ppm
Zinc (Zn)	12.0 ppm	80.0 ppm

Source: Yin, Xinhua and Tony J. Vyn, 2002. Soybean Responses to Potassium Placement and Tillage Alternatives following No-Till. Agron. J. 94:1367–1374.

[1] Yield loss due to nutrient deficiency is expected with nutrient concentrations at or below the "critical" concentration.
[2] Maximum normal concentrations are more than adequate but do not necessarily cause toxicities.

Micronutrients

Manganese

Manganese (Mn) is the only micronutrient deficiency diagnosed in soybeans in Ontario, although zinc deficiency may appear where the topsoil has been lost through erosion.

Manganese deficiency symptoms appear on upper leaves, ranging from pale-green (slight deficiency) to almost white (severe deficiency) with green veins (Photo 2–7). Soil tests and plant analyses are useful in predicting where manganese deficiencies are likely to occur. Both are available at the OMAFRA-accredited laboratories, listed in Appendix C, *Accredited Soil-Testing Laboratories in Ontario*.

To correct a manganese deficiency, a foliar application of Mn is suggested. If the deficiency is severe, a second application may be beneficial.

Photo 2–7. Manganese (Mn) deficiency. Upper leaves appear pale green to almost white with green veins.

Caution: When applying micronutrients with a sprayer that has been used to apply herbicides, it is essential to clean out the spray tank to avoid crop injury.

Soil application is not an effective method of applying manganese, regardless of the source, due to the large amounts required. Application of manganese chelates to the soil has resulted in yield reductions.

In general, soybeans will give a profitable response to manganese in the parts of the field where manganese deficiency is evident. There is no benefit to applying manganese to soybeans without deficiency symptoms.

Harvest and Storage

Minimize Harvest Losses

Soybeans are direct combined, preferably with a combine equipped with a floating flexible cutterbar and automatic header height control. Soybeans can be harvested when moisture levels are under 20%, but they must be stored at 14% moisture or lower.

Photo 2–8. Combine with air reel to minimize losses.

Harvest losses and mechanical damage may be high when soybeans are harvested below 12% moisture. A loss of just 43 beans/m^2 (4/ft^2) represents an overall loss of 67 kg/ha (1 bu/acre). Losses can be minimized if a ground speed of 4–5 km/h is maintained. The reel speed should be adjusted to match crop conditions.

A floating cutterbar cuts off the soybean plants, close to ground level. To improve harvest, adjust:

- the cleaning fan to provide maximum air without blowing soybeans into the return elevator or out the back end
- the chaffer to allow the fan to separate pods and stalk pieces from the soybeans
- the sieve to allow only soybeans through
- the air speed, chaffer and sieve settings throughout the day as the weather conditions and soybean moistures change

Header maintenance is important. The majority of soybean losses occur at the header. The cutter bar must be sharp, and the knife sections must make good contact with the guard ledger plates to allow quick cutting action and rapid movement of the cut beans into the header. Add belting to the bat reel, or use an air reel to get short beans into the feed auger quickly.

If soybean plants remain standing and uncut behind the header:

- check blades and guards
- consider reducing ground speed

Quality and Identity Preservation (IP)

Preharvest

If the soybean crop is destined for an identity-preserved (IP) market, make a special effort to maintain seed quality. Staining and mechanical damage are the main problems at harvest that can downgrade quality. Mechanical damage can result in an entire load being rejected. Staining can occur from weeds, immature beans, dirt and dust. Prior to harvest, thoroughly clean combines, trucks, wagons and other handling equipment and bins to prevent contamination. Scout and rogue fields for off-types and other volunteer crops (e.g., corn). Check fencerows and roadsides for glass, metal, fence posts and other trash. Harvesting of IP beans must wait until soybean stems and weeds have dried down completely to avoid green staining of the seed. Remove weeds such as Eastern black nightshade and American pokeweed from the field before harvest, or have the combine operator avoid weed-infested areas.

Photo 2–9. Soybeans showing purple seed staining.

Harvest and Storage

When harvesting IP beans that are a different variety from the previous field harvested, it is best to thoroughly clean out the combine from top to bottom to remove trapped beans. An alternative, although less-effective, method of combine cleaning involves combining a small area of IP beans separately and loading them into a “slush” wagon. The sample can be used to check moisture and combine set-up, and can be marketed as non-IP soybeans.

Other harvest tips include:

- Oversee custom harvesters to make sure their equipment is ready to harvest.
- Keep a copy of the IP contract on hand to determine the quality parameters at harvest. IP harvesting starts later and ends sooner in the day than for commercial beans, mainly to prevent staining. Once contaminated, a combine is difficult to clean.
- It is best to harvest at moisture levels close to 14% to avoid the need for anything other than ambient air drying. Harvesting at or above 12% moisture, and gentle handling, are necessary to avoid cracked seed coats.
- Adjust the combine to varying harvest conditions throughout the day. Adjustments to reduce mechanical damage may increase dockage (pick) but are more than compensated for by premiums.
- Store IP soybeans in separate bins that are free of other soybean varieties and other grains and oilseeds.

If the crop was produced under contract, all of these requirements will be outlined in the signed agreement. With or without a contract, failure to comply can result in lost premiums.

Soybean Drying

> Many IP varieties cannot be artificially dried, especially with heat. Producers should contact the buyer concerning acceptable moisture levels and possible drying of IP soybeans.

Grain Dryers

The three basic general types of grain dryers used on the farm are:

- in-bin
- batch
- continuous flow

No single drying system is superior to all others in every respect. System selection is dependent on desired features. These features include:

- drying capacity
- grain quality
- fuel/drying efficiency (kJ/kg or BTU/lb of water removed)
- convenience, manpower required to run the dryer
- ability to dry a variety of crops
- maintenance required and capital cost

All dryers move heated air past the grain to evaporate moisture from the grain and carry the water vapour away. Heat is added to this drying air to reduce its relative humidity, thereby increasing its ability to pick up moisture. Wet grain can be dried at higher temperatures since it will be cooled as the moisture evaporates from the kernels. As the grain dries, it will approach the temperature of the drying air. The longer the grain kernels are in contact with this heated air, the drier and hotter the kernels will get.

Drying Soybeans With Heated and Unheated Air

Soybeans are sometimes harvested at a higher moisture content due to wet weather or are harvested earlier than expected to reduce combine losses. All drying methods are adaptable to soybeans with some restrictions on the use of heat and handling practices.

Caution is required when using heated air to dry soybeans that are higher in moisture than desired, for safe, long-term storage. The relative humidity of the drying air must be kept above 40% to prevent seed coats from splitting. Experience has shown that with as little as 5 minutes exposure to high heat, it is possible to cause 100% of the soybeans to crack. Most instructions for drying commercial soybeans suggest a maximum temperature of 55°C–60°C. In good drying weather, this drying temperature may need to be reduced to control seed coat cracking. Check the number of split seeds before and after drying to gauge the drying effect.

Seed soybeans should be dried at temperatures below 40°C. This should only be attempted after several years of experience. Some seed companies disapprove of the use of any heat in conditioning seed soybeans. Enquire with the seed company as to the method of conditioning it allows or prefers for seed beans.

With bin dryers, use caution in any system that involves moving the soybeans in the bin with re-circulators or stirring devices. Damage from handling can be severe, especially as the moisture content drops to 12% or below.

Natural-Air Drying

Soybeans just slightly above storage moisture can be dried with natural air under good drying conditions. Natural-air drying of soybeans requires careful management by the operator, since soybeans lose and take on moisture easily. The fan must be run only when the outside conditions will aid in drying progress. Do not run the fan continuously, night and day, as re-wetting will occur at night, reversing any progress made during the day.

Minimum Requirements for Natural-Air Drying Soybeans

- full aeration floor in the bin
- level soybean surface across the whole bin
- minimum airflow of more than 6.5 L/sec/m^3 (0.5 CFM/bu)
- clean beans with no pods or fines accumulations
- accurate moisture reading of the beans in the bin
- accurate outside air temperature and relative humidity measurement
- an understanding of soybean equilibrium moisture content
- an on/off switch for the fan

A full aeration floor is essential to move air uniformly through the entire bin contents. With a partial aeration floor, or air duct system, dead areas will exist leading to potential spoilage problems. Bean pods, trash and fines accumulations in the bin will restrict or divert airflow. Air moving through the bean mass will take the path of least resistance.

Determining Airflow

Sufficient airflow is needed to move drying air through the whole bean mass. To remove moisture, the minimum airflow required is 6.5 L/sec/m^3 (0.5 CFM/bu). Anything less will only change temperature but not the moisture content of soybeans. Airflow rates of 26 L/sec/m^3 (2 CFM/bu) or higher, only get the job done more quickly. In order to determine the (L/sec/m^3 or CFM/bu) value for a bin, determine the number of bushels in the bin and the static pressure that the fan is operating against. A manometer is a simple device that can be used to measure the static pressure in the air plenum, between the perforated floor and the concrete pad under a grain bin. It will display the static pressure in centimetres or inches of water column. See Figure 12–1, *Home-built manometer*. Determine fan output at the measured static pressure by using the fan performance curve. Divide the L/sec (CFM) output of the fan by the number of cubic metres (bushels) in the bin to give the L/sec/m^3 (CFM/bu) airflow. One strategy to get adequate airflow is to only partially fill the bin. This way, the fan will be operating at less static pressure and deliver higher airflow rates per bushel.

Equilibrium Moisture Content

Researchers have developed equilibrium moisture content tables that aid in predicting the final moisture content of soybeans when exposed to air at a certain temperature and relative humidity. See Table 2–20, *Equilibrium moisture content for soybeans exposed to air (% wet basis)*. To determine, for example, the equilibrium moisture content of soybeans exposed to outside air at 10°C and 70% relative humidity, find the point at which the 10°C row and the 70% relative humidity column intersect. This point will be the equilibrium moisture content for soybeans. Given enough time, the soybeans will dry down to 13.2% moisture content.

Table 2–20. Equilibrium moisture content for soybeans exposed to air (% wet basis)

	Relative Humidity				
Temperature	**50%**	**60%**	**70%**	**80%**	**90%**
0°C	10.0	11.8	13.7	16.2	19.8
5°C	9.8	11.5	13.5	15.9	19.6
10°C	9.5	11.2	13.2	15.7	19.4
15°C	9.2	11.0	13.0	15.5	19.2
20°C	9.0	10.7	12.8	15.2	19.0
25°C	8.7	10.5	12.5	15.0	18.8

Measuring Relative Humidity

To air-dry soybeans, it is important to know the accurate relative humidity of the outside air, which can be challenging to measure. In some cases, this reading can be obtained from a nearby weather station, however conditions can vary from one location to another. Household hygrometers tend to be inaccurate and are not suggested for measuring relative humidity when air-drying tough beans. A sling psychrometer or a good quality hygrometer is ideal for this purpose.

When to Run the Fan

Fan operation is not limited by the time of day, but rather by air temperature and relative humidity levels. On some days, drying can be accomplished from 9 a.m. until midnight, while on others it may only be from 9 a.m. to 6 p.m. Check the temperature and relative humidity of the air numerous times throughout the day. The outside air must be drier than the inside air for making drying progress. If the equilibrium moisture content on a given day is less than the moisture content of the wettest beans, drying is possible, and the fan should be on. Humidistats are available that will activate the fan at pre-set humidity levels. The operator can adjust the relative humidity level at which the fan is activated.

The beans at the top of the bin will be the last to dry. Each day of fan operation will push a drying front up through the bin. This drying front may not reach the top of the bin as quickly as expected. Be sure to take moisture samples at the same depth each time to know how the moisture content is changing at that depth. Bins with stirring devices — stirrators — will have fairly uniform moisture levels throughout the whole bin.

Other Crop Problems

Insects and Diseases

Figure 2–5, *Soybean scouting calendar* illustrates the type and timing of insects and diseases that can cause damage and yield loss in a soybean field. Treatment guidelines to control insects, pests and diseases can be found in OMAFRA Publication 812, *Field Crop Protection Guide*.

Frost and Hail Damage

Early Season

Plants damaged below the cotyledons by early-season frost or hail will not recover (Photo 2–10). If frost or hail damages the growing point of the seedling, but not the stem portion below, the plant will send out new shoots from the base of the leaves or cotyledons. Wait 3–4 days and watch for new growth to emerge from the point where leaves attach to the stem (leaf axils). Research trials show that leaf loss at early growth stages has little impact on final yield or maturity. Table 2–21, *Percent yield loss of indeterminate soybean at various levels of leaf area loss and growth stages,* summarizes the expected yield loss from leaf loss at various life stages.

Photo 2–10. Hail damage. Soybeans are most vulnerable to hail damage during flowering and pod fill.

Table 2–21. Percent yield loss of indeterminate soybean at various levels of leaf area loss and growth stages

LEGEND: – = no data available

Growth Stage	Percent Leaf Area Destroyed									
	10	20	30	40	50	60	70	80	90	100
VC–Vn	–	–	–	–	–	–	–	–	–	–
R1	–	1	2	3	3	4	5	6	8	12
R2	–	2	3	5	6	7	9	12	16	23
R2.5	1	2	3	5	7	9	11	15	20	28
R3	2	3	4	6	8	11	14	18	24	33
R3.5	3	4	5	7	10	13	18	24	31	45
R4	3	5	7	9	12	16	22	30	39	56
R4.5	4	6	9	11	15	20	27	37	49	65
R5	4	7	10	13	17	23	31	43	58	75
R5.5	4	7	10	13	17	23	31	43	58	75
R6	1	6	9	11	14	18	23	31	41	53
R6.5	0	1	1	3	4	5	7	13	18	23

Stem Damage

Broken or cut-off stems have greater impact than leaf loss on yield and maturity. If stem loss is under 50% prior to flowering, yield loss will be less than 10%. When evaluating hail damage, check for bruising on the plant stem. Severe damage to the stem will make it more difficult for the plant to recover. It can also make the plant more susceptible to disease. Bruising, which does not cause stem breakage, results in minimal yield loss.

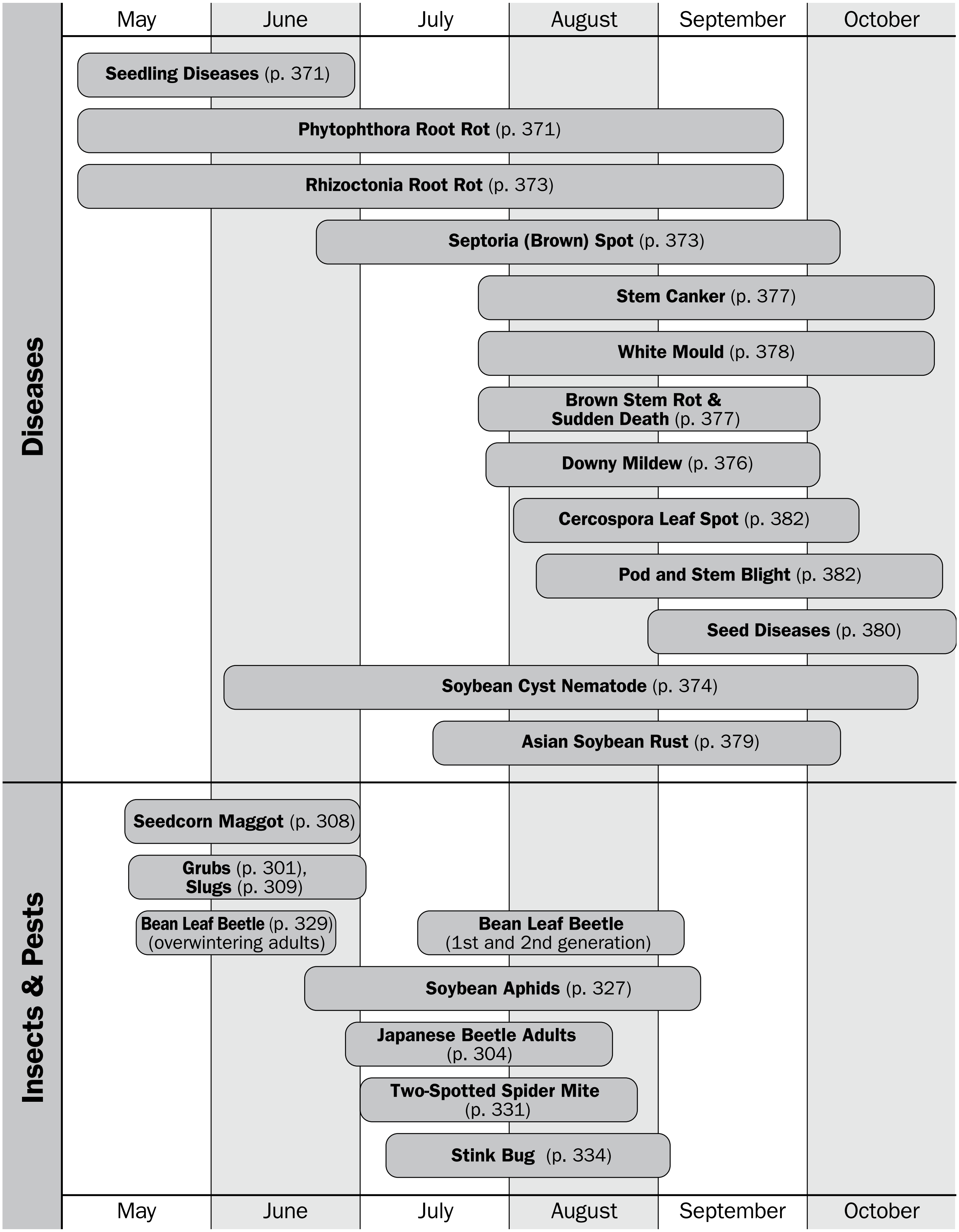


Figure 2–5. Soybean scouting calendar.

In terms of yield reduction, soybeans are most vulnerable during the flowering and seed fill period. This is particularly true if stems are broken, resulting in a reduction in the number of pods and seed size. Delays in maturity also occur.

Late Season Cold Temperature and Frost Injury

Soybeans are regarded as a warm-season crop and are therefore more susceptible to cold temperatures, especially during flowering. It is believed that sustained cold temperatures (less than 10°C) during flowering affect proper formation of pollen in the flower. Sustained cold temperatures result in poorly developed pods called parthencarpic pods (also known as "monkey pods"). There is some variety difference in tolerance to cold temperatures.

Varieties that have tawny pubescence (i.e., yellowish-brown hair) are often more tolerant of cold than those with grey pubescence.

Soybeans are easily injured by frost until they reach physiological maturity, which is attained at the R7 stage (when one pod has changed to brown/grey on main stem). Frost after physiological maturity generally does not damage soybean plants if pods remain intact. Prior to this stage, grain and seed quality will be affected in injured soybeans. A severe frost during flowering or pod fill can reduce yield by up to 80%. Freezing during pod fill will result in severely damaged beans with a greenish, "candied" appearance. Even moderately frosted beans with a greenish colour and slightly wrinkled seed coat are considered damaged and can be discounted when present in excess of limits. The seed will eventually dry down with a wrinkled seed coat. Frost-injured plants may reach maturity earlier but will have seed moisture equal to non-frosted plants. Germination will also be severely reduced. The Grain Commission classifies frost-damaged soybeans as those "whose cotyledons, when cut, are green or greenish-brown in colour with a glassy, wax-like appearance."

Yield reductions from late season frost injury are smaller as the crop matures. Frost during the R5 stage reduces yield by 50%–70%. Frost at the R6 stage will cause losses of 20%–30%. Once the crop reaches the R7 stage only a 5%–10% yield loss is expected. No yield reductions occur once the plants have reached full maturity.

Lightning Damage

Lightning damage is confined to small circular or oval regions with a diameter of 5–10 m (13–30 ft). Damaged areas take on the shape of the standing or running water that accumulated during the thunderstorm. Plants are usually killed but can survive on the edges of the affected area. The affected area has a clearly defined margin, making diagnosis relatively straightforward (Photo 2–11). The affected area does not grow over time. Stems are often darkened with dead leaves remaining attached to the plant.

Photo 2–11. Lightning damage occurs in small circular areas that have a clearly defined margin.

Mature Green Seed

An extremely dry growing season can result in green soybean seed at harvest, even if seed moisture is below 13% (Photo 2–12). The problem is generally the most severe in those regions that are extremely dry during July and August, in soils with poor water holding capacity. Since the beans are dry, the "activity" inside the seed is minimal. The enzyme that normally breaks down the chlorophyll cannot function at such low moistures; therefore the green colour will not disappear over time. There may be some reduction of the green tinge on the outside of the bean over time, but the green discolouration inside the bean will remain if left in the field or in storage. There is little that can be done to avoid having green beans since this problem is weather-related. A good crop rotation combined with choosing varieties best suited for the area is the best defense.

Photo 2–12. Mature green seed occurs when chlorophyll is not broken down during pod fill in drought-stressed plants. The right side shows mature green seed damage.