AGRONOMY GUIDE FOR FIELD CROPS

Publication 811

Ministry of Agriculture,
Food and Rural Affairs

Ontario

2. Soybeans

Over 809,000 ha (2 million acres) of soybeans are grown annually in Ontario. The development of earlier maturity varieties, a wider selection of herbicides, adaptability to no-till production and the relative low cost of production have contributed to the widespread adoption of soybeans in the province.

Glyphosphate-tolerant varieties make up about two-thirds of the crop, while about one-third is non-GMO (genetically modified organisms). 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.

Tillage Options

The wide adaptation of soybeans to various tillage systems, particularly no-till, has contributed to the expansion in soybean acreage. Approximately two-thirds of the soybean crop is grown under no-till systems or with reduced tillage systems. Field experience and research trials have shown similar yields between tillage systems. Management of the tillage system used is as important as the actual system selected.

Table 2–1. Soybean Yield Response Under Various Tillage Systems

	Row Width cm (in.)				
	Single 76 cm (30 in.)	**Twin 76 cm (30 in.)**	**56 cm (22.5 in.)**	**38 cm (15 in.)**	**19 cm (7.5 in.)**
Tillage[1]	**Soybean Yields t/ha (bu/acre)**				
No-till	2.72 (40.4)	3.04 (45.3)	2.93 (43.6)	3.06 (45.5)	3.06 (45.5)
Fall moldboard	2.94 (43.8)	3.02 (44.9)	2.93 (43.6)	3.12 (46.4)	3.21 (47.7)
Fall zone-till	2.78 (41.3)	2.93 (43.6)	–	–	–
Spring zone-till	2.71 (40.3)	3.02 (45.0)	–	–	–
Least Significant Difference[2] (P = 0.05) = 2.42 bu					

[1] Average of nine sites per year. University of Guelph (1998–2000). Trials were conducted on clay loam, silty-clay loam, silt loam and Guelph loam soil types. Spring zone-tillage conducted approximately 1 day prior to planting.

[2] Where the difference between two treatments exceeds 2.4 bu/acre, there is a less than 1-in-20 chance that it is due to random variation.

No-Till and Minimum Tillage

Ontario tillage research found that no-till soybean yields were similar to the fall moldboard 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*, this page). Although the yields were comparable between the two tillage systems, no-till input costs were often lower and profit higher. Where single 76-cm (30-in.) rows were used, moldboard plowing produced the highest yields. When soybeans were planted in twin rows, soybean yields improved over 76-cm (30-in.) rows for all tillage systems. In this study, zone tillage showed no significant yield improvement over no-till. Some Ontario research trials have shown a small yield advantage (0.13 t/ha, 2 bu/acre) to conventional tillage over no-till. In general, there is a greater positive response to tillage in fields with a poor crop rotation compared to a rotation with fewer soybeans.

The keys to successful no-till production are to minimize compaction, manage residue and plant only when soil conditions are fit. The adoption of no-till on heavy textured soil types (clay, silty clay loam or silty clay) can be more challenging than on lighter soils. In some years, growers have experienced reduced no-till soybean yields on these soil types compared to conventional tillage. However, as demonstrated in Table 2–2, *Soybean Yields for Ridgetown College, University of Guelph, 1992–2000*, this page, research on Brookston clay soils resulted in equal yields for no-till and fall moldboard tillage over the long term.

Planting in no-till fields is often done later than in conventionally tilled fields due to wetter and cooler soil conditions. Some producers mitigate this problem with springtime minimal tillage (pre-tillage). Tillage with

Table 2–2. Soybean Yields for Ridgetown College, University of Guelph, 1992–2000

	Average Yield[1] (excluding 1996)	
Tillage Treatment	**t/ha**	**bu/acre**
Fall moldboard plow	3.21 a	47.7 a
No-till	3.21 b	47.8 a
Fall chisel plow	3.05 b	45.4 b
Ridge tillage	2.96 b	44.1 b
Zone tillage	3.06 b	45.5 b
Least Significant Difference (P = 0.05) = 2.2 bu		

[1] Values followed by the same letter are not significantly different at the 5% level.

Table 2–3. Soybean Yield Response to Spring Minimal Tillage (2003–05)

Treatment[1]	Average Yield[2] (excluding 1996) t/ha	Average Yield[2] (excluding 1996) bu/acre
No-till drill	3.03 c	45.1 c
No-till drill with coulters (3.8-cm depth)	3.05 c	45.4 c
No-till drill with coulters (9-cm depth)	3.09 b	46.0 b
Pre-tillage (operated 1–3 days prior to seeding at 9 cm)	3.15 a	46.9 a
Least Significant Difference (P = 0.05) = 0.4 bu		
Source: Bohner, OMAFRA.		

[1] Values based on 40 trials seeded with a JD 1560 no-till drill. Coulters run at seeding time in the row (2-cm or 0.75-in. coulters). Pre-tillage coulter unit operated 1–3 days before seeding at a depth of 9 cm (4.5 cm or 1.75 in. coulters). No coulters run on JD drill for pre-tillage treatment.
[2] Values followed by the same letter are not significantly different.

a one-pass coulter unit has shown a small yield benefit over straight no-till. Coulters run 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 2–3, *Soybean Yield Response to Spring Minimal Tillage (2003–05)*, this page.

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. In research trials done at the University of Guelph, removal of the wheat straw improved seedbed conditions, stand establishment, growth and yield of no-till soybeans. The results are shown in Table 2–4, *Effect of Tillage and Wheat Residue Management on Soybean Yields (1994–96)*, this page. 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. Minimum tillage in the fall or spring without the need for secondary tillage improves seedbed conditions and creates looser, finer soil to improve early soybean growth, while maintaining adequate residue to reduce erosion.

It is best to avoid tillage along highly erodable 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.

Table 2–4. Effect of Tillage and Wheat Residue Management on Soybean Yields (1994–96)

Tillage (and Straw Management)	Soybean Yield t/ha	Soybean Yield bu/acre
Fall moldboard/straw baled	3.29	48.9
Fall chisel/straw baled	3.30	49.1
Fall disk/straw baled	3.21	47.8
Fall zone-till/straw baled	3.19	47.5
No-till/all straw and stubble remain	2.27	33.8
No-till/straw baled but stubble remains	3.00	44.7
No-till/straw baled and stubble removed	3.28	48.8
Based on research at Centralia & Wyoming.		
Source: T. Vyn, G. Opuku and C. Swanton, University of Guelph.		

Note: 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 1.25-in. coulter. The no-till planter was equipped with tine row cleaners.

Crop Rotation Considerations

Soybeans are very responsive to crop rotation. Table 2–5, *Soybean Yield Response Under Various Crop Rotations (1997–2000)*, this page, summarizes the results of rotation studies conducted at Ridgetown College, University of Guelph. A rotation of soybeans, winter wheat and corn provided the greatest yield response. The continuous soybean rotation had the lowest yield. A short rotation leads to a build-up of disease and other long-term problems. Soybean cyst nematode (SCN) populations can increase rapidly, further reducing yields (see *Soybean Cyst Nematode*, on page 235). Maintaining a 3–4-year rotation with other non-host crops will also reduce the incidence of white mould. In fields with a history of phytophthora root rot, a short rotation contributes to an increase in the severity and number of races of the disease. The repeated use of Group 2 Herbicides–ALS inhibitors will encourage the spread of Group 2–resistant weeds.

Table 2–5. Soybean Yield Response Under Various Crop Rotations (1997–2000)

Crop Rotation	Soybean Yield t/ha	Soybean Yield bu/acre
Continuous soybeans	2.89	43
Corn, soybeans	3.09	46
Winter wheat, soybeans	3.23	48
Winter wheat, corn, soybeans	3.23	48
Ridgetown College, University of Guelph, 1997–2000.		

Table 2–6. Soybean Maturity Dates for 2,950-, 3,050- and 3,150-Heat Unit Varieties (1990–99)

		Soybean Maturity Dates[1]		
Year	Planting Date	2950 Heat Unit Variety	3050 Heat Unit Variety	3150 Heat Unit Variety
1990	May 28	Sept. 20	Sept. 25	Sept. 30
1991	May 11	Sept. 8	Sept. 13	Sept. 20
1992	May 15	Sept. 25	Sept. 27	Oct. 2
1993	May 20	Sept. 21	Sept. 26	Oct. 1
1994	May 27	Sept.14	Sept. 16	Sept. 21
1995	May 23	Sept.16	Sept. 18	Sept. 21
1997	May 23	Sept.17	Sept. 21	Sept. 27
1998	May 21	Sept.14	Sept. 17	Sept. 23
1999	May 12	Sept.10	Sept. 13	Sept. 19

Source: Ablett, Ridgetown College, University of Guelph.

[1] These dates are for physiological maturity. Combining would be 3–10 days after these dates.

Winter Wheat Following Soybeans

If winter wheat is to be grown following soybeans:

- Select a variety that requires about 100–200 heat units less than the number available in your area. Research from Ridgetown College, University of Guelph (1990–99), indicated that a variety requiring 100 CHUs less than a full-season variety advanced the maturity by an average of 5 days (range: 3–7 days). Going a further 100 CHUs less advanced the maturity 9 days compared to full-season varieties (see Table 2–6, *Soybean Maturity Dates for 2,950-, 3,050- and 3,150-Heat Unit Varieties (1990–99)*, this page).
- Plant the soybean crop early, as late planting will delay wheat planting.
- The wheat planting date can be calculated using the soybean planting date and the days to maturity of the soybean variety.
- Select a full-season soybean variety if broadcasting the winter wheat into a standing crop.
- Refer to the winter wheat planting dates in *Planting Dates*, on page 92.

For more information on soybean crop rotations and precautions under different tillage systems, see *Crop Rotation*, on page 147.

Variety Selection

There are over 200 soybean varieties, and their turnover in the marketplace is relatively quick. Aside from maturity and yield, base variety selection on resistance or tolerance to disease, aphids, standability and soybean cyst nematode resistance.

Maturity and CHUs

Soybean development is affected by heat unit accumulation, day-length 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.

Select a variety that corresponds to the heat unit rating for the area. Figure 1–1, *Crop Heat Units (CHU-M1) Available for Corn Production*, on page 9, shows approximate CHUs for Ontario. Selecting full-season varieties will make maximum use of the growing season and offer the opportunity to maximize yield. When growing specialty soybeans, such as the white hilum types, selecting shorter-season varieties 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.

Choosing Superior Varieties

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

- yield potential
- 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 characteristics of a variety

The Ontario Oil and Protein Seed Crop Committee conduct performance trials each year at various locations across the province. Results are published each fall in the Ontario Soybean Variety Trials brochure. This brochure is available on the Internet at www.gosoy.ca. These trials are valuable for comparing the yield potential of varieties as well as providing ratings for maturity, plant height and lodging. In Southwestern Ontario, at locations with clay soil types, varieties are evaluated for resistance to phytophthora root rot. Varieties with resistance to phytophthora root rot are recommended on heavier soils. In fields with soybean cyst nematodes (SCN), include varieties with SCN resistance regularly in the rotation (see *Soybean Cyst Nematode*, on page 235).

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

Plant fields on medium-to-light-textured soils and fields that have regular manure application or high residual nitrogen levels to a variety with reduced lodging potential. If the soybeans are intended for on-farm livestock feed, choose a variety with a high protein index.

Individual varieties may perform differently depending on growing conditions. Grow more than one variety to 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 has 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 grower.

The premiums offered for producing IP varieties must be weighed against their increased costs, time and management. Limit the acreage planted to a size that can be harvested in a timely fashion. Performance information for some specialty-trait varieties may not be available. Data for these varieties 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 a number of food-grade soybeans are conducted by the Ontario Oil and Protein Seed Crop Committee. This information is available on the Ontario Oil and Protein Seed Crop Committee website at www.gosoy.ca. For crop insurance purposes, Agricorp provides a yield adjustment factor for a number of specialty soybeans.

Biotechnology

Varieties carrying special traits, such as resistance to certain herbicides, are available in Ontario. These may have value for growers trying to address specific weed problems. They can also be useful in certain tillage systems. These varieties 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 must meet purity and germination standards. The quality of 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*, on page 263).

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 that in 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. In addition to germination, many seed distributors routinely test and report seed vigour.

Figure 2–1, *The Relationship Between Seed Vigour, Viability and Deterioration*, opposite page, 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 if soybeans are being grown for seed.

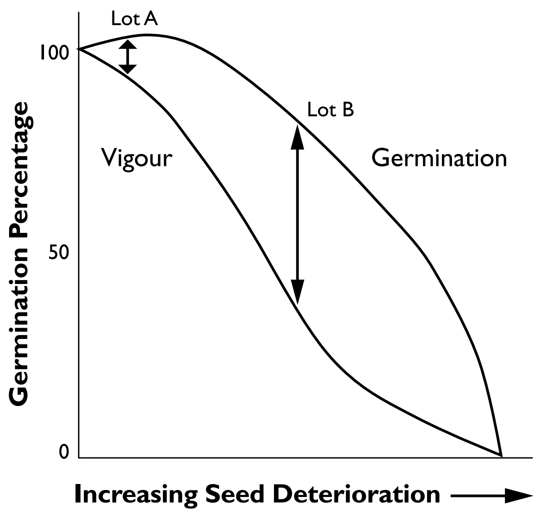


Figure 2–1. The Relationship Between Seed Vigour, Viability and Deterioration
Source: Delouche and Caldwell, 1960.

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 210 lb/acre of nitrogen. Some of this nitrogen comes from residual nitrogen in the soil, but between 40%–75% will come from the nodules depending on how much soil N is available.

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 usually applied by a commercial seed treater and are compatible with many fungicide and insecticide seed treatments. In trials conducted by the University of Guelph, 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.

When soybeans are grown on land for the first time, inoculation with soybean rhizobia is essential for high yields. The use of two different products or at least two different lots of the same product can improve the chances of good inoculation.

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 growers 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.

Inoculant is 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 recommended for each soybean crop. A grower who is not certain that previous soybean crops were well nodulated should inoculate to avoid the possibility of poor nodulation. Ontario trials 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 supply 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 ground 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.

Table 2–7. Effect of Planting Date on Yield and Plant Height

Planting Date	Yield t/ha (bu/acre)	Percent of Full Yield (%)	Plant Height cm
May 10	3.23 (48)	100	104
May 24	2.96 (44)	92	93
June 7	2.75 (41)	85	89
Source: Bohner, OMAFRA, 2004–06.			

Table 2–8. Row Spacing vs. Days to Full Canopy (May Planting)

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

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 14 nodules per plant indicate adequate nodulation at first flower.

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. Once the nodules have established and start providing nitrogen, the leaves will turn a dark-green colour. If proper nodulation, sufficient nutrients and moisture are present, soybeans will remain yellow for only 7–10 days.

Planting Date

Planting date is an important management tool to maximize yield potential. The highest yields of soybeans are obtained from early plantings, generally the first 10 days of May. Later plantings are likely to incur significant reductions in yield as shown in Table 2–7, *Effect of Planting Date on Yield and Plant Height*, this page.

> 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.

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 at maturity. Delayed planting can reduce the vegetative growth period. This results in shorter plants with lower pods. Late planting also reduces the number of pods per plant because of the shorter flowering period. Planting date also has some effect on the duration of the pod-filling period.

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

When planting is delayed beyond June 15, reduce the estimate of heat units available for crop growth by 100–200 CHUs. Planting after July 1 has largely been unsuccessful in Ontario. If planting must be delayed past July 1, select a full-season, light-hilum variety. An early frost may cause dark hilums to "bleed" into the soybean. Planting a short-day variety late in the season will result in extremely short plants with few pods.

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 10%. This will increase the height of the lowest pods as well as the number of pods per acre.

Double Cropping Soybeans

Occasionally, a small number of soybean growers in the southernmost regions of Ontario have attempted to grow soybeans immediately following the harvest of their winter cereal or pea crop. Unfortunately, double cropping of soybeans in Ontario is often unsuccessful. 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.

Table 2–9. Effect of Row Width on Yield

Soybean 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 the 3,250-CHU area. Greater response would be anticipated in shorter season regions. The response to row-width reductions is reduced under stressful growing conditions.

Table 2–10. Solid Seeded vs. Planter Unit Yields

Seeding Rate Seeds/ha (seeds/acre)	19-cm (7.5-in.) Drill t/ha (bu/acre)[1]	38-cm (15-in.) Planter t/ha (bu/acre)
370 500 (150 000)	2.92 (43.4) b	3.03 (45.0) ab
494 000 (200 000)	3.11 (46.2) a	3.12 (46.4) a
Least Significant Difference (P = 0.05) = 2.2 bu		
Source: Bohner, OMAFRA.		

[1] Values followed by the same letter are not significantly different.

The following management tips will increase the chances of a successful double crop:

- At harvest, leave approximately 20 cm (8 in.) of stubble to promote soybean stem elongation and higher pod set.
- Plant immediately after a timely cereal or pea harvest.
- Plant 1 cm (½ in.) into moisture, but do not plant deeper than 7.5 cm (3 in.).
- Select tall, clear-hilum, full-season varieties if possible.
- Plant in narrow rows using high seeding rates.

Row Width

Soybeans grow well under a wide range of row widths 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.)

Wide rows allow for inter-row cultivation and are less affected by soil crusting. Narrow rows allow the crop canopy to fill in more quickly, providing maximum light interception Table 2–8, *Row Spacing vs. Days to Full Canopy (May Planting)*, opposite page, shows relative time differences to canopy cover. Quick canopy development also contributes to weed suppression.

On heavier soil types such as clay, wider row widths increase the number of seeds per foot of row, which can aid in emergence. On clay soils prone to crusting, a minimum row width of 38 cm (15 in.) has shown better emergence than solid seeded beans. Improved air movement in wider rows will also help reduce the severity of white mould.

The increase in yield potential from growing soybeans in narrow rows is greatest in the short-season areas. The yield advantage decreases towards Southwestern Ontario. Row widths of 18 cm (7 in.) are recommended in short-season areas (less than 2,800 CHUs).

Grow fields prone to white mould in row widths of 38 cm (15 in.) or greater, even in short-season areas. 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*, this page, 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.

Table 2–10, *Solid Seeded vs. Planter Unit Yields*, this page, shows the yield impact of drilled, solid-seeded stands versus wider rows using planter units. The negative yield impact associated with slightly wider rows is offset by the more accurate seed placement when using a 38-cm (15-in.) planter compared to a drill. When using very low seeding rates, the planter will outperform the drill.

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 may increase lodging and disease. Soybeans should be planted based on seeds/ha (seeds/acre) not simply by the kg/ha or 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 2–2, *Soybean Yield Response to Seeding Rates*, next page. Higher seeding rates (10%) are required for maximum yield potential on heavy clay soils or when using poor quality seed.

Table 2–11. Recommended Soybean Seeding Rates

Seeds/ Kilogram	Seeds/ Pound	Row Width cm (in.)			
		19 (7.5)	38 (15)	56 (22)	76 (30)
		Seeds/hectare (seeds/acre)			
		480,000 (194,000)	437,000 (177,000)	425,000 (172,000)	400,000 (162,000)
		Number of Seeds/m of row (per ft of row)			
		9 (2.8)	17 (5.1)	24 (7.2)	30 (9.3)
		Seeding Rate kg/ha (lb/acre)[1]			
4,400	2,000	109 (97)	99 (89)	98 (86)	91 (81)
4,900	2,200	98 (88)	89 (80)	88 (79)	82 (74)
5,300	2,400	91 (81)	82 (74)	82 (72)	76 (68)
5,700	2,600	84 (75)	77 (68)	76 (66)	70 (63)
6,200	2,800	77 (69)	70 (63)	70 (62)	65 (58)
6,600	3,000	73 (65)	66 (59)	65 (58)	61 (54)
7,100	3,200	68 (61)	62 (55)	61 (54)	57 (51)
7,500	3,400	64 (57)	58 (52)	58 (51)	53 (48)

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

Recommended seeding rates are listed in Table 2–11, *Recommended Soybean Seeding Rates*, this page. 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. An emergence rate of 75%–80% is considered normal. Full yield potential is achieved in Ontario with final plant stands 309,000–370,000 plants/ha (125,000–150,000 plants/acre), depending on row width. Seeding rate must be adjusted upward for seed with a lower germination or vigour rating or for soils that tend to crust.

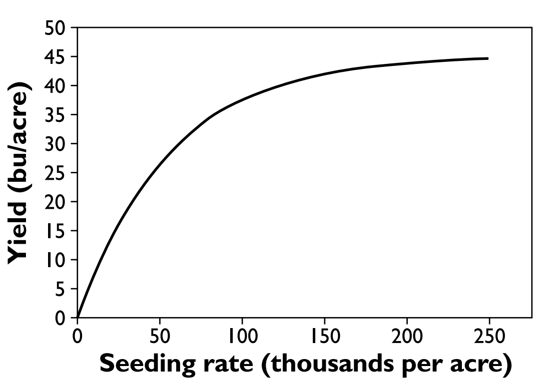


Figure 2–2. Soybean Yield Response to Seeding Rates
Values based on results from 45 Ontario trials in 38-cm. (7.5-in.) rows. Source: Earl, Bohner, University of Guelph, OMAFRA (2005–07).

Give special consideration to fields prone to white mould. Variety selection, wider rows 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 no white mould develops, this strategy can significantly reduce white mould severity during wetter summers. Grow fields prone to white mould 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:

Seeds needed per m (ft) of row

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

Seed size differences affect seeding rates. 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.

Table 2–12. Soybean Plant Stand and Yield Response to Seed Treatments

Seed Treatment[1]	Plants/ha (plants/acre)[2]	Yield[3] t/ha (bu/acre)
Control	345 000 (139 700)	3.3 (49.2) b
Fungicide	355 700 (144 000)	3.4 (50.4) a
Fungicide + Insecticide	369 500 (149 600)	3.4 (51.2) a
Least Significant Difference (P = 0.05) = 1.0 bu		
Source: Hooker, Bohner, University of Guelph, OMAFRA.		

[1] Values based on 35 seed treatment trials in Ontario.
[2] Plant stands taken at 30 days after seeding.
[3] Values followed by the same letter are not significantly different.

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, clay soils or early planted fields. Stand and yield response are dependent on the weather conditions following seeding and the level of disease and insects pressure. Of 35 Ontario trials conducted, 23% showed an increased plant stand with the use of a fungicide + insecticide seed treatment, while 17% of the trials increased yields. Table 2–12, *Soybean Plant Stand and Yield Response to Seed Treatments*, this page, shows average trial results. When conditions were favourable for quick 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. 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 into moisture (approximately ½ in.), but never deeper than 6.4 cm (2.5 in.). 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.

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 chance 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. However, if conditions are very dry, rolling can improve emergence because moisture is conserved.

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.

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, plan to break the crust before the seedlings are attempting to break through.

Light tillage with a rotary hoe, harrows, coulter cart or even the planter or seed drill can help break the soil crust and aid bean emergence. Typically these operations can cause 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 thin stands (e.g., 60%) where full yield potential already exists. See Table 2–13, *Expected Yield of Soybeans in Optimum and Reduced Stands*, next page, to determine yield potential.

Table 2–13. Expected Yield of Soybeans in Optimum and Reduced Stands

% of Full Stand	Expected Final Yield as % of Optimum	Plants per Hectare			
		18-cm rows (7-in.)	36-cm rows (14-in.)	53-cm rows (21-in.)	76-cm rows (30-in.)
100	100	553,300	402,600	392,700	405,100
80	100	442,100	323,600	313,700	323,600
60	100	331,000	242,100	237,100	244,500
40	87	222,300	160,600	158,100	163,000
20	62	111,200	81,500	79,000	81,500
Divide plants/ha by 2.47 to calculate plants/acre.					

Source: University of Guelph, Huron Research Station and Kemptville College

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 crop can be difficult. One of the main challenges in making a decision is that stand reductions are rarely uniform, so parts of a field may need to be treated 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:

- the population and health of existing stand. Normal seeding rates include a margin of safety to ensure emergence of an adequate stand.
- 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.
- the uniformity of the remaining plant stand
- the yield potential of the existing stand compared to the yield potential of the replanted stand. Yield potential begins to decline after the optimum planting date and declines throughout June.
- the cost of replanting and possibly additional weed control costs 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 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 slightly 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

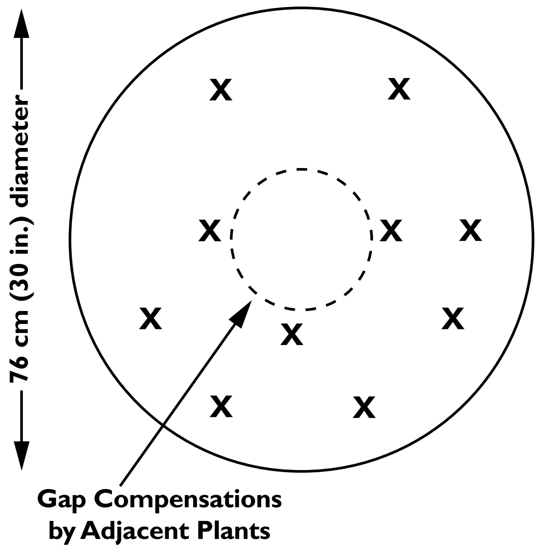
Accurately assess the stand for the population, spacing and health of the remaining plants. To determine plant population, see the hula-hoop method in Appendix K, *Hula Hoop Method for Determining Plant and Pest Populations*, on page 268.

Table 2–13, *Expected Yield of Soybeans in Optimum and Reduced Stands*, this page, 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 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*, on page 268.
- Estimate the yield potential of the reduced stand. See Table 2–13, this page.
- Estimate the yield potential of the replanted full stand. The later date will reduce the yield potential. See Table 2–7, *Effect of Planting Date on Yield and Plant Height*, on page 36.
- Estimate the cost of replanting
- Compare the value of reduced stand to replanted stand. (see Figure 2–3, *Reduced Stand in the Field*, opposite page).



Example

A field planted on May 12 is estimated to have a yield potential of 45 bu/acre if there were a full stand. On June 6, a reduced stand of solid-seeded, 18-cm-row (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% (39 bu/acre) of a full stand (Table 2–13). Yield expectation from replanting on June 6 would be about 38 bu/acre because of the later planting date (45 bu x 85% – from Table 2–7). Replanting would not be justified in this situation.

Figure 2–3. Reduced Stand in the Field

Patching or Thickening Thin Stands

In cases of poor stand establishment, replanting alongside the established seedlings to patch up or thicken the existing stand seldom improves yields unless the stand is very poor. If patching is contemplated, use the same variety and do not destroy the original stand. Repair planting often leads to timing difficulties with weed control and harvest date.

Plant Development

Table 2–14, *Vegetative Growth Stages in Soybean*, next page, and Table 2–15, *Reproductive Growth Stages in Soybean*, on page 43, show the growth stages of the soybean plant from emergence to full maturity.

The system used to describe soybean growth stages divides plant development into vegetative (V) — leaves and nodes — and reproductive (R) — flowers, pods and seeds — stages. 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 so 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 (single leaflets) occurring opposite each other at the first node above the cotyledons. Subsequent leaves are trifoliate (three leaflets) 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.

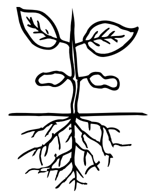
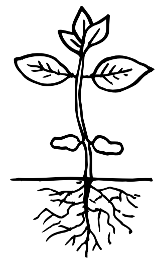
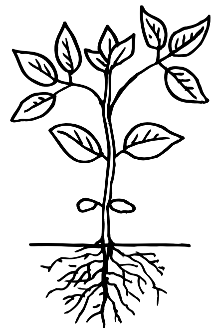
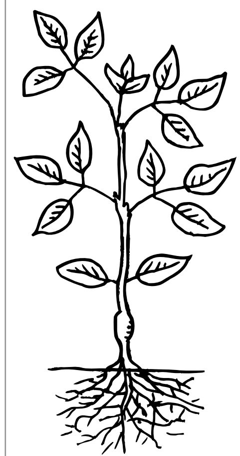
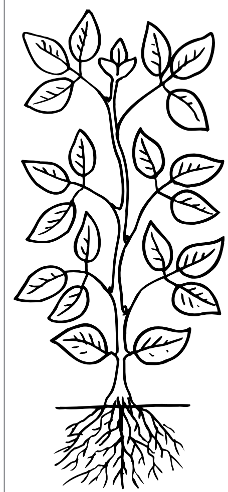
When planted at the optimal time, soybeans will develop 5–7 trifoliates before flowering begins. Flowering is triggered mainly by day length and temperature changes. Very early-maturing soybeans are nearly insensitive to day length. Instead, flowering is controlled mainly by accumulated heat units. Later-maturing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

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.

Most commercial soybean varieties in Ontario are indeterminate. Indeterminate varieties 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.

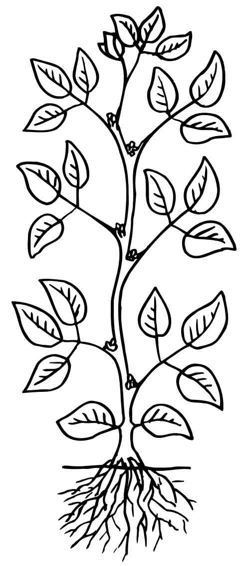
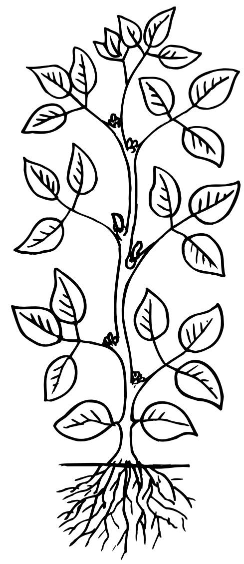
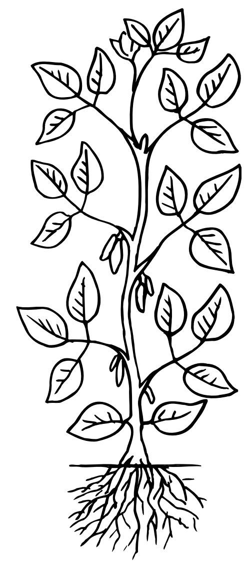
Table 2–14. Vegetative Growth Stages in Soybean
(Not all V stages are presented here.)

						
Stage Abbreviated[1]	VE	VC	V1	V3	V5	Vn
Stage Title	Emergence	Unifoliate	First Trifoliate	Third Trifoliate	Fifth Trifoliate	Nth Trifoliate
Trifoliate Leaves	0	0	1	3	5	n
Days to Achieve Stage[2]	12	5	~ 5 days/fully expanded trifoliate leaf			~3 days/trifoliate leaf (V6–Vn)
Range in Days[3]	5–21	3–10	3–10	3–10	3–10	
Notes	• Seedlings emerge from soil, and cotyledons are above soil surface. • Emergence can be hindered by soil crusting.	• Hypocotyl straightens, cotyledons unfold. • Unifoliate leaves unroll so that leaf edges are not touching. • Growing point is above soil surface. • Frost can kill the plant. • Stem severed below the cotyledons will kill the plant.	• First trifoliate has emerged and opened (unifoliate leaves are now considered fully developed). • Start of critical weed-free period.	• 3 trifoliate leaves emerged and opened (3 nodes on main stem with fully developed leaves, starting with the unifoliate node). • End of critical weed-free period. • Nitrogen fixation has begun.	• 5 trifoliate leaves emerged and open (5 nodes on main stem with fully developed leaves, starting with the unifoliate node). • 50% leaf loss has little impact on final yield. • Early maturity soybeans reach R1 at approx. V4.	• n = number of nodes on the main stem with fully developed leaves, beginning with the unifoliate node. • The number of nodes is a function of maturity rating, planting date and climatic conditions.

[1] V refers to the vegetative stages of soybean development. Vn = number of nodes on the main stem with fully developed leaves beginning with the unifoliate node. A fully developed leaf is defined as one that has a leaf above it (at the next node) with an unrolled leaf.
[2] An estimate of the number of days required to move from one stage to the next.
[3] Range is an estimate of days within a specific stage of development and is influenced by planting date, maturity rating and climatic conditions and can vary considerably within and between seasons.

Table 2–15. Reproductive Growth Stages in Soybean

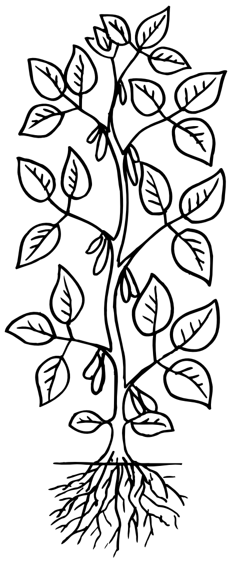
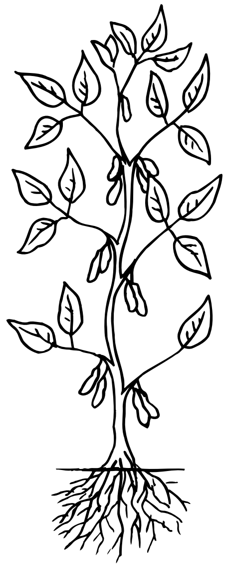
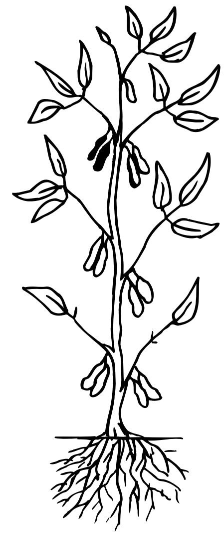
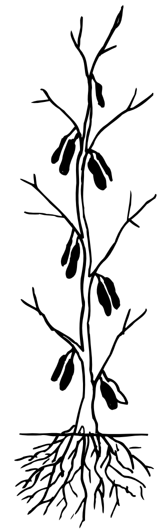
Each vegetative (V) or reproductive (R) stage is reached when 50% or more of the plants in a field of soybeans are at or beyond that stage.

				
R Stage[1]	**R1 – Beginning Bloom** One open flower visible from any node on stem.	**R2 – Full Bloom** Open flower on one of the top 2 nodes of main stem.	**R3 – Beginning Pod** Short pods visible at top 4 nodes of main stem with fully developed leaves.	**R4 – Full Pod** Pods 2 cm (.75 in.) long at top 4 nodes of main stem.
Target Event	Flowering	Flowering	Pod Development	Pod Development
Notes	• Triggered by changing day length and temperature. • Flowering begins near node 5 (V4) and moves up and down the stem. • Root growth rates increase. • Extreme heat (i.e., over 32°C) can reduce growth, flowering and pod development.	• 50% height and dry weight accumulation. • Stress does not usually reduce yield. • Nitrogen fixation increasing rapidly.	• Look for 2–3 seeds per pod. • Flowering peaks.	• Stress occurring between R4–R6 can result in significant yield loss.

[1] R refers to the various reproductive stages of soybean development.

Table 2–15. Reproductive Growth Stages in Soybean

Each vegetative (V) or reproductive (R) stage is reached when 50% or more of the plants in a field of soybeans are at or beyond that stage.

				
R Stage[1]	**R5 – Beginning Seed** Seed 0.3 cm long within upper (top 4) pods.	**R6 – Full Seed** Seeds within top 4 pods fill cavity in the upper pods.	**R7 – Beginning Maturity** One major pod has changed to brown colour on the main stem.	**R8 – Full Maturity** 95% of pods have changed to brown colour.
Target Event	Seed Development	Seed Development	Plant Maturity	Plant Maturity
Notes	• Flowering completed except for some branches. • Plant reaches max. height, nodes and leaf area. • Nitrogen fixation rates reach maximum and begin to decline. • Rapid nutrient uptake and redistribution to pods.	• Pods reaching full length. • Root growth slows substantially. • Above-ground dry weight accumulation slows. • Rapid leaf yellowing begins. • Leaves in lower canopy begin to fall.	• Moisture begins to decline in seeds. • Physiological maturity reached, maximum dry weight. • Seed moisture is about 60%.	• Harvest moisture reached in 1–2 weeks after R8.

[1] R refers to the various reproductive stages of soybean development.

Fertility Management

Nitrogen

Nitrogen fertilizers are not usually required for soybeans. (see *Inoculation*, on page 35). Research into nitrogen fertilizer applied at planting has shown that nitrogen, even in small amounts, can delay nodule fixation.

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

Phosphate and Potash

Phosphate and potash recommendations for soybeans are given in Table 2–16, *Phosphate and Potash Recommendations for Soybeans Based on OMAFRA-Accredited Soil Tests*, opposite page. Occasionally, potassium deficiency will appear in soybeans as yellowing or browning of margins in older leaves (see Plate 14 on page 281).

For additional information about soil testing or soil test recommendations, see *Fertilizer Recommendations*, on page 158.

Methods of Application

Do not place fertilizer 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 plowed down or 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 Table 9–21, *Maximum Safe Rates of Nutrients*, on page 176.

Table 2–16. Phosphate and Potash Recommendations for Soybeans Based on OMAFRA-Accredited Soil Tests

Sodium Bicarbonate Phosphorus Soil Test (ppm)	Rating[1]	Phosphate (P_2O_5)[2] Required kg/ha	Ammonium Acetate Potassium Soil Test (ppm)	Rating	Potash (K_2O)[2] Required kg/ ha
0–3	HR	80	0–15	HR	120
4–5	HR	60	16–30	HR	110
6–7	HR	50	31–45	HR	90
8–9	HR	40	46–60	HR	80
10–12	MR	30	61–80	MR	60
13–15	MR	20	81–100	MR	40
16–30	LR	0	101–120	MR	30
31–60	RR	0	121–150	LR	0
61 +	NR[3]	0	151–250	RR	0
			251+	NR[3]	0

100 kg/ha = 90 lb/acre

[1] HR, MR, LR, RR, and NR denote, respectively, high, medium, low, rare and no probabilities of profitable crop response to applied nutrient. 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.

[2] Where manure is applied, reduce fertilizer applications according to the amount and quality of manure (see *Manure*, on page 144). Example of fertilizer application: If a soybean crop is not manured, and the soil tests are 9 for phosphorus and 85 for potassium, the phosphate requirement is 40 kg/ha and the potash requirement 40 kg/ha. These nutrients can be supplied by broadcasting or banding 200 kg/ha 0-20-20 fertilizer.

[3] For a nutrient that has an "NR" rating by soil analysis, the application of this nutrient in fertilizer or manure may cause problems due to reduced crop yield or quality. Phosphate additions may jeopardize water quality. Potash additions may induce magnesium deficiency on soils low in magnesium.

Plant Analysis

For soybeans, sampling the top fully developed leaf (three leaflets plus stem) at first flowering is recommended. See Table 2–17, *Interpretation of Plant Analysis for Soybeans*, this page. For sampling at times other than first flower, take samples from both deficient and healthy areas of the field for comparative purposes.

Take a soil sample from the same area and at the same time as a plant sample.

Micronutrients

Manganese

Manganese is the only micronutrient deficiency diagnosed in soybeans in Ontario, although zinc deficiency may show up in the future where the surface soil has been lost by erosion.

The symptoms of manganese deficiency are upper leaves ranging from pale-green (slight deficiency) to almost white (severe deficiency) with green veins (Plate 15 on page 281). 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*, on page 260.

Table 2–17. Interpretation of Plant Analysis for Soybeans

Nutrient	Units	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)	ppm	20.0	55.0
Copper (Cu)	ppm	4.0	30.0
Manganese (Mn)	ppm	14.0	100.0
Molybdenum (Mo)	ppm	0.5	5.0
Zinc (Zn)	ppm	12.0	80.0

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

[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.

To correct a manganese deficiency, spray the foliage with 2 kg/ha of actual manganese (8 kg/ha of manganese sulphate) in 200 L of water. A "spreader-sticker" in the spray is recommended. If the deficiency is severe, a second application may be beneficial.

> **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. See Chapter 12, *Weed Control*, for more details.

Soil application is not a recommended 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, beans 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 beans 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 at moisture levels below 20%, but they must be stored at 14% moisture or lower.

Harvest losses and mechanical damage may be high when soybeans are harvested below 12% moisture. A loss of just 4 beans/900 cm^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 can be used to cut the soybean plants off, closer to ground level. Adjust the cleaning fan to provide maximum air without blowing soybeans into the return elevator or out the back end. Adjust the chaffer to allow the fan to separate pods and stalk pieces from the soybeans. Adjust the sieve to allow only soybeans through. Adjust the air speed, chaffer and seive settings throughout the day as the weather conditions and soybeans 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.

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. 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

Grain Dryers

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

- in-bin
- batch
- continuous flow

These three broad groups of crop driers can be further broken down into different types. 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 (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.

Take care 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 recommendations for drying commercial soybeans suggest a maximum temperature of 55°C–60°C. In good drying weather, you may need to reduce this drying temperature 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 frown on the use of any heat in conditioning seed soybeans. Ask your seed company what 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 stirrators. Damage from handling can be severe, especially as the moisture content drops to 12%.

Natural-Air Drying

Tough soybeans can be dried with natural air under good drying conditions. Natural-air drying of soybeans requires careful management by the operator, since soybeans give up and take on moisture easily. The fan must be run only when the outside conditions will result 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 6.5 L/sec/m^3 (0.5 CFM/bu), preferably more
- 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 will not change moisture content of soybeans. Higher airflow rates of 26 L/sec/m^3 (2 CFM/bu) or greater, only get the job done quicker. In order to determine the CFM/bu value for a bin, determine the number of bushels in the bin and the static pressure that the fan is operating

Table 2–18. Equilibrium Moisture Content (% Wet Basis) for Soybeans Exposed to Air

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

against. A simple manometer connected to the air plenum below the perforated floor will display the static pressure in inches of water column (see Figure 11–1, *Home-Built Manometer*, on page 183). Determine fan output at the measured static pressure by using the fan performance curve. Divide the CFM output of the fan by the number of bushels in the bin to give the 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 2–18, *Equilibrium Moisture Content (% Wet Basis) for Soybeans Exposed to Air*, this page). 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.

Measuring Relative Humidity

Accurately measuring the relative humidity of the outside air presents a bit of a challenge. In some cases, this reading can be obtained from a nearby weather station. It is important to determine if a nearby weather station is an accurate reflection of conditions at a specific location. To air-dry soybeans, it is important to know the accurate relative humidity of the outside air. Household hygrometers tend to be inaccurate and are not recommended for measuring relative humidity when air-drying tough beans. A sling psychrometer or a good quality hygrometer are recommended 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 AM until midnight, while on others it may only be from 9 AM to 6 PM. 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 stirrators will have fairly uniform moisture levels throughout the whole bin.

Other Crop Problems

Insects and Diseases

Figure 2–4, *Soybean Scouting Calendar*, opposite page, shows insects and diseases that could be causing the symptoms in the field. Individual descriptions of insects and diseases, scouting and management strategies can be found in Chapter 13, *Insects and Pests of Field Crops*, or Chapter 14, *Diseases of Field Crops*.

Recommended treatments 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. 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 (Plate 16 on page 281). Wait 3 or 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 2–19, *Percent Yield Loss of Indeterminate Soybean at Various Levels of Leaf Area Loss and Growth Stages*, on page 50, summarizes the expected yield loss from leaf loss at various life stages.

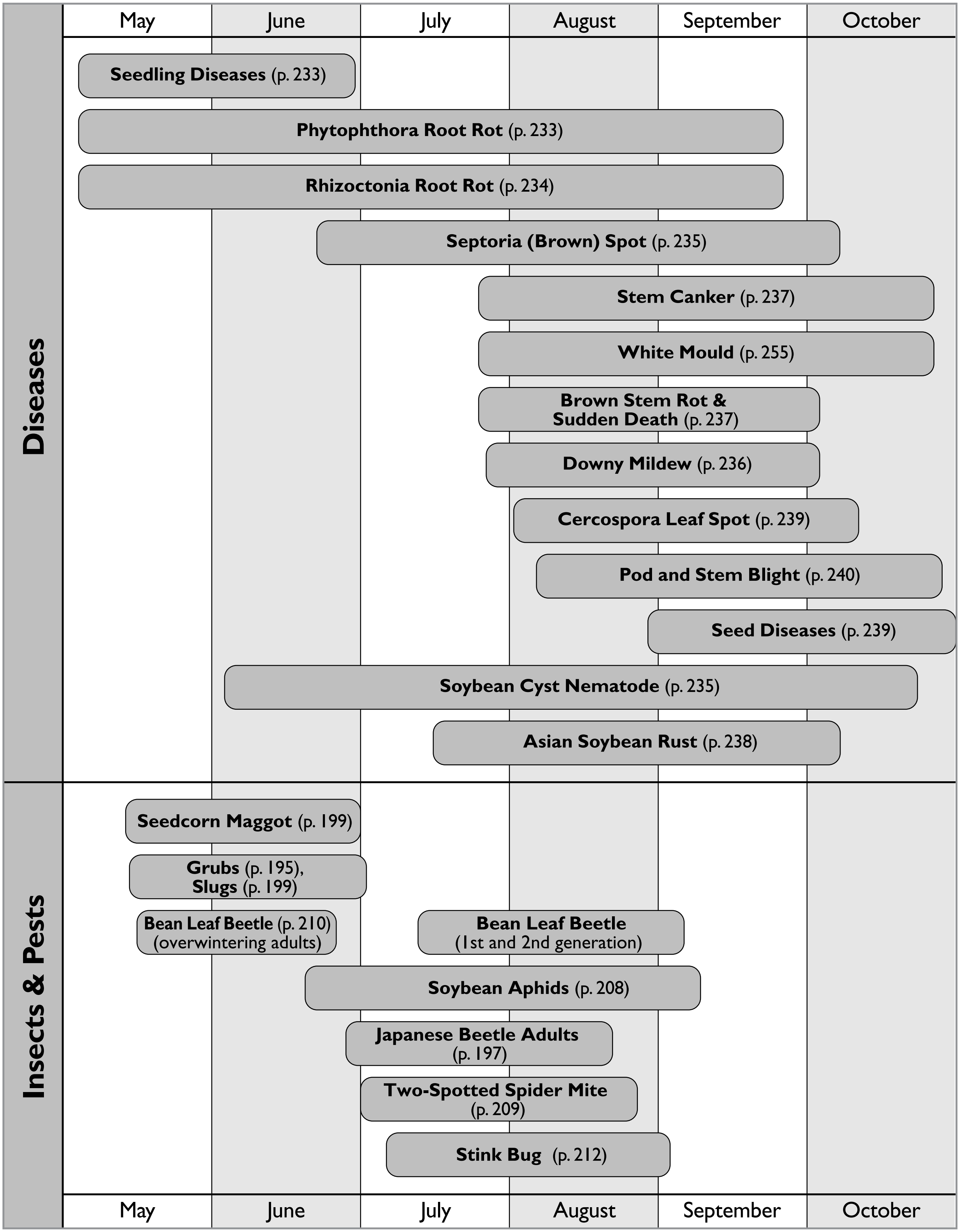


Figure 2–4. Soybean Scouting Calendar

Table 2–19. Percent Yield Loss of Indeterminate Soybean at Various Levels of Leaf Area Loss and Growth Stages

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

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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 (Plate 17 on page 281). It can also make the plant more susceptible to disease. Bruising, which does not cause stem breakage, causes minimal loss in yield.

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. Delays in maturity and seed size 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. This results in poorly developed pods called parthencarpic pods (also called "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 cold tolerant than those that have grey pubescence.

Frost during flowering and pod fill can drastically reduce yield and quality. A severe frost during these stages 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 if 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 Canadian Food Inspection Agency classifies frost-damaged soybeans as those "soybeans 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% 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. Plants are usually killed but can sometimes survive on the edges of the affected area. The affected area has a clearly defined margin, making diagnosis relatively straight forward (Plate 18 on page 281). The affected area does not grow over time. Stems are often darkened with dead leaves remaining attached to the plant.

Mature Green Seed

An extremely dry growing season can result in green soybean seed at harvest even if seed moisture is below 13% (Plate 19 on page 282). 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 improvement to 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 along with choosing the best varieties suited for the area is the best defence.