4. Cereals

Cereal crops are an integral part of the cropping system in Ontario, and are grown on approximately 25% of the arable acreage (approximately 607,000 ha or 1.5 million acres). Cereals offer many benefits to producers, from excellent profit potential to greatly improved soil structure and manure management options, as well as spreading out the workload. Cereals respond very well to management and with attention to detail, many producers find cereals to be one of their most profitable crops.

Tillage

Tillage Options

Cereal crops do not respond significantly to tillage. Research comparing the yield response of winter wheat to various tillage options demonstrated an economic advantage to reduced tillage with no significant yield difference among mouldboard plowing, minimum tillage and no-till systems, as shown in Table 4–1, *Winter wheat yield response to tillage systems*. While yields are not affected greatly by tillage systems, good seed-to-soil contact and soil moisture for germination are essential.

The selection of a tillage system will impact other components in the system. The tillage method chosen must fit with factors such as fertility, insect and disease pressure and weed control for producing high-yielding, profitable crops. Risks associated with more intensive tillage in winter crops include greater potential for frost-heaving and increased risk of snow mould. Erosion is a concern with tillage in all crops.

There are several options for seeding cereals that include:

- no-till seeding
- conventional tillage
- frost seeding
- aerial seeding of winter cereals
- broadcast seeding

No-Till Seeding

Most winter wheat is grown using a no-till system. Yields in a no-till system are often equal to yields obtained in a conventional tillage system. No-till drills can follow the combine in the same field, which advances seeding date, therefore increasing yields. Winter cereals seeded in a no-till system are better able to resist frost heaving, as the plant anchors itself in firmer soil.

The success of a no-till system requires consideration of fertilizer management, drill capability and weed control. No-till cereals show more response to seed-placed starter fertilizer, especially phosphorus, compared to conventional tilled crops, refer to *Corn Row Syndrome*.

Seed-to-soil contact is critical for moisture uptake. No-till drills must be able to cut through residue and penetrate into hard soil to accurately place seed. Adding seed-firming wheels or plastic “hockey stick” seed firmers will help press the seed into the bottom of the seed trench, which will help increase seed-to-soil contact and improve seed depth uniformity. Weed

Table 4–1. Winter wheat yield response to tillage systems

Tillage Systems	Comparative Yield[1]	Comparisons	Economic Advantage to Reduced Tillage
Minimum vs. mouldboard	5.2 vs. 5.1 t/ha (77.5 vs. 75.4 bu/acre)	12	$37.80/ha ($15.31/acre)
No-till vs. mouldboard	4.8 vs. 5.0 t/ha (71.7 vs. 74.9 bu/acre)	36	$46.60/ha ($18.85/acre)
No-till vs. minimum	4.4 vs. 4.3 t/ha (65.0 vs. 64.6 bu/acre)	22	$18.65/ha ($7.55/acre)

Source: Tillage Ontario Database

[1] Average yields vary because comparisons come from a range of sites.

control is critical in no-till systems. A burndown before planting ensures control of dandelions and other winter annual weeds and should be a standard practice. See OMAFRA Publication 75, *Guide to Weed Control,* for burndown guidelines. To reduce disease incidence, use a fungicide seed treatment. For further information on seed treatments, see the OMAFRA Publication 812, *Field Crop Protection Guide*.

The addition or use of tillage coulters may show some benefit in a no-till system. Slight loosening of dry, hard soils allows for better, more rapid root development and growth. In a wet fall season, light tillage may speed soil drying and allow for planting into better conditions. These limited tillage methods should be used when dictated by soil conditions.

Conventional Tillage

Cereals have been grown for generations using the plow, disc and cultivator for seedbed preparation. Many spring cereals are still grown using conventional tillage. While this system works well, erosion concerns, fuel and labour costs, and limited yield response to tillage continue to shift acres into reduced tillage. The guidelines regarding seed-to-soil contact, planting into moisture and seeding depth accuracy are consistent with the no-till section. The tillage operations used in the conventional system replace the herbicide burndown.

Frost Seeding of Spring Cereals

Seeding spring cereals into frost can advance seeding dates and increase yields.

"Frost seeding" refers to no-till seeding cereals into a light frost in early spring. After the snow has melted and the frost is out of the ground, there are often several cold nights with below-zero temperatures. Seeding into this light frost avoids compaction or rutting, as the frost will support the tractor. It is not essential to close the seed trench when frost seeding, as the soil will naturally fall in and cover the seed as the frost comes out of the ground. Simply set no-till equipment to make a shallow seed trench, 2.5 cm (1 in.) and firm the seed into the bottom of the trench. Do not leave seed on top of the ground since stand establishment will be very poor. The window of opportunity for this method of seeding is short. Best results are generally achieved when cereals are seeded as the frost is just beginning to firm the soil, about -3°C to -4°C, often near midnight. It is critical to stop as soon as frost begins to soften in the morning sun, as thawed soil will stick and plug equipment in as little as 15 m (50 ft) of travel.

Do not attempt frost seeding when air temperatures drop below −8°C. The ground will be frozen hard enough to damage the no-till equipment, and seed will be left on the soil surface with poor results

While this narrow window of opportunity may not occur every year, the increase in yield from early planting using this technique can be as much as 25%. Table 4–2, *Frost seeding vs. seeding into dry soil for spring cereals*, shows the yield and quality advantage of frost seeding. Frost seeding of winter cereals in the late fall or early winter has also been successful. However, in these situations it is critical that seed placement is at least 2.5 cm (1 in.) deep, and that yield expectations are realistic.

Table 4–2. Frost seeding vs. seeding into dry soil of spring cereals

Treatment[1]	Yield		Test Weight	
	Frost	Dry Soil	Frost	Dry Soil
Oats	5.3 t/ha (140.3 bu/acre)	4.6 t/ha (120.6 bu/acre)	46.5 kg/hL (37.3 lb/bu)	44.6 kg/hL (35.8 lb/bu)
Spring wheat following soybeans	4.6 t/ha (67.7 bu/acre)	3.9 t/ha (57.5 bu/acre)	75.9 kg/hL (60.9 lb/bu)	73.7 kg/hL (59.1 lb/bu)
Spring wheat following corn	4.1 t/ha (60.5 bu/acre)	2.6 t/ha (39.4 bu/acre)	74.6 kg/hL (57.9 lb/bu)	64.8 kg/hL (52.0 lb/bu)

Source: Johnson, OMAFRA, Thorndale 2006–2007.

[1] Each treatment represents an average of three different populations: 0.8, 1.2 and 1.6 million seeds/acre for oats, and 1.2, 1.6 and 2.0 million seeds/acre for spring wheat (seeds/acre x 2.47 = seeds/ha).

Aerial Seeding Winter Wheat

Aerial seeding is most successful when seed is flown on before 10% of the soybean leaves have dropped. Soybean leaves will cover seed and help retain moisture for wheat germination.

Results from aerial seeding have been variable. The seed is extremely vulnerable to slug damage. Slugs feed on the germ of the kernel, which can severely thin or destroy the stand, particularly on headlands. The seed will appear to still be on the surface, as if waiting to germinate, but on closer examination, the damage to the kernel becomes evident (Photo 4–1). Reseeding of headlands after soybean harvest can help overcome this problem.

Photo 4–1. Slug eating germ out of seed.
Photo courtesy of T. Meulensteen C & M Seeds.

The shallow root system that develops from aerial-seeded wheat is more prone to heaving injury and wind damage, refer to *Depth of Seeding* (later in this chapter). In the spring, wheat plants will be attached to the soil by only one hair root. If this hair root breaks as plants twist with the wind, the plant dies.

With these inherent risks, yields from aerial-seeded wheat are often 10% lower than from drilled wheat, (limited on-farm trial data). Therefore, aerial seeding is not a standard practice. Where aerial seeding is attempted, increase the seeding rate to 5.0 million seeds/ha (2 million seeds/acre) to compensate for stand loss.

Broadcast Seeding

Broadcast seeding can greatly speed-up the planting process. It is important to get good seed-to-soil contact and a uniform seeding rate across the width of the spread pattern and between passes of the spreader.

Using airflow units is an effective way to achieve a uniform spread pattern. Till fields at a shallow depth, 7.5 cm (3 in.), twice, at right angles, to help prevent streaking in the seeding pattern, and then pack the crop to improve seed-to-soil contact.

Broadcast seeding produces an inconsistent seeding depth. Variable maturity and a 5%–10% reduction in yield are often the result. Increasing seeding rates by 10% will help compensate for the potential variability of broadcast seeding.

Variety Selection

The principles of selecting a winning variety do not vary greatly from crop to crop. Quality factors for specific end-use products and the impact on price and yield are confounding factors with wheat variety selection. Ontario grows more types of wheat than any other region in northeastern North America. Milling and horse oats markets also have specific quality parameters, as does barley for food or malting purposes.

Standard Variety Selection Criteria:

- Select varieties based on local growing conditions and planned end-use. Compare varieties for potential yield, standability, disease tolerance and other agronomic factors. Understanding the limitations of a field or farm will help with variety selection.
- Use all information sources available. Cereal crops have an excellent performance testing system. This information is available on the Ontario Cereal Crop Committee website at www.gocereals.ca.
- Use long-term data over many locations when comparing variety performance. Varieties that excel under one set of environmental conditions may suffer considerably under another year's conditions. For example, an oat variety that excels in a year without rust pressure may be the worst performer the year rust infects the crop early. Using long-term, multi-site data will lead to the selection of the best, yield-stable varieties. Try the "Head to Head" function on the GoCereals website at www.gocereals.ca to view comparisons of specific varieties and traits over time.
- Select two or three of the best available varieties. It is always good management to spread the risk. Selecting different varieties reduces disease potential and can spread the harvest workload.

Harvest Sprout Tolerance

Seed dormancy, or sprouting resistance, varies greatly between varieties. Several genes are responsible for the dormancy factor in wheat. One of the strongest of these genes is linked to the genetic coding for red wheat or the red colouration of the bran. In general, red wheat varieties will not sprout as readily as white wheat varieties, and often hard red wheat varieties will sprout less readily than soft red varieties. White wheat varieties lack sprout tolerance, therefore producers are advised not to grow more white wheat than what can be combined in 2–3 days. Harvest white wheat varieties first, as soon as possible, and dry if necessary. This will ensure crop quality and maximize profitability.

Sprouting tolerance should not be confused with germination of the crop once planted. Seed dormancy is dependent on time, light and temperature. By the time the seed is planted in the fall, enough time has passed, and the dark, cool conditions of the soil will overcome any dormancy. The speed of emergence after planting is entirely related to the seed vigour of the variety and seed lot, and not at all to colour or market class.

Winter Hardiness and Cold Tolerance

Winter wheat can tolerate extremely cold temperatures (-23°C) in its most hardy state. Winter barley cannot withstand as severe conditions (-10°C). While the threat of cold temperature injury often exists, Ontario conditions rarely cause plant death, except where icing occurs. Snow offers excellent insulation from cold temperatures, while ice conducts cold directly to the plant. More detailed information on cold tolerance and winter hardiness is available in the University of Saskatchewan *Winter Wheat Production Manual,* Chapter 12, *Winter Survival* at https://www.usask.ca/agriculture/plantsci/winter_cereals/.

Factors Unique to Cereal Crops

Straw

The need and value of straw can be significant. Straw quality is often a factor. Moisture absorbency is an important criteria for most livestock bedding. Dry loose straw has an approximate density of 40 kg/m^3 (2.5 lb/ft^3), while baled straw has an approximate density of 80 kg/m^3 (5 lb/ft^3) and water absorption of 293–335 L/m^3). The horse industry is only interested in "dust-free" straw. Straw has been one of the driving forces for producers to continue growing barley rather than spring wheat, even though the economics of grain production often favours spring wheat.

Spring barley produces the least straw volume, but the best straw quality. Oat straw quantity and quality are good. Wheat straw is less absorbent than oats or barley straw, refer to Table 4–3, *Straw quantity vs. straw quality*. There are huge differences in straw yield between varieties within each crop as well. Straw yield data can be found on the "traits" page, Area V, of Ontario Cereal Crop Performance Trials at www.gocereals.ca.

Table 4–3. Straw quantity vs. straw quality

Rank	Quantity (most to least)	Quality (best to worst)[1]
1	winter wheat	spring barley
2	winter barley	mixed grain
3	spring oats	spring oats
4	spring wheat	winter barley
5	mixed grain	spring wheat
6	spring barley	winter wheat

[1] Straw quality based on livestock bedding preferences.

Producers who need and value the straw can also increase its quality by using fungicides to control crop diseases. This is especially important for providing dust-free straw to the horse industry. Consider winter barley for higher yields of straw in an area where winter survival is not a problem.

Straw Value

The value of straw is often a hotly debated question. Straw has value from both the nutrients removed and the organic matter addition it will return to the soil. Table 4–4, *Straw nutrients*, shows the range of nutrients that straw may contain. Straw nutrient concentration can vary greatly, Straw from hard wheat varieties will generally contain less nitrogen — approximately 1.25 kg/t (3.03 lb/ton) — than soft wheat straw. Potash concentration varies tremendously in straw, as potash is readily leached from straw by rainfall after maturity (up to a 500% difference). The only accurate way to determine nutrient value is through an analysis.

There is added debate about whether the nitrogen or sulphur component (approximately 2.1 kg/t or 5 lb/ton) should be included in the value of straw. The carbon:nitrogen ratio of straw is quite high (approximately 80:1), which requires additional nitrogen (short-term) for breakdown by soil organisms.

Thus, many producers do not add nitrogen into the value of straw calculation. The same scenario holds true for sulphur. Using average nutrient concentrations, straw value can be calculated, with or without N and S, using the formulas shown in Table 4–4, *Straw nutrients*.

Table 4–4. Straw nutrients

Straw value $/tonne (P and K only) = $/tonne MAP x 0.003 + $/tonne potash x 0.014

Straw value $/tonne (N, P, K, S) = $/tonne urea x 0.015 + $/tonne sulphur x 0.006 + value of P, K (equation above)

To change value to cents/pound, divide answer by 22.05.

Nutrient	Mean	Minimum	Maximum
Nitrogen (N)	7.0 kg/t (14.0 lb/ton)	4.2 kg/t (8.4 lb/ton)	10.7 kg/t (21.3 lb/ton)
Phosphorus (P_2O_5)	1.6 kg/t (3.2 lb/ton)	0.9 kg/t (1.8 lb/ton)	3.0 kg/t (6.0 lb/ton)
Potassium (K_2O)	8.4 kg/t (16.8 lb/ton)	4.0 kg/t (8.0 lb/ton)	21.2 kg/t (42.5 lb/ton)

Source: OMAFRA 2003/2004 and Falk, 2004/2005.

The value of the organic matter that straw returns to the soil is much more difficult to calculate. There is no doubt that the organic matter value is extremely significant. Estimates range from at least equal value to the nutrient removal, to estimates that removal of four high-yield straw crops could reduce soil organic matter by 0.1%. Depending on soil texture and conditions, this 0.1% organic matter could be capable of holding up to 4.4 cm (1.75 in.) of available water for crop growth. In theory, in dry seasons, this amount of water might result in an additional 0.24 t/ha (3.5 bu/acre) of soybeans, or 0.88 t/ha (14 bu/acre) of corn yield. While these are simply mathematical estimates of the organic matter impact, they drive home the value of straw organic matter contributions.

Considerations for Selling Straw

There is always great debate over whether or not straw should be sold, based on its value for soil organic matter. Long term rotation research at the Elora Research Station has clearly demonstrated that the value of cereals in the rotation, even with straw removed, far outweighs any negative impact of straw removal. Even with straw removed and no cover crop (red clover), yields of subsequent corn and soybean crops increased dramatically (corn 12%, soybeans 14%), and soil health parameters, such as organic matter and water stable aggregates, are improved considerably. If selling the straw improves the profitability of cereal production to the point that producers keep cereals in the rotation more frequently, then the producer should sell the straw. However, there is about 1 cent/pound of fertilizer nutrients in the straw; therefore, the first 1 cent/pound is not profit. That 1 cent/pound should be used to purchase potash and phosphorus to replace the nutrients removed in the straw.

Market Class

Within wheat, the number of market classes continues to increase, refer to Table 4–5, *Characteristics of various cereal market classes*. Since the mid-1980s, when only spring feed wheat and soft white winter wheat were grown in Ontario, the number of market classes has expanded dramatically. The increase in wheat classes is likely to continue, with varieties for other specific market uses in development. Many of these market classes have yield and price premium implications that must be considered when selecting varieties. For example: hard red wheat varieties generally have 10% lower yields than soft red wheat. Price premiums must be sufficient to overcome the yield penalty to make growing hard red wheat viable.

Each farm will have different outcomes based on specific farm characteristics. It is much easier to achieve high protein and earn premiums on farms with more inherent soil nitrogen (i.e., livestock farms with manure and/or forages). On cash crop farms, it often takes significantly more nitrogen to achieve optimum protein levels in these non-pastry wheat varieties, see *Red Winter Wheats*. All these factors must be considered when selecting varieties.

Cereal Species

Barley

All barley has the genetic potential to develop six rows of grain in the head (six-rowed barley). Two-rowed barley only develops two of these rows. In general, two-rowed varieties are larger seeded, shorter and more resistant to leaf rust and mildew. Two-rowed varieties generally have lower yields than six-rowed types. Six-rowed varieties usually have better resistance to scald and are more tolerant of heat and moisture stress, making them more tolerant of late planting.

Table 4–5. Characteristics of various cereal market classes

Market Class	Uses and Traits	Notes
Soft white winter wheat	• pastry wheat • low protein • high yield	• susceptible to sprouting • do not over-apply nitrogen
Soft red winter wheat	• pastry wheat • low protein • high yield	• do not over-apply nitrogen
Non-pastry red winter wheat (hard red winter wheat)	• bread blend wheat, crackers, pizza dough • high protein desirable • lower yielding than soft wheat	• requires more nitrogen • quality more variable • price premiums may apply
Non-pastry white winter wheat (hard white winter wheat)	• whole grain flour products • Asian noodles • beer making	• susceptible to sprouting • requires more nitrogen • limited variety availability
Winter durum wheat	• pasta • low yield	• high fusarium susceptibility • limited variety availability
Specialty winter wheat varieties	• variable	• must be maintained and identified by variety
Spring milling wheat varieties	• bread blend wheat • high protein • low yield	• highly responsive to early planting • high price
Spring hard white	• whole grain bread products • high protein • low yield	• highly responsive to early planting • high price • limited variety availability
Spring durum	• pasta • low yield	• highly responsive to early planting • high price • high fusarium susceptibility • limited variety availability
Spring feed wheat varieties	• high protein • moderate yield	• responds best to early planting • must not be co-mingled with milling wheat
Winter barley	• high yield • poor winter hardiness • poor standability	• plant early • difficult to remove awns during threshing
Six-row barley	• typically feed barley • excellent straw quality • more heat tolerant • more tolerant of late planting	• less desirable grain sample • do not over-apply nitrogen
Two-row spring barley	• milling and malting types available • excellent straw quality	• do not over-apply nitrogen
Oats	• milling and horse oats require high quality • good straw	• responds well to early planting • tolerates poor drainage

Winter Barley

Both spring and winter types of barley are grown in Ontario. Winter barley requires a period of cold temperatures to “vernalize” the plant and initiate flowering and grain development. Winter barley planted in the spring will not produce grain. Spring barley does not require vernalization.

Winter barley is much higher yielding than spring barley but is considerably less winter hardy than winter wheat. It survives only in areas with milder winter conditions or excellent snow cover. Winter barley must be planted earlier than winter wheat, making it more prone to barley yellow dwarf virus (BYDV) and snow mould. Winter barley matures earlier than winter wheat, and some years may be suitable for double cropping. In areas that are adapted to winter barley production, yields of up to 8.1 t/ha (150 bu/acre) have been achieved.

Hulless Barley

Covered or hulled barley consists of approximately 10% hull and 90% kernel. With hulless types, much of the hull is removed at harvest. Hulless barley has a higher test weight and lower fibre content than covered barley. The seeds must be handled carefully, as the embryo (germ) is susceptible to damage. The amount of hull removed from the grain is somewhat dependent on weather conditions at harvest. Hulless barley will yield less than regular varieties, because the weight of the hulls is left in the field, but the concentration of energy and protein will be greater.

Oats

Oats is a traditional feed crop in Ontario, particularly for horses. Oats has better balanced protein and higher fibre content than barley. Leaf rust-resistant varieties are preferred. Buckthorn acts as the alternate host for leaf rust in oats. Remove buckthorn from field margins whenever possible.

Genetic resistance to crown rust was overcome by a new rust "race" in 2006. Until varieties with resistance to this new variant are available, oats must be sprayed with a fungicide just prior to heading, or yields and quality can be severely impacted (75% yield loss, 50% test weight loss). The exception to this rule is northern Ontario, which does not yet have a rust problem.

Milling Oats

Milling oats is used for human consumption and therefore must meet special quality requirements, including plump kernels, high test weight and groats (grain) that are free of discolouration and foreign material (insects, weeds or other crop seeds). Requirements for milling oats can be found at www.grainscanada.gc.ca then click on "Grain Quality," to find the *Official Grain Grading Guide,* under "Guides and Manuals."

Hulless Oats

Hulless oats may be of interest to pig and poultry producers because the grain (groat) has approximately the same metabolizable energy as corn. Hulless oats has good quality protein and high protein content (14%–20%). Diets can be formulated with hulless oats as a major energy source and only small amounts of soybean meal, canola meal or the amino acid lysine need to be added to obtain performance comparable to a standard corn-soybean meal diet.

Hulless oats becomes groats when they are threshed. The thin hulls are left in the field as chaff, resulting in a kernel weight loss of 25%–30% compared to regular varieties where the hull is retained. Current varieties have a coating of fine hair on the groat that prevents the oats from flowing freely. These hairs cause itching, making the oats unpleasant to handle. New varieties have greatly improved on these issues.

Take special care at planting, harvesting, handling and storage of hulless oats. Since the hull does not protect the seed, the germ is easily damaged. Take care during the planting process. Embryo damage can occur during harvest and handling. The high oil content at the surface of the seed makes the seed more attractive to storage insects. Moistures should be below 10% to ensure the grain does not lose quality in storage.

Mixed Grains

Mixed grains occupy a significant acreage in the province. Most mixed grains are a combination of oats and barley, but mixtures may include spring wheat or field peas. Mixed grains are only grown for feed.

No specific guidelines regarding the best mixtures can be made. Generally, the highest yielding varieties of oats and barley in pure stands also perform best in mixtures, but maturity ratings of the components of a mixture must be matched. The addition of wheat or peas to the mix will increase the energy or protein of the grain, but yields will be reduced.

Leaf and head diseases are usually much less severe with mixed grains than where oats or barley is grown alone. Mixtures of oats and barley are more tolerant of variable drainage conditions, with the barley component becoming predominant in drier areas of the field and the oats component producing more in poorly drained areas.

Winter Wheat

Winter wheat is grown on the largest acreage of any of the cereal crops and is grown across the province. Like winter barley and winter rye, winter wheat requires vernalization, a period of cold temperature (below 5°C), that induces the crop to shift from a vegetative to a reproductive state. While wheat vernalizes most effectively at the five-leaf stage, the vernalization process can be completed once germination begins. Therefore winter wheat can be planted at any time in the fall, right until freeze-up, and still head out normally the following year. Winter wheat planted in the spring will not enter the reproductive stage, as it has not been vernalized. In some cases, winter wheat has been spring planted to give the appearance of a lawn that almost never needs cutting.

Spring Wheat

Feed Wheat

Feed wheat is a more concentrated source of protein and energy for livestock than barley or oats. In non-ruminant diets, take care to limit the amount of feed wheat in the ration to avoid digestive problems. The general guideline is to include no more than 25% of the total ration as wheat. Be sure to consult a nutritionist for further information.

Some feed wheat varieties can produce yields that are competitive with oats and barley as feed grain. At times, these varieties may achieve quality that allows them to be included in the milling wheat market. Check the website www.gocereals.ca to determine if a variety is milling or feed quality. When feed wheat varieties make milling quality, consider it a bonus and not something to depend upon.

Milling Wheat

To ensure market acceptance, take care to grow a quality product. This includes factors such as selecting the proper variety, early planting and good weed control. Spring wheat varieties generally have a very open canopy, making weed control more critical, especially for annual grass control. This open canopy makes them ideal as a nurse crop for underseeded alfalfa or hay crops.

Rye

Both spring and winter types of rye are available in Ontario, but winter rye is more commonly grown. Typically, winter rye is grown on the light sandy soils of tobacco and vegetable farms to control wind erosion and build up organic matter. Spring rye is occasionally grown as an annual forage crop. Unlike the other cereal crops, rye is quite susceptible to ergot, which is detrimental to its use as either feed or food.

Winter rye is the most winter hardy of all the winter cereals. It is early maturing — well ahead of either winter wheat or winter barley. Rye is hard to thresh, and despite the early maturity is often not harvested until after wheat and barley crops. This allows the straw to degrade and facilitates the threshing of the grain from the head.

Some livestock producers looking for extra forage plant winter rye after corn silage harvest. This rye will begin to head about mid-May the following spring, when it is cut for baleage or haylage. Soybeans or dry edible beans are then planted with almost no yield loss due to delayed planting. Concerns from this practice include potential allelopathic effects (the toxic effects of rye residue breakdown during new crop growth) from the rye residue and the possibility of volunteer rye in wheat crops in succeeding years.

Triticale and Spelt

Both triticale (a cross between wheat and rye) and spelt are grown in Ontario on a limited basis. Both winter and spring triticale are available. Winter triticale is used as a forage as with rye (above), while spring triticale is only grown as emergency forage when hay crops winterkill, mostly in combination with peas, see *Warm-Season Annual Grasses* in Chapter 3, *Forages*. Spelt, an earlier version of modern day wheat, is mostly grown for the organic market. There is almost no genetic difference between spelt and wheat, only the genetic coding for the "chaff" to either adhere to the grain or be easily removed. In wheat, the chaff comes away easily, while in spelt it does not.

Biotechnology and Cereal Crops

Most crop plants are diploids, meaning that they have one pair of each chromosome. Both barley and oats are diploids. Durum wheat is a tetraploid: having two pairs of chromosomes (aabb genome). All other wheats grown in Ontario are hexaploid, with three pairs of chromosomes (aabbdd genome). This makes gene transfer in wheat somewhat more difficult. The profit margin in cereals for seed production and breeding is much less than in many other crops. Additionally, the acceptance of genetically modified wheat plants by consumers has been very low, resulting in less investment in biotechnology in wheat. Thus, cereal crops have been at a standstill in the development of varieties having special traits using gene transfer technology.

This situation appears ready to change. How the industry and consumer will respond to these changes has yet to be determined. Producers should be aware of these developments and the criteria for identity preservation and separation that may go along with any new developments.

Planting and Crop Development

Depth of Seeding

Seeding depth can have a significant impact on plant development, refer to Figure 4–1, *Days to emergence at various seeding depths,* but soil conditions at the time of planting must always dictate seeding depth. Do not plant shallow into dry soil in anticipation of rain for germination. Plant into moisture to ensure quick and uniform emergence, even if it requires planting deeper. However, when soil conditions are too wet, consider shallow planting or making an additional tillage pass in an attempt to dry the soil.

Cereals are lagging far behind corn and soybeans in the development and adoption of technology to accurately control seeding depth. With current drills, seed depth can vary from 1.25–7.5 cm (0.5–3 in.) in the same row, depending on soil conditions.

Producers can attempt to minimize this variation in depth by using seed firmers, which hold the seed at the bottom of the trench. Level fields and slower planting speeds will help reduce variability. Seeding depth accuracy in cereals will not match corn as long as depth gauge wheels (press wheels) trail double disc openers, or single coulters without parallel linkage are standard equipment.

Cereals are the most responsive crops to early, timely seeding, see *Planting Dates.* When cereals are seeded too deep, delayed emergence of 1 week or more may occur, see Figure 4–1. Delayed emergence is equivalent to an equal delay in seeding date, resulting in an equal reduction in yield. It is evident that the accuracy of seeding equipment requires improvement.

At typical fall temperatures of 15°C days and 5°C nights (15°C + 5°C = 20/2 = 10 GDD/day), 8 days would be required for germination and an additional 5 days for each inch of planting depth to reach emergence. Cooler temperatures will slow this process.

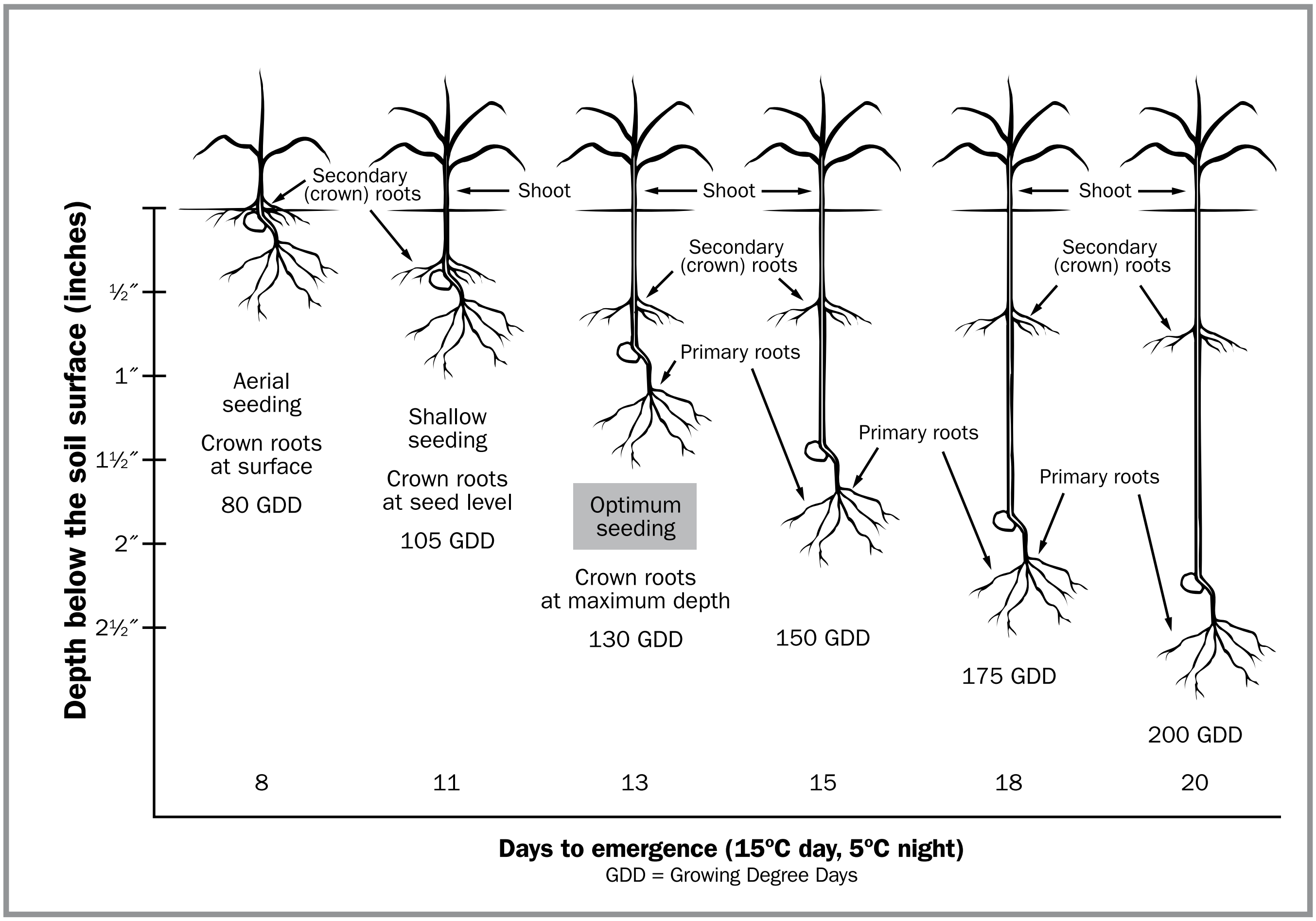

Figure 4–1. Days to emergence at various seeding depths.

Optimum Seeding Depth

Cereals should be planted uniformly at a depth of 2.5 cm (1 in.). This encourages early emergence and rapid development of an extensive secondary root system. Moisture availability is an overriding factor, and seed must be placed into moisture. A 2.5 cm (1 in.) planting depth is of little value if moisture is not available at this depth.

While seed depth of 2.5 cm (1 in.) is optimum, most drills are not capable of that level of accuracy. The yield penalty from too shallow is almost always greater than the yield penalty from a deeper planting depth. When drill accuracy is factored in, the target seeding depth should range from 3–4 cm (1.25–1.5 in.). Producers that do an accurate job of seeding winter wheat will experience better winter survival and higher yields.

Cereal Development

The development of the cereal seedling can be determined by following growing degree day (GDD) accumulations. GDD calculations are discussed in greater detail in *Growing Degree Days,* Chapter 10, *Scouting*. For cereal crops, use GDD base 0 calculations.

Generally, cereals require 80 GDDs for the seed to germinate and 50 additional GDDs for emergence, for each inch of planting depth.

Figure 4–2, *Cereal growth stages,* shows detailed cereal crop development according to the Zadoks Scale. (Feekes is another cereal development scale, often used in the U.S., but not shown here.) These stages are critical in many management decisions that producers make. Nitrogen and herbicide applications must be completed during the tillering stage; while disease control is most critical in the stem extension and heading stage. Knowing the growth stage of the crop is essential to accurately schedule management inputs and control measures.

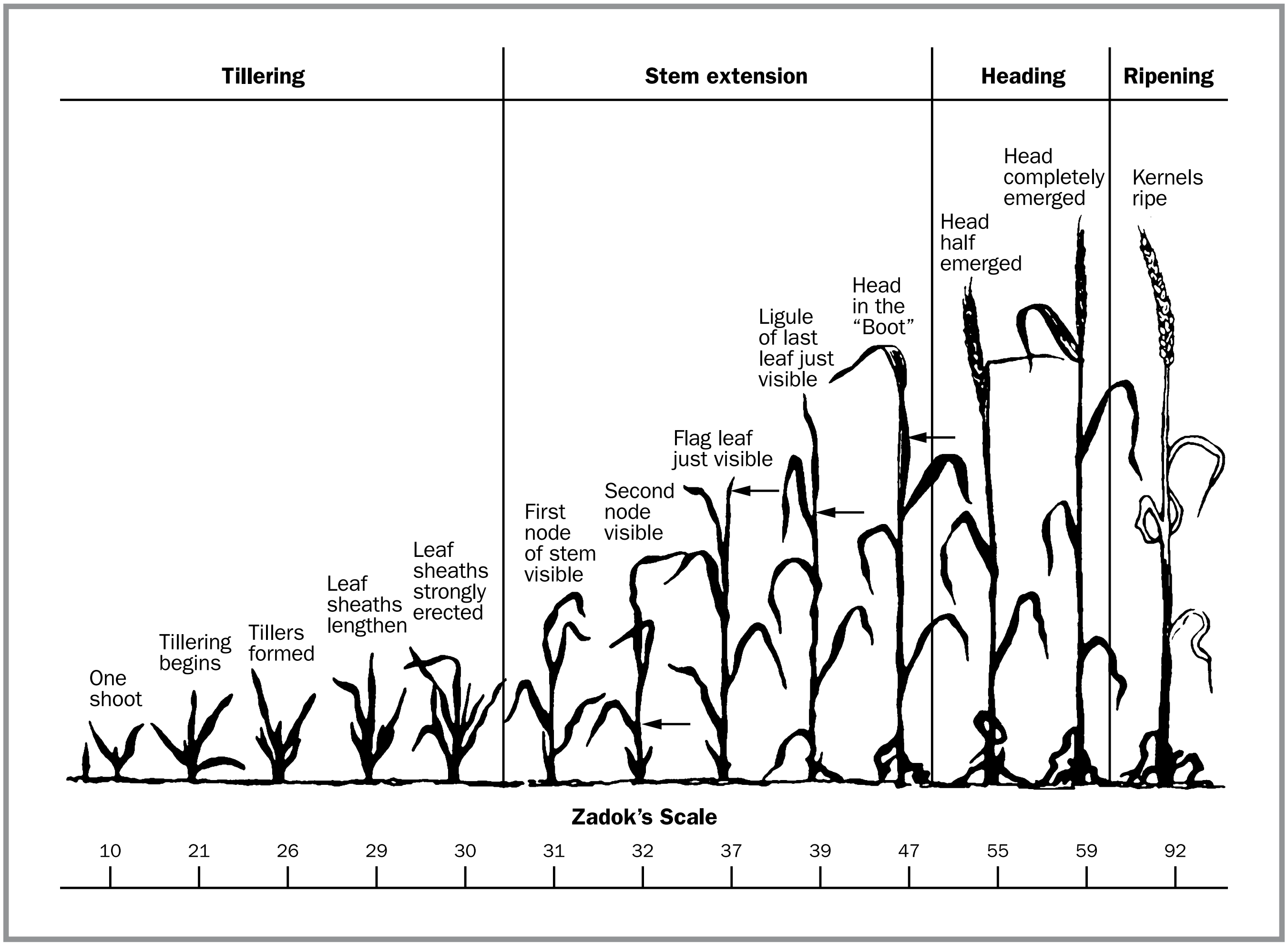

Figure 4–2. Cereal growth stages.

For more detailed information and identification of cereal growth stages, refer to the *Cereal Staging Guide* at www.bayercropscience.ca (under Resources and Guides).

Planting Dates

Cereal crops are more responsive to planting date than corn. Ontario research shows a 0.07 t/ha/day (1.1 bu/acre/day) decrease in yield for each day that cereal planting is delayed beyond the optimum date.

Provincial winter wheat yields from 1981 to 2014 are illustrated in Figure 4–3, *Provincial winter wheat yield for 1981–2014*. The record yield in 2006 was primarily due to early planting the previous fall, while low yields in 1993 were the result of late seeding in the fall of 1992. The low yield of 1996 was caused by a severe fusarium (FHB) infection.

Early Planting

Winter cereals can be seeded too early. Seeding more than 10 days before the optimum date introduces risk from Hessian fly, snow mould, and barley yellow dwarf virus (BYDV) infection. While Hessian fly is often cited as a concern, there has not been an infestation of significance in Ontario since at least 1985, thus it should not limit early seeding. BYDV is spread by aphids, which feed on wheat seedlings. Seed-applied insecticides can minimize the risk of spread of BYDV but will not eliminate the risk. Check varietal response to BYDV in the performance trials at www.gocereals.ca.

Aphids are very susceptible to low temperatures. Aphid numbers and related concerns drop off as cool fall temperatures arrive. For more information on Hessian fly, cereal aphids or BYDV, see Chapter 15, *Insects and Pests of Field Crops* and Chapter 16, *Diseases of Field Crops*.

While seeding of winter cereals can be too early, the risk of not planting in a timely fashion carries far greater yield risk for producers on heavy, poorly drained clay soils. In these situations, plant if the soil conditions are fit. When seeding more than 10 days prior to the optimum date, decrease the seeding rate by 25%. Using lower seeding rates in this situation reduces the risk of snow mould and lodging. Yields often increase with lower seeding rates at these early planting dates.

As winter barley must be seeded early, select a variety with tolerance to BYDV, or utilize seed-applied insecticides that control aphids. See Publication 812, *Field Crop Protection Guide*.

Spring Cereals

It is virtually impossible to seed spring cereals too early, unless soil conditions are excessively wet. This tremendous response to early seeding is convincing some producers to consider frost seeding. Cool, moist spring conditions promote tillering and production of large heads. The flowering dates of the crop are also advanced, avoiding the hot, dry conditions that often exist in late June and July.

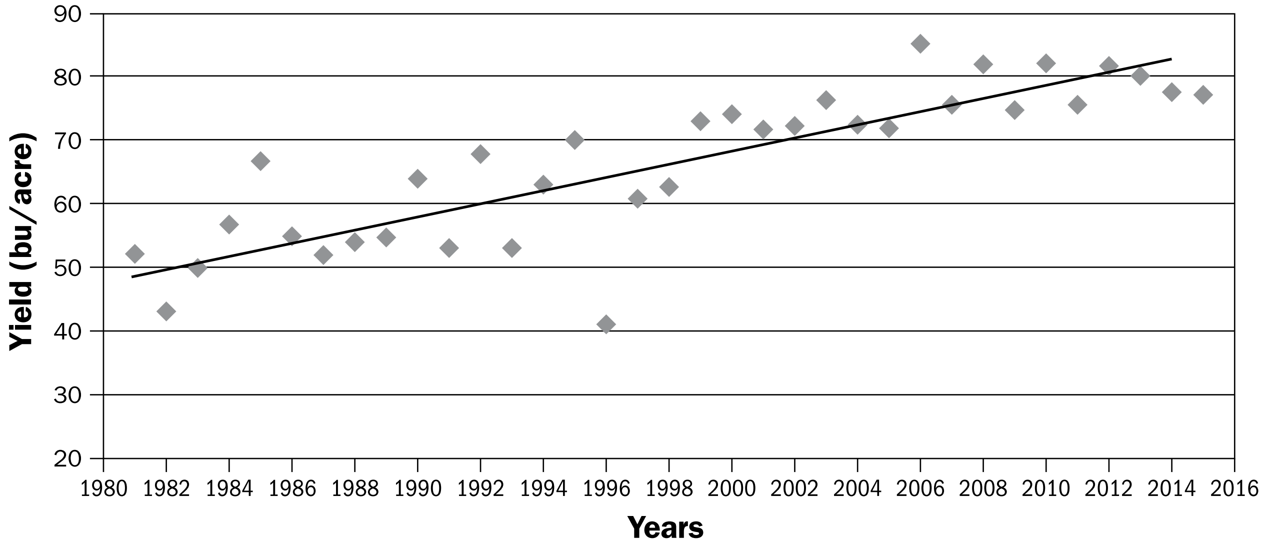

Figure 4–3. Provincial winter wheat yield for 1981–2014.

The target date for planting spring cereals is April 10 for southwestern Ontario, April 15 for central and eastern Ontario and May 10 for northern Ontario. In areas of greater than 3,100 CHUs, spring cereals are generally not recommended and should definitely not be grown if planting is delayed beyond April 20. Check with Agricorp for latest seeding dates to be eligible for production insurance.

Winter Cereals

The seeding date for winter wheat is often determined by the date soybeans are harvested. This can delay optimal planting dates for winter wheat, resulting in reduced yields. Wheat grown after soybeans is easily facilitated by following the simple guidelines outlined in, *Winter Wheat Following Soybeans,* Chapter 2, Soybeans.

Figure 4–4, *Optimum date to seed winter wheat across Ontario,* shows the ideal seeding dates for winter wheat. The isolines on the map are based on average weather conditions from 1960 to 1990; actual results will vary from year to year. Seed winter barley 7–10 days prior to the optimum dates for winter wheat to improve winter survival. Winter barley has less winter hardiness than winter wheat.

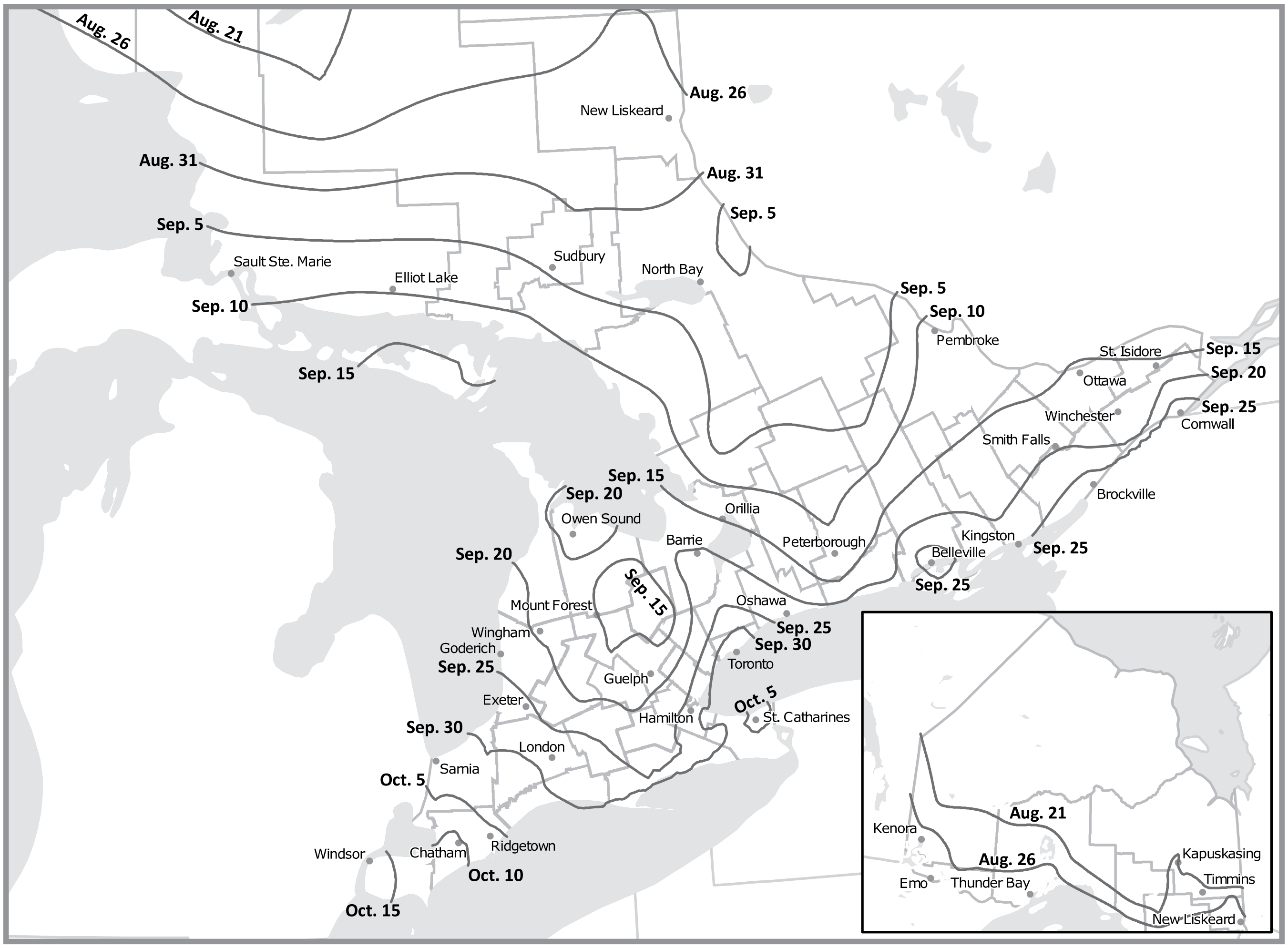

Figure 4–4. Optimum date to seed winter wheat across Ontario.

Table 4–6. Determining yield potential for various plant stand counts

Plant Spacing	Yield Potential	Yield	
		Oct. 5 planting date	Oct. 15 planting date
66 plants/m of row (20[1] plants/ft of row)	100%	5.34 t/ha (80 bu/acre)	4.84 t/ha (72 bu/acre)
33 plants/m of row (10 plants/ft of row)	95%	5.11 t/ha (76 bu/acre)	4.57 t/ha (68 bu/acre)
23[2] plants/m of row (7 plants/ft of row)	90%	4.84 t/ha (72 bu/acre)	4.37 t/ha (65 bu/acre)
20 plants/m of row (6 plants/ft of row)	85%	4.57 t/ha (68 bu/acre)	4.10 t/ha (61 bu/acre)
16 plants/m of row (5 plants/ft of row)	80%	4.30 t/ha (64 bu/acre)	3.90 t/ha (58 bu/acre)

Source: Smid, Ridgetown College, University of Guelph, 1986–90.

[1] Full stand.

[2] 23 plants/m (7 plants/ft) of row, healthy and evenly distributed, will still achieve 90% of yield potential and does not require replanting. A field with an average of 23 plants/m (7 plants/ft) of row without relatively uniform distribution, or with plants severely damaged by heaving and other injury factors, will not yield satisfactorily. Consider replanting in this case.

Replanting

Winter cereals are one of the few crops that provide a second opportunity to assess the crop in spring and replant to another crop if winter survival was not acceptable. Assess the wheat crop during April and early May. Leave the replant decision as late as possible to accurately determine plant stand and plant health.

Damaged plants will often recover under good weather conditions, while plants that are expected to recover may die if hot dry conditions exist. Table 4–6, *Determining yield potential for various plant stand counts,* indicates yield potential for various plant stand counts. The planting date will have an impact on the replant decision.

Seeding Rates

Historically, the seeding rates of cereal crops were recommended in bu/acre, with 2 bu/acre (135 kg/ha) a standard that covered most cereal crops.

Blanket statements of this nature are no longer acceptable. Seed size affects seeding rate. Set optimum seeding rates for each cereal crop. Table 4–7, *Guidelines for cereal crop plant populations* gives the ideal seeding rates for each crop. Table 4–8, *Calculating seeding rate by row width to achieve target plant density* indicates the seeds per metre of row and kilograms of seed per hectare required to achieve various desired plant populations. Table 4–9. *Calculating seeding rate by amount of seed to achieve target plant density* indicates the amount of seed required to achieve the desired plant population.

The seeding rate can be determined using this formula:

$$\text{Seeding rate (kg/ha)} = \frac{\text{seeds/ha}}{\text{seeds/kg}} \times \frac{100}{\text{\% germination}}$$

$$\text{Seeding rate (lb/acre)} = \frac{\text{seeds/acre}}{\text{seeds/kg}} \times \frac{100}{\text{\% germination}}$$

Sample Seeding Rate Calculation

Seeds/kg (seeds/lb) should be stated on the seed tag or bag. For instance, if 3.7 million seeds/ha (1.5 million seeds/acre) is desired, with a germination rate of 95% and 26,500 seeds/kg (12,000 seeds/lb), the seeding rate would be 147 kg/ha (132 lb/acre).

$$\text{Metric} = \frac{3{,}700{,}000}{26{,}500} \times \frac{100}{95} = 147 \text{ kg/ha}$$

$$\text{Imperial} = \frac{1{,}500{,}000}{12{,}000} \times \frac{100}{95} = 132 \text{ lb/acre}$$

Table 4–7. Guidelines for cereal crop plant populations

	Target Plant Population	
Crop	**Number of Plants**	**Seeds Required (x 1,000)**
Barley	250–350 plants/m^2 (23–33 plants/ft^2)	2,500–3,500 seeds/ha (1,000–1,400 seeds/acre)
Oats	200–300 plants/m^2 (19–28 plants/ft^2)	2,000–3,000 seeds/ha (800–1,200 seeds/acre)
Mixed grain	200–350 plants/m^2 (19–33 plants/ft^2)	2,000–3,500 seeds/ha (800–1,400 seeds/acre)
Spring wheat	300–400 plants/m^2 (28–37 plants/ft^2)	3,000–4,000 seeds/ha (1,200–1,600 seeds/acre)
Winter wheat	350–450 plants/m^2 (33–42 plants/ft^2)	3,500–4,500 seeds/ha (1,400–1,800 seeds/acre)

Table 4–8. Calculating seeding rate by row width to achieve target plant density

Use planned row width to determine required number of seeds/metre of row (seeds/foot of row).

	Desired Plant Population (x 1,000)							
Row Width	**2,000/ha (809/acre)**	**2,500/ha (1,012/acre)**	**3,000/ha (1,213/acre)**	**3,500/ha (1,416/acre)**	**4,000/ha (1,619/acre)**	**4,500/ha (1,861/acre)**	**5,000/ha (2,024/acre)**	**5,500/ha (2,226/acre)**
25 cm (10 in.)	49 (15)	62 (19)	75 (23)	89 (27)	102 (31)	112 (34)	125 (38)	138 (42)
20 cm (8 in.)	39 (12)	49 (15)	62 (19)	69 (21)	82 (25)	92 (28)	100 (32)	110 (35)
19 cm (7.5 in.)	38 (12)	46 (14)	56 (17)	66 (20)	75 (23)	85 (26)	94 (29)	104 (32)
18 cm (7 in.)	36 (11)	43 (13)	52 (16)	62 (19)	69 (21)	79 (24)	88 (27)	97 (30)
15 cm (6 in.)	30 (9)	39 (12)	46 (14)	52 (16)	59 (18)	69 (21)	75 (24)	83 (26)
10 cm (4 in.)	20 (6)	25 (8)	30 (9)	36 (11)	41 (12)	45 (14)	50 (15)	55 (17)

Table 4–9. Calculating seeding rate by amount of seed to achieve target plant density

Use the number of seeds per kg or per lb (often found on the seed tag) to determine the required seeding rate in kg/ha (lb/acre).

	Desired Plant Population (x 1,000)							
Amount of Seed	**2,000/ha (809/acre)**	**2,500/ha (1,012/acre)**	**3,000/ha (1,213/acre)**	**3,500/ha (1,416/acre)**	**4,000/ha (1,619/acre)**	**4,500/ha (1,861/acre)**	**5,000/ha (2,024/acre)**	**5,500/ha (2,226/acre)**
17,600/kg (8,000/lb)	114 (101)	142 (127)	170 (152)	199 (178)	227 (202)	256 (233)	284 (253)	313 (278)
19,800/kg (9,000/lb)	101 (90)	126 (112)	151 (135)	177 (158)	202 (157)	227 (207)	252 (225)	278 (247)
22,100/kg (10,000/lb)	90 (81)	112 (101)	134 (121)	157 (142)	179 (162)	202 (186)	226 (202)	249 (223)
24,300/kg (11,000/lb)	82 (73)	102 (91)	122 (109)	142 (127)	162 (145)	184 (164)	206 (185)	226 (204)
26,500/kg (12,000/lb)	75 (67)	93 (83)	112 (100)	131 (117)	149 (133)	168 (150)	189 (170)	208 (187)
28,700/kg (13,000/lb)	69 (62)	86 (77)	103 (92)	121 (108)	138 (123)	155 (138)	174 (157)	192 (172)
30,900/kg (14,000/lb)	64 (55)	80 (71)	96 (86)	112 (100)	128 (114)	144 (128)	162 (146)	178 (160)
33,200/kg (15,000/lb)	59 (53)	75 (67)	90 (80)	104 (93)	120 (107)	134 (120)	151 (136)	166 (149)
35,400/kg (16,000/lb)	56 (50)	71 (63)	84 (75)	99 (88)	112 (100)	127 (113)	141 (127)	155 (140)

Use the higher rates in Table 4–7, Table 4–8 and Table 4–9:

- where emergence and early seedling establishment are likely to be poor (for example, due to poor seedbed and aerial or broadcast seedings)
- for late planting where tillering will be reduced
- on very heavy clay soils

Row Widths

Considerable research has been conducted on cereal row widths for maximum yield. A summary of some winter wheat row width research from across Ontario and the northern U.S. and from Ontario on-farm results concludes that there is no evidence to support narrowing row widths below the standard 18–19 cm (7–7.5 in.) spacing for winter crops.

There appears to be a yield penalty with wider rows. The most recent Ontario row-width research shows an 8% decrease in yield when moving to 38 cm (15 in.) rows from 19 cm (7.5 in.). In some cases, this yield loss may be offset by reduced equipment costs and result in more profit if less equipment investment is required. 25 cm (10 in.) row corn/soybean planters have more accurate seed placement than 19 cm (7.5 in.) drills. With the importance of seeding depth, this improved accuracy may partially overcome the row width impact, as indicated by Essex, Middlesex and Ohio data, where accurate planting equipment was used for the 25 cm (10 in.) row widths.

For spring cereal crops, trials in northern Ontario have shown yield increases of more than 5% when row width was reduced from 18–10 cm (from 7–4 in.) spacing. Moving to 10 cm (4 in.) rows in this production area may prove beneficial. However, it is difficult to achieve these narrow row widths in a no-till system.

Crop Rotation for Winter Wheat

Crop rotation is an integral part of any production system. The greatest benefit to a good crop rotation is increased yields. A well-planned crop rotation will help with insect and disease control and aid in maintaining or improving soil structure and organic matter levels. In addition to increasing yields, using a variety of crops can reduce weed pressures, spread the workload, protect against soil erosion and reduce risk. Table 4–10, *Management considerations for wheat following various crops in rotation*, shows some of the risks associated with, and management options for, wheat following other crops.

Table 4–10. Management considerations for wheat following various crops in rotation

Following:	Comments
Processing peas	• best rotation • best option for early planting • residual nitrogen results in lower N requirement for wheat • lodging may be an issue
Edible beans	• excellent rotation • timely planting often possible • higher yielding than wheat after soybeans
Soybean	• excellent rotation • when soybean harvest is delayed, wheat planted later will have lower yield potential • on sandy soils, European chafer populations can reduce plant stands
Canola	• excellent rotation • timely planting possible • response to starter P may be greater (canola is non-mycorrhizal)
Corn (silage or grain)	• highest risk of fusarium • timely planting is possible (silage) • for wheat after corn, plant a variety that is MR for fusarium (see www.gocereals.ca) and plan to apply a fungicide to prevent fusarium
Alfalfa (pure stands)	• timely planting is possible • insect damage is a concern • nitrogen credit is not fully utilized because of timing of N release relative to crop requirements. Up to half the N is released after crop uptake is complete.
Grass hay	• poor rotation • primary risk is take-all, a root disease that infects the crop in the fall with a potential yield loss of over 50%, and other root diseases • later planting combined with seed-placed potash fertilizer provides some take-all suppression

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Table 4–10. Management considerations for wheat following various crops in rotation

Following:	Comments
Oats	• reasonable rotation. • timely planting possible • few diseases cross over between wheat and oats
Barley	• fair rotation • timely planting possible • root diseases cross over between barley and wheat. • later planting combined with seed-placed potash fertilizer provides some take-all suppression
Wheat	• worst choice since not a rotation • leaf disease and root disease pressure will be at its maximum • take-all, eyespot and cephalosporium stripe are at high risk with little or no management options • expect a minimum 10% yield loss

Additional Management Opportunities

Growth Regulators

Lodging of cereal crops can be a major harvest issue, and causes significant yield loss when it occurs early in the growth of the crop. Huge varietal differences exist in resistance to lodging (visit www.gocereals.ca). Nitrogen rates, use of manure, seeding rates, seeding dates, and disease infections all play a major role in lodging susceptibility.

Plant Growth Regulators (PGRs) can be used to shorten the crop and improve resistance to lodging. PGR's stiffen the stem, and often improve lodging resistance without shortening the plant at all. Typical height differential is 5–7 cm (2–3 in.). Some PGRs have impacts beyond plant height: for example, chlormequat chloride can reduce apical dominance, increase tillering, or allow tiller's to catch up in development. It also affects stomatal closure; often increasing yield slightly even when lodging is not an issue Refer to Table 4–11, *Response to plant growth regulators*. However, under severe moisture stress, yields may be reduced for this same reason.

Cereal crops vary greatly in their response to PGRs, and potential concerns for phytotoxicity (crop injury from PGR application). Weather extremes interact with most PGRs, occasionally causing severe injury. When possible, avoid low (<5°C) temperatures, high (>25°C) temperatures, or wide temperature fluctuations (>20°C), the day before, the day of, and the day after application. Typically, winter wheat is far more tolerant than spring cereals, and spring wheat can be the most sensitive. Varietal differences also exist within species. Read and follow label directions carefully when using PGRs.

Table 4–11. Response to plant growth regulators

LEGEND: – = no data available

Treatment	Yield	Gain
Check	6.89 t/ha (102.5 bu/acre)	–
1.2 L/ha (0.5 L/acre) Cycocel	7.04 t/ha (104.7 bu/acre)	2.2%
2.5 L/ha (1.0 L/acre) Cycocel	7.06 t/ha (105.0 bu/acre)	2.5%
1.8 L/ha (0.72 L/acre) Manipulator	7.10 t/ha (105.6 bu/acre)	3.0%

Source: P. Johnson, S. McClure. 9 locations 2011–2014.

Fungicides

Fungicides have become an integral part of the integrated pest management (IPM) for cereal production in Ontario over the past decade. This is due to several factors including: higher grain prices, better genetics, better fungicides, and breakdown of genetic disease resistance. Fungicide application for disease control should be based on scouting and presence of disease whenever possible. However, in the case of rust on oats or fusarium in wheat, fungicides must be applied as a preventative part of an IPM strategy if it is known that the likelihood of disease is high. Further information on disease identification and control can be found in Chapter 16, *Diseases of Field Crops*, and in OMAFRA Publication 812, *Field Crop Protection Guide*. Thresholds for disease control vary, depending on which disease is present, the stage of growth, crop condition and weather patterns. In general, it is important to scout the top two leaves of the cereal crop, at any stage of growth. If disease is moving onto one or both of these leaves, determine if the control threshold has been reached and if control is warranted.

Fungicide timing has moved to a new naming convention:

- early timings (Growth stage (GS) 30–31, weed control timing) are referred to as T1
- flag leaf timings (GS 37–39) are referred to as T2,
- fusarium timing (GS 58–61) are referred to as T3

In general terms, the later fungicides are applied to cereal crops, the higher the yield response, up until T3. Protecting the upper leaves of the cereal crop during grain fill has the greatest impact on yield. However, the yield difference between application at T2 and T3 is small. Earlier fungicide applications have less yield impact, as is shown in Table 4–12, *Fungicide timing response*. Economic yield response under Ontario growing conditions is marginal with two fungicide applications and rare with three fungicide applications. Where producers chose to apply more than one fungicide, use of different or multiple modes of action is essential to delay the development of disease resistance.

Table 4–12. Fungicide timing response

Application Timing	Delta Yield
T1	0.11 t/ha (1.6 bu/acre)
T2	0.46 t/ha (6.9 bu/acre)
T3	0.54 t/ha (8.0 bu/acre)
T1 + T2	0.54 t/ha (8.0 bu/acre)
T1 + T3	0.60 t/ha (8.9 bu/acre)
T2 + T3	0.73 t/ha (10.8 bu/acre)
T1 + T2 + T3	0.87 t/ha (12.9 bu/acre)

Source: Brinkman University of Guelph. 2009–2011 SMART data.

Fusarium Head Blight

Ontario conditions pose a high risk of fusarium head blight (FHB) in cereal crops virtually every year. In wheat production, fusarium outbreaks result in fusarium damaged kernels and toxins (especially deoxynivalenol (DON) in the grain) which can make it unfit for human consumption, and in severe cases, unfit for livestock feed. Due to the humid climate in Ontario, and the constant threat of fusarium, use of a fusarium fungicide is an accepted and almost essential practice. Malt barley, or cereal grains grown as hog feed, have similar concerns.

Spraying Basics: Fusarium Control in Wheat

Application of fusarium control fungicides requires specialized nozzles or nozzle combinations to achieve optimum results. Maximizing wheat head coverage requires both proper timing and the best nozzle configurations.

Maximize Spray Coverage of Wheat Heads

The key to applying fungicides to prevent fusarium head blight (FHB) is to spray all sides of all wheat heads with product. Heads that are missed or only partially sprayed are not protected adequately. Many spray nozzles and nozzle combinations to maximize spray coverage on all sides of the wheat heads have been evaluated.

Results showed that the closer the nozzles sprayed to horizontal, in a forward and back manner, the better the spray coverage. Nozzles that spray close to vertical had significantly less spray coverage on the heads. Figure 4–5, *Suggested nozzle orientation of a forward-and-back double nozzle assembly,* shows a boom-end view of the recommended nozzle orientation of a forward-and-back double nozzle assembly. Turbo FloodJet® nozzles alternating forward and back every 51 cm (20 in.) along the boom also have this 15°-below-horizontal spray inclination. These two nozzle set-ups provide the best spray coverage for FHB control.

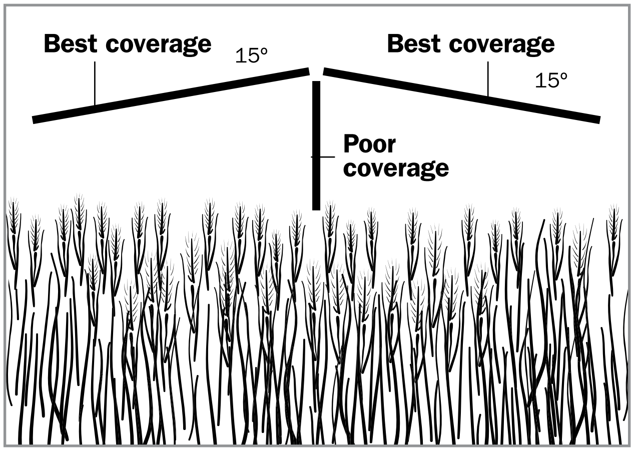

Figure 4–5. Suggested nozzle orientation of a forward-and-back double nozzle assembly.

Nozzles with a shallow attack angle, such as forward-and-back double nozzles and alternating turbo floodjets, have significantly better spray coverage of wheat heads than nozzles spraying straight down.

Water Volumes

Follow label directions. More water should improve spray coverage, especially in windier conditions. For ground application keep water volumes in the 170–190 L/ha (18–20 U.S. gal/acre) (GPA) range. Do not exceed 20 GPA application rates.

Spraying Speed

Spray coverage levels are very near equal from 10–20 km/h. Travel speed does not change the ranking or coverage level of the different nozzles.

Nozzle-to-Target Distance

Forward-and-back double nozzle assemblies and alternating Turbo FloodJets should be operated at 25–30 cm (10–12 in.) above the wheat canopy. Operate other nozzles a sufficient height above the canopy — about 50 cm (20 in.) — to allow full pattern development. Operating nozzles higher than this minimum nozzle-to-target distance will result in a significant reduction in spray coverage. Operating the boom at double the minimum nozzle-to-target distance from the wheat heads could reduce head coverage by as much as 50%.

Application Timing for Fungicides for FHB Control

Day 0 occurs when 75% of the heads on the main stems are fully emerged. Target spray applications for Day 1 to Day 4, with optimum timing being Day 2.

Rain Fastness

Current FHB fungicides (Prosaro®, Caramba® and Proline®) are all rainfast in 1 hour. Apply fungicide once wheat heads are fairly dry. Moisture droplets on the heads may cause spray to run off, thereby reducing coverage levels. Updated information can be found in OMAFRA Publication 812, *Field Crop Protection Guide*.

Sprayer Cleanout Before Spraying Wheat

It is essential to clean out sprayers totally, including boom end caps. Wheat at heading is very sensitive to any tank contamination, with yield loss approaching 100% in severe cases. If sprayer cleanout is not adequate, producers would be better not to spray for FHB.

Fusarium Forecasting

Weather INnovations Incorporated (WIN) offers the DONcast forecast modelling system. Visit the WIN website at www.weatherinnovations.com and follow the prompts.

Fungicides and Crop Maturity

Fungicides help keep plants healthy, which reduces infection by disease. Healthier plants result in higher yields but delay harvest by 2–3 days. Delayed harvest gives the impression that fungicides delay maturity when in fact, fungicides delay premature death brought on by disease. This delay extends the grain fill period, allows the crop to fully mature, and results in increased yield.

Fungicide/Nitrogen Interactions

Recent research has shown a synergy between nitrogen and fungicides (Hooker et al, 2014, Johnson and McClure, field data, 2008–2014) in winter wheat. When high nitrogen rates are applied in conjunction with fungicides, yield increases are more than just the additive result of fungicide plus nitrogen as shown in Figure 4–6, *Nitrogen response with and without fungicides*. The fungicide keeps the plant healthy, allowing the crop to utilize the higher nitrogen application. This synergistic response is clearly evident in winter wheat, where genetic yield potential and earlier maturity (reduced heat stress) allow better utilization of applied nitrogen. Work is currently underway to determine the extent of this synergy in spring cereals. Initial results in other cereals are not as encouraging.

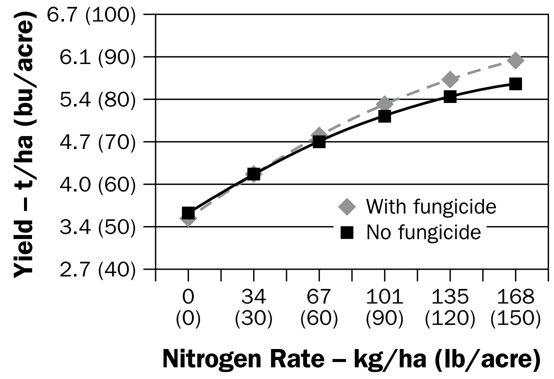

Figure 4–6. Nitrogen response with and without fungicides.

Source: P. Johnson and S. McClure, OMAFRA 2013-2014

Fertility Management

Nitrogen

Cereals are members of the grass family and are very responsive to nitrogen. Over-application of nitrogen causes lodging in cereal crops, resulting in reduced yield, quality and harvestability (Photo 4–2). The optimum rate of nitrogen for a particular field will depend on the crop being grown, past applications of manure or fertilizer to the field, soil type crop rotation and weather. Use general guidelines as a starting point but combine them with observations of crop growth and lodging tendency.

Photo 4–2. Lodging due to overlaps and/or excessive rates of nitrogen fertilizer.

The interaction of fungicides with nitrogen on winter wheat will also impact nitrogen application guidelines. See Figure 4–6, *Nitrogen response with and without fungicides*. Value of the crop, price of nitrogen and cost of fungicides will all play a role in determining the maximum economic rate of nitrogen.

General Guidelines

General nitrogen fertilizer guidelines for cereal crops are given in Table 4–13, *Nitrogen requirements for cereal crops*, Table 4–14, *Nitrogen requirements for pastry wheat* and Table 4–17, *Nitrogen guidelines for spring barley based on nitrate-nitrogen soil tests*.

Table 4–13. Nitrogen requirements for cereal crops

As N rates increase, density of the plant canopy increases, which increases the risk of foliar diseases. Yield responses to increased N rates are not expected unless accompanied by adequate control of leaf and head diseases with fungicides. With the use of a T2 or T3 fungicide and where lodging has not been a concern, spring N application rate may be increased by 30 kg N/ha (27 lb N/acre).

Crop	N Required[1]
Barley (areas receiving 2,800 CHUs or less)[2]	70–90 kg/ha (63–81 lb/acre)
Barley (areas receiving more than 2,800 CHUs)	45–60 kg/ha (40–54 lb/acre)
Cereals seeded as a nurse crop for forages	15 kg/ha (14 lb/acre)
Mixed grain, spring triticale (S. Ontario)	45–60 kg/ha (40–54 lb/acre)
Mixed grain, spring triticale (N. Ontario)	70–90 kg/ha (63–81 lb/acre)
Oats, spring rye (S. Ontario)	35–50 kg/ha (32–45 lb/acre)
Oats, spring rye (N. Ontario)	55–75 kg/ha (50–68 lb/acre)
Spring wheat	70–100 kg/ha (63–91 lb/acre)
Winter barley, winter rye[3]	90 kg/ha (81 lb/acre)
Winter triticale	80 kg/ha (72 lb/acre)
Winter wheat	See Table 4–16.

100 kg/ha = 90 lb/acre

[1] Where manure is applied or the preceding crop is a legume sod, reduce the N rates as shown in Table 9–9. *Adjustment of nitrogen requirement, where crops containing legumes are plowed down*, and Table 9–10. *Typical amounts of total and available nitrogen, phosphate and potash from various organic nutrient sources.*

[2] See Nitrate-Nitrogen Soil Test for Spring Barley.

[3] When not in rotation with tobacco.

Table 4–14. Nitrogen requirements for pastry wheat (most profitable N application)

For soft red or soft white pastry wheat. A maximum of 10 kg N/ha may be applied at seeding and the remainder top-dressed in early spring.

Nitrogen:Wheat Price Ratio[1]	Expected Yield 4 t/ha (60 bu/acre)	5 t/ha (75 bu/acre)	6 t/ha (90 bu/acre)	7 t/ha (105 bu/acre)	8 t/ha (120 bu/acre)
5	75 kg N/ha	95 kg N/ha	110 kg N/ha	125 kg N/ha	140 kg N/ha
6	70 kg N/ha	85 kg N/ha	105 kg N/ha	120 kg N/ha	135 kg N/ha
7	65 kg N/ha	80 kg N/ha	100 kg N/ha	115 kg N/ha	130 kg N/ha
8	60 kg N/ha	75 kg N/ha	95 kg N/ha	110 kg N/ha	125 kg N/ha

100 kg/ha = 90 lb/acre

[1] The price ratio is the cost of the nitrogen (N) in the fertilizer ($/kg N), divided by the selling price of the wheat ($/kg of wheat).
Price Ratio Example:
Price of UAN is $350/T.
Price/kg N is $350 ÷ 280 = $1.25/kg.
Wheat value at $250/T is $0.25/kg.
Price ratio is $1.25 ÷ $0.25 = 5.
It takes 5 kg of wheat to pay for 1 kg N.

Hard Winter Wheats (Red and White)

The current recommended hard winter wheat varieties in Ontario are not equivalent to Canadian Western Red Spring Wheat (CWRS) but are mid-strength or blend varieties with bread-baking and other unique qualities. High protein content is required in these varieties to meet quality specifications. To achieve these protein levels, a higher rate of nitrogen fertilizer is often required. The optimum rate of nitrogen is in the range of 35–70 kg/ha (30–60 lb/acre) greater than for pastry (soft) wheat. Split nitrogen applications increase protein, but often these increases are small enough that the split application is not economical. Ontario research data indicates that split N applications increase yield by 0.5%, on average.

As N rates increase, density of the plant canopy increases which increases the risk of foliar diseases. Yield responses to increased N rates are not expected unless accompanied by adequate control of leaf and head diseases with fungicides. With the use of a T2 or T3 fungicide and where lodging has not been a concern, spring N application rate may be increased by 30 kg N/ha (27 lb N/acre).

Nitrogen for grain protein production is required later in the development of the plant than the nitrogen for yield. This makes hard wheat varieties ideally suited to use the nitrogen from slow-release nitrogen sources or organic sources (legume plowdown or livestock manure). Desired protein levels are often easier to achieve on livestock farms due to these factors. Similar to split nitrogen applications, research on Environmentally Stable Nitrogen (ESN) (poly coated urea, 44-0-0) has shown a 0.5% increase in protein when included at 50%–65% of the nitrogen applied as shown in Table 4–15, *Managing for increased protein*. There was no increase or decrease in yield with ESN in these studies.

Table 4–15. Managing for increased protein

Management Input	Protein Increase
35 kg/ha additional N	0.5%
70 kg/ha additional N	1.0%
Split N (GS 30 + 32)	0.5%
Post Anthesis N (GS 30 + 69)	0.75%
Split N (GS 30 + 32 + 69)	1.0%
Agrotain Plus	0.2%
ESN 50%	0.5%
ESN 100%	0.75%

Source: P. Johnson, S. McClure, 2008–2014 averages from research trials.

Nitrate-Nitrogen Soil Test for Spring Barley

Application of fall nitrogen is discouraged under Ontario growing conditions. It brings no value to the producer, and may be an environmental concern from nitrate reaching groundwater. While this practice is viable in other winter cereal growing regions, those regions have warmer winters that allow for some continued growth over the winter months. Due to snow cover and cold winter conditions, winter cereals become totally dormant in Ontario. Fall nitrogen is not taken up because there is no growth. Nitrogen is subject to leaching or denitrification over the wet conditions of late fall, winter, and early spring. Research shown in Table 4–16, *Fall applied* *nitrogen,* suggests that over 50% of the fall applied nitrogen is lost overwinter. With no benefit and potential environmental impact, fall nitrogen (other than the small amount that comes along with starter phosphorus) is strongly discouraged.

Table 4–16. Fall-applied nitrogen

Nitrogen timing	Yield	Yield Impact[1]
100 kg/ha (90 lb/acre) spring	5.53 t/ha (82.2 bu/acre)	0
34 kg/ha (30 lb/acre) fall + 100 kg/ha (90 lb/acre) spring	5.69 t/ha (84.6 bu/acre)	–0.26 t/ha (–3.8 bu/acre)
135 kg/ha (120 lb/acre) spring	5.94 t/ha (88.4 bu/acre)	0
34 kg/ha (30 lb/acre) fall + 135 kg/ha (120 lb/acre) spring	5.96 t/ha (88.7 bu/acre)	–0.16 t/ha (–2.4 bu/acre)
168 kg/ha (150 lb/acre) spring	6.13 t/ha (91.1 bu/acre)	0

Source: P. Johnson, S. McClure 2011–2013 (18 locations).

[1] Yield compared to equal nitrogen all applied in spring.

Since soils can vary greatly in their ability to supply nitrogen, the general guidelines found in Table 4–13, *Nitrogen requirements for cereal crops*, may not be the most profitable for some fields. The amount of nitrate-nitrogen present in the soil near planting time can be a useful indicator of a soil's ability to supply nitrogen.

The nitrate-nitrogen soil test can be used to predict nitrogen requirements for spring barley in areas other than eastern Ontario that receive less than 3,000 CHUs, see Figure 1–1, *Crop heat units (CHU-M1)* available for corn production.

Consider a guideline based on a spring nitrate-nitrogen test to be a useful indicator for formulating a nitrogen management program for spring barley, see Table 4–17, *Nitrogen guidelines for spring barley based on nitrate-nitrogen soil tests*.

Time and Depth of Sampling

Collect samples as close to planting time as practical (within 5 days of planting), allowing for sample shipping, analysis and receipt of results. Contact the accredited lab to determine sample turnaround times.

It is important that all cores in a field be taken to a 30 cm (12 in.) depth. To ensure that the sample is representative of the field, take the same number of cores and use a sampling pattern similar to that recommended for the standard soil test described in *Soil Sampling*. Also refer to Appendix C, *Accredited Soil-Testing Laboratories in Ontario*.

Where Caution is Required

There are situations where the fertilizer recommendations based on nitrate-nitrogen soil tests should be adjusted. The nitrogen in manure or legumes applied or plowed down just before sampling will not have converted into nitrate and will not be detected by the soil test. Information will be provided with the soil test results on how to make appropriate adjustments.

Table 4–17. Nitrogen guidelines (most profitable rate) for spring barley based on nitrate-nitrogen soil tests

For areas outside of eastern Ontario that receive less than 3,000 CHUs.

Spring Soil Nitrate-Nitrogen 0–30 cm[1]	Price Ratio[2]			
	8	7	6	5
10 kg/ha	138 kg/ha	147 kg/ha	156 kg/ha	165 kg/ha
20 kg/ha	107 kg/ha	114 kg/ha	122 kg/ha	129 kg/ha
30 kg/ha	76 kg/ha	81 kg/ha	87 kg/ha	93 kg/ha
40 kg/ha	44 kg/ha	49 kg/ha	53 kg/ha	57 kg/ha
50 kg/ha	13 kg/ha	16 kg/ha	18 kg/ha	21 kg/ha
60 kg/ha	0	0	0	0

100 kg/ha = 90 lb/acre

[1] To convert to nitrate-nitrogen soil test (30-cm depth) from kg/ha to ppm, divide by 4.

[2] The price ratio is the cost of the nitrogen (N) in the fertilizer ($/kg N), divided by the selling price of the barley ($/kg of barley). Price Ratio Example: see Table 4–13.

Exercise caution if the recommendation is for large quantities of nitrogen and there is a history of barley lodging at lower rates of nitrogen. The nitrate-nitrogen soil test has not been adequately evaluated for:

- legumes or manure plowed down in the late summer or fall
- barley following legumes in a no-till system employing chemical burndown of the legumes

Uniformity of Nitrogen Fertilizer Application

To maximize yield, nitrogen must be applied uniformly across the field. Uniform application is more critical than the form of nitrogen fertilizer applied. Table 4–18, *Yield loss associated with inaccurate nitrogen application patterns*, indicates the potential yield loss associated with inaccurate spread patterns. A 1.48 t/ha (22 bu/acre) yield difference was found between the fully fertilized and under-fertilized strips in the field.

Table 4–18. Yield loss associated with inaccurate nitrogen application patterns

Based on two locations in Middlesex County, 1998, three replications at each location.

Application pattern	Yield Loss
Low N	3.72 t/ha (55.3 bu/acre)
Full N	5.20 t/ha (77.3 bu/acre)

Source: P. Johnson, OMAFRA.

Urea-Ammonium Nitrate Solution (UAN) (28-0-0 or 32-0-0) applied with streamer nozzles gives excellent, uniform nitrogen application and has shown small yield advantages 0.17 t/ha (2.5 bu/acre) as shown in Table 4–19, *UAN as a herbicide carrier*. Urea or ammonium nitrate or calcium ammonium nitrate can be applied using airflow technology, improving uniformity, although uniformity is not guaranteed. During humid days, urea can build up in the airflow tubes, restricting flow and affecting distribution. Be sure to maintain clear hoses to achieve a uniform spread pattern.

Spinner spreaders often have the greatest inconsistency in spread pattern. If spinners are employed, consider double spreading the field at half the rate (6 m (20 ft) centres instead of 12 m (40 ft) centres, to overcome this inconsistency). European style spinner spreaders, which are able to adjust the fertilizer drop onto the spinner, are much more accurate in spread pattern. However, until the fertilizer industry in Ontario advances as it has in Europe, with granule size and density for each load, this improved technology will be of limited value.

Pendulum spreaders have performed very well in accuracy tests with dry fertilizer. However, with small hoppers and narrow spread patterns, this type of spreader is not very common in Ontario.

UAN applied through streamer nozzles causes little or no leaf burn. Applying 28% nitrogen (UAN) as an overall broadcast treatment (using flood jet or tee-jet nozzles) to emerged cereal crops is **NOT ADVISED**. Table 4–19 shows the potential yield loss associated with this practice. The addition of 28% to a herbicide application, especially contact herbicides, will greatly increase leaf injury and yield loss (Photo 4–3).

Table 4–19. UAN as a herbicide carrier

Application combination	Visual Injury	Yield
200 L/ha water (18 gal/acre[1] water)	0%	6.4 t/ha (95 bu/acre)
150 L/ha water + 50 L/ha UAN (13.4 gal/acre water + 4.5 gal/acre UAN)	3%	6.4 t/ha (95 bu/acre)
100 L/ha water + 100 L/ha UAN (9 gal/acre water + 9 gal/acre UAN)	5%	6.1 t/ha (91 bu/acre)
50 L/ha water + 150 L/ha UAN (4.5 gal/acre water + 13.4 gal/acre UAN)	7%	6.1 t/ha (91 bu/acre)
200 L/ha UAN (18 gal/acre UAN)	9%	6.0 t/ha (89 bu/acre)

[1] 1 gallon (Imperial) = 1.2 U.S gal

Source: Sikkema, University of Guelph (RCAT), 2008–2013.

Photo 4–3. UAN 28% leaf burn. Applications of 28% nitrogen fertilizer can burn leaves and reduce yields.

A range of streamer nozzles exist for UAN application. Tests have shown that boom height can have a major impact on some nozzles. For example, three-stream nozzles work well at the correct 50 cm (20 in.) nozzle to target distance. However, if booms with three-stream nozzles vary in height due to rolling topography or rough field conditions, at 75 cm (30 in.) height their pattern is much less ideal. Chafer streamer bars give excellent uniformity, regardless of boom height: but nozzles can turn on the boom, and folding the boom with these large nozzle bodies can be problematic.

Timing of Nitrogen Application

Most nitrogen fertilizers for spring cereals are applied before planting and worked into the soil. This allows optimum crop utilization of the fertilizer, while minimizing the risk of losses through run-off or volatilization. It is acceptable to top-dress emerged spring cereals, particularly if a starter fertilizer has been applied at planting.

Phosphate and Potash

Phosphate and potash recommendations for cereals are in Table 4–20, *Phosphate (P_2O_5) guidelines for cereals* and Table 4–21, *Potash (K_2O) guidelines for cereals.*

These fertilizer guidelines are based on OMAFRA-accredited soil tests. For information on the use of these tables, or if an OMAFRA-accredited soil test is unavailable, see *Fertilizer Guidelines* in Chapter 9, *Soil Fertility and Nutrient Use.*

Table 4–20. Phosphate (P_2O_5) guidelines for cereals

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	**Spring Barley, Spring Wheat, Mixed Grain**	**Oats, Spring Triticale, Spring Rye**	**Winter Wheat, Winter Rye, Winter Barley, Winter Triticale**	**Winter or Spring Grains Seeded Down**
	Phosphate Required[1]			
0–3 ppm	110 kg/ha (HR)	70 kg/ha (HR)	70 kg/ha (HR)	130 kg/ha (HR)
4–5 ppm	100 kg/ha (HR)	60 kg/ha (HR)	60 kg/ha (HR)	110 kg/ha (HR)
6–7 ppm	90 kg/ha (HR)	50 kg/ha (HR)	50 kg/ha (HR)	90 kg/ha (HR)
8–9 ppm	70 kg/ha (HR)	30 kg/ha (HR)	30 kg/ha (HR)	70 kg/ha (HR)
10–12 ppm	50 kg/ha (MR)	20 kg/ha (MR)	20 kg/ha (MR)	50 kg/ha (MR)
13–15 ppm	20 kg/ha (MR)	20 kg/ha (MR)	20 kg/ha (MR)	30 kg/ha (MR)
16–20 ppm	20 kg/ha (MR)	0 (LR)	20 kg/ha (MR)	20 kg/ha (MR)
21–25 ppm	0 (LR)	0 (LR)	20 kg/ha (MR)	20 kg/ha (MR)
26–30 ppm	0 (LR)	0 (LR)	20 kg/ha (MR)	20 kg/ha (LR)[1]
31–40 ppm	0 (RR)	0 (RR)	0 (LR)	0 (LR)
41–50 ppm	0 (RR)	0 (RR)	0 (RR)	0 (RR)
51–60 ppm	0 (RR)	0 (RR)	0 (RR)	0 (RR)
61 ppm +	0 (NR)[2]	0 (NR)[2]	0 (NR)[2]	0 (NR)[2]

100 kg/ha = 90 lb/acre

[1] For winter cereals seeded down only.

[2] 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 4–21. Potash (K_2O) guidelines for cereals

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	Spring Barley, Spring Wheat, Mixed Grain	Oats, Spring Triticale, Spring Rye	Winter Wheat, Winter Rye, Winter Barley, Winter Triticale	Winter or Spring Grains Seeded Down
	Potash Required[1]			
0–15 ppm	90 kg/ha (HR)	70 kg/ha (HR)	50 kg/ha (HR)	90 kg/ha (HR)
16–30 ppm	80 kg/ha (HR)	50 kg/ha (HR)	40 kg/ha (HR)	80 kg/ha (HR)
31–45 ppm	70 kg/ha (HR)	40 kg/ha (HR)	30 kg/ha (HR)	70 kg/ha (HR)
46–60 ppm	50 kg/ha (HR)	30 kg/ha (HR)	20 kg/ha (HR)	50 kg/ha (HR)
61–80 ppm	40 kg/ha (HR)	20 kg/ha (MR)	20 kg/ha (MR)	40 kg/ha (HR)
81–100 ppm	30 kg/ha (MR)	20 kg/ha (MR)	20 kg/ha (MR)	30 kg/ha (MR)
101–120 ppm	20 kg/ha (MR)	0 (LR)	20 kg/ha (LR)	20 kg/ha (MR)
121–150 ppm	20 kg/ha (MR)	0 (RR)	0 (RR)	20 kg/ha (MR)
151–180 ppm	0 (LR)	0 (RR)	0 (RR)	0 (LR)
181–210 ppm	0 (RR)	0 (RR)	0 (RR)	0 (RR)
211–250 ppm	0 (RR)	0 (RR)	0 (RR)	0 (RR)
251 ppm +	0 (NR)[1]	0 (NR)[1]	0 (NR)[1]	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.

Corn Row Syndrome

No-till crops grown without starter fertilizer often develop "corn row syndrome" symptoms. Wheat plants growing over old corn rows will be significantly taller and more vigorous than plants growing between the rows. This is primarily due to higher phosphorus availability from the corn starter fertilizer band, even though the corn crop was grown 2 or 3 years prior to the wheat crop. Fields receiving 58 kg/ha (52 lb/acre) of supplemental P_2O_5 (100 lb/acre MAP) overcame the variability in wheat growth. The addition of low rates of P with a liquid starter reduced the corn row effect but did not eliminate it. Table 4–22, *Corn row syndrome* and Photo 4–4 show the visual and yield impact of corn row syndrome. Winter wheat is one of the most responsive crops to phosphorus fertilization. This is shown in Table 4–23, *Yield response to starter fertilizer*, which summarizes 4 years of comparisons on fields with a large range of fertility levels. Even on soils with high fertility there is a response to seed placed starter fertilizer. Note that seed placed starter fertilizer is 4–5 times more efficient than broadcast. Additionally, fall broadcast phosphorus that is not incorporated is subject to movement off target and can be an environmental concern. If the drill is not equipped for seed placed phosphorus seed can be blended with fertilizer (MAP, 11-52-0) and the blend seeded through a single box. Seed and fertilizer do not separate, and this has been a successful practice on many farms. Set seed cups one notch more open than the wheat setting, and target a seed drill setting of 10% less than the total of the seed and fertilizer weight/acre as a starting point. Further drill calibration will be required from there. If broadcast phosphorus is chosen as the method of phosphorus application, be sure that the fertilizer is incorporated to prevent off-target concerns.

Photo 4–4. Corn row syndrome of winter wheat is caused by fertilizer or pesticide carryover in the rows of previous crops.

Table 4–22. Corn row syndrome

Location	Phosphorus Soil Test	Height	Tissue Phosphorus Levels (DM Basis)	Yield
In row	19	107 cm (42 in.)	0.16% P	5.13 t/ha (76.3 bu/acre)
Between row	9	89 cm (35 in.)	0.12% P	4.51 t/ha (67.1 bu/acre)

Source: P. Johnson, OMAFRA (2013).

Table 4–23. Yield response to starter fertilizer

		Yield Increase over Check		
Fertilizer	**P Applied**	**Soil Test P[1] 6–13 ppm** (10 sites)	**Soil Test P[1] 13–21 ppm** (9 sites)	**Soil Test P[1] 21–56 ppm** (9 sites)
Liquid 6-24-6				
95 L/ha (10 US gal/acre) (in furrow)	30 kg P_2O_5/ha (27 lb P_2O_5/acre)	12.0%	6.2%	3.3%
40 L/ha (5 US gal/acre) (in furrow)	14.5 kg P_2O_5/ha (13 lb P_2O_5/acre)	9.7%	2.7%	1.8%
21 L/ha (2.5 US gal/acre) (in furrow)	3 kg P_2O_5/ha (7 lb P_2O_5/acre)	6.3%	2.9%	0.9%
Dry 7-34-20				
170 kg/ha (150 lb/acre) (in furrow)	58 kg P_2O_5/ha (52 lb P_2O_5/acre)	17.3%	6.2%	4.8%
56 kg/ha (50 lb/acre) (in furrow)	19 kg P_2O_5/ha (17 lb P_2O_5/acre)	10.9%	4.7%	3.5%
225 kg/ha (200 lb/acre) (broadcast)	76 kg P_2O_5/ha (68 lb P_2O_5/acre)	12.0%	3.5%	4.6%
	Average Check Yield	5.31 t/ha (79.0 bu/acre)	5.95 t/ha (88.5 bu/acre)	6.0 t/ha (89.0 bu/acre)
	Minimum Difference[2]	0.2 t/ha (3.2 bu/acre)	0.2 t/ha (3.2 bu/acre)	0.2 t/ha (3.1 bu/acre)

Source: Johnson, McClure, Janovicek 2010–2013.

[1] Plant available P based on accredited Ontario soil test.
[2] Minimum yield difference required to be confident that differences are not due to random chance.

Methods of Application

Where phosphate fertilizer is required for cereal crops, it is best drilled with the seed. Seed-placed fertilizers may include some or all of the required nitrogen and potash, depending on rates of application. For further information, see Table 9–22, *Maximum safe rates of nutrients* in Chapter 9, *Soil Fertility and Nutrient Use.*

Sulphur

With the reduction of sulphur from atmospheric deposition, sulphur is becoming a more critical and necessary component of a good fertility package. Considerable research over the period from 2010–2015 has found significant sulphur response (0.67–0.94 t/ha or 10–14 bu/acre) on some fields, some years. Other fields, for example, fields with regular manure application, have shown very little response. Figure 4–7, *Sulphur response in wheat,* shows average yield increase of responsive fields. In these trials, 13 out of 22 sites (59%) were responsive, with an average response of 0.26 t/ha (3.8 bu/acre). Across all trials the average response was 0.13 t/ha (2 bu/acre).

At this time, there is no predictive tool (soil test, tissue test) to determine responsive fields. Additionally, there is a significant year-to-year interaction. Early warm springs kick start soil biological activity and have little response to sulphur additions while cool, wet springs have much greater response. The best strategy for producers is to conduct their own sulphur trials, to determine responsive fields. Responsive fields have a much greater chance of response year after year. When response is unknown, producers could chose to apply sulphur based on the year (early and dry vs wet and late), or apply sulphur as an "insurance" policy, just in case.

If sulphur applications are considered, Figure 4–7 suggests that optimum application rates are 10–15 kg/ha (9–13 lb/acre) of spring applied sulphate or thiosulphate fertilizer. Some regions suggest sulphur applications on a 10 units nitrogen: 1 unit sulphur basis, as this is the relative proportion in the plant of both nutrients. However, this ignores the sulphur still available from atmospheric deposition. Research, to date, has shown the N:S ratio to be of little value In Ontario. Producers should apply sufficient N and S, and not follow any particular ratio of each.

Fall sulphur is another option to consider. However, fall sulphate sulphur will leach over winter, so fall applications must be in the elemental sulphur form. Elemental sulphur must be transformed to sulphate to be taken up by plants, therefore during cool springs this process may not happen quickly enough to supply the wheat crop's early season's demand. Response to fall applied sulphur in research trials has been inconsistent. Spring sulphate is preferred, as availability is known. If fall elemental sulphur applications are chosen, 22–56 kg/ha (20–50 lb/acre of actual S should be applied.

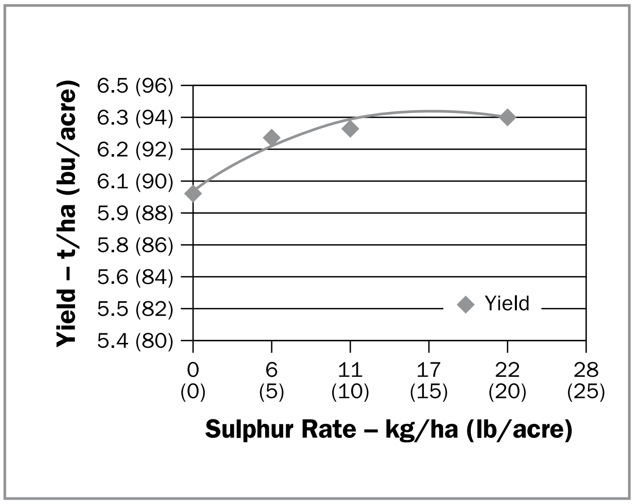

Figure 4–7. Sulphur response in wheat.

Source: P. Johnson, S. McClure 2012-2014. Summary of 13 responsive sites.

Plant Analysis

For cereals, sample the top two leaves at heading. Sample plants suspected of nutrient deficiency as soon as the problem appears. For plants less than 20 cm (8 in.) tall, sample the entire plant. For sampling at times other than heading, take samples from both deficient and healthy areas of the field for comparison purposes.

Photo 4–5. Sulphur deficiency in wheat. Courtesy of Marieke Patton Bayer.

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

Plant tissue analysis results should fall between the critical (low) and normal maximum concentrations. To interpret plant tissue results, refer to Table 4–24, *Interpretation of plant analysis for cereal crops* and Appendix I, *Diagnostic Services.*

Table 4–24. Interpretation of plant analysis for cereal crops

Values apply to the top two leaves sampled at heading.

LEGEND: — = no data available

Nutrient	Critical Concentration[1]	Maximum Normal Concentration[2]
Nitrogen (N)	2.0%	2.7%
Phosphorus (P)	0.1%	0.5%
Potassium (K)	1.0%	3.0%
Calcium (Ca)	—	1.0%
Magnesium (Mg)	0.15%	1.0%
Boron (B)	3 ppm	25 ppm
Copper (Cu)	3 ppm	50 ppm
Manganese (Mn)	15 ppm	200 ppm
Zinc (Zn)	10 ppm	70 ppm

[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 deficiency frequently occurs when wheat, oats or barley are grown in an organic (muck) soil. It can occasionally occur in mineral soils high in organic matter, or with high soil pH, and in very sandy soils with low organic matter. On oats, manganese deficiency appears as irregular, oval, grey spots on the leaves (Photo 4–6). On barley and wheat, it appears more commonly as a light yellow colour on the leaves with the veins in the leaf remaining slightly darker green (Photo 4–7). Both soil tests and plant tissue analyses are useful in predicting where manganese deficiencies are likely to occur. Both analyses are available at OMAFRA-accredited soil testing laboratories.

Photo 4–6. Manganese deficiency on oats looks like irregular, oval gray spots.

Photo 4–7. Manganese deficiency on winter wheat (pale-yellow interveinal stripes on the leaves) occurs most frequently on high pH, sandy soils or on organic soils.

Correct the deficiency as soon as it is detected by a foliar spray of 2 kg/ha (1.8 lb/acre) manganese, which can be provided from 8 kg/ha (7 lb/acre) manganese sulphate in 200 L (53 gal) of water. Use a “spreader-sticker” in the spray. If the deficiency is severe, a second spray may be beneficial. Winter cereals growing in areas of severe manganese deficiency may require an application in the fall to ensure winter survival. Be cautious of manganese products that are a “shotgun blast” of all nutrients. These products rarely supply more than one-tenth of a kg/ha at maximum application rates, and are much more expensive per unit of Mn. These low rate applications may briefly correct the deficiency; however repeated applications are often required for acceptable results.

Soil application is not recommended, regardless of source, due to the large amounts of manganese that would be required. In most cases, plant deficiencies are caused by a low availability of manganese from the soil rather than a lack of manganese. Adding more manganese to the soil will not often correct this. However, when small areas of the field are continually deficient, while the balance of the field is fine, soil applications can be attempted in the problem zones to avoid foliar applications on the entire field year after year. Apply from 22 kg/ha (20 lb/acre) Mn from manganese sulphate ($MnSO_4$) to the deficient zone. Repeated applications may be necessary.

Copper

Copper deficiency may occur in organic (muck) soils and could be suspected on rare occasions in very sandy soils. Response to copper has never been established on sandy soils. The most common deficiency symptom is dieback from the tip of the leaf, often accompanied by twisting of the upper leaves. For information on correcting copper deficiencies, see *Micronutrient Fertilizers,* Chapter 9, *Soil Fertility and Nutrient Use.* Many claims have been associated with copper applications, especially in regards to disease control. Ontario studies have not been able to substantiate any disease control benefit from copper applications.

Boron

Boron deficiency has not been diagnosed in cereals. Boron applications can be toxic, causing a bleaching of leaf tissue in seedlings. Many tissue samples come back indicating boron deficiency: however, when boron is applied in these situations, no response occurs. Critical values for boron in wheat leaf tissue needs to be reassessed.

Zinc

Zinc deficiency in cereals does not appear to be a problem. Trials on cereals using Micro-Essentials Sulphur Zinc (MESZ) 10-40-0-10-2 have found no benefit from the zinc in this product.

Do not apply mixtures of herbicides and foliar fertilizers to crop foliage unless recommended by reliable agronomists. Always consult the herbicide label.

Harvest and Storage

Optimizing Combine Adjustments

Operator manuals contain the best starting point for setting up a small grain harvester. Occasionally, conditions arise that require further adjustments. Harvest of *Fusarium*-damaged grain, lodged crops or crops infected with dwarf or common bunt requires special attention. The easiest and best way to improve the grain sample in these situations is with proper combine adjustment. Often the difference between a marketable crop and sample grade wheat is in the combine set-up. Don't be afraid to experiment.

Storage of the crop allows the opportunity to upgrade the grain before delivery to an elevator or mill. This is particularly important for wheat infested with any of the bunt diseases. Many producers have experimented with re-cleaning the grain through screen cleaners, seed cleaners and fanning mills to upgrade the crop to a better sample. Elevator operators can also do this, for a fee. This can have tremendous economic benefit, where grain can be moved from salvage grade to milling grade. Upgrading the grain makes it much easier for the elevator to handle the crop and find a purchaser for the grain.

Fusarium-Damaged Grain

Combines use air blast to separate grain from the chaff in a normal harvest operation. Many of the *Fusarium*-infected kernels are small, shrunken and lighter than sound kernels. It is often possible to blow a large proportion of these *Fusarium*-damaged kernels out the back of the combine by increasing the air blast above normal ranges. In 1996, many producers operated combines at the maximum windblast to increase grade. Research conducted by Dr. A Schaafsma (University of Guelph, Ridgetown Campus) in 1996 found a tenfold decrease in *Fusarium*-damaged kernels in the grain when fan speeds were operated at maximum blast (up to 300 rpm above book settings). Operating cleaning fans at these levels causes an additional loss of good kernels, up to 0.13 t/ha (2 bu/acre) Refer to Table 4–25, *Effect of different fan-speeds on wheat yield*. This small yield reduction is insignificant if the crop can be made marketable, rather than being downgraded to feed, sample or salvage.

Table 4–25. Effect of different fan-speeds on wheat yield

Case International 1644, Harus Wheat, Essex County, July 17,1996. Travel speed 6.8 km/h (4.2 mph). Rotor speed 880 rpm.

	Fan Speed							
	Sieve Setting: 6 mm (0.25 in.)							**Front Closed**
Comparison	**1,160 rpm**	**1,190 rpm**	**1,220 rpm**	**1,250 rpm**	**1,280 rpm**	**1,320 rpm**	**1,330 rpm**	**1,330 rpm**
Good kernels on ground	172/m^2 (16/ft^2)	125/m^2 (11.6/ft^2)	340/m^2 (31.6/ft^2)	263/m^2 (24.4/ft^2)	379/m^2 (35.2/ft^2)	446/m^2 (41.4/ft^2)	470/m^2 (43.6/ft^2)	461/m^2 (42.8/ft^2)
Loss	0.06 t/ha (0.8 bu/ acre)	0.04 t/ha (0.6 bu/ acre)	0.11 t/ha (1.6 bu/ acre)	0.08 t/ha (1.2 bu/ acre)	0.12 t/ha (1.8 bu/ acre)	0.14 t/ha (2.1 bu/ acre)	0.15 t/ha (2.2 bu/ acre)	0.14 t/ha (2.1 bu/ acre)
Loss at 4.03 t (60 bu) yield	1.38%	0.97%	2.63%	2.03%	2.93%	3.45%	3.63%	3.56%

Source: Dr. Art Schaafsma, University of Guelph, Ridgetown College, 1996.

Harvest *Fusarium*-damaged grain as quickly as possible. Fusarium levels can increase dramatically when harvest is delayed. Fusarium can continue to grow whenever grain moisture exceeds 19%, which occurs frequently in wheat any time there is precipitation. However, moistures above 16% reduce the ability to blow out lighter *Fusarium*-damaged kernels. Early harvest, and harvesting at lower moisture, often work against each other. Slowing the forward ground speed of the combine may further reduce *Fusarium* levels. This allows increased separation of the grain mass, giving the increased windblast time to separate the good kernels from the infected kernels. Consider adjusting the cleaning sieves (chaffer) to a more wide-open setting. This directs the air blast vertically, slowing rearward movement of the grain mass and aiding cleaning and separation. Use caution to keep heads and straw particles out of the grain sample if the chaffer is opened.

Unfortunately, there will be times that the grain quality cannot be raised to milling standards. If this occurs, consider storing as much of the damaged grain as possible. Often, as harvest finishes, the pressure eases on those involved in handling the crop. Marketers and millers are able to assess the markets that do exist and determine the best way to condition wheat to fit that market.

Wheat going into storage must be dry (14% moisture or below). Damp wheat allows the *Fusarium* to continue to grow and produce toxins, further downgrading the crop. Check stored grain frequently to ensure that the grain stays in condition.

Lodged Grain Crops

Setting up a combine for lodged wheat takes extra time and care while in the field. Although flexible cutter bars on floating soybean heads are standard on modern combines, there are several effective options for harvesting lodged grain crops.

- **Grain Lifters:** lift the crop above the cutter bar and is an inexpensive way to maximize yields.
- **Knife Adjustment:** On floating cutter bars, leave the knife tilted down and run the header in the float position similar to harvesting a soybean crop. Take care not to feed rocks into the combine if choosing this option.
- **Reel Adjustment:** Most reels are permanently on the best setting for soybean harvest. Newer combines have hydraulic adjustments from the cab, but this setting is not appropriate for a lodged cereal crop. Set the reel forward and adjust the tine angle to be more aggressive, allowing the reel to physically lift the crop up off the ground and above the knife. Check the operator's manual for suggested settings and fine-tune from there.
- **Harvesting Direction:** The last option, some years, is to harvest the grain in one direction so the lodged grain is tilted towards the header rather than away.

Bunt-Infected Wheat

To avoid being forced into harvesting a bunt-infected crop, use resistant varieties of properly treated seed. However, when bunt does infect the crop, harvest and storage must focus on minimizing bunt balls in the sample and reducing the "fishy" odour following harvest.

Do not harvest bunt-infected crops at high moisture. Spores from broken bunt balls adhere more easily to damp grain. Harvest dry grain using slow cylinder speeds and open concave clearance to minimize the number of bunt balls broken during the harvest process. Operate cleaning fans at high speed to blow as many of the bunt balls and bunt spores out the back of the combine as possible.

Storage of bunt-infected wheat is an effective way to upgrade the grain. Aeration is the key. Store bunt-infected grain in storage facilities with lots of aeration capability. Aerate the grain until the odour has disappeared. Take care when removing the grain from storage, as the handling process can break remaining intact bunt balls and re-contaminate the grain. Belt conveyors are preferable to augers when moving bunt-infected grain. Use of aspiration during the handling process will often lift out remaining bunt balls and keep the grain in condition.

Never contaminate or attempt to blend bunt-infected wheat with clean wheat. It takes very little bunt to downgrade the grain. Blending will simply contaminate the good grain, not improve the damaged grain. For more information, refer to *Dwarf Bunt* and *Common Bunt* in Chapter 16, *Diseases of field crops*.

Drying and Storing Wheat

Winter wheat is sometimes harvested at higher moisture contents because of impending wet weather or to reduce harvest losses. Wheat is considered dry at 14.5% moisture by the Canadian Grain Commission (CGC), however the Ontario industry moved to 14% to align more closely to other world standards. Drying charges could be implemented to wheat at greater than 14% moisture.

Winter wheat must be dried to 13%–14% moisture content for safe, long-term storage.

Drying Systems

Three different systems can be used to dry wheat:

- natural-air drying bin
- low-temperature dryers (less than 40°C)
- high-temperature or high-speed dryers (temperatures greater than 40°C)

Natural-Air and Low-Temperature Drying

Natural air drying of wheat will only occur when the relative humidity of the outside air is below the equilibrium moisture content of the grain. The effectiveness of natural air drying systems is greatly reduced during rainy periods and at night when temperatures are cool and relative humidity levels are normally high. When air temperatures fall below 10°C, forced ambient air will not pick up as much moisture, and supplemental heat may be required. Extended periods of humid weather may also require additional heat to affect drying. Raising the temperature of the incoming air by 5°C will dry the air but should not over-dry the grain at the bottom of the bin. Refer to Table 4–26, *Suggested airflow for natural-air and low-temperature wheat drying,* for airflow rate guidelines for natural-air and low-temperature wheat drying.

Table 4–26. Suggested airflow for natural-air and low-temperature wheat drying

LEGEND: CFM = cubic feet per minute

Moisture Content (wet basis)	Minimum Airflow	
16%	6.5 L/sec/m^3	0.5 CFM/bu
17%	9.75 L/sec/m^3	0.75 CFM/bu
18%	13 L/sec/m^3	1.0 CFM/bu

Adapted from Wilcke, William F., Hellevang, Kenneth J. *Wheat and Barley Drying*. FS-5949-GO, 1992. University of Minnesota, Extension Service.

Minimum requirements for natural-air drying:

- full aeration floor in the bin
- level grain surface across the entire bin
- minimum airflow of 6.5 L/sec/m^3 (0.5 CFM/bu), preferably 9.7 L/sec/m^3 (0.75 CFM/bu) or more
- clean wheat with no weed seeds or fines
- accurate moisture determination of the wheat in the bin
- accurate outside air temperature and relative humidity measurement
- an understanding of wheat equilibrium moisture content
- 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. Weed seeds, green trash and fines accumulations in the bin will restrict or divert airflow. Air moving through the wheat mass will take the path of least resistance.

High-Temperature Drying

With high-temperature drying, large volumes of heated air, 40°C or higher, are used to accomplish drying in a few hours or days. Corn dryers could be used but it may be necessary to reduce the drying temperature to avoid loss of starch quality and germination. It is important not to exceed the recommended maximum air temperatures for drying milling wheat which are dependent on the type of dryer used and the end use of the wheat, refer to Table 4–27, *Guidelines for maximum air temperatures for drying milling and seed wheat*.

For safe drying, the temperature of grain kernels should never exceed 60°C. Check the contract to determine if heated air drying is allowed to condition seed wheat.

Table 4–27. Guidelines for maximum air temperatures for drying milling and seed wheat

Dryer Type or Wheat End Use	Max. Temperature
Non-recirculating batch dryers	60°C
Recirculating batch dryers	60°C–70°C
Cross-flow continuous dryers	60°C
Parallel-flow dryers	70°C
Seed wheat[1]	40°C

[1] Wilcke, William F., Hellevang, Kenneth J. *Wheat and Barley Drying*. FS-5949-GO, 1992. University of Minnesota, Extension.

Copyright: Farm Drying of Wheat. Canadian Grain Commission. Sept 1992.

The baking quality of wheat is reduced if the temperature of the grain reaches 60°C for any significant length of time. When heated air dryers are used, it is a worthwhile precaution to have samples evaluated to ensure the dried grain meets market standards.

Tough wheat can be dried with natural air under good drying conditions. Natural-air drying of wheat requires careful management by the operator since wheat loses and takes on moisture easily. Only run the fan when outside conditions will result in drying progress.

Do not run the fan continuously, night and day, as the wheat will re-wet at night. The progress made during the day will be undone during the night. Use of automatic humidity sensors, or the BINcast model (www.weatherinnovations.com), will ensure that fans run only when drying will occur.

Determining Airflow

Sufficient airflow is needed to move drying air through the entire wheat mass. To remove moisture, the minimum airflow required is 6.5 L/sec/m^3 (0.5 CFM/bu); anything less will only change the temperature but not the moisture content of the wheat. Higher airflow rates of 9.75 L/sec/m^3 (0.75 CFM/bu) or greater help speed up the drying process. These higher airflow rates may be difficult to achieve, requiring much higher fan horsepower. The small kernel size of wheat causes the spaces between the kernels to be small. Moving large amounts of air through deep beds of wheat will take a large fan with high static pressure capability. If this bin and fan combination is capable of supplying 26 L/sec/m^3 (2 CFM/bu) when filled with corn, only fill it one-half to one-third that depth with wheat. With axial flow fans, filling the bin with wheat to one-third the depth of corn is a good starting point.

To determine the L/sec/m^3 (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 simple manometer connected to the air plenum below the perforated floor will show the static pressure (inches of water displaced in the column). Refer to Chapter 12, Figure 12–1, *Home-built manometer* for a diagram of a homemade manometer. Determine the fan output at the measured static pressure using the fan performance curve.

To calculate L/sec/m^3(CFM/bu airflow, divide the L/sec/m^3 (CFM/bu) output of the fan at the measured static pressure by the number of bushels in the bin (1 CFM/bu = 13 L/sec/m^3).

If adequate airflow cannot be achieved, one strategy is to partially fill the bin. In this way, the fan will be operating at less static pressure and will deliver higher airflow rates per bushel.

Equilibrium Moisture Content

Researchers have developed equilibrium moisture content tables, that allow the prediction of the final moisture content of winter wheat when exposed to air with a certain temperature and relative humidity, refer to Table 4–28, *Equilibrium moisture content for soft winter wheat exposed to air.*

Table 4–28. Equilibrium moisture content for soft winter wheat exposed to air

	Relative Humidity				
Temperature	**50%**	**60%**	**70%**	**80%**	**90%**
0°C	12.5	13.5	14.6	16.1	18.2
5°C	12.1	13.1	14.2	15.7	17.9
10°C	11.7	12.7	13.9	15.3	17.5
15°C	11.4	12.4	13.5	15.0	17.2
20°C	11.1	12.1	13.2	14.7	17.0
25°C	10.8	11.8	13.0	14.4	16.7

For example, you can find the equilibrium moisture content of wheat exposed to outside air at 25°C and 80% relative humidity. In Table 4–28 find the point at which the 25°C row and the 80% relative humidity column intersect. This point will be the equilibrium moisture content for wheat at the outside air conditions stated. Given enough time, the wheat will dry down to 14.4% moisture content.

When to Run the Fan

Air temperature and relative humidity levels should determine fan operation, not the time of day. 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 frequently throughout the day. As the wheat loses moisture, drier outside air is needed to continue to make drying progress. If the equilibrium moisture content on a given day is less than the moisture content of the wettest wheat, drying is possible and the fan should be on. Install a humidistat that will activate the fan at preset humidity levels. The operator can adjust the relative humidity level at which the fan is activated.

The wheat 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 that same day. 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 entire bin as a result of the mixing that has been done.

Other Crop Problems

Insects and Diseases

Figure 4–8, *Cereal crops scouting calendar,* shows insects and diseases that could be causing symptoms in the field. Individual descriptions of insects and diseases, scouting and management strategies can be found in Chapter 15, *Insects and Pests of Field Crops* and Chapter 16, *Diseases of Field Crops*.

Treatment guidelines to control insects, pests and diseases can be found in OMAFRA Publication 812, *Field Crop Protection Guide*.

Winterkill

Winter cereals can be destroyed during the winter and early spring period by frost heaving, ice, low temperatures and snow mould. Varieties differ in their ability to withstand these different winter stresses. This explains the regional adaptation of some varieties that may not perform well across the province.

Select varieties to address the winterkill concerns for specific areas. Varieties grown in the Ottawa Valley need ice tolerance; those grown in the Lake Huron snow belt need snow-mould tolerance, while those grown in the heavy clays of Essex, Lambton and the Niagara peninsula need resistance to frost heaving.

Refer to the replanting section and Table 4–6, *Determining yield potential for various plant stand counts* for information on assessing the winter wheat crop stand and making a replant decision.

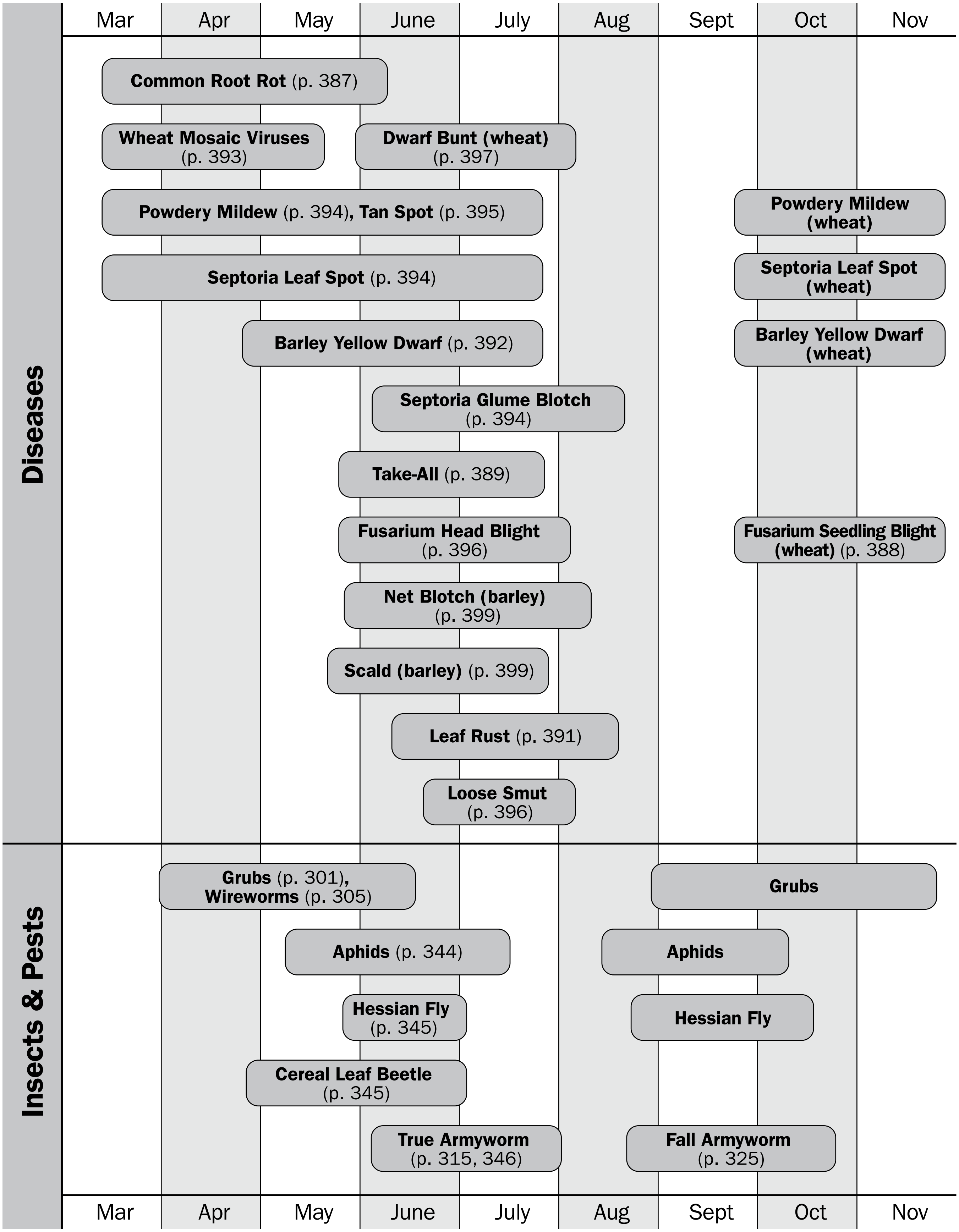

Figure 4–8. Cereal crops scouting calendar.

Frost Heaving

The freeze/thaw cycles of early spring are one of the main reasons for winterkill in Ontario. The risk is highest in heavy-textured soil and/or soils with limited sub-surface drainage. As frost goes into the ground, it works under the crown and "lifts" the plant up (Photo 4–8). If these freeze/thaw cycles are repeated, the plant is ejected or "jacked" out of the soil. Roots are broken and left exposed above the soil, causing death of the plant due to desiccation. This process is referred to as frost heaving.

Photo 4–8. Frost heaving of winter wheat is caused by freeze/thaw cycles of early spring, lifting up the crown.

Deep-seeded wheat is not more resistant to frost-heaving injury. The primary root system does not anchor the plant in the soil. The secondary root system anchors the wheat plant in the soil, protecting against frost-heaving injury. The secondary root system of the wheat plant cannot develop deeper in the soil than the depth of the seed, see Figure 4–1, *Days to emergence at various seeding depths.* When wheat is seeded deep, the plant develops the crown and secondary root system at about 2–2.5 cm (0.75–1 in.) deep, as the crown develops in response to light. Regardless of planting depth, the secondary roots will not develop below 2.5 cm (1 in.). To maximize resistance to frost heaving, wheat plants need an extensive secondary root system developed as deep as possible.

In frost heaving prone soils, increased seeding rate can also reduce damage. At higher seeding rates, and with some root growth, roots "interlock" and plants are more resistant to frost heaving action.

Ice

When there is a rapid snow melt or winter rain is followed by below-freezing temperatures, ice can form as a thick sheet across ponded areas. Even when the water is able to drain away below the ice sheet, the ice itself may prevent oxygen from getting to the plants and the wheat will suffocate and die below the ice.

Surface and subsurface drainage can help reduce the ponding, which leads to this problem. Should an ice sheet form (for example, during January and February), dormant wheat will only survive for approximately 2 weeks. Break the ice surface to allow gas exchange and to keep the wheat alive: be careful, as there may be deep water under the ice. In some situations, compaction from combine tires results in sufficient depressions and reduced drainage resulting in icing that will occur in the combine wheel tracks only. Low pressure tires or tracks on combines can reduce compaction sufficiently to prevent this problem.

Cold Injury

Wheat will survive extremely cold temperatures before plant death occurs. Plants that have "hardened off" (gone dormant) can survive temperatures down to -24°C. Snow cover acts to insulate the crop from extremely cold temperatures, and even 7.5 cm (3 in.) of snow is sufficient to protect the crop from colder temperatures. Leaf tissue on plants that have not hardened off will withstand -9°C, making late spring frosts of little consequence. There was only 1 year in the last century (1900–1999) when cold temperatures destroyed the wheat crop in Ontario.

While the wheat crop survives cold temperatures well, cold injury can reduce vigour and final yield. In severe winterkill situations, marginal areas suffering cold injury may not rebound as expected. However, this phenomenon is impossible to predict.