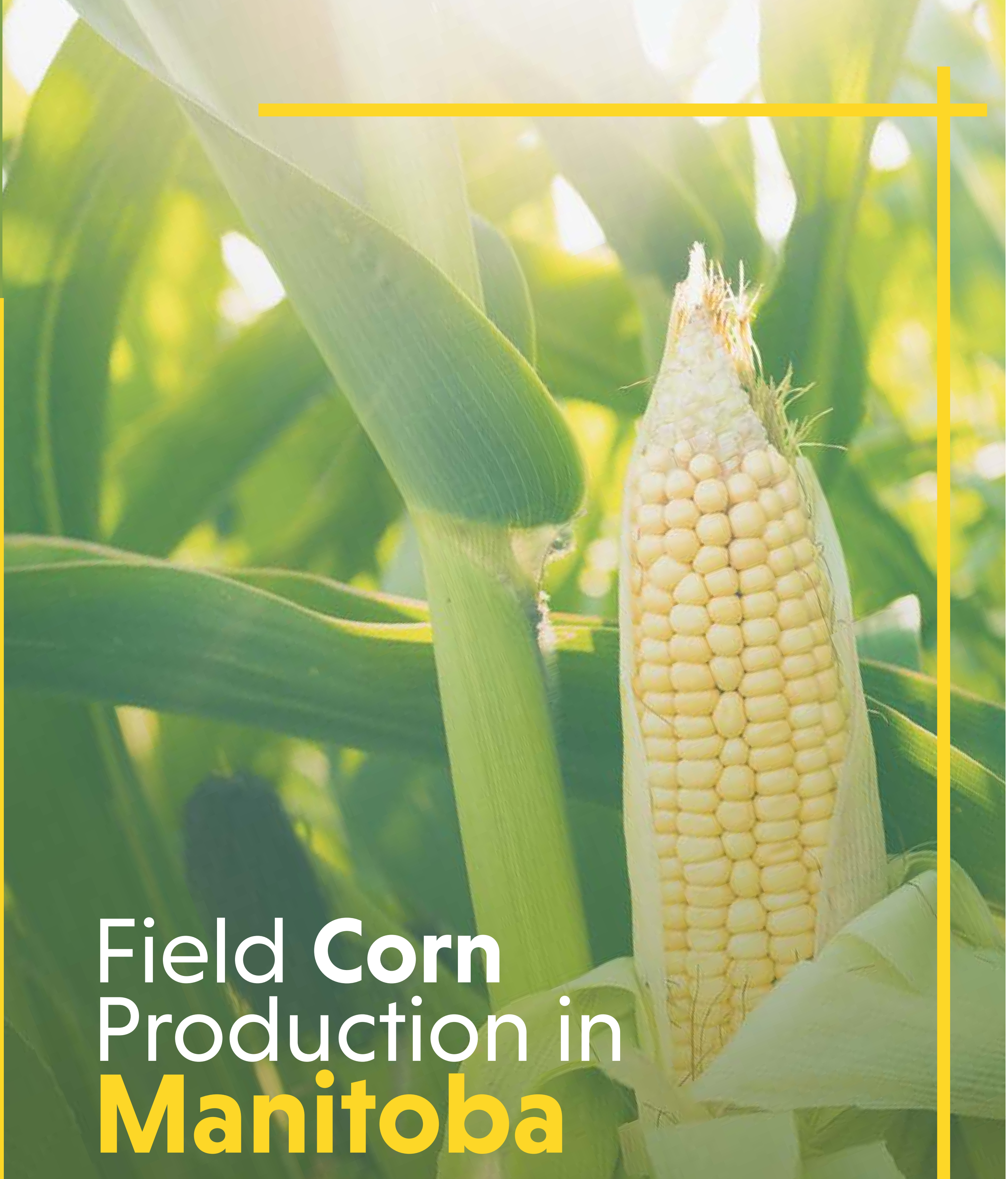
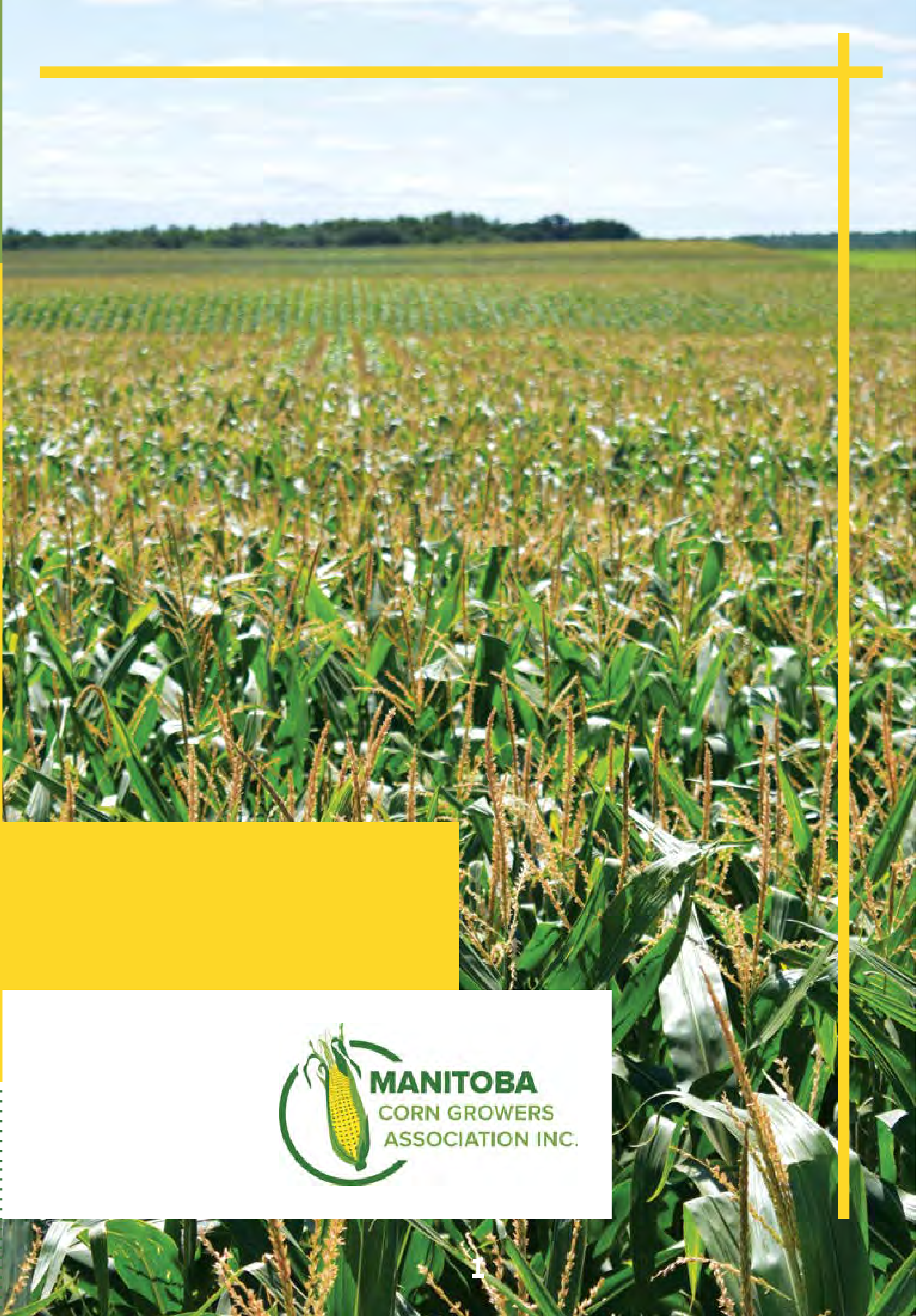


Field **Corn** Production in **Manitoba**

A Guide for Crop Management & Agronomy

MANITOBA CORN GROWERS ASSOCIATION INC.



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Acknowledgments

Special thanks is given to those who helped with reviewing and updating:

- Anne Kirk, Cereal Crop Specialist, Manitoba Agriculture
- Holly Derksen, Field Crop Pathologist, Manitoba Agriculture
- John Gavloski, Entomologist, Manitoba Agriculture
- John Heard, Soil Fertility Specialist, Manitoba Agriculture
- Marla Riekman, Land Management Specialist, Manitoba Agriculture
- Tammy Jones, Industry Development Specialist – Weeds, Manitoba Agriculture

For any questions, please contact the Manitoba Corn Growers Association office.

The First Edition of this guide (1999) was funded by Covering New Ground.

The Second Edition of this guide (2004) was funded by Covering New Ground, Manitoba Corn Growers Association and Manitoba Rural Adaptation Council.

The Third Edition of this guide (2013) was funded by Manitoba Corn Growers Association.

FOURTH EDITION

Published by:

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SECTION 1

INTRODUCTION TO CORN PRODUCTION

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Introduction to Corn Production

In Manitoba, field corn is grown for grain or silage production. The majority of grain corn produced in Manitoba supplies the ethanol and feed industries, but a small portion is sold to the distillery in Gimli. Silage corn is used as dairy and beef feed. Silage corn production makes up approximately 22% of total corn production in Manitoba.

ADAPTABILITY TO MANITOBA

The three main climatic variables that affect adaptation in Manitoba are day length, temperature (both heat and frost-free period), and rainfall. Day length and temperature affect development, i.e., flowering and maturity, and temperature and rainfall affect growth, i.e., yield.

CORN HEAT UNITS

Corn Heat Units (CHU) are better than calendar days for measuring time between stages because in warmer regions, more CHU are accumulated per day so that corn develops faster per day than in cooler regions.

When calculating daily CHU for corn, there are several considerations:

- Day and night temperatures are treated separately
- No growth is assumed to occur with night temperatures below 4.4˚C or day temperatures below 10˚C
- Maximum growth occurs at 30˚C and decreases with higher temperatures

CHU for each day are calculated by the formula:

$$CHU = \frac{1.8(Tmin - 4.4) + 3.3(Tmax - 10) - 0.082(Tmax - 10)^2}{2}$$

where: Tmin = Daily minimum temperature (˚C)
and: Tmax = Daily maximum temperature (˚C).

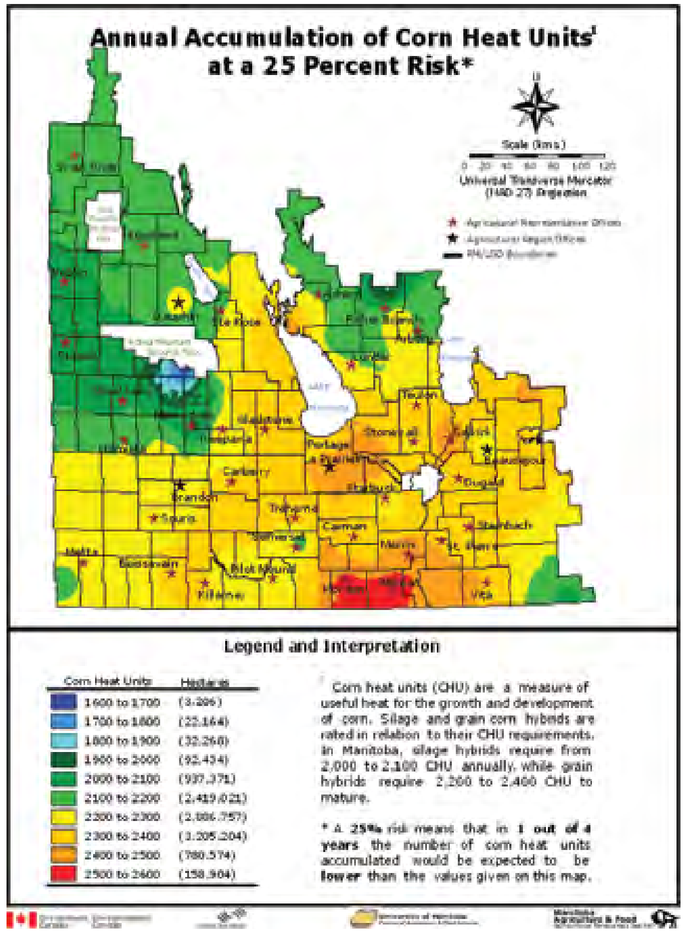

FIGURE 1. Average accumulation of corn heat units in Manitoba.

GROWING DEGREE DAYS AND RELATIVE MATURITY

Another rating that is gaining popularity and preference in Manitoba is the Relative Maturity (RM) rating system, which has a direct correlation to Growing Degree Days (GDD). It is important to note that RM is not a reference to how many calendar days it takes for a corn plant to reach a specific point in development.

> NOTE: *Relative Maturity is simply a reference developed by seed companies, and it may not be consistent from company to company.*

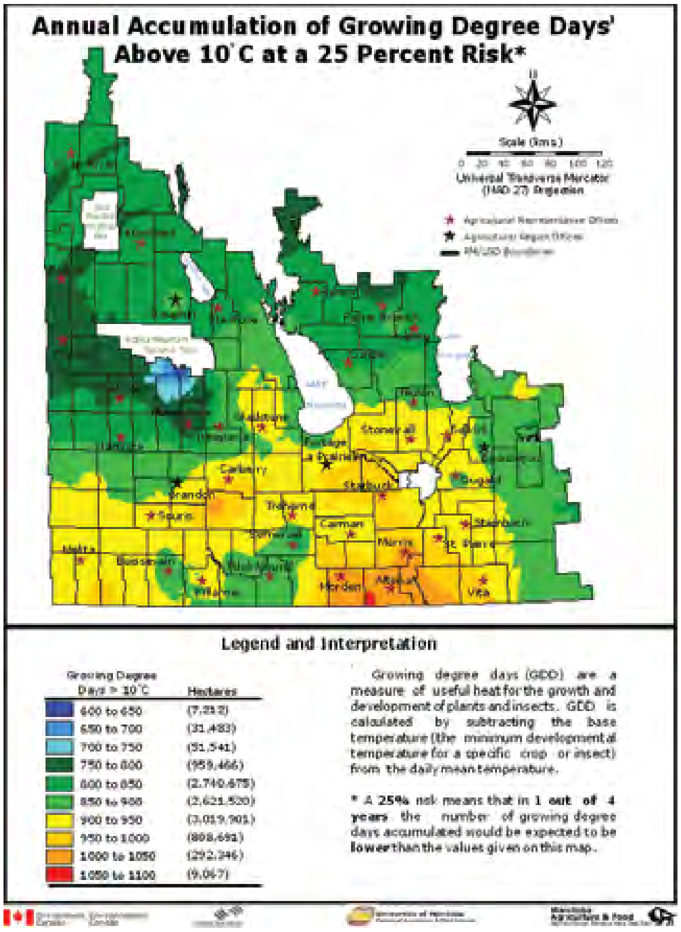

FIGURE 2. Average accumulation of growing degree days in Manitoba.

When calculating daily GDD, follow the same considerations as when calculating CHU with regards to daily high and low temperatures, but with the following constraints:

- If Daily Max Temp > 30˚C, it is set equal to 30˚C.
- If Daily Min Temp < 10˚C, it is set equal to 10˚C.

Daily Corn GDD (˚C) =
((Daily Max Temp ˚C + Daily Min Temp ˚C)/2) – 10˚C

The development of each plant is controlled by its genetic make-up and how these genes react to the environment in which the plant is growing. This is why it is critical to correctly match the CHU or RM rating of the hybrid with the CHU or GDD rating of the farm. If the hybrid's rating is too high, maturity may not be reached.

WATER USE BY CORN

Corn requires increasing amounts of water as the season progresses. In an average year, a 120 bu/ac corn crop uses about 21 inches. Corn takes up and evaporates through its leaves about 350 litres of water for every kilogram of dry matter that is produced. Peak water use is during the reproductive phases of silking and pollination.

The amount and distribution of rainfall in Manitoba is generally suited to corn production. Problems can arise each year in specific areas where rainfall patterns influence corn yields.

A water shortage occurring at any time during the year can limit yield potential. Drought stress early in the growing season can reduce growth, thereby affecting the photosynthetic area. Drought during pollination may decrease yields by affecting silk elongation. If water stress occurs during grain filling, kernels may abort or not fill out, reducing yield and quality.

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SECTION 2

GROWTH STAGES

Growth Stages

Corn plants slowly increase in weight early in the growing season. As the season progresses and sunlight exposure becomes more intense, increasing the amount of dry matter accumulation, corn plants gain weight at a quicker pace. The leaves of the plant are produced first, followed by the leaf sheaths, stalk, husks, ear shank, silks, cob and finally the grain.

Unfavourable growing conditions in early stages of growth may affect the leaves (the photosynthetic factory) or root development, leading to decreased yield potential. In later stages, similar conditions can reduce the number of silks produced, resulting in poor pollination of the ovules, decreasing kernel numbers and size.

IDENTIFYING STAGES OF DEVELOPMENT

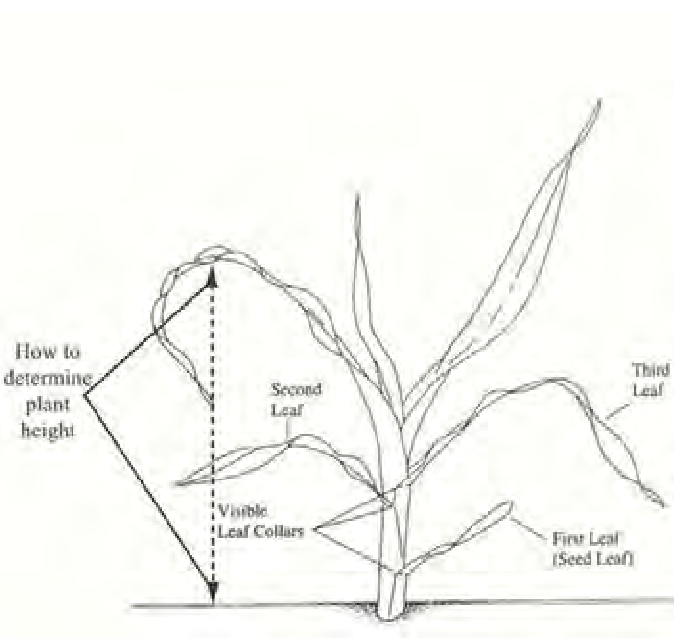

FIGURE 3. V3 corn plant. Author unknown.

There are several methods of counting leaves to determine crop staging. Three common methods are:

Leaf Tip Method:

Count all leaves, including any leaf tips that have emerged from the whorl at the top of the plant.

Leaf Over Method:

Count the number of leaves, starting from the lowest (the coleoptile leaf with a rounded tip) to the last leaf that is arched over (tip pointing down). Younger leaves that are standing straight up are not counted.

Leaf Collar Method (V-stage):

Count the number of leaves with visible collars. This method is the most common staging system and involves dividing plant development into vegetative (V) and reproductive (R) stages. The leaf collar method is used throughout this manual.

Vegetative

VE	emergence
V1, V2, V3, etc	1, 2, 3 leaves fully emerged, leaf collar visible
VT	tasseling, final vegetative stage

Reproductive

R1	silking
R2	blister
R3	milk
R4	dough
R5	dent
R6	physiological maturity

VEGETATIVE DEVELOPMENT (VE-VT)

Germination and Seedling Development (VE), key points:

- Germination begins when soil temperature is 10°C.
- Under optimal conditions, germination occurs in three to five days.
- With ideal temperature and moisture conditions, you should see the corn twice in the first week: Once at planting, and again at emergence (approximately seven days to emergence).

EARLY VEGETATIVE DEVELOPMENT:

V1 - V4

Growing point remains below the soil surface for the first three to four weeks after emergence, which is where the leaves are produced.

Therefore, early frost will damage only the leaves and the plant will recover since the growing point is not damaged. All of the leaves and ear shoots that the plant will produce are starting to be formed at this stage.

FIGURE 4. Corn plant in VE stage.
Photo credit: Morgan Cott, MCGA

FIGURE 5. Corn plant in V1 stage (foreground).
Photo credit: Morgan Cott, MCGA

MID VEGETATIVE DEVELOPMENT

V5 - V8

- All the leaves are formed by the time the seedling reaches the 5- to 6-leaf stage. The number of leaves produced depends on the hybrid.
- At approximately V6, the growing point and tassel are above the soil surface, the stalk is elongating, and the ear shoots and tillers may be visible, though tillers may never fully develop.
- Ears can be initiated at several nodes along the growing point, but only the upper one or two ear shoots will develop into harvestable cobs.
- At V8, ear size and the number of ovules that will produce silks are determined. Losses at this time cannot be completely compensated for by good growing conditions later on. Adverse growing conditions, such as drought, nutrient deficiency, flooding, herbicide damage, or very high temperatures can limit the number of ovules formed.
- At V8, the roots will have reached the middle of the corn rows, to a depth up to 18 inches. Cultivation and mid-row banding would do extensive damage at this stage.
- Removal of all of the unfurled leaves at this stage (via frost or hail) may result in 10 - 20% reduction in final grain yield.
- Spraying with 2,4-D and/or dicamba may cause the developing stalk to become temporarily brittle, and the stalks can easily be broken at the soil surface.

LATE VEGETATIVE DEVELOPMENT:

V9 - V12

- At V9, many ear shoots are now visible, generally six to eight inches below the tassel. The tassel is developing rapidly and the stalk continues to develop.
- Brace roots begin to emerge and enter the soil. They serve as support and absorb phosphorus and other nutrients from the soil.
- Plant available moisture is critical at this stage because stress conditions can reduce seed set.
- Hail and/or frost will create greatest yield losses at this stage in comparison to previous stages.

TABLE 1. Comparative growth stage estimate using three different leaf counting methods.

Leaf Tip Method	Leaf Over Method	Leaf Collar Method
3	2	1
5-6	4	3
7-8	6	4-5
9-10	8	5-6
12	10	8
14-15	12	19

NOTE*: It is important when reading pesticide labels or other information to know which leaf counting method is being referred to.*

TASSELING STAGE (VT)

- At VT, the last branch of the tassel is fully emerged. This occurs approximately 2 – 3 days prior to silking.
- The number of days between VT and R1 is short and can fluctuate as a result of environmental factors.

NOTE: *Drought is an example of an environmental factor that can significantly lengthen the VT stage.*

FIGURE 6. VT (tasseling) stage.
Photo credit: Morgan Cott, MCGA

SILKING STAGE (R1)

- Silks are visible outside the husk.
- Silks are pollinated within four to 10 days after tassel emergence. Each silk is attached to an individual ovule, or potential kernel.
- Pollen lands on a silk and germinates to produce a pollen tube, which must grow down the entire length of the silk before fertilization can occur.
- Good growing conditions are vital for successful silking and pollination.

FIGURE 7. Silking stage.
Photo credit: Morgan Cott, MCGA

BLISTER STAGE (R2)

- Starch is beginning to accumulate and the kernels are starting a period of rapid dry matter accumulation, lasting 30 – 40 days.

MILK STAGE (R3)

- Kernels are yellow in colour and inner fluid is milky white, due to starch accumulation.
- Grain filling and dry matter accumulation is still occurring at a rapid rate.
- Kernel moisture is about 80%.

DOUGH STAGE (R4)

- Starch accumulation in the endosperm has caused the milky inner fluid to thicken to a paste.
- Kernels begin to dent.
- Kernel moisture is about 70%.
- Kernels have accumulated almost half their dry matter weight.

DENT STAGE (R5)

- Nearly all kernels are denting near their crowns.
- Milk line will be visible near the top of the kernels, marking the boundary between the milky and starchy areas of the maturing kernels.

FIGURE 8. Dent stage.
Photo credit: Dane Froese, Manitoba Agriculture

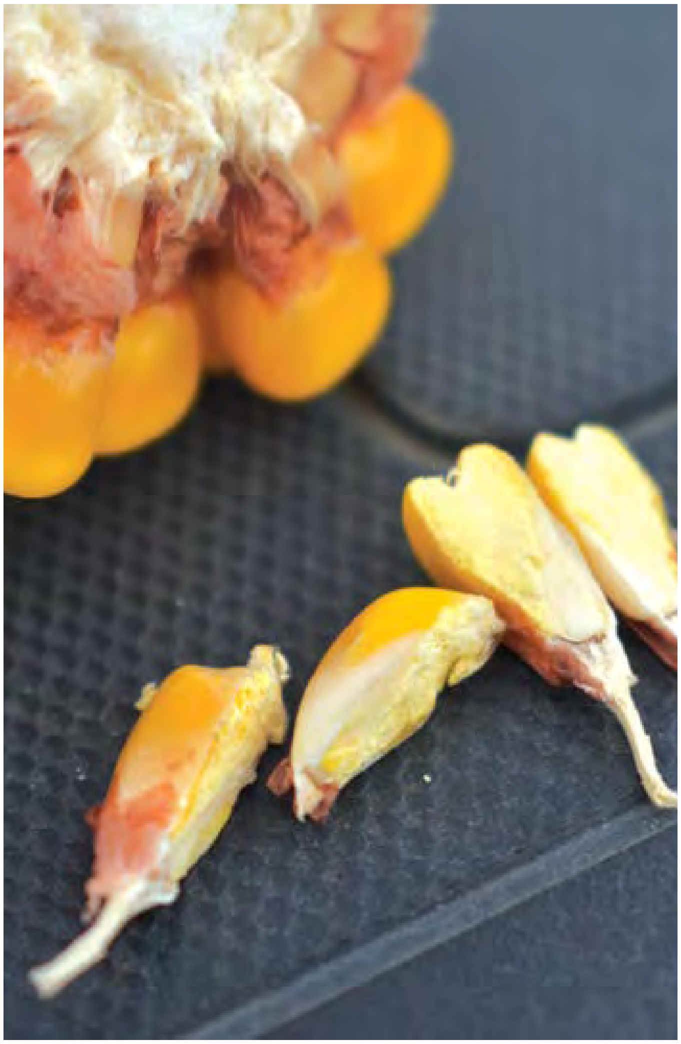

FIGURE 9. Physiological maturity of corn.
Photo credit: Morgan Cott, MCGA

PHYSIOLOGICAL MATURITY (R6)

- All kernels have reached their maximum dry weight, noticeable when black layer is visible at the base of the kernel. Occurs when moisture content of grain is 31 - 35%.
- Black layer formation can occur at higher moisture content if kernel development is stopped by frost or disease.
- Crop is not ready for harvest just yet. Desirable moisture content of grain for harvest is about 20 - 27%.

SECTION 3

HYBRID SELECTION

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Hybrid Selection

One of the most important decisions in growing corn is hybrid selection. Choosing a hybrid that will perform under a farm's unique growing conditions and specific management practices is the first step in optimizing yield potential. There are several factors producers should consider when choosing potential corn hybrids for their farm.

FACTORS IN CHOOSING A HYBRID FOR GRAIN CORN

Corn Heat Unit Accumulation and Maturity Rating

The first consideration in choosing a grain corn hybrid is the ability of the hybrid to reach maturity before frost in the fall. Frozen, immature corn is of sub-standard quality and difficult to market. The yields of frozen corn are lower and the percentage of broken kernels is higher than for mature corn. However, a hybrid that matures too early for its region usually yields less because it does not make full use of the growing season.

Once the heat unit rating for a farm has been established, the producer should select hybrids requiring 200 CHU less than the CHU expected. This should ensure that corn planted by mid-May will reach full maturity before a killing frost, nine years out of 10. If planting is delayed beyond mid-May, the estimated number of heat units available should be reduced by 100 for each additional week.

YIELD POTENTIAL

Producers should continually evaluate newer hybrids coming into the market, as well as continually evaluate the better-known, proven hybrids. The following are factors to consider when evaluating yield potential:

- Look for data across years and locations to determine if a particular hybrid will perform under a wide range of environmental and growing conditions. For example, take the top 10 hybrids from different regions in three different years. Look at the hybrids that pop up in the top slots each year as these hybrids show more reliability and flexibility to environmental conditions.
- See if several site years of data are available. The more years the hybrid is tested, the more reliable the data will be. This will also show how well the hybrid performs under different growing conditions.
- If statistical analysis is provided, look at the coefficient of variation (CV). CV is a measure of variation in a trial. A small CV (less than 20) is desirable. A high CV indicates that the difference in values between hybrids may be due to factors other than hybrid differences. Also, look at the site yield average. This will give an indication of how well all the hybrids performed at that site, as well as show how a particular hybrid did relative to the site average.
- Look at different sources of information. The Manitoba Corn Committee (MCC) evaluates different hybrids in various growing regions in Manitoba. The data is published annually in Seed Manitoba and can also be found at http://manitobacorn.ca/manitoba-corn-committee/. In addition to this source, check with local seed representatives for their demonstration plots and hybrid evaluation trial data.

HYBRID TRAITS

Most grain corn seed companies and dealers will have data on all of the following traits:

Standability/Stalk Strength

Under optimum growing conditions, producers won't likely see problems with lodged corn. However, when growing conditions are poor, lodging may increase, leading to decreased yield potential. This is due to the reserves of carbohydrates stored in the stalk moving into the grain during the final stages of grain filling.

For example, some hybrids gain a high yield potential at the expense of stalk strength by 'draining' the stalk of all its reserves.

Under good growing conditions, the stalk may contain enough carbohydrates to fill a large ear while maintaining stalk strength. However, if conditions have been stressful, reserves in the stalk will be low and depleted quickly. The result will be premature death of the stalk and severe lodging or breakage.

Thus, these hybrids can produce exceptionally high yields under good growing conditions, but under poor conditions they will likely have decreased yields and/or lodging issues. Assessing the stalk strength of a particular hybrid will also be important when seeding at higher populations.

Disease Resistance/Tolerance

Many grain corn companies will have resistance/tolerance ratings for various diseases, such as Fusarium ear rot, head smut, Gibberella ear rot and Goss's wilt for their hybrids.

Test Weight or Density

Markets will often require a minimum test weight or density. As well, the feed markets often want high quality grain corn. Density, like protein in wheat, can be highly influenced by management practices

and environmental conditions. However, producers should look at test weight data across years and locations to determine if a particular hybrid will achieve high test weights under a wide range of environmental and growing conditions.

Dry Down Rate

Grain corn is physiologically mature at a moisture content of 31 - 35%. However, corn is usually harvested at a moisture content of 20 - 27%. The rate of dry down depends mainly on the weather, though differences between hybrids are also important as some types tend to give up moisture more slowly than others. Plant characteristics related to the rate of dry down include husk leaf number, thickness of husk leaves, rate of husk leaf senescence, husk coverage of the ear and husk tightness.

Typically, most hybrids are now rated on their grain drydown, which is another important piece of data to consider when choosing hybrids.

Herbicide Tolerance

There are hybrids available that have tolerance to glyphosate and glufosinate herbicides, and newer hybrids that have tolerance to dicamba and 2,4-D.

NOTE*: Some hybrids have reduced tolerance to sulfonylurea herbicides.*

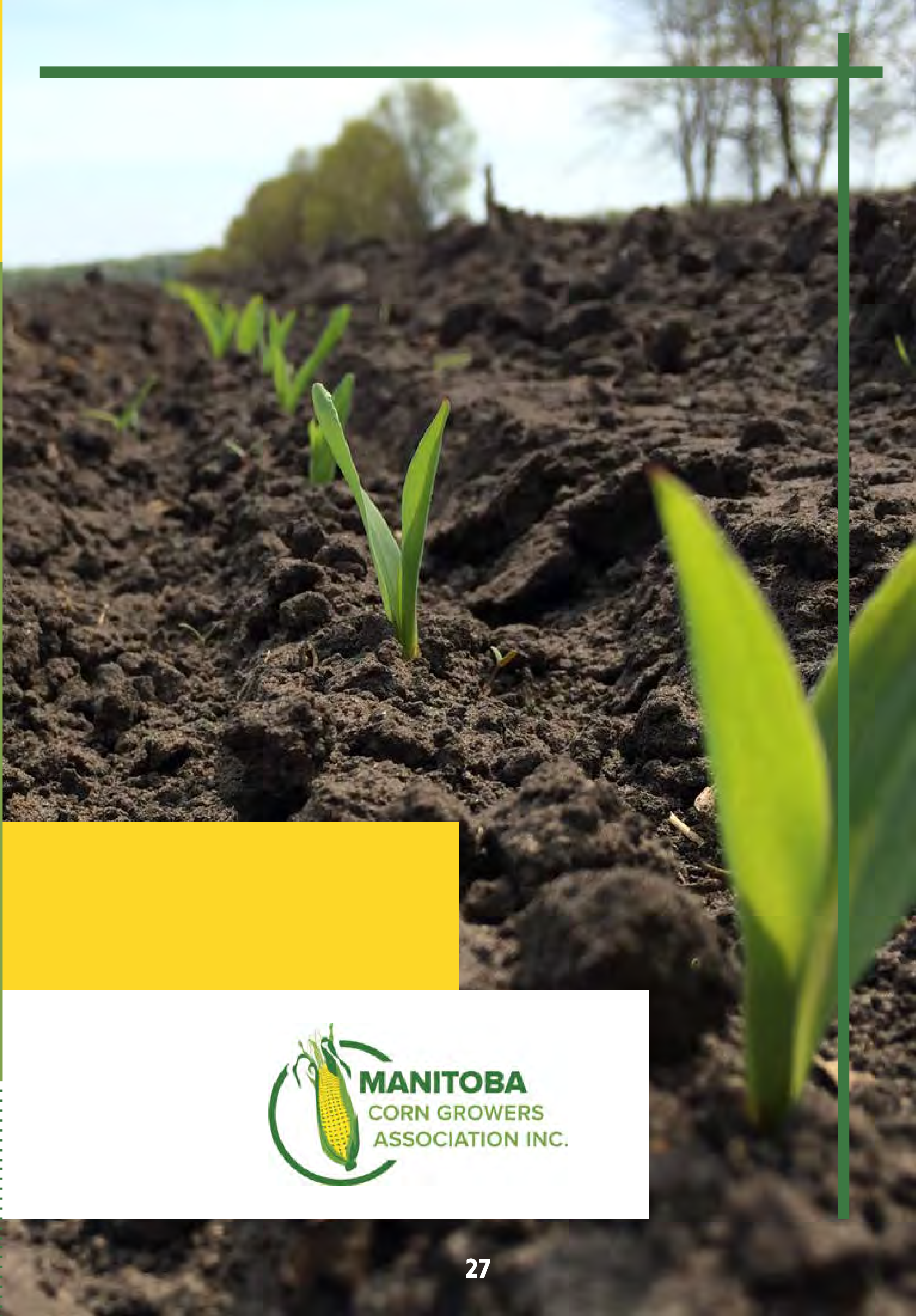
FACTORS IN CHOOSING A HYBRID FOR SILAGE CORN

Yield, maturity and lodging resistance are also important considerations in choosing a hybrid for silage. Corn makes the best silage once it has reached the dent stage (R5). At this stage, the whole plants contain 65 - 70% moisture. Choose the highest yielding hybrid that generally reaches this stage before frost damage.

It is a common error to choose late-maturing hybrids that look attractive because of their vigorous growth. In this case, a hard frost can cause lodging in plants with over 75% moisture and poor silage may also result due to low dry matter content, high sugar content and low silage pH. Also, there will be fewer issues with freezing and spoilage in piles or bunkers of silage made at the proper moisture level.

Experience has demonstrated that hybrids producing high grain yields also produce good silage yields. When choosing hybrids specifically for whole-plant silage, a yield advantage can usually be obtained by selecting hybrids rated 100 to 200 heat units later than those selected for grain.

Since it is unlikely that one hybrid will excel in all of the desired areas, judgement is still necessary in making a selection. Producers growing corn for the first time should choose two or three hybrids on the basis of test information to find out which one is best for their farm. The producer who grows corn regularly and has established preferences should review hybrid selection every year as new hybrids are continually coming on the market.



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SECTION 4

SOIL MANAGEMENT AND FERTILITY

Soil Suitability

DRAINAGE AND WATER-HOLDING CAPACITY

The major physical soil characteristics influencing corn production are drainage and water-holding capacity. The relative effect of soil texture on these soil properties is reported in Table 2. Well-drained soils with a sandy loam or silty clay loam texture are best suited to corn production. These soils have good internal drainage which allows the soil to dry out and warm up early in the spring, yet store moderate amounts of moisture for crop use.

Excessively wet soils negatively impact corn growth and production in several ways:

- Wet soils remain cooler in the spring, which delays emergence and growth
- Corn is more susceptible to injury or death. Seedlings can only tolerate flooding for 3-4 days, whereas 24" tall corn will suffer after only 24 hours of flooding
- Reduced oxygen levels in wet soils restricts root growth and nutrient uptake
- Nitrogen loss due to leaching and denitrification can be substantial
- May prevent timely field operations, such as seeding, weed control, side-dressing N fertilizer and harvest

TABLE 2. Soil suitability for corn according to texture.

Texture	AWHC* (in/4 ft depth)	Water infiltration (in/hr)	Limitations
Coarse sand	4 in	> 10 in/hr	Droughtiness
Sand loam	9 in	2 in/hr	Droughtiness; poor drainage on "wet sands" over clay
Loam	11 in	1 in/hr	
Clay loam	12 in	0.5 in/hr	Poor natural drainage
Clay	14 in	0.04 in/hr	Poor natural drainage

* Available water holding capacity in 4 foot rooting zone = the amount of water a soil can hold at field capacity that is available for crop uptake and growth.

Soils heavier in texture than clay loams can be satisfactory for corn production if they are naturally well-drained or surface and sub-surface drainage is provided.

Soils coarser in texture than sandy loams have low water-holding capacity, but will produce satisfactory corn yields if adequate moisture can be provided by frequent rainfall or irrigation. During pollination, corn transpires up to 1/3" of water per day, at which time moisture stress has greatest impact on yield. Coarse soils are also vulnerable to leaching losses of nitrate-nitrogen in periods when the crop is not aggressively using soil water.

SALINITY

Salinity causes germination problems and poor corn growth. One of the main effects of salinity is it limits water uptake and any slight moisture stress will aggravate the problem. Corn yield declines rapidly with increasing salinity (Figure 10); therefore, soils having electrical conductivity (EC) greater than 2 mS/cm must be avoided and those with EC of 1-2 mS/cm must be managed properly.

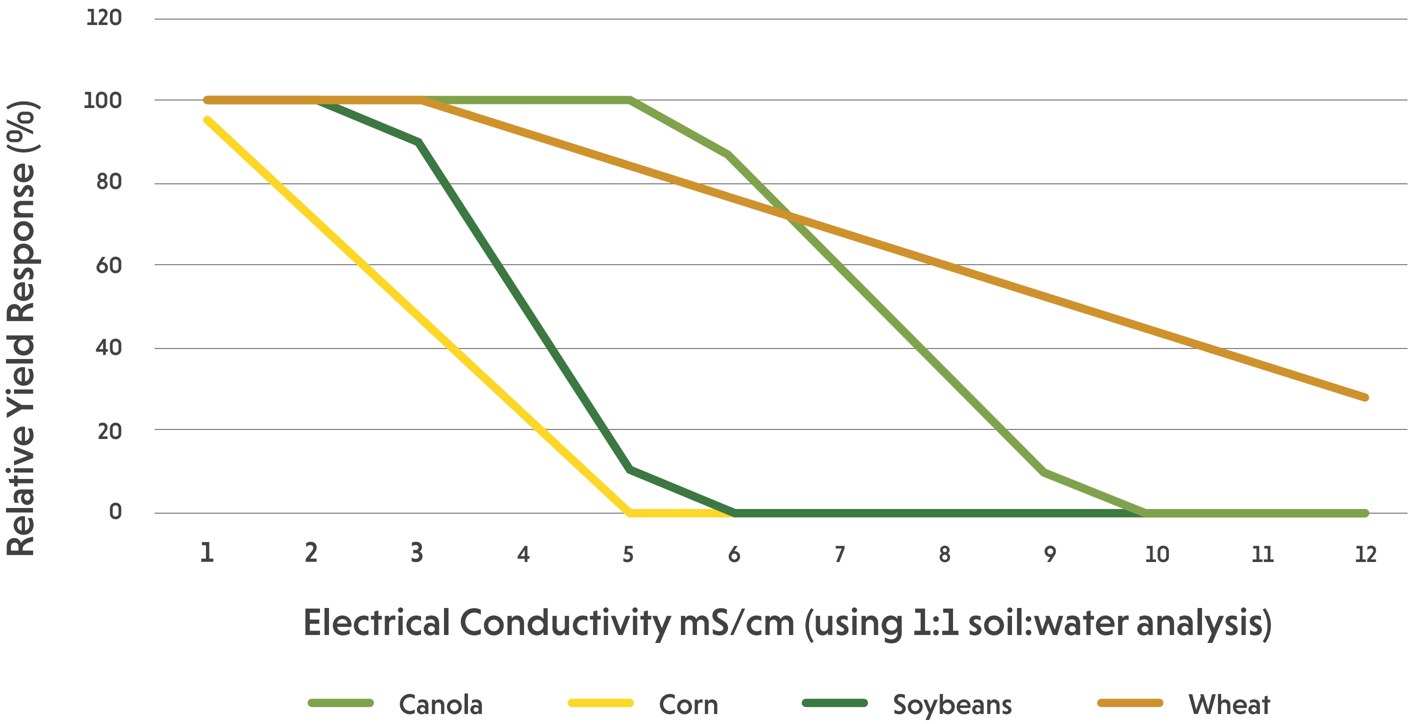

FIGURE 10. Relative yield response to increasing levels of soil salinity (adapted from Franzen 2013. Managing Saline Soils in North Dakota)

Tillage and Residue Management

Soil preparation for corn should follow the same general good management practices as for most other crops. The goal should be to achieve a firm seed bed with minimum moisture loss and no erosion.

Research on tillage implements in Manitoba has shown that high-disturbance shallow tillage, such as vertical tillage with aggressive gang angle or high speed shallow discs, is as effective in warming the seedbed as regular-depth discs (Figure 11). The use of strip tillage warms the seedbed even more as all residue is pushed away from the seed row and only the strip of soil to be seeded is tilled. The area between the rows stays cool as it is insulated by crop residue.

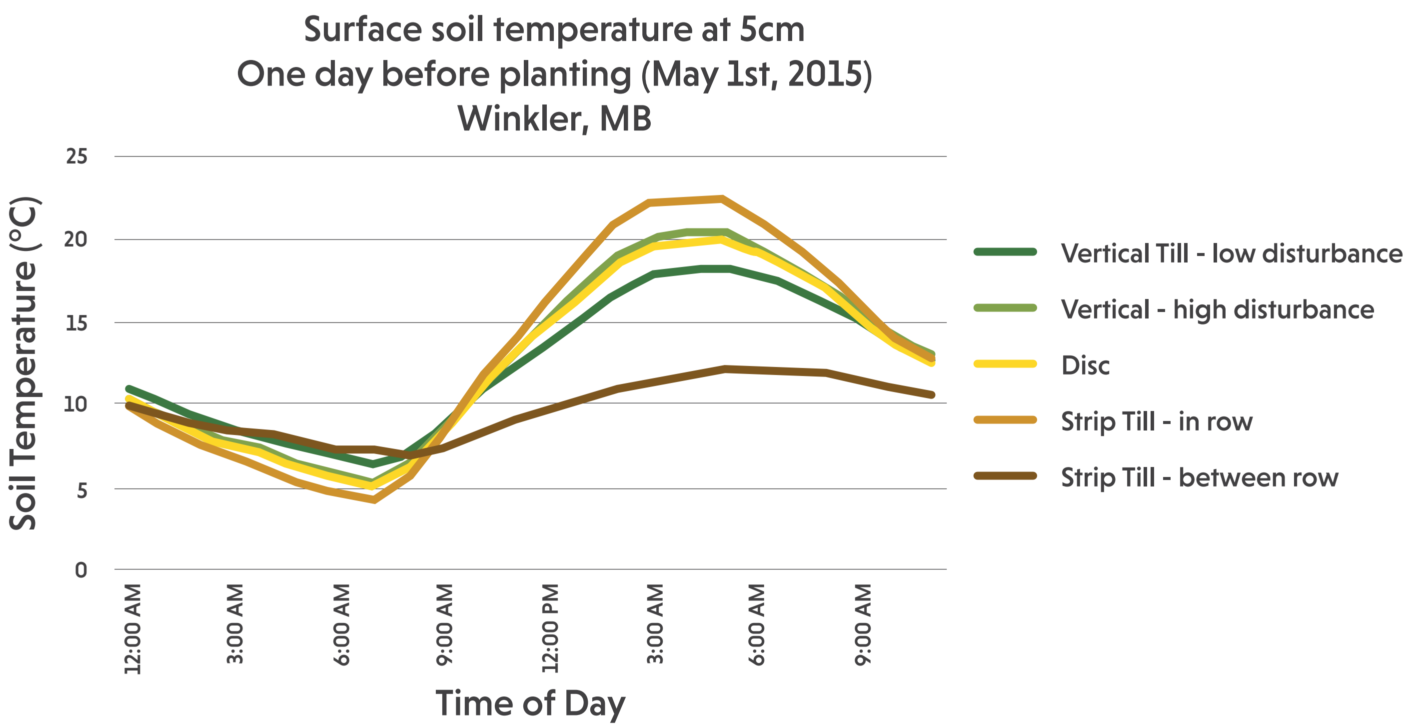

FIGURE 11. Effect of tillage operation on surface soil temperature at 5 cm depth over a 24 hour period one day before planting (May 1, 2015) at Winkler, Manitoba. (Source: P. Walther MSc thesis, University of Manitoba)

In general, producers should try to reduce tillage intensity in all cropping systems to maintain soil organic matter and soil structure. Zero-till planting of corn can be successful on coarse-textured soils with good internal drainage and little residue cover. However, it is often the management of the corn residue itself that inhibits zero-till practices where corn is in the rotation. The use of low-disturbance vertical tillage or strip tillage may help to manage corn residue, while minimizing soil disturbance. Strip tillage only sees tillage in the row to be planted so the space between the rows is left undisturbed, mimicking zero-till.

Rogalsky et al (2017) found that strip till produced corn yields equal to those on conventional tillage, while reducing the overall width of tillage across the field. Similarly, when seeding into corn residue, strip tillage has been shown to perform as well as conventional tillage. In a recent Manitoba study, there was no significant difference in soybean yield between double disc, vertical till high and low disturbance, and strip tillage treatments in corn stubble (P. Walther MSc thesis, University of Manitoba. Data not shown). However, strip tillage also provides greater soil protection, causes less disturbance, and uses less labour and fuel.

While vertical tillage covers a high number of acres per hour, there is usually more than one tillage pass required which decreases its overall efficiency. Strip tillage only requires a single pass and even though it is at a slower speed, it ultimately requires less labour.

The single-pass requirement of strip tillage also means that it requires less fuel to complete the tillage operation. Reducing tillage intensity can also help minimize the impact of soil salinity on crop growth.

Excessive tillage may aggravate salinity on even slightly saline soils through encouraging evaporation which pulls salts from below. As corn is very sensitive to salinity, it may be beneficial to reduce tillage as much as possible to limit the upward movement of water due to evaporation.

Nutrient Requirements

Adequate fertility is essential for profitable corn production. Sixteen essential plant nutrients are required for growth, and an insufficient supply of any of these essential nutrients can have a detrimental effect on plant growth and ultimately, crop yields. All but three of the essential nutrients (carbon, hydrogen, oxygen) are derived from the soil. Nitrogen (N), phosphorus (P), and to a lesser degree, potassium (K) and sulphur(S), are likely to be of concern for Manitoba crop production. Calcium (Ca) and magnesium (Mg) are used in modest amounts by corn. Since Manitoba soils are largely derived from dolomitic limestone, these nutrients are naturally well-supplied. Typical nutrient uptake and removal of a corn crop is reported in Table 3.

Other elements, including chlorine (Cl), boron (B), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) and molybdenum (Mb) micronutrients are required in smaller amounts (Table 3). Many soils in Manitoba are adequately supplied with micronutrients. Cu and Zn are the two micronutrients most likely to be deficient in Manitoba soils. Cu availability may be low in both peat soils and sandy soils with high pH and low organic matter. Corn is sensitive to Zn deficiency, which may be found on highly calcareous (high lime content) soils and when subsoil has been exposed by erosion or land levelling. Soil testing, tissue sampling and visual deficiency symptoms are used to diagnose micronutrient deficiencies.

FERTILIZER APPLICATION

Soil and tissue testing are two ways to determine the available nutrient status of a field. Reliable test results and recommendations depend upon:

- Proper soil and tissue sampling
- Proper analysis techniques
- Sound fertilizer recommendation guidelines

Details on these principles are covered in Manitoba Agriculture's "Soil Fertility Guide" (Manitoba Agriculture, 2007).

TABLE 3. Nutrient uptake and removal by a 150 bu/ac grain corn crop (adapted from Manitoba Soil Fertility Guide. Manitoba Agriculture, 2007).

Nutrient	Uptake (lb/ac)	Removal (lb/ac)
N	230	146
P_2O_5	95	65
K_2O	194	42
S	23	11
Ca	11	0
Mg	24	11
B	0.15	0.05
Cu	0.06	0.02
Fe	1.01	0.26
Mn	0.36	0.05
Zn	0.41	0.32

FERTILIZER PLACEMENT, TIMING AND RATES

Corn performance and efficiency of applied fertilizer N, P and K is influenced greatly by fertilizer placement and timing.

NITROGEN (N)

Nitrogen is required for proper growth and development. It is taken up continuously by the plants through to maturity. A large part of the N accumulated in the leaves and stem is translocated to the grain as it matures and about 2/3 of the N in the plant will be found in the grain at maturity (Figure 12). Depending on fertilizer management (source, placement and timing), N may be vulnerable to losses during the extended time between application and uptake. Potential losses include leaching and denitrification loss of nitrate-N in wet soils, volatilization of surface applied fertilizer, or immobilization by crop residue and weed uptake.

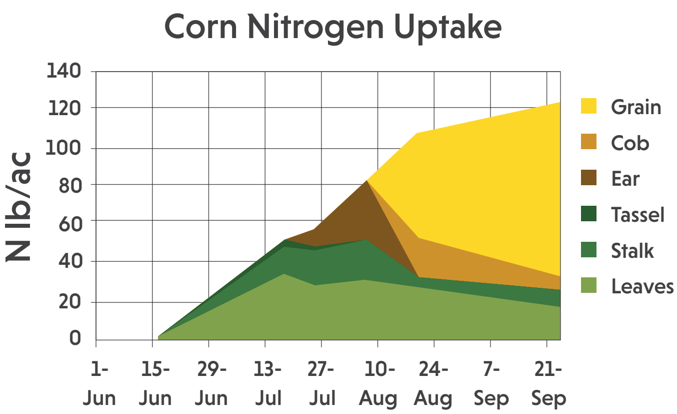

FIGURE 12. Nitrogen uptake and partitioning in grain corn (Heard, 2004).

PLACEMENT AND TIMING

Timing and method of application should be based not only on the needs of the crop and potential losses from the soil, but also on the co-ordination of the soil fertility program with an efficient overall farm management system.

Select a time and method of N application that permits preparation of a good seedbed, conserves soil moisture, aids in prevention of soil erosion, allows for timeliness of operations and is consistent with maximization of net returns.

In-soil banding enhances N fertilizer efficiency by minimizing potential losses due to immobilization, denitrification, leaching, volatilization and weed uptake. Band placement of N is generally considered 20% more efficient than broadcast application. N losses are expected to be higher for fall-applied than spring-applied, and on average, spring-applied is considered to be 20% more efficient. This risk of loss is greater if N is applied to warm soils in early fall.

In Manitoba, fall banded anhydrous ammonia is common on clay textured soils, whereas spring applications predominate on sandy soils, which are more vulnerable to leaching losses. Fall banded N should be applied in an ammonium form once soils have cooled to 10˚C so that conversion to the nitrate form is slow.

Under high risk of nitrate loss, growers should use a controlled release N form (ex. ESN 44-0-0) or a nitrification inhibitor (ex. N-Serve for anhydrous ammonia, eNtrench for urea or SuperU). Co-banding P with the ammonia band is a good way to meet the P needs of the crop (Figure 16).

Spring preplant banded N can be efficient but risks crop injury where the crop rows intersect the N band (Figure 65). Preplant application bands should be no more than 20" apart, placed well below the seed depth and applied on a slight angle to the direction of planting. On lighter textured soils, damage may occur in dry springs using either anhydrous ammonia or urea.

Broadcast and incorporated N prior to seeding is generally safe, but reduces N efficiency and risks drying out the seedbed. Surface applied N is dependent on rainfall, or some kind of incorporation, to move it into the root zone, to reduce losses. When rainfall is delayed, surface applications of urea-based fertilizer (including UAN solutions) are vulnerable to loss due to volatilization, particularly under conditions of high temperatures, drying winds and low organic matter, high pH, light-textured soils. Under such conditions a urease inhibitor, like NBPT (N-(n-butyl) thiophosphoric triamide) should be used.

Corn is very sensitive to N and K_2O placed with the seed due to ammonia toxicity and/or salt injury. A limit of 10 lb total seed placed N and K2O/ac is suggested for 30" wide row corn. Risk of injury increases for dry seedbeds and coarse-textured, sandy soil. See page 105 in the Diagnostics section for more information on fertilizer damage.

Side-banding fertilizer at planting, 2" to the side and 2" below the seed, is optimal placement for P fertilizer. However, efficiency may be reduced if excessive rates of N and/or K are included. High rates may burn seedling roots or inhibit root growth into the concentrated band to access critical early season P. For this reason, no more than 300 lb/acre of total fertilizer product should be applied in the side band.

POST-EMERGENT NITROGEN

Post-emergent N applications are well-suited for corn. However, research has shown that splitting N into two applications (one pre-plant or at planting, and one in-crop) is an efficient use of N fertilization in corn. Corn doesn't require a large amount of N in the spring. Rather, the bulk of its nitrogen needs begin roughly 4 - 6 weeks after emergence. Economically, this can be beneficial because at this stage, the producer should have a good indication if the crop has the potential to be high-yielding and the corn can be topped up with N accordingly.

NOTE: Post-emergent nitrogen applications also fall under the 4R nutrient management guidelines, which encourage fertilizer applications to follow the right source, right rate, right time and right place methodology.

When split N applications are planned, 1/3 to 2/3 of the total amount should be applied near seeding. If the in-season application is planned for a late crop stage, the majority of the N should be applied at or near seeding to avoid starving the crop.

There are several methods that can be used to scout for N sufficiency in the corn crop. These may detect early season losses due to leaching, denitrification or increased N availability due to mineralization of soil organic matter, manure, or previous crop residue. Such tools include the pre-side dress nitrate test (PSNT), chlorophyll meters, or optical sensors of crop biomass. Similarly, post-harvest corn stalk nitrate test (CSNT) levels can indicate if the crop was adequately supplied with N (Figure 19). If using the PSNT or CSNT test, consult the soil testing laboratory for guidelines. Chlorophyll and optical sensors require a N rich or over-fertilized area as a reference. Guidelines for such sensors are not yet well established for Manitoba.

Surface banded N after seeding is usually done by dribble banding UAN solutions. Although volatilization losses are not eliminated, they are minimized compared to broadcast application.

Broadcast applications of urea into growing corn may injure the growing point if granules fall into the whorl. Likewise, dribbled UAN solution should be directed between the corn rows to reduce flow into the whorl.

Corn is well suited for in-season applications of sub-surface placed N or "side-dressing". Side-dress applications should be conducted when corn is 6 – 12" tall (Figure 17 and 18) as delaying application any further will risk root pruning. Corn belt studies indicate that "skip-row" application of side-dressed N (placed between every second row) is as efficient as placing N between every row. With these skip-row applications, the same rate per acre is maintained, but output per shank is doubled with half the amount of shanks applying fertilizer.

Liquid N can also be applied in taller corn and directed towards the base of the plant. Current Manitoba studies show this to be as good as preplant applied N, while still allowing adjustment for early season N losses or mineralization.

Nitrogen can also be applied in irrigation water for "fertigation". Under irrigation the N is typically split among preplant, side-dress and fertigation with approximately 25 lb N/ac applied per watering.

NITROGEN RATES

Manitoba N recommendations for corn were developed under much lower yield potential than current hybrids and production systems. Research is underway to update these recommendations. A typical thumb rule has been to supply 1.2 lb N (fertilizer plus soil nitrate-N in 0 - 24" soil depth) per bushel of expected yield. However, with newer hybrids and improved N management, this requirement may as low as 1.0 lb N/bu.

Preliminary Manitoba research suggests nitrogen rates of 180 lb N/ac less soil test N for high yielding corn (150 - 200 bu/ac), and 150 lb N/ac less soil test N for modest yielding corn (100 - 125 bu/ac). These will be validated with ongoing research. These values are similar to North Dakota recommendations which are based on crop economics including corn value and nitrogen cost (Franzen, 2017).

Deficiencies

See Diagnostics section for nutrient deficiency symptoms.

Phosphorus (P)

Phosphorus is required for plant growth and seed development. Considered immobile in the soil, P is taken up by the root by diffusion over short distances through the soil solution. Phosphorus is taken up continuously during the growing season. Large amounts of P are required after tasseling and during the ripening period. Most of the P accumulated in the leaves, stalks and husks is translocated to the grain. At maturity about 70% of the P in the plant is in the grain.

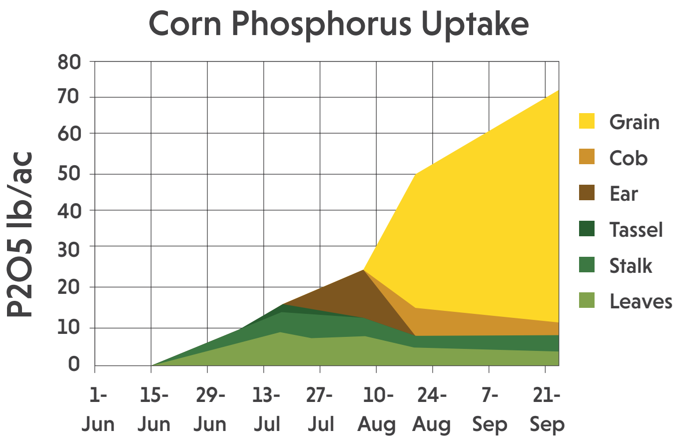

FIGURE 9. Phosphorus uptake and partitioning in grain corn (Heard, 2004).

PLACEMENT AND TIMING

Starter P fertilizer placed with or close to the seed is very important since much of our corn is planted early into cool soils when diffusion of soil P and root growth is very slow. Proper placement is dually important to create a high probability that plant roots will contact these applied nutrients, and to minimize soil contact which will result in more availability. Banding a small amount of P near the seed can result in more vigorous growth of the seedling, referred to as a 'pop-up' or 'starter' effect.

Band applications of P are superior to broadcast applications under conditions frequently observed in Manitoba; low soil test P levels, cold and wet soil conditions at seeding, and calcareous soils that fix substantial quantities of P. Broadcast applications may need to be 2-4 times greater in order to equal growth and yield achieved by band placement.

Some Manitoba farmers have modified planters to place fertilizer in a side-band (2" below and 2" beside the seed) with delivery through an air cart. This permits meeting the full maintenance amount of P in an efficient and safe manner. Manitoba corn research evaluating strip tillage has shown spring side-banded P is superior to fall deep banded P placement in the strip. Seed-placed or side-banded P does not always increase yield, but frequently increases early season growth, advances crop development and maturity resulting in lower moisture levels at harvest.

Phosphorus uptake is impaired following canola (brassica crops) or summerfallow due to low levels of vesicular arbuscular mycorrhizae which aids in P uptake. Research is being conducted to determine if supplemental applied P will make up for the reduced P availability as a result of corn after canola syndrome. More information on mycorrhizal fungi in the Cultural Practices section.

PHOSPHORUS RATES

Traditional P recommendations have been developed with the "sufficiency approach", using conservative rates of fertilizer to produce good economic returns for that year without consideration of soil P depletion. These rates were based on soil testing and generally recommend 35-40 lb P_2O_5/ac on low testing soil (<10 ppm soil test P), 20 - 30 lb P_2O_5/ac on medium test soil (10 - 15 ppm) and 10 - 15 lb P_2O_5/ac on higher testing soils (>15 ppm). However, these rates are less than crop removal values of current corn yields in Manitoba (65 - 70 lb P_2O_5/ac for 150 bu/ac) and will lead to soil P depletion. A longer-term, sustainable approach considers applying the crop removal amount of P for medium test soils and greater than removal for low testing soils to slowly build into the medium range. Manitoba studies are underway to further refine such guidelines (refer to Manitoba Agriculture's Soil Fertility Guide).

Deficiencies

See Diagnostics section for nutrient deficiency symptoms.

POTASSIUM (K)

Many Manitoba soils contain sufficient K for crop uptake. However, soils that are likely to be low in K are frequently those same lighter-textured soils that are suited to corn production, so soil testing is recommended. Rapid uptake of K starts at about the same time as the start of rapid plant growth and is maintained only until the grain starts to be formed, at which time the uptake of K is complete. Most of the K taken up by the plant remains in the leaves and stalk. Large quantities of K can leach from senescing leaves during the grain dry down stage.

Considered immobile in the soil, K is taken up by the root by diffusion over short distances through the soil solution.

Efficiency of band application of K is greater than broadcast application, especially when requirements are low. Band options include preplant banding or side-banded at seeding. The N and K content of fertilizer restrict the quantity of fertilizer that can be safely seed-placed due to ammonia and salt toxicity (see diagnostic section for more information).

Fertilizer rates of potash (K2O) are based on the soil test of exchangeable K. Approximately 65 - 100 lb K2O/ac is recommended on low testing soil (<100 ppm soil test K) and 30 - 65 lb K2O/ac on medium to high test soil (100 - 200 ppm K). The above rates are based on band applied potash. If potash fertilizer is broadcast, rates should be increased by a factor of 2 to produce equivalent yield response.

Deficiencies

See Diagnostics section for nutrient deficiency symptoms.

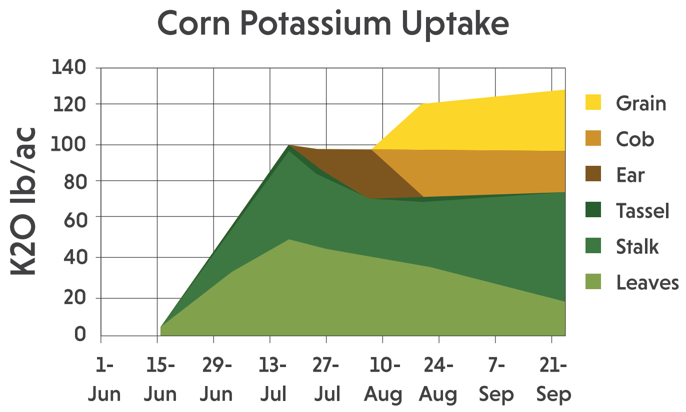

FIGURE 14. Potassium uptake and partitioning in grain corn (Heard, 2004).

SULPHUR (S)

Sulphur is a key component of several important amino acids that are required for the development of proteins and enzymes, and is taken up by the roots in the form of sulphate.

Elemental S fertilizer must be oxidized by soil micro-organisms to the sulphate form. Sulphate-S may leach in coarse soils, and levels within the field often vary, depending upon soil type and slope position.

It is not uncommon for low lying, heavy soils to contain many times more sulphate-sulphur as light-textured hilltops.

Soils testing low in S (less than 30 lb sulphate-S in 0 - 24”) should receive 20 lb S/acre. The sulphate form is required for plant uptake and can be applied as ammonium sulphate (21-0-0-24S) or ammonium thiosulphate (ATS 15-0-0-20S). The placement is not critical but should not be placed with the seed. If elemental S is used, it should be applied in previous years so that it converts to the sulphate form.

Deficiencies

See Diagnostics section for nutrient deficiency symptoms.

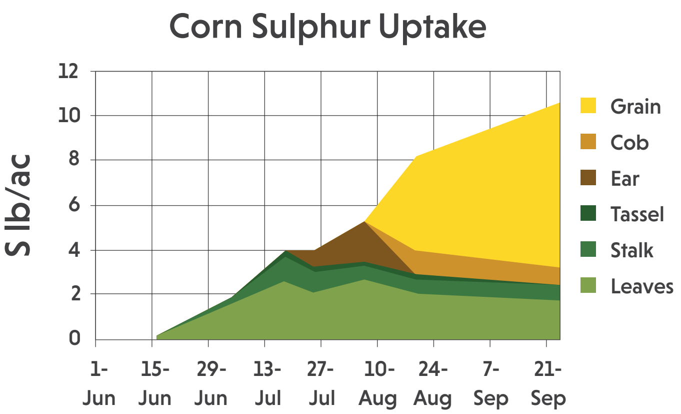

FIGURE 15. Sulphur uptake and partitioning in grain corn (Heard, 2004).

MICRONUTRIENT DEFICIENCIES

The micronutrient most likely to be deficient for corn in Manitoba is zinc (Zn). See Diagnostic section for nutrient deficiency symptoms. Deficiency occurs most frequently on high pH, low OM soils in years with cold wet springs. The critical level of soil Zn is 1.0 ppm using the DTPA extractant. Corn is likely to respond to applied Zn on soils testing less than this level.

There are several options for source, timing and application method of micronutrient fertilizers. Application options are broadcast and incorporated, soil banded or foliar. Broadcast and thoroughly incorporated application generally maximizes nutrient uptake by increasing opportunity for root interception. Broadcast and incorporate 10 - 15 lb/ac Zn as zinc sulphate or 2 - 3 lb/ac Zn as zinc EDTA chelate. This rate of broadcast zinc sulphate will increase soil levels for more than 10 years

Banded Zn can be applied in starter fertilizer in a chelated or ammoniated form but the residual effect will be short and there will need to be an application each year of corn. Likewise, foliar applications may be effective to correct deficiencies diagnosed early in the growing crop.

MANURE

Corn has a high demand for nutrients and is a very suitable crop for manure application. Typical values of nutrients available for the following corn crop are reported in Table 4.

As with fertilizer nutrients, manure N is optimized through sub-surface banding. In order to maintain timely planting and to minimize soil compaction, manure should be applied to dry soils in the fall prior to seeding. Unlike cereals, corn will tolerate areas of inadvertent excessive manure application without lodging.

TABLE 4. Available nutrients in typical manure (adapted from Properties of Manure, Manitoba Agriculture, 2014).

Manure Type	Available N*	Available P_2O_5**	K_2O	S
Liquid				
Swine	17-28	7-8	11-17	1-3
Dairy	14	6	24	-
Solid				
Beef	4	2.3	13	2
Poultry	32	20	18	4

* available N = all of ammonium N plus 25% of organic N

**available P_2O_5 = 50 % of total P x 2.3 to convert to fertilizer equivalent.

FIGURE 16. Fall dual banding of ammonia-N and phosphorus.

FIGURE 17. Side-dress ammonia in corn.

FIGURE 18. Side-dress UAN application.

FIGURE 19. End of season corn stalk nitrate test

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SECTION 5

CULTURAL PRACTICES

MANITOBA
CORN GROWERS
ASSOCIATION INC.

Cropping Management

CROP ROTATION

It is important to consider the effect of the previous crop on corn yield, as well as how corn will fit into the overall rotation. Corn yields vary depending on the previous crop in rotation (Table 5), due to a combination of factors including disease and insect pressure, crop residue effects, soil fertility, water use, and herbicide residues and resistance. To reduce disease pressure, corn typically follows a broadleaf crop.

Previous Crop	Yield response compared to corn after corn	% of MB corn acreage following this crop
Corn	100	7
Red spring wheat	110	8
Winter wheat	108	5
Oats	111	3
Barley	103	4
Canola	111	23
Flax	88	0
Peas	106	1
Soybeans	116	26
Navy Beans	125	2
Sunflowers	107	2
Potatoes	102	6

TABLE 5. Relative yield response (% of 2010 - 2015 average) and frequency of corn following various crops in Manitoba. Adapted from: Relative Stubble Yield Response and Relative Acreage by Stubble Type, Manitoba Agricultural Services Corporation.

Fertility factors to consider when planning a crop rotation include the nitrogen (N) credits following crops as well as phosphorus (P) needs. Pulse crops or heavily fertilized crops may leave residual N in the soil (Table 6). Corn has the potential to root 4 to 5' deep and can retrieve N that has leached below the root zone of other crops.

TABLE 6. Nitrogen replacement value of previous crops. Adapted from: Manitoba Soil Fertility Guide 2007.

Previous Crop	lb N/acre
Dry beans, soybeans	0-10
Peas	25
Alfalfa*	45-90

*N credit of forage stands declines as the legume content of the stand decreases.

Early season P uptake in corn is strongly dependent on colonization by arbuscular mycorrhizal fungi. Mycorrhizal fungi aid in P uptake and form a strong association with corn and most other crops, excluding canola. Studies recently conducted at the University of Manitoba found that canola planted before corn resulted in lower corn biomass, lower P uptake, lower mycorrhizal colonization, and shorter plant height at the V6 stage in corn, in comparison to corn following soybeans. While the preceding crop influenced early season growth, corn grain yield was not effected (Brar et al. 2018).

Quick planting information

Date: May 1 to 15
Depth: 1 to 2"
Target plant stand: 30,000 to 36,000 plants/acre
Row spacing: Typically 20 to 30"

PLANTING DATE

Planting date has a large impact on yield and moisture of a harvested crop. Ideally, corn should be planted between May 1 and May 15. Earlier planting when possible is acceptable as emerged corn recovers readily from frost injury. Germination of corn is very temperature-dependent. Under adequate soil moisture conditions, corn will germinate and begin growing when soil temperature is 10°C at 2 - 4".

When planted late, yield potential is reduced significantly and the risk of crop failure increases. On average, a yield reduction of 1 bu/acre/day occurs when the date of planting is delayed beyond mid-May. When planting earlier than the first week in May, a 5% increase in plant population would be advised to allow for losses.

When planted early to mid-May, corn is able to tolerate spring frosts fairly successfully. The growing point is normally below the soil surface until the six leaf stage, and by the time the growing point is above the soil surface the risk of frost is generally over. In fact, there is a greater risk to final yield from planting too late than too early. However, there are risks to planting corn too early since as planting dates are moved earlier, soil temperature becomes a more important consideration. When soil and air are cool, germination and growth can take significantly longer, during which time micro-organisms and insects can cause damage leading to stand establishment problems. As well, there is the possibility that plants can be damaged from late spring frosts if the growing point emerges above ground level.

An additional effect of planting date on final grain yield is the soil moisture deficit that normally occurs at silking. Rainfall and evapo-transpiration patterns on the prairies result in an average moisture deficit of 4 inches on July 31 and 8 inches on August 31. Early planting, resulting in early emergence, usually allows silking to occur during the best possible moisture conditions. An additional five to six weeks are normally required for grain to mature following anthesis, which for early hybrids is reached in the last week in August. After grain maturity, fall frosts are no longer a significant factor.

TABLE 7. Yield (bushels per acre) of grain corn planted weekly in Manitoba (2013-2017). Yield is reported as a provincial average and by risk area (RA). Source: Manitoba Agricultural Services Corporation.

Week:Month						Yield (bu/acre)				
	Province	RA 1	RA 2	RA 3	RA 4	RA 5	RA 10	RA 11	RA 12	RA 14
1:04	130	-	-	-	109	-	-	-	139	138
2:04	165	-	-	-	-	-	-	-	165	-
3:04	124	36	98	-	130	134	-	112	173	103
4:04	120	92	125	108	150	133	154	151	150	134
1:05	139	106	130	108	125	129	131	128	144	140
2:05	129	93	115	97	125	129	122	124	136	123
3:05	115	85	109	84	102	115	115	121	132	121
4:05	109	76	102	95	106	102	105	119	129	103
1:06	100	52	85	-	111	117	105	105	109	114
2:06	121	0	154	-	84	120	113	-	134	105
3:06	110	0	-	-	-	-	75	-	142	89
4:06	113	105	-	-	-	-	120	-	-	-
Average Yield	132	90	115	97	121	125	122	126	142	123
Acres	303,874	5,478	15,626	3,093	21,297	15,247	44,552	13,333	161,163	20,414

DEPTH

Optimal planting depth for corn is 1.5 - 2” deep. Corn planted shallower than 1.5” will be exposed to warm daytime temperatures, but also to surface drying. Planting into dry soil can result in uneven emergence or reduced plant stands. An additional concern with shallow planted corn is poor nodal root development. Corn planted deeper than 2” will be exposed to cool soil temperatures, and may result in delayed emergence and reduced plant establishment.

Uniform planting depth and reduced planting speeds contribute to uniform plant emergence. Substantial yield losses can occur when plant emergence is not uniform.

PLANTING RATE & ROW SPACING

Determining Planting Rate

Optimum planting rate is influenced by many factors including climatic conditions, soil type, planting date, hybrid characteristics, available growing degree days, purpose of the crop, and economics. Maximum interception of solar radiation is important to reach yield potential, which can be done by using optimum planting rate and row spacing.

Generally, desired plant stands range from 30,000 to 36,000 plants/acre. Planting rates to achieve the target plant stand should factor in a 10 - 15% loss to account for germination and seedling mortality. Silage can be planted at rates 10% higher than grain corn because lodging is less of a concern in silage.

Planting Rate = Target Plant Population/ Expected Planting Survival (%, includes germination and mortality)

Ex. Target plant population = 30,000 plants/acre; Germination = 95%; Expected mortality = 10%

Planting rate = 30,000/.85 = 35,294

Choice of target plant population depends on actual yield response in climatic conditions, the cost of seed, and the price of grain. In highly productive environments, an increased plant population results in higher yields due to the increased number of ears per unit of land. Yield generally increases with increasing plant population, and plateaus at a certain point. At this point, population increases will not result in a yield increase and at high enough

populations yield will eventually decline. High plant populations result in increased stress through inter-plant competition for light, moisture, and nutrients. Greater inter-plant competition results in smaller ears, more barren plants, thinner stalks, and increased stalk breakage. If the population is pushed too high, these factors combine to cause a yield reduction and higher harvest losses.

Hybrid selection is a critical factor in determining the optimum plant population. It is important to look at the stalk lodging resistance of the hybrid. Under high plant populations, there is often increased incidence of lodging due to a reduction in average stalk diameter. Hybrids with good stalk strength can generally handle the shift to higher populations.

Increased plant densities are not appropriate for all situations because of the many factors that interact with plant population to place the crop under stress. Factors such as drought, weeds, insects, diseases, soil compaction, inadequate fertility and poor drainage can exaggerate the stressful effects of increased plant populations. The more severe these stresses are, the lower the optimum plant population.

Row Spacing

Row spacing typically varies from 20 to 30", with 30" row spacing being most common in Manitoba. Few yield differences are expected between 30" and narrower rows, but there may be other benefits to planting in narrower rows. Corn planted at the same density in narrow (15 - 20") rows will have reduced weed competition, increased light interception per plant, and less in-row crowding compared to corn planted in 30" rows.

Calculating Plant Population

Plants can be counted after emergence to determine actual seedling mortality and evaluate planter performance. This information is useful to adjust planting rates in future years.

TABLE 8. Plants per three feet of row and corresponding plant populations at a range of row spacings.

Plants/3 ft of row	Plant Population (plants/acre)				
	30" Rows	28" Rows	26" Rows	22" Rows	20" Rows
2	11,616	12,446	13,403	15,889	17,424
3	17,424	18,669	20,105	23,833	26,136
4	23,232	24,891	26,806	31,778	34,848
5	29,040	31,114	33,508	39,722	43,560
6	34,848	37,337	40,209	47,667	52,272
7	40,656	43,560	46,911	55,611	60,984
8	46,464	49,738	53,612	63,556	69,696

SPACING WITHIN THE ROW

Uniform seed distribution within the row should be the goal of a planting operation, but corn can tolerate some variability in seed spacing. Yield is not significantly affected by small gaps as long as the proper planting rate is delivered. Producers should evaluate planter performance to ensure uniformity of plant spacing. A well-tuned planter operating at a reasonable speed should help to minimize non-uniformity of plant spacing within the row. Planting at high speeds with a poorly maintained planter can result in a large number of doubles (two-plant hills) and skips (missing plants). Doubles can result in barren stalks and skips can cause yield loss, both resulting in lost yield potential for the field. Producers can also do some crop scouting once the crop is up and growing to determine if plant spacing is acceptable.

SEED TREATMENT

Seed corn is sold treated with a fungicide to protect the seed against decay organisms. Seed may also be sold treated with an insecticide to give protection from soil insects such as wireworms and seed maggots. For seed treatment recommendations, consult the Manitoba Agriculture's Guide to Field Crop Protection.

SEED QUALITY

Canada has a Seeds Act to assist producers in purchasing high quality seed. In addition, companies have seed quality control programs. Farmers should therefore encounter few problems with vigor and germination levels of corn seed. However, if emergence problems occur, it may be necessary to check the quality of the seed involved. Tags on each bag of seed corn indicate the germination level, the date it was tested and the seedlot from which it was obtained. Unless these tags are saved it is impossible to identify the seedlot that was sown. Therefore, it is also impossible to recheck the quality of the seed if a problem arises. A set of tags from each seedlot along with a small sample of seed should be saved to assist in tracing the cause of such problems.

WHEN TO REPLANT

Poor seed quality, cool weather, wireworms, seed corn maggots, seed rots, incorrect seed placement, herbicide damage, fertilizer burn or extremes in soil moisture content can all result in reduced emergence. With poor emergence, the question of replanting arises.

A very significant reduction in stand is needed before replanting can be justified. Consider the following factors:

- The yield potential of replanted corn will be reduced because of the later planting date.
- Additional costs for tillage, seed, planting and perhaps chemicals.
- Replanting corn will usually be less profitable than accepting the reduced stand if it is over 16,000 plants per acre. Even at lower populations, replanting is not always advisable.

Replanting should be undertaken only after carefully weighing the costs against any potential gain.

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SECTION 6

WEED MANAGEMENT

Weed Management

The conditions and farming inputs necessary to produce high yields and good quality also favour vigorous weed growth. Corn, owing to its erect growth habit, competes poorly with weeds until the leaf canopy has closed over the inter-row area. Early weed control and timing is essential to optimize yield potential. This is particularly true when many post-emergent weed control options have little to no residual activity.

As with any crop type, the critical period of weed control in corn is important to understand when considering the weed control program. The critical period of weed control is the interval in the life cycle of the crop when it must be kept weed-free to prevent yield loss.

The critical weed free period (CWFP) can be dynamic and varies depending on the year and field conditions. Research suggests weed control may be required as early as the time of crop emergence (VE). Typically, weed control does not provide an economic benefit after V4 stage of development. The CWFP is influenced by climatic conditions, relative time of crop and weed emergence, weed density, weed species, soil type and fertility, and crop canopy closure.

Weeds in corn may be controlled by two basic methods – cultural or chemical – or by combination of both. While herbicides can be effective in controlling weeds, it is important to include cultural control methods in a weed management strategy to minimize the risk of herbicide tolerant weeds.

CULTURAL CONTROL

Cultural weed control can include the selection selection of a fast-growing corn hybrid, planting in narrow row widths, proper fertilizer placement or inter-row cultivation.

Narrow row width:

Corn is a poor competitor with weeds until canopy closure. Corn planted in 30” rows offers space and time for weeds to be very competitive, using nutrients, soil moisture and sunlight which results in yield loss. Narrow rows (15 – 22”) give the corn crop a more competitive edge and the ability to use resources more wisely. The combination of early herbicide applications and narrow row spacing is good weed management practice.

Mechanical weed removal:

Inter-row cultivation is an effective way to remove weeds between corn rows. Cultivation must occur early enough to avoid pruning of the corn roots.

Fertilizer amount and placement:

Early season weed competition reduces nitrogen use efficiency as weeds growing between corn rows scavenge for available nutrients before corn roots can access those areas. Delaying herbicide application until weeds were 4” or 12” tall resulted in fields requiring an additional 20 – 60 lbs N/ac or 65-160 lb N/ac, respectively, to achieve yields equivalent to a weed-free crop. Precision placed fertilizer is the most economical method to minimize nutrient losses from weed uptake. In the event that fertilizer is broadcast, weed management may need to be more aggressive and heavier rates of fertilizer should be applied to compensate.

CHEMICAL CONTROL

Herbicide timing:

Herbicides are available for pre-plant, pre-emergence, and in-crop weed control in corn. When used alone, they are a good method of weed management, but they are most effective when used in conjunction with cultural control methods.

Spring preplant/pre-emergent burndown treatments are critical in allowing the crop to develop without weed interference during early growth phases. Herbicides in this category may also provide residual benefits for up to two weeks following application. This will allow the corn to get a healthy start, without the interference of weed competition at the most integral stages of growth. With the application of a good preplant/pre-emergent herbicide, there may only be one in-crop herbicide application needed, depending on growing conditions and timing of subsequent weed emergence.

FIGURE 20. Corn field with heavy infestation of grassy weeds. A meta-analysis of 71 studies conducted in Ontario over a nine year period found a 102 bu/ac or 49% yield loss in corn with no weed management. Photo credit: Morgan Cott, MCGA

Post-emergent herbicide use has expanded with the development of herbicide tolerant corn hybrids. Glyphosate is the most commonly used chemical input in corn, but as herbicide resistant weeds become more prevalent, weed management is becoming increasingly complex. In-crop herbicide options in Manitoba are broadening, providing greater access to herbicides with improved crop safety while reducing weed populations. Proper research is required before applying a herbicide to a corn crop, including weed species present, weed staging, weed populations, crop staging, tank-mixing options, environmental conditions, and recropping restrictions. When applying post-emergent herbicides, proper corn growth staging is extremely important. Herbicide labels often refer to plant height, crop growth stage (leaves or collars), or both. A review of common methods for determining growth stage can be found on page 15.

Additional management in no-till cropping systems will help to control perennial weeds and weed species that are new to the system due to a shift in weed populations. According to the 2016 Manitoba Weed Survey, conducted by Agriculture and Agri-Food Canada (AAFC) and Manitoba Agriculture, yellow foxtail, broad-leaved plantain and biennial wormwood all appeared in the top 20 weed species for the first time in Manitoba across all crops sampled. Volunteer canola, dandelion, round-leaved mallow, volunteer wheat, chickweed, barnyard grass and false cleavers are examples of weed species that have also increased in size since the 1970s.

Although current weed management practices are more intense than the past 40+ years, they may not be customized to the weed spectrum present and changes need to be considered.

TABLE 9. Top 10 ranking weed species in Manitoba.

	Weed Species	
Rank	All Crops* (659 fields)	Corn (41 fields)
1	Green foxtail	Barnyard grass
2	Wild buckwheat	Wild buckwheat
3	Barnyard grass	Canola
4	Wild oat	Lamb's-quarters
5	Canola	Round-leaved mallow
6	Yellow foxtail	Green foxtail
7	Dandelion	Redroot pigweed
8	Redroot pigweed	Purslane
9	Wheat	Broad-leaved plantain
10	Round-leaved mallow	Yellow foxtail

* All crops: barley, canola, corn, flax, oat, soybean, spring wheat and sunflower.

Managing Glyphosate-Resistant Volunteers/Weeds

Herbicide resistant weeds, including volunteer herbicide tolerant (HT) crops, require additional management considerations when growing herbicide tolerant corn.

Preplant and pre-emergent herbicide applications, using multiple modes of action, are commonly used when HT volunteers are present. Early control of HT volunteers minimizes competition for crop resources (eg. fertilizer) and lessens the risk of crop injury, as corn is more sensitive to certain active ingredients as it matures, and smaller weeds are easier to control.

There is growing awareness in the Prairies of glyphosate resistant weeds. In 2013, glyphosate resistant kochia was first confirmed in Manitoba, and has since slowly increased its presence. Ontario and the northern US states have seen cases of resistance to various herbicides including glyphosate resistance in waterhemp, palmer amaranth and Canada fleabane. While some of these weeds have been detected in Manitoba, they have not yet become established. Hugh Beckie, former weed scientist with AAFC Saskatoon, also had a predictive model that puts the Prairies at risk of glyphosate resistant wild oats, green foxtail and possibly cleavers in the future. In corn, tankmixing partners will be a great tool to decrease populations, but do not rule out cultural methods of weed management to keep populations in check.

FIGURE 21. Herbicide tolerant crop volunteers may be successfully controlled with the addition of a tank-mix partner.
Photo credit: Morgan Cott, MCGA

Herbicide Damage

See Diagnostics section for herbicide damage symptoms.

Herbicide Interactions

Sulfonylurea herbicides (Accent, Ultim) have been known to interact with organophosphate (OP) insecticides. Post-emergent application of sulfonylurea herbicides to corn that has been treated with an OP insecticide can result in foliar and root injury. Observe label restrictions if applying a foliar OP insecticide following a sulfonylurea application.

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SECTION 7

DISEASES AND DISORDERS OF CORN

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Diseases and Disorders of Corn

Disease outbreaks are a result of three things: the presence and type of pathogen, the susceptibility of the host, and the environmental conditions surrounding the pathogen and host. To manage corn for disease effectively, it is best to prevent or manage a disease outbreak when the disease is at low levels, instead of when the crop is infested.

Points for managing disease prevention:

- scout weekly — identify diseases, mapping problem areas
- review field history
- plant disease-resistant hybrids
- rotate crops
- when possible, use a tillage system that chops and covers corn residues with soil

Field scouting on a weekly basis can provide information on what diseases are present, the severity, and potential for crop loss if untreated. Through crop scouting, informed decisions can be made on disease management tactics. Reviewing the field history, identifying the diseases, and mapping the location of disease problems in the field are all beneficial investments of time that will assist in the management of corn diseases.

The decision on what hybrid(s) of corn to grow can be a difficult one, and accounting for disease resistance can increase the difficulty. In some cases, higher yield performance and a high level of disease resistance may not be possible (as in the cases of stalk rots), or resistant hybrids may not even be available. Whenever possible, it is always a good idea to use hybrids resistant to a disease, especially if a particular disease has been a problem in the past.

Growing corn in the same field for successive years may be desirable for several reasons. There are risks, however, in not rotating other crops. A lack of crop rotation allows pathogen populations to build up over time, increasing the likelihood of a large outbreak of disease with subsequent crop loss. Generally, diseases of corn are not of great concern in Manitoba. However, Goss's wilt has become an increasing problem since its first detection in 2009. There are also increasing instances of crop loss due to root and stalk rots, in addition to the recurring problems with both common and head smut.

Brief descriptions of the more common diseases observed in Manitoba corn are provided. General recommendations for disease management are also included. Specific information on disease management can be found in the Guide to Field Crop Protection.

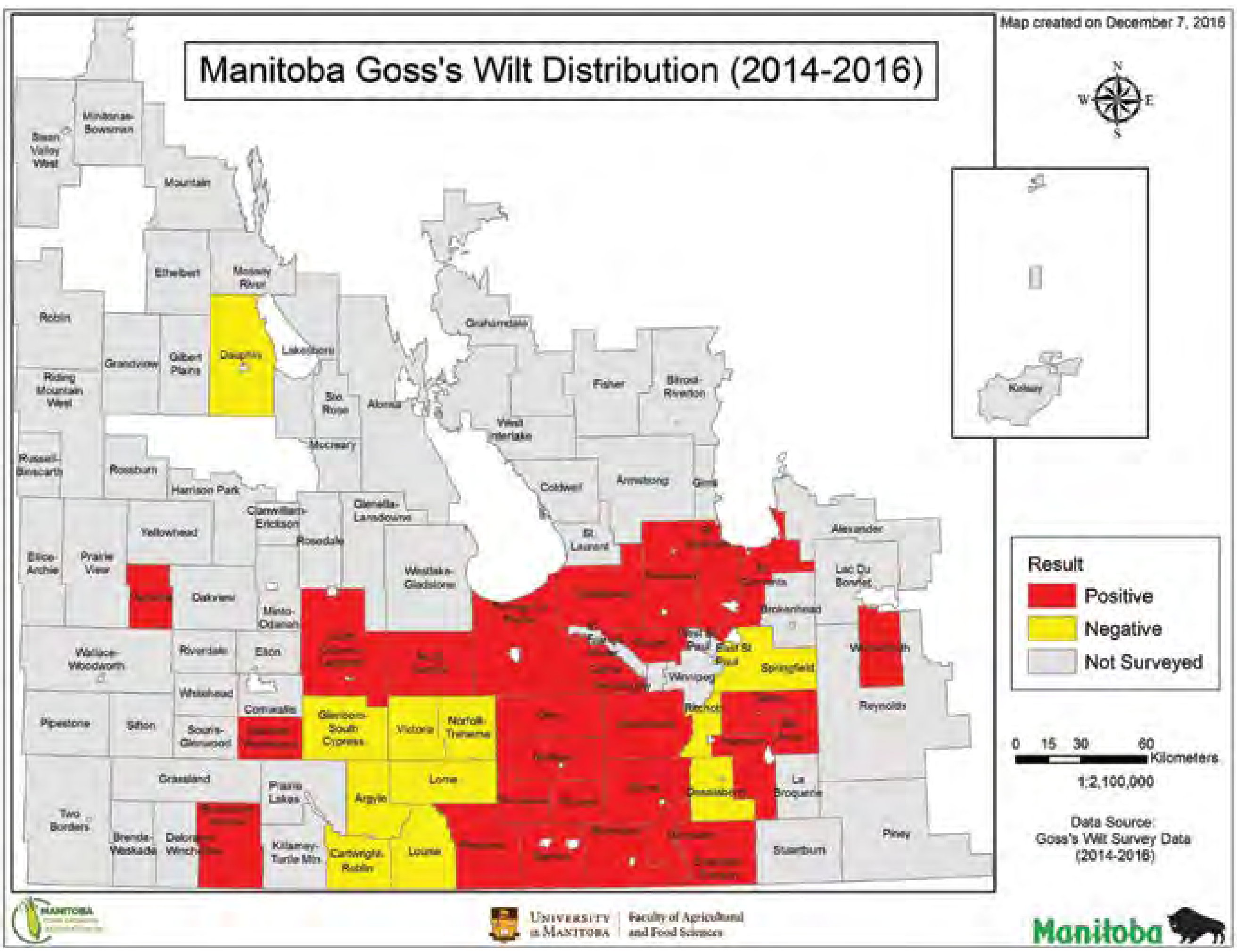

FIGURE 22. Goss's wilt distribution in Manitoba. Manitoba Agriculture 2016.

Seedling Diseases

When to look for: End of May to end of June

One of the most susceptible stages in the development of any plant species is the seedling stage. At this stage of development, the plant needs to allocate the majority of its resources to growth and development leaving limited energy to combat stress, biotic or abiotic.

DAMPING-OFF AND SEEDLING BLIGHT

A large number of soil and seed-borne fungi including *Pythium* spp., *Fusarium* spp., *Rhizoctonia* spp., and to a lesser extent, *Penicillium* spp. and *Trichoderma* spp. cause these diseases. Germinating corn kernels may be attacked and severe infection may kill the embryo before germination (pre-emergence seedling blight) or destroy the seedling after emergence (post-emergence seedling blight). These diseases are prevalent in poorly drained, cold and wet soils.

Planting depth, soil type, age and quality of seed, mechanical injury to the seed coat, and genetic resistance to infection all influence disease severity.

Disease organisms responsible for seed rot and seedling blights can be divided into two main groups:

1. Pathogens in or on the seed at planting
2. Pathogens in the soil at planting

Symptoms

- Poor stand establishment
- Varying emergence
- Gaps in rows
- Stunting, yellowing, wilting and death of leaves on individual plants

Seed rots and blights may be confused with mechanical or chemical injury or insect damage. Examination of plant parts under the ground is therefore necessary for accurate diagnosis. In pre-emergence seedling blight, the coleoptile and developing root system appear brown, wet and slimy. In post-emergence seedling blight, the seedlings may have a constricted stem at the soil line, appear yellow, wilt and die.

Disease Cycle

- Spores (which are commonly present in Canadian soils) germinate in the presence of susceptible hosts
- Infected plants die off prematurely (in the case of seedling blights or severe root rot) or naturally senesce and the pathogen produces spores, especially at the crown
- Spore production continues on infected stubble
- Spores remain dormant in the soil until next susceptible host is present

Pythium spp., *Fusarium* spp., and *Rhizoctonia* spp. commonly cause seedling blight and root rots in corn. The disease cycle above applies to both seedling diseases and root rots caused by these pathogens. Specific details of the disease cycle will vary depending on the causal organism.

Management

- Plant injury-free seed
- Plant in warm, moist soil
- Prepare seed bed properly
- Use correct fertilizer placement
- Improve field drainage where possible
- Use seed treatments

Root Rots

When to look for: Throughout the season.

A number of different fungi and bacteria cause root rots. Generally, the disease cycles are similar, and many of these fungi also cause stalk rots. Root rot organisms can survive on corn refuse and in the soil. Plants under stress from other factors will be more susceptible to yield loss from root rots.

FUSARIUM ROOT ROT (*FUSARIUM* SPP.)

Symptoms

- Slightly abnormal browning of roots to complete destruction of roots
- Pink tinge of roots could indicate *Fusarium graminearum* infection (same causal agent as Fusarium head blight of cereals)

Disease Cycle

See disease cycle of damping-off and seedling blight.

Management

- Use seed treatments labelled for protection against Fusarium root rot - protection only lasts up to three weeks after planting
- Crop rotation

PYTHIUM ROOT ROT (*PYTHIUM* SPP.)

Symptoms

- Roots are brown to black in colour
- Outer portion of root may be discoloured, while inner portions remain white
- Yellowed and stunted plants

Disease Cycle

See disease cycle of damping-off and seedling blight.

Management

- Improve soil drainage
- Use seed treatments labelled for protection against Pythium root rot - protection only lasts up to three weeks after planting

Foliar and Aboveground Diseases

ANTHRACNOSE LEAF BLIGHT (*COLLETOTRICHUM GRAMINICOLA*)

When to look for: Late June to late September

The anthracnose pathogen can cause both stalk rot and leaf blight in corn as well.

Symptoms

- Large, oval spots (up to 15 mm in diameter) with tan centres and reddish-brown or yellowish brown margins
- Infection occurs on lower leaves first, spreading to upper leaves under wet conditions
- Infected leaves wither and die prematurely

Disease Cycle

- Pathogen overwinters on corn residue
- Spores on crop debris are rain splashed to nearby plants where the pathogen penetrates the leaf
- Infection is most severe after prolonged periods of cloudy, wet weather

Management

- Use resistant hybrids; note that leaf blight resistant hybrids may not necessarily be stalk rot resistant
- Crop rotation
- Tillage of residues to minimize early infections (will have little impact on late season or stalk rot infections)

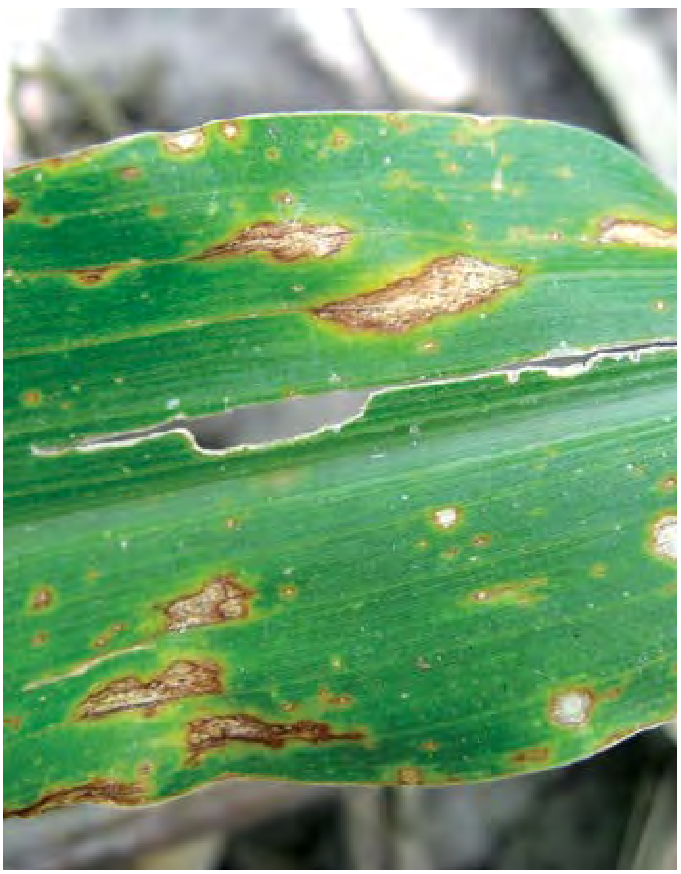

FIGURE 23. Anthracnose leaf blight on corn leaf.
Source: Alison Robertson, Iowa State University

FIGURE 24. Anthracnose leaf blight.
Source: Alison Robertson, Iowa State University

COMMON RUST (*PUCCINIA SORGHI*)

When to look for: Late July to late September

Symptoms

- Golden-brown blisters on corn leaves
- As disease progresses, blisters split open and release characteristic powdery, rust-coloured spores
- Does not normally develop until late in the growing season and is relatively minor

FIGURE 25. Early common rust lesions on corn leaf. Photo credit: DuPont Pioneer

FIGURE 26. Advanced common rust lesions on corn. leaf. Photo credit: DuPont Pioneer

Disease Cycle

- Windborne spores blow in from southern states, where the pathogen overwinters
- Spores may arrive in Manitoba as early as late June
- Moderate temperatures and high relative humidity at time of rust spore arrival favours infection
- Younger leaves are more susceptible to infection than older leaves

Management

- Can use foliar fungicides at correct timing, but rarely is disease severe enough to see return on investment
- Earlier planting to ensure corn crop reaches more resistant growth stage prior to spore arrival

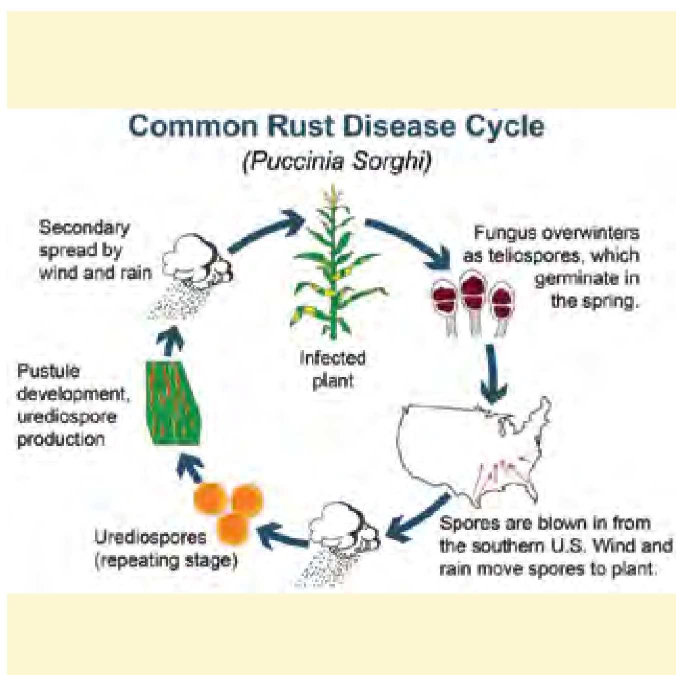

FIGURE 27. Common rust disease cycle. Photo credit: DuPont Pioneer

COMMON SMUT (*USTILAGO MAYDIS*)

When to look for: Mid July to October

Aboveground parts of the plant are susceptible, particularly young, actively growing tissues, such as silks, cob tissues, and developing kernels. Plants with galls on lower stalks may be barren or produce several small ears. Though uncommon, early infection of the growing point may kill young plants.

Symptoms

- Conspicuous swellings or galls on cob tissues or kernels
- Later, interior of galls darkens and ruptures, releasing masses of powdery dark brown to black spores
- As galls on cob tissues mature, they may reach 15 cm in diameter
- Leaf galls appear more blister-like and do not rupture
- Leaf galls range in size from 0.6 to 1.2 cm in diameter

Disease Cycle

- Resistant, thick-walled spores overwinter for several years in soil or on crop residue
- Spores germinate under favourable conditions and produce smaller spores that spread by wind or water
- Spores germinate and infect the leaves via wounds or directly through cell walls
- Smut development is favoured by temperatures between 26° and 34°C

Disease incidence is generally higher among plants grown in soils high in nitrogen or after heavy manure application. Injuries due to frost, insects, hail, blowing soil particles, de-tasselling and herbicides can greatly increase the likelihood of smut infection.

FIGURE 29. Common smut on corn.
Photo credit: Morgan Cott, MCGA

Management

- Crop rotation
- Any practice to avoid injury to plants
- Maintain balanced fertility
- Plant resistant hybrids - most corn hybrids have enough resistance to common smut to prevent serious infestations, although smut is present in most fields

FIGURE 28. Common smut on young corn plant.
Photo credit: Morgan Cott, MCGA

HEAD SMUT (*SPHACELOTHECA REILIANA*)

When to look for: Mid July to October

Symptoms

- Not visible until tassel and ears develop
- Cobs usually replaced by mass of black spores enclosed completely by husks
- Infected tassels may look like black sooty brush
- When tassel is infected, ear will also be infected, however, other plants may have infected ears without infected tassels

Disease Cycle

- Head smut spores overwinter in the soil
- Disease cycle of head smut is similar to that of common smut but head smut pathogen attacks seedlings
- In spring, pathogen grows systemically through infected seedling, eventually invading developing flower tissue
- Corn under stress during emergence is more susceptible to infection

Management

- Plant resistant hybrids
- Use seed treatments labelled for protection against head smut
- Maintain adequate levels of nitrogen

The highest incidence of head smut occurs in continuous corn when the levels of fungus have built up over time. Crop rotations and cultivation may have little impact on disease, as the smut spores can survive for long periods in the soil.

FIGURE 30. Head smut on corn.
Photo credit: Morgan Cott, MCGA

CRAZY TOP/DOWNY MILDEW (*SCLEROPHTHORA MACROSPORA*)

When to look for: Early July to mid-August

Crazy top is caused by a systemic infection of downy mildew.

Symptoms

- Infected plants are stunted, crooked and produce abundant tillers
- Tassel often replaced with mass of twisted, leafy tillers

Disease Cycle

- Oospores overwinter within infected tissue or in the soil
- Infection occurs when soil is flooded for 24 to 48 hours between planting and 4 to 5 leaf stage of crop
- Oospores germinate and produce zoospores that swim in water-logged soil and infect growing points of young corn plants

Management

- Adequate drainage offers best means of management

Crazy top is of little economic importance but arouses considerable attention when it occurs because of the peculiar appearance of infected plants.

FIGURE 31. Corn field infected with Goss's wilt.
Photo credit: Morgan Cott, MCGA

GOSS'S WILT (*CLAVIBACTER MICHIGANENSIS* SUBSP. *NEBRASKENSIS*)

When to look for: May to September

Symptoms

- Initially, lesions appear as water-soaked streaks (Figure 34)
- Lesions develop long, greyish, wavy pattern, following the leaf veins
- Within lesions, irregular, water-soaked, dark green to black "freckles" develop - a distinct symptom of Goss's wilt
- Sticky exudate develops within the lesions after a rain event or in high humidity and appears shiny after it has dried
- Lesions may join with other lesions, forming large necrotic areas, potentially taking over entire leaf
- Systemic infection, which occurs earlier in development (even at the seedling stage), results in discoloured xylem tissue and wet, slimy bacterial exudate within the stalk tissues
- Following systemic infection, plants may be stunted, become wilted and die
- Systemic infection is rarely observed in Manitoba

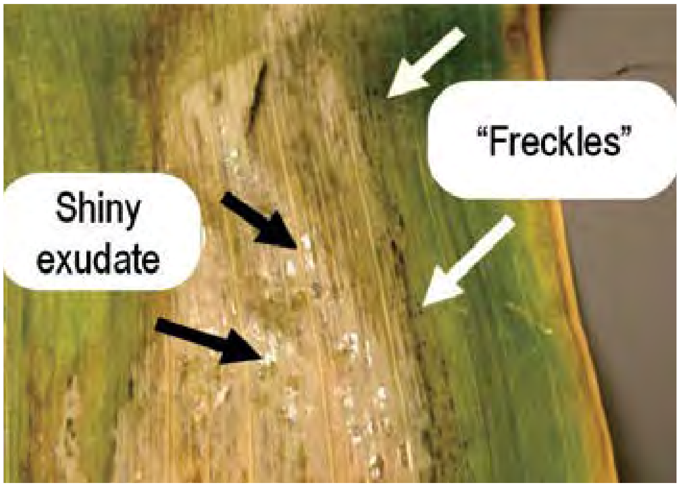

FIGURE 32. Leaf lesions with "freckles" and shiny exudate, distinctive of Goss's wilt.
Photo credit: DuPont Pioneer

Disease Cycle

- Primary source of inoculum is infected corn residue and other host plants (eg. green foxtail and barnyard grass), where pathogen has overwintered
- Pathogen enters corn plant through lesions caused by mechanical damage, winds, heavy rains, hail, etc., and potentially, even through stomates in the leaves
- Transfer of pathogen is mostly via rain splash
- Infection may occur at any stage of development
- Goss's wilt favours wet, humid weather

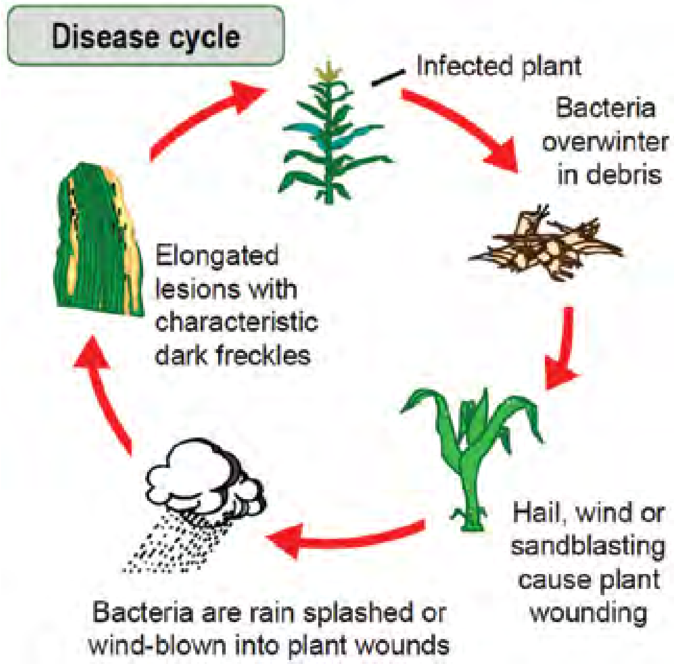

FIGURE 33. Goss's wilt disease cycle.
Photo credit: DuPont Pioneer

Management

- Trash management (tillage) to prevent build up of infected corn residue
- Crop rotation to reduce residue, but disease can also spread from previously infected nearby fields
- Control host weeds including green foxtail and barnyard grass
- Hybrid tolerance is available; individual seed companies assign ratings to their own hybrids

FIGURE 34. Early Goss's wilt lesions.
Photo credit: Morgan Cott, MCGA

FIGURE 35. Advanced Goss's wilt lesions.
Photo credit: Morgan Cott, MCGA

Stalk Rots

When to look for: Mid-August to early October

Stalk rots are typically an issue later in the season during the grain filling stage of plant development. Early in development, corn stalks contain high levels of carbohydrates and, even in the presence of stalk rots, remain structurally strong.

Later in development, as grain filling reduces the reserves of carbohydrates in the stalks, the plants become more susceptible to the effects of the stalk rot pathogens. Therefore, even though symptoms may only appear later in the season, the time of infection may have been weeks earlier.

Scouting for Corn Stalk Rots

When scouting the crop, note any general wilting of the plant. This will occur 40 to 60 days after pollination. Over the next few days, leaves will appear grey, the ear drops, and the outside of the lower stalk turns brown. When the outer stalk tissue has turned brown, the pith tissue in the lowest internode has rotted and separated from the rind, eventually hollowing and, therefore, weakening the stem.

Two methods can be used for scouting for stalk rots:

The Push Test:

Randomly select 20 plants from five areas of the field. Push the top portion of the plant and note whether the plant lodged or not. Record the number of lodged plants.

The Pinch Test:

Randomly select 20 plants from five areas of the field. Remove lower leaves and pinch or squeeze the stalk above the brace roots. Easily squeezed stalks are rotting on the inside. Record the number of rotted stalks.

If 10 to 15% of the plants are affected, then early harvest should be considered to avoid difficulty with lodged plants. Any extra drying costs may be balanced by the increased efficiency of harvest.

ANTHRACNOSE STALK ROT (*COLLETOTRICHUM GRAMINICOLA*)

It is important to note that the same pathogen that causes anthracnose stalk rot can also cause leaf blight in corn.

Symptoms

- Several internodes may be showing infection
- Lodging before maturity
- Sometimes plant portions above ear will die while the lower portions remain green
- Shiny black discolouration at base of stalk initially and later in top killed portions of plant
- Blackened areas may be uniform or in patches
- Internal stalk tissues are often blackened or discoloured, appearing shredded
- Stalk is easily squeezed between thumb and forefinger

FIGURE 36. Midseason symptoms of anthracnose stalk rot, called "top dieback".
Photo credit: Alison Robertson, Iowa State University

FIGURE 37. Anthracnose stalk rot.
Photo credit: Alison Robertson, Iowa State University

Disease Cycle

- Pathogen survives on some weed species or overwinters on infected seed or corn residue
- Infection occurs via roots or when spores splash onto stalk
- Spores produced in leaf lesions act as a secondary source of inoculum
- Insect feeding sites and other wounds also serve as entry points
- Infested corn residues generally spread infection to nearby crops
- The fungus can also enter new fields by wind dissemination of spores associated with dry leaf pieces

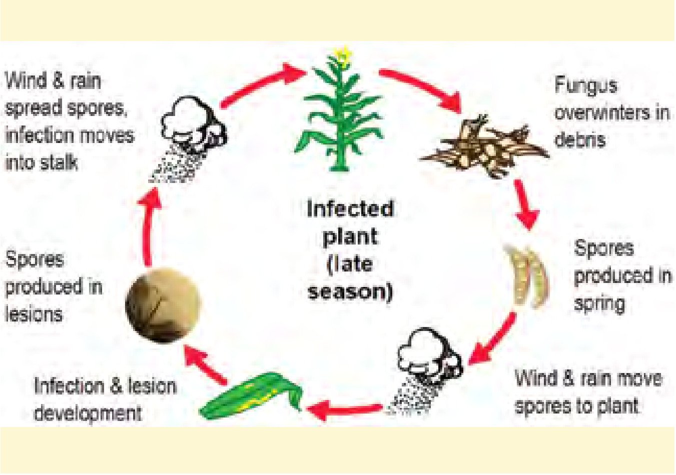

FIGURE 38. Anthracnose stalk rot disease cycle.
Photo credit: DuPont Pioneer

Management

- Crop rotation
- Minimize crop stress - balanced fertility, control damage from insect like European corn borer
- Hybrid selection

FUSARIUM STALK ROT (*FUSARIUM* SPP.)

Symptoms

- Shredding of internal tissues
- Brown streaks on lower internodes
- Rotting stem tissues may appear a hybrid of colours, from beige to whitish pink to orange pink (less intense than pink-red stain of Gibberella stalk rot)
- Decay begins after pollination, increasing in severity as plants mature and more prevalent under warm, dry conditions

Disease Cycle

- Pathogen survives in soil and/or on crop residue
- Favourable conditions encourage infection of roots or wounds on stalks or leaves
- Spore dispersal can occur by wind, rain, insects or birds

Management

- Stress-reducing management practices and avoiding injury to plant, especially the roots
- Hybrid selection

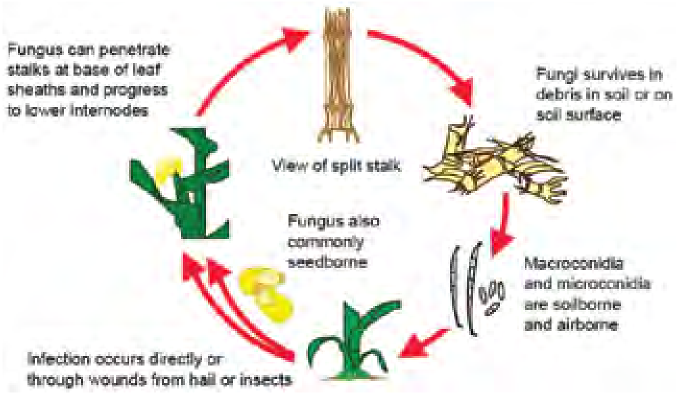

FIGURE 39. Fusarium stalk rot disease cycle.
Photo credit: DuPont Pioneer

FIGURE 40. Fusarium stalk rot on corn stalk.
Photo credit: DuPont Pioneer

DIPLODIA/STENOCARPELLA STALK ROT (*STENOCARPELLA MAYDIS*)

Symptoms

- Initially, a brown to tan discolouration of lower stem
- Internal tissues of lower plant portions appear shredded and easily crushed
- White strands or mats of fungal growth, especially during extended moist periods
- Tiny dark brown to black spots will appear on lower portions of plant, similar to Gibberella stalk rot

FIGURE 41. Corn stalk showing symptoms of Diplodia stalk rot. Photo credit: DuPont Pioneer

FIGURE 42. Corn stalk with Diplodia stalk rot symptoms. Photo credit: DuPont Pioneer

Disease Cycle

- Pathogen survives on stalk debris either in or on soil surface
- In warm, moist conditions and rain, spores are released and spread by wind or insects
- Infection typically occurs through crown, root, mesocotyl and lower nodes
- Insect damage or any wound provides entry points for infection
- Wet weather two to three weeks after silking is suitable for disease development

Management

- Reduce stress on plant
- Hybrid selection
- Rotations of at least one year between corn crops
- Reduce debris in field

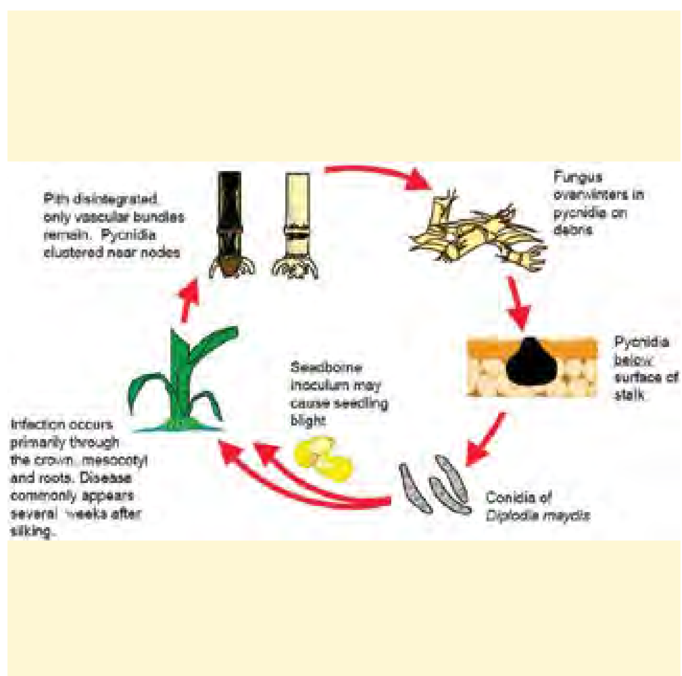

FIGURE 43. Diplodia stalk rot disease cycle. Photo credit: DuPont Pioneer

GIBBERELLA STALK ROT (*GIBBERELLA ZEAE*)

Symptoms

- Wilting leaves, light to dull grey-green in colour
- Lower portions of stalk soften and turn light brown
- Tiny superficial round black specks (perithecia) produced and visible on nodes and surrounding areas; specks are easily scraped off stalk surface
- Internal pith tissue breaks down, leaving only thread-like vascular bundles
- Reddish-pink discolouration observed inside the stalk is a prime symptom of Gibberella stalk rot

Disease Cycle

- Fungi survive on infested overwintering crop residues
- Inoculum may be produced as splash dispersed conidia
- Stalk infections usually occur shortly after pollination, developing at the base of leaf sheaths or near brace roots
- Pathogen may also enter through roots and grow up into the lower stem
- *Gibberella zeae* also causes Fusarium head blight and seedling blights of wheat, barley, oats, and rye

FIGURE 44. Gibberella stalk rot on interior and exterior of corn stalk. Photo credit: DuPont Pioneer

Management

- Crop rotation of a minimum of one year between cereal or grass crops and corn, especially if reduced tillage is practiced
- Plow under residue
- Control weedy hosts and volunteers
- Reduce crop stress
- Hybrid selection

FIGURE 45. Cross section of Gibberella stalk rot on corn stalk. Photo credit: DuPont Pioneer

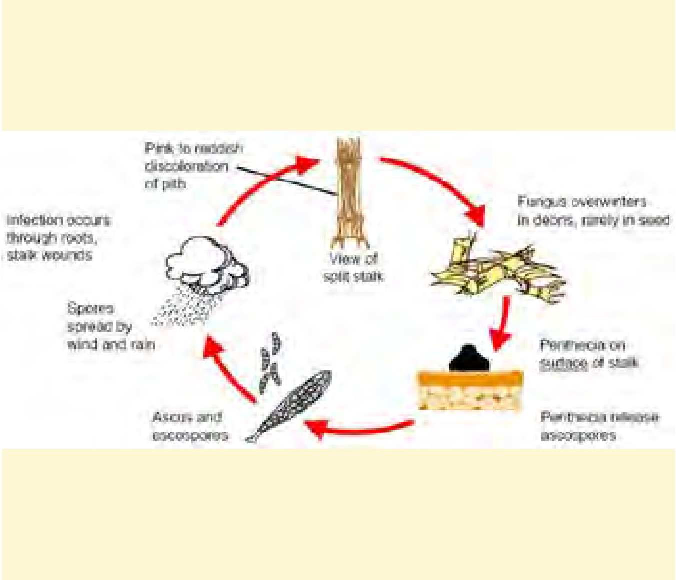

FIGURE 46. Gibberella stalk rot disease cycle. Photo credit: DuPont Pioneer

FIGURE 47. Gibberella stalk rot.
Photo credit: DuPont Pioneer

PYTHIUM STALK ROT (*PYTHIUM APHANIDERMATUM*)

Symptoms

- Generally restricted to internode closest to soil line
- Soft, collapsed, and dark green tissues
- Even after lodging, plants usually remain green as vascular system remains intact
- If infection occurs before flowering, lowest internode decays and infected stalks may have a strong odour
- Internodes may twist, causing plant to lodge, but greenish-brown stem colour remains for weeks
- If infection occurs during milk stage (R3), roots and several lower internodes will become water soaked, leading to early plant death

Disease Cycle

Species of Pythium are water moulds, acting differently from other stalk rot fungi.

- Pathogen overwinters as oospores (tiny hardened structures) which survive dry cold conditions of winter in soil and crop residues
- In spring, oospores germinate and release zoospores or threads of mycelium
- Threads of mycelium infect plants directly
- Zoospores swim through moist soil towards plants and infect via roots
- Oospores may remain viable for years
- The pathogen may be able to survive on weeds

Management

- Avoid poorly drained areas or improve soil drainage

FIGURE 48. Pythium stalk rot on corn plant.
Photo credit: Iowa State University Extension and Outreach

Ear and Kernel Rots

When to look for: Mid-August to October (and during storage)

Reduction in yield and grain quality due to infection by fungi of ears and kernels during both the growing season and while in storage can be severe. In addition, a major concern with many ear and kernel rots (those caused by *Aspergillus*, *Fusarium*, and *Gibberella* species) is the production of mycotoxins. These toxic compounds, produced by the fungal pathogens, can adversely affect the feed value and marketability of the grain. Most mycotoxin contamination occurs in the field, but they may also be produced during storage.

Generally, the likelihood of corn ear or kernel rots increases when seed is damaged. Any factor that promotes the lodging of stalks and enables the ears to contact the ground increases the risk of kernel or ear rots. Ears that are well covered by husks and maturing in a downward position tend to be less prone to rots than ears with open husks or that mature upright. Broken grain particles typically contain higher levels of mycotoxins and may be removed by cleaning the grain.

Ear and Kernel Rots That Begin in the Field

GIBBERELLA EAR ROT OR RED ROT (*GIBBERELLA ZEAE*)

Of all the ear rots, Gibberella ear rot is generally regarded as the most destructive and economically important.

Symptoms

- Dark pink to red mould that progresses from the tip of the ear, downward to the base
- Pinkish-white cottony growth (mycelium) may be visible on husks
- Husks begin to appear bleached and adhere tightly to ear

FIGURE 49. Gibberella ear rot.
Photo credit: Morgan Cott, MCGA

Disease Cycle

- Pathogen survives in soil and on all cereal crop debris
- Fusarium head blight outbreaks in nearby cereals can act as source of inoculum
- Infection occurs either directly through silks or by wounds from insects and birds
- Kernels remain susceptible to infection until physiological maturity

Management

- Hybrid selection – tighter husked hybrids tend to be more severely infected
- Reduce crop residue
- Crop rotations that avoid other cereals
- Scout after silking to determine the levels of disease in the field - if rotted ears are found, early harvest is recommended
- *Gibberella zeae* is still capable of growing and producing the DON (deoxynivalenol) mycotoxin in stored grain

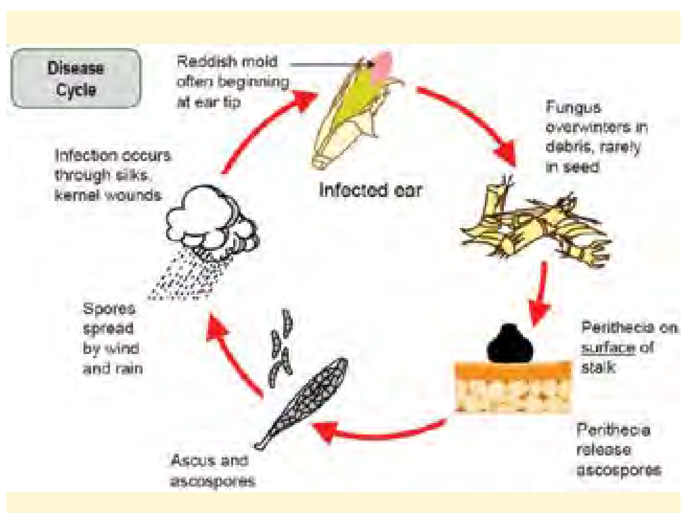

FIGURE 50. Gibberella ear rot disease cycle.
Photo credit: DuPont Pioneer

FUSARIUM EAR AND KERNEL ROT (*FUSARIUM* SPP.)

Symptoms

- Fungal growth on kernels and silks range in colour from almost white with a pinkish tinge to light purple
- Growth can often be found at tip or near damaged parts of ear
- "Starburst" patter of growth (light streaks, radiating from white centre on kernel surface) may be observed
- In severe infections, whitish fungal growth may be observed on and between kernels and entire ear has whitish, weathered appearance

Disease Cycle

- Pathogens overwinter in soil and on crop debris
- Moist weather is favourable for spore production
- Spores infect kernels via the silks
- *Fusarium moniliforme* may also invade the ear via systemic stalk infection
- Warm, wet weather, two to three weeks subsequent to silking, ideal for disease development

Management

- Balanced moisture, fertility and any practice to reduce wounds

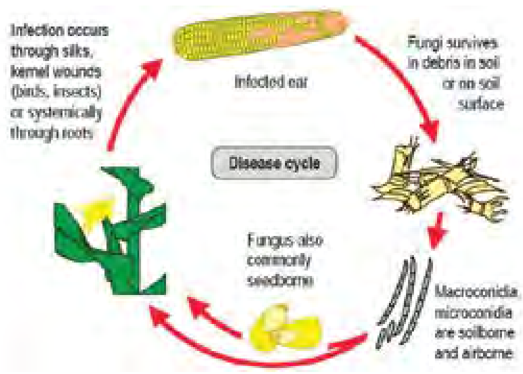

FIGURE 51. Fusarium ear rot disease cycle.
Photo credit: DuPont Pioneer

FIGURE 52. Kernels infected by fusarium ear rot.
Photo credit: DuPont Pioneer

Ear and Kernel Rots That Develop in Storage

Storage rots are caused principally by species of *Aspergillus* (dark brown to green colour), *Penicillium* (bluish-green in colour) and a number of *Fusarium* (light pink to purple to red in colour). These fungi are the most important mycotoxin producers, and they are well adapted to surviving at low moisture content levels. The invasion of these fungi on grain in storage often results in discolouration, heating, caking, and the occurrence of a musty odour.

Storage decay is favoured when kernel moisture content is above 20% and storage temperature is between 21° and 32°C. At moisture contents below 15% and temperatures below 10°C, the risk of storage decay is reduced.

Management

- Store kernels under dry conditions to prevent production of fumonisin mycotoxins

Mycotoxins and Mycotoxin Management

Mycotoxins are potentially poisonous by-products of ear and kernel rots both in the field and in storage. These mycotoxins can be toxic to humans and animals when consumed at high concentrations. Presence of mycotoxins in animal feeds may result in increased mortality, feed refusal, reduced productivity and depressed growth.

Deoxynivalenol (DON) is a mycotoxin responsible for a number of problems in livestock, most notably swine. *Fusarium graminearum*, the causal agent of both Fusarium head blight of wheat and Gibberella ear rot of corn is the major producer of DON in corn. *Fusarium proliferatum* and some forms of *F. moniliforme* can produce fumonisins.

After harvest, it is best to dry down the corn as soon as possible to reduce the growth of fungi, which can continue to produce mycotoxins until the moisture content falls below 15%, depending upon the species involved. However, even though fungal growth has stopped, the mycotoxin level in the corn will not decrease. Mycotoxin contamination in storage is usually the result of improper drying or storage conditions.

To minimize mycotoxin production:

- Follow harvesting recommendations to minimize grain damage as damaged kernels are more susceptible to storage decay
- Dry corn that has been harvested above 18% moisture, unless it is frozen. Corn should be dried to 14 - 15% moisture as quickly as possible
- Thoroughly clean grain bins and grain, if feasible, before storage to remove soil, dust, crop debris and cracked or broken kernels
- Prevent insect, rodent and water damage to corn in storage

Analysis of a feed sample is necessary to detect the presence of mycotoxins. Even if only a few kernels are highly contaminated, the concentration of mycotoxins may be high enough to cause a problem if consumed. When taking grain samples from a bin, collect from a number of areas as storage bins can have "hotspots" within them that are very suitable for mycotoxin production.

Nematodes

When to look for: End of June to mid-September

Nematodes are very small, worm-like organisms that can feed on plants, including corn. Virtually all plant parasitic nematodes live in the soil, feeding on roots and underground stem portions.

Soil temperature, moisture and aeration affect survival and movement of nematodes in the top 15 to 30 cm of soil. Nematode populations contain themselves around plant roots, and generally only spread throughout a field, or to new fields, if assisted by equipment, water runoff, or birds.

NOTE*: As diagnosis based on symptoms alone is not sufficient to conclude a nematode problem is responsible for a reduction in yield, a nematode test is required to identify the levels of nematodes present in the soil. A number of laboratories can perform this service.*

Control of nematodes can be quite difficult and is not always cost effective. As nematodes have a very broad host of ranges, crop rotations may only reduce the numbers of some nematodes, not eliminate them.

Nematodes that are known to cause problems in corn that have been found in Manitoba soils (though not necessarily in cornfields), include the following:

ROOT KNOT NEMATODES (*MELOIDOGYNE* SPP.)

Symptoms

- Similar to symptoms of nutrient deficiencies, soil compaction and low pH soils
- Plants appear stunted or water stressed with knotted, galled, or stunted roots
- Scattered patches of infected plants in the field

ROOT-LESION NEMATODES (*PRATYLENCHUS* SPP.)

Symptoms

- Fibrous and coarse corn roots have dark brown dead patches that may cover the entire root system
- Infected roots may develop a significant number of lateral roots
- Severely stunted plants may be distributed in patches or suppress the growth of the entire field
- In severe infestations, plants appear chlorotic
- Yield losses can be as high as 100%

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Wise, K., Mueller, D., Sisson, A., Smith, D., Bradley, C., & Robertson, A. (Eds.). 2016. A Farmer's Guide to Corn Diseases. St. Paul, MN: APS Press.

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SECTION 8

INSECTS IN CORN

Belowground and Surface Feeders

Insects that may feed belowground on corn include cutworms, wireworms, seedcorn maggot and corn rootworms. Cutworm feeding varies with the species, and some may also defoliate seedlings above the soil surface.

CUTWORMS

Several species of cutworms can occur in corn fields in Manitoba. Appearance can vary greatly, depending on the species. Most cutworms feed at night and most damage occurs between mid-May and the end of June, depending on the stage of the crop and species of the cutworm.

Cutworm infestations are infrequent and unpredictable. Some species of cutworms will cut plants off at the soil surface, while other species will defoliate but are less likely to cut plants. Sometimes only part of a field, or distinct patches will have high levels of cutworms. In such instances, only spraying patches or part of the field may be practical. If high populations are noticed in an area, scout several areas of the field to determine the distribution throughout the field.

Sampling and Thresholds

Sampling Technique:

Early detection of economic infestations means that an insecticide can be applied before serious damage occurs. Scouting for cutworms should begin as soon as the corn emerges and continue at least weekly until the plants reach the 6-leaf stage.

To monitor for cutworm damage, randomly check 20 plants in each of 5 areas of a field (100 total plants).

While walking through the field, observe the evenness of cutworm infestations.

Cutworms remain hidden in the soil or under crop residue during the day. Look for live cutworms around freshly damaged plants. First, check under clods or plant residue around the base of plants. Then, dig up an area about 8 cm in radius and 8 cm deep around the plant. Under dry conditions, cutworms are found lower in the soil. If most residue is between the rows, the cutworms may be found there instead.

Record the number and average length of the live cutworms, and the species causing the damage if you know this. Also record the number of cut or damaged plants for each area and the field as a whole.

Economic Thresholds:

Foliar insecticides are recommended when 2 - 4% of the plants are cut below the ground or 6 - 8% of the plants are cut above the soil surface, and cutworms less than 1 inch long are present.

Damage below ground is more likely to kill the growing point, which is below ground until the 6-leaf stage. Plants are more likely to survive feeding if it occurs above the growing point of the plant.

Control

Biological Controls:

Ground beetles can be important predators of cutworms. Bees, flies, tachinid flies and a several species of parasitic wasps may parasitize cutworms. Wet soil conditions during the larval stage promote fungus diseases among cutworms and also force them to feed at the soil surface where they are subject to the attack of parasites and predators.

Insecticides:

Foliar insecticides are available for controlling cutworms after economic populations appear. Since cutworms are most active on a warm night, best control can be obtained if spraying is done on a warm evening. Insecticides used for control of cutworms are best applied just before cutworms emerge, or shortly afterwards, because the cutworm will ingest the treated plant material, and die. Seed treatments are also available to help manage cutworms in corn.

For recommended insecticides and rates of application, see the Manitoba Agriculture publication "Guide to Field Crop Protection".

FIGURE 53. Dingy Cutworms.
Photo credit: John Gavloski, Manitoba Agriculture

WIREWORMS

Wireworms are larvae of a family of beetles known as click beetles (*Elateridae*). There are many species that can feed on crops, and in Canada there are about 30 economically important species of wireworms. Larvae can live for several years, and different species may prefer different conditions.

Wheat, rye, corn, beans, potatoes and many other crops are susceptible to injury by wireworms. Corn grown in newly broken, lighter soils is at a higher risk of damage by wireworms and other soil pests. Wireworms bore into the kernels soon after planting and eat the contents. Later, they feed on the underground portion of the stem, causing the young plants to wilt and die. Wireworms do the most damage in early spring when they are near the soil surface. During summer months, larvae move deeper into the soil where it is cool and moist.

Identification:

Wireworms are slender, have hard bodies, and have 3 pairs of legs behind the head. The last abdominal segment is flattened with a keyhole-shaped notch. Wireworms do not curl up when disturbed, as cutworms will do.

Sampling and Thresholds

Sampling Techniques:

Baits or sieving soil can be used to sample wireworms. Baits buried at marked locations in the spring or late summer can indicate where wireworms are present. Several types of bait have been studied for monitoring wireworm populations, including presoaked corn/wheat mixtures, oats, and potatoes.

Baits are buried 7.5 to 15 cm deep in the soil, and checked for wireworms 7 to 10 days later. Competition from an abundant food supply in the soil around where the baits are buried can greatly reduce the number of wireworms recovered. Soil may also be sieved through a screen to look for wireworms.

Economic Thresholds:

Not established

Control

Cultural Controls:

Shallow seeding into moisture and firm packing may reduce damage.

Insecticides:

Where it seems evident from previous crop damage that a wireworm population sufficiently large to be economically damaging is present, the use of a seed treatment containing an insecticide may be profitable.

FIGURE 54. Wireworm larvae.
Photo credit: John Gavloski, Manitoba Agriculture

SEEDCORN MAGGOT (*DELIA PLATURA*)

Adult seedcorn maggots are greyish flies that are very similar to house flies, but about half the size.

Eggs are laid on moist soil high in organic matter, or near decaying vegetation. The larvae, or maggots, have no legs, are cylindrical in shape and they taper at their head area. Mature larvae are about 8 mm long.

Damage

Crop damage is caused solely by the larval/maggot stage, as they burrow into and feed on the corn or other seeds and destroy the seed germ. The seed may still germinate, producing weak plants, but often the seed is left unviable and no plant is produced, reducing yield. Seedcorn maggots also feed on underground stems, leading to weakened plants that rarely survive.

The female flies prefer to lay their eggs in recently plowed fields with decaying organic matter (such as when manure or green plant residue has been incorporated). The maggots may feed on this decaying organic matter before they move to the germinating seeds.

Any conditions that delay germination may increase damage from seedcorn maggot. Damage is more severe under cool temperatures and wet soil conditions.

FIGURE 55. Seedcorn maggot and damage in bean seed.
Photo credit: John Gavloski, Manitoba Agriculture

Sampling and Thresholds

Sampling Method:

Examine soil by digging in areas where plants have failed to emerge. Check un-germinated seed for injury and presence of maggots.

Economic Thresholds:

Not established.

Control

Biological Controls:

Ground beetles and rove beetles feed on eggs, larvae and pupae. Fungal and bacterial pathogens may also provide some control.

Cultural Controls:

Planting under ideal conditions is a good management practice, since it allows the crop to germinate and emerge quickly and overcome insect stresses.

Delaying planting after tillage, to allow maggots to develop through to pupation, can help reduce damage.

Insecticides:

For fields at high risk, a seed treatment can reduce damage to seeds. Check Manitoba Agriculture's Guide to Field Crop Protection for a list of seed treatments registered for seedcorn maggot in corn. Foliar insecticides are not a control option.

NORTHERN CORN ROOTWORM (*DIABROTICA BARBERI*)

Damage

Corn rootworm larvae feed on corn roots, clipping the roots back and tunneling into the larger nodal and brace roots.

This can result in yield loss, as the damaged roots may not be able to acquire needed nutrients, or physically support the growing plant.

Damaged plants may lodge or develop a curved "goosenecked" stalk. Lodged plants often pollinate poorly and are difficult to harvest, contributing to yield losses. Lodging in corn can also be caused by other factors, however, such as severe winds, especially after a rainfall, or feeding injury from other root-feeding insects.

Sampling Methods and Thresholds

Larvae:

Sampling for larvae can be done between mid-June and mid-July. Use a knife to cut the plant stalk off at about 30 cm above the ground. Using a spade or shovel, cut an 18 cm cube of soil around the base of each plant, making certain that the blade of the tool enters the ground vertically to avoid cutting roots. Lift the plant and soil out of the ground and place them on a small piece of dark canvas or plastic. Slowly break the soil away from the roots, and carefully examine the soil and roots for larvae. The dark background will make it easier to find the small white larvae. The soil and root sample can also be washed in a pail of water to extract the larvae. The rootworms will float to the top and can be counted.

Adults:

After corn pollination, visual counts of adults can be done to determine the potential for larval problems the next year. Start scouting three weeks after pollination and continue once per week until silks are dry and brown. Randomly select 10 nonconsecutive plants in 10 representative locations throughout the field for a total of 100 plants. During inspection of corn ears, carefully cover the silk with one of your hands, then count the number of adults present by slowly allowing your hand to open. Gently disturb silks near the ear tip to dislodge and force beetles to exit. Also check the stalk, upper and lower leaves, leaf axils and tassel for corn rootworm beetles. Pull leaves down when inspecting the leaf axils because adults often hide inside them. Count and record the average number of adults per plant.

FIGURE 56. Northern corn rootworm.
Photo credit: Morgan Cott, MCGA

As a threshold for first-year corn: Management in the following year's corn crop is recommended if counts average two or more adults per plant for northern corn rootworm. For continuous corn, management in the following year's corn is recommended if a field averages three or more adults per plant for northern corn rootworm.

Corn rootworm adults can also be monitored using yellow sticky traps. Put traps out starting in early August. Attach the sticky trap on the corn stalk at ear height. Replace traps once per week for four to six weeks, or until the threshold is reached. Count and record the number of beetles caught on each trap. As a threshold, a capture rate of six or more beetles per trap per day indicates that a high corn rootworm population is expected the following year, and management options will likely be necessary to protect the following year's corn crop.

Control

Crop rotation:

Crop rotation is the primary management strategy for control of northern corn rootworm. Larvae can survive only on the roots of corn and a limited number of grasses, and cannot travel far in search of food. If there are no corn roots to feed on when larvae hatch in the spring, larvae will starve.

Biological Controls:

Natural enemies of corn rootworm include ground beetles, rove beetles, ants, mites, spiders and centipedes.

Resistant Cultivars:

Some cultivars of Bt corn are resistant to feeding by corn rootworm. A table of registered Bt corn cultivars in Canada is available on the Canadian Corn Pest Coalition website at:

www.cornpest.ca/bt-corn

Insecticides:

There are seed treatments registered to help manage corn rootworm, although much higher rates are needed than would be used for other early-season insects in corn such as wireworms and seedcorn maggot.

Sap Feeders

Insects that feed on the sap of corn plants include aphids and spider mites. This can be by either feeding on the phloem sap, as aphids do, or biting into cells and consuming the content, as spider mites do.

TWOSPOTTED SPIDER MITES (*TETRANYCHUS URTICAE*)

The twospotted spider mite has tiny, straw-coloured eggs which take from 3 to 19 days to hatch, less in warmer temperatures. Their larvae are initially six-legged, colourless and have a body shape comparable to that of the nymph or adult, but their size is more similar to that of the eggs.

Twospotted spider mites later turn into eight-legged nymphs and look like an adult, yet smaller and sexually immature.

Adults range in colour from pale yellow, green, orange to brown. They have two pigmented spots that are visible when viewed from above, but they are actually the gut contents that are visible through the body wall. Adult males are approximately 0.3 mm long and females are 0.4 mm long. Adults overwinter in non-crop and weedy areas such as grassy waterways, roadsides, weeds, set-aside acres, and pastures.

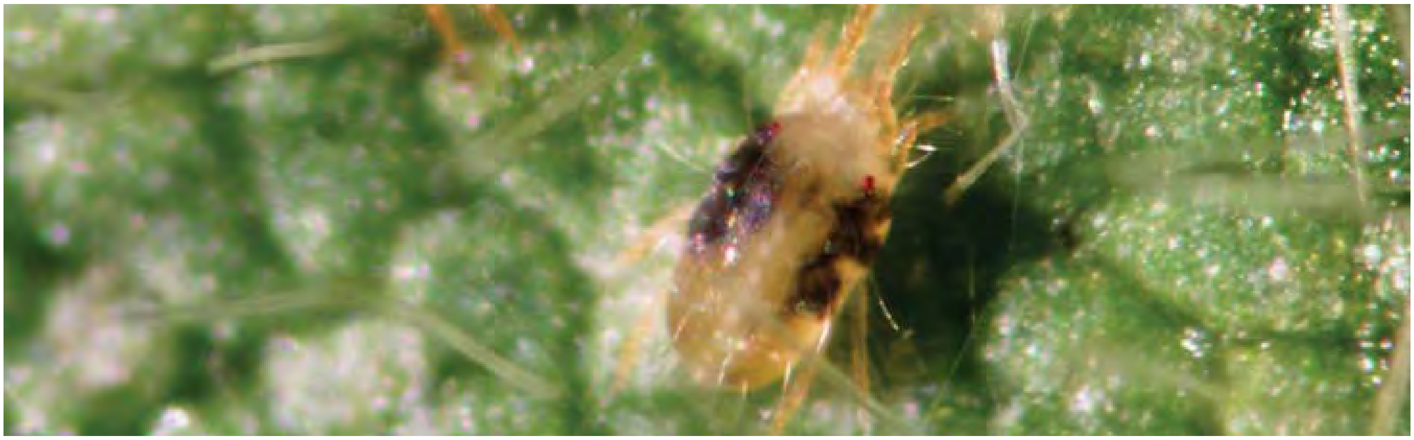

FIGURE 57. Twospotted spider mite on soybean leaf.
Photo credit: John Gavloski, Manitoba Agriculture

Damage

The twospotted spider mites feed by biting into leaf cell walls and sucking out the contents, killing that cell. Damage will appear as leaf yellowing and the development of brown, necrotic leaves, followed by stunted plants. Leaves will have a mottled or "sand blasted" appearance. Damage in corn often begins near overwintering sites.

Populations may increase significantly if high temperatures are associated with dry conditions. Dry conditions can reduce naturally occurring pathogenic fungi and predators that normally keep populations at non-economic levels.

Outbreaks may be enhanced when corn has been treated with some insecticides and fungicides. These pesticides, although not normally toxic to twospotted spider mites, greatly reduced the numbers of predators and pathogens that normally keep populations in check.

Sampling and Thresholds

Sampling method:

If hot, dry conditions persist for several weeks, watch for leaf discoloration (yellowing) especially along field borders or near grassy areas within fields. Carefully inspect these areas for the presence of spider mites. Shake some discolored leaves over a white piece of paper or a tray and watch for small dark specks moving on the paper or tray.

Also look for webbing on the undersides of discolored leaves. If spider mites have been identified as the cause of the damage, scout the whole field to determine the range of the damage. Estimate the average percentage leaf discoloration for the plants within the damaged area.

Threshold:

Control may be necessary when 15% to 20% of the leaf area is covered with spider mite colonies, moderate damage is noted, and hot, dry conditions are expected to continue.

The greatest benefit from control normally occurs when miticides are applied from the pre-tassel through the soft dough stages of plant development. It is unlikely that application of a miticide will be cost effective once the dent stage is reached.

Control

Biological Control:

Some naturally occurring fungal pathogens, which are favoured by humid conditions, can reduce damage by spider mites. Twospotted spider mites also have many natural predators, including lady beetles.

Miticides:

Miticides are available for spider mite control in corn. Thorough coverage of corn leaves with a miticide is difficult, but necessary for spider mite control. Note that product choice is crucial as some insecticides may increase spider mite levels.

Borers

Insects that may bore into the stalks of corn include the European corn borer, and the stalk borer (*Papaipema nebris*).

EUROPEAN CORN BORER (*OSTRINIA NUBILALIS*)

The European corn borer will feed on grain, silage and sweet corn, but has a wide variety of other host plants, including potatoes, beans, hemp and many species of large stemmed flowers and weeds.

In Manitoba, there is only one generation of corn borer per year. Infestations are quite variable from year to year with some areas experiencing heavy infestations while other areas have little or no damage.

Life Cycle

The European corn borer has four stages in its life cycle:

Adult:

Adult moths are tan coloured, with brown markings on the wings. The male moths are darker with darker markings than females. The adult moths emerge from the pupae in late June and early July. They are about 12 mm long with a wingspan of 25 mm and are strong fliers.

Newly emerged adults seek out dense areas of vegetation, preferring grassy ditches where they congregate and mate. After mating, females lay eggs during calm, warm summer evenings on the underside of corn leaves near the mid-rib.

Egg:

Each egg mass consists of 10-40 eggs. Newly laid eggs are white and overlap, resembling fish scales (Figure 58, upper egg mass). Just before the eggs hatch, they appear black, caused by the dark heads of the young borers inside the eggs (Figure 58, lower egg mass). This is referred to as the "black-head" stage, and these eggs normally hatch within 24 hours.

FIGURE 58. Egg masses of European corn borer.
Photo credit: John Gavloski, Manitoba Agriculture

Larvae:

There are five larval instars of the corn borer. The first instars are whitish with black heads. The first two instars complete development in 7-10 days. The third larval instar bores into the stalk, after which point it's too late to achieve effective chemical control. The later instars (3rd to 5th) feed within the stalk and ear shanks. These full grown larvae vary in colour from gray to creamy white and have numerous black spots. Once they are finished feeding, the mature larvae overwinter in corn stalks, cobs and plant debris on the soil surface.

FIGURE 59. European corn borer larva.
Photo credit: John Gavloski, Manitoba Agriculture

Pupae:

In the spring, mature larvae that survived the winter turn into pupae.

Damage

Yield loss from European corn borer is primarily from stalk tunnelling, which causes physiological stress. The later in the development of the crop that larvae begin tunnelling, the less direct impact on yield occurs. Restricted nutrient flow in the plant can result in the production of smaller cobs. In addition to the direct impacts of the tunneling, tunnelling in stalks and ear shanks increases the risk of stalk breakage and dropped ears with persistent autumn winds.

Sampling and Thresholds

Sampling for Egg Masses and Young Larvae:

Field scouting for corn borer should begin in early July. Prioritize fields by planting date and relative maturity, scouting oldest fields first.

In each field, check 10 locations (10 plants at each location) for egg masses and young larvae. Females are attracted to corn silks and lay more egg masses on leaves near the ear. The egg masses are most commonly found on the underside of the leaf, in the midrib and leaf axil.

At each location, pull open the whorl to check for larvae feeding. If the majority of the larvae have bored into the stalk, it is no longer economical to apply an insecticide, as it won't reach the larvae. If no larvae or egg masses are found, repeat scouting every 5-7 days, and continue scouting until larvae start to tunnel into the stalk or the end of July if no egg masses or larvae are found.

Thresholds:

For grain corn, the average grain weight reduction when stalk feeding was initiated during the 10-leaf, 16-leaf, blister, and dough stages were 5.94, 5.01, 3.13, and 2.41 percent per larvae per plant, respectively. Using an average of 5% yield loss per corn borer, the following economic threshold table can be used:

TABLE 10. Economic threshold of European corn borer in grain corn.

	Crop Value[1] ($/Acre)								
Control Costs[2] ($/Acre)	200	250	300	350	400	450	500	550	600
6	0.75	0.60	0.50	0.43	0.38	0.34	0.30	0.27	0.25
8	1.00	0.80	0.67	0.57	0.50	0.45	0.40	0.37	0.34
10	1.25	1.00	0.83	0.71	0.63	0.56	0.50	0.46	0.42
12	1.50	1.20	1.00	0.86	0.75	0.67	0.60	0.55	0.50
14	1.75	1.40	1.17	1.00	0.88	0.78	0.70	0.64	0.59
16	2.00	1.60	1.33	1.14	1.00	0.89	0.80	0.73	0.68
18	2.25	1.80	1.50	1.29	1.13	1.00	0.90	0.82	0.75

[1]Crop Value = expected yield (bu/acre) X projected price ($/bu)
[2]Control Costs = insecticide price ($/acre) and application costs ($/acre)

Control

Cultural Control:

Mowing corn stalks after harvest can reduce overwintering populations. Corn harvested for silage results in high corn borer mortality.

Crop rotation will help control populations.

Biological Control:

Natural enemies that will feed on corn borer larvae include lady beetle adults and larvae, hover flies, green lacewing larvae, and parasitoids. Minute pirate bugs will feed on eggs of European corn borer and other caterpillars on corn.

Heavy rains that occur before larvae are able to burrow into the plant may kill borers by drowning them or by physically removing them from the plant. In addition, rain accompanied by high winds may reduce levels of adult European corn borers.

Insecticides:

Insecticide recommendations can be found in Manitoba Agriculture's "Guide to Field Crop Protection".

> CAUTION: *Honey bees will forage for pollen from corn, with peak foraging in the morning and early afternoon. If the corn is producing pollen and insecticides toxic to honey bees are to be used, insecticide application to corn should be timed to avoid this peak foraging activity of honey bees.*

Bt Corn:

Bt corn is a type of corn that has been genetically modified. Bt stands for *Bacillus thuringiensis*, a bacterium that has insecticidal properties when ingested by certain types of insects. In Bt corn cultivars the Bt is right in the corn plant. The only way insects are exposed to it is by eating the corn tissue. Some cultivars of Bt corn may also control other moth larvae such as corn earworm.

A table of currently registered Bt corn hybrids in Canada, and refuge requirements, can be found at the Canadian Corn Pest Coalition website:

www.cornpest.ca/bt-corn

Resistance Management:

The European corn borers have the potential to develop resistance to the Bt proteins found in Bt corn, so measures must be taken to ensure that resistance does not develop, or is delayed.

The simplest approach is to not plant Bt corn every year, or use Bt hybrids only in fields where the risk from corn borer infestation warrants the price premium for the seed. In addition to this approach, a refuge of non-Bt cultivars is required to be planted to reduce the odds of European corn borer developing resistance to Bt corn. There are 2 types of refuge.

Some cultivars of Bt corn will be purchased containing an integrated refuge (sometimes referred to as refuge-in-a-bag), where seeds of a refuge cultivar have been pre-mixed with seeds of the Bt cultivar in the bag. This integrated refuge typically comprises 5% or 10% of the seeds in the bag.

Other Bt cultivars will not have an integrated refuge blended in, in which case blocks or strips of a cultivar of corn susceptible to European corn borer needs to be planted within or adjacent to the Bt cultivar.

This is called a structured refuge. Planting a non-Bt refuge is a requirement set by the Canadian Food Inspection Agency. Failure to comply with refuge requirements may lead to insect resistance, slow down the introduction of new Bt corn technologies, and affect individual grower's access to these products.

Growers of Bt corn are also required to monitor their crop for the presence of European corn borer and any feeding damage.

On or In the Cob

Insects that are found primarily on or in cobs of corn include corn earworms and the fourspotted sap beetle. Neither of these are considered major pests of field corn, although corn earworm can be a significant pest of sweet corn.

Corn Earworm (*Heliocoverpa zea*)

Corn earworm has a wide host range, feeding on many cultivated crops and weeds. The damage to field corn is not considered economic, however it can be a major problem on sweet corn. Earworms feed almost exclusively on the tips of the ears, leaving no visible damage on the husks or leaves.

Corn earworms do not overwinter in Canada. Adult moths are good flyers however, and in some years can migrate from crops in northern Mexico and southern United States into Canada.

FIGURE 60. Corn earworm larva.
Photo credit: John Gavloski, Manitoba Agriculture

Identification:

Corn earworm eggs are spherical, and approximately the same color and width as the corn silk it is laid on.

Larvae will grow to be about 38 mm long. Their bodies can be any range in colour from pale greens, brown to nearly black, and they have very distinct stripes running down their bodies.

FIGURE 61. Corn earworm larva on sweet corn.
Photo credit: John Gavloski, Manitoba Agriculture

Corn earworm moths are tan-coloured with a 38 mm wingspan. Their front wings have an irregular, wavy dark marking at the back and a brown “comma-shaped” dot in the middle of the wing that is more easily visible from the underside of the wing.

Damage

Corn is susceptible to eggs being laid and larval feeding when at the silking stage. Moths lay their eggs on the silks and, upon hatching, the larvae travel down the silks and start feeding on the kernels. They feed on each other as well, which tends to limit the number of larvae to one per ear. As the larvae grow, they move further down the cob, normally not reaching past the top third of the cob. When scouting, you will notice the ear tips have been fed on and some large, moist pellets (fecal matter of the earworm) in the silk channel. When done feeding, mature larvae will fall to the base of the corn plant and pupate in the soil.

Sampling and Thresholds

Sampling:

Adult corn earworms can be monitored using pheromone-baited traps, starting before silks appear. Continue monitoring until the last planting no longer has any fresh silk showing.

Thresholds:

Control of corn earworms with insecticides is generally not economical in field corn.

In sweet corn, corn earworms may need to be controlled every three to seven days while fresh silks are present, depending on trap counts. For best results, insecticide applications can be based on trap counts and temperature.

Control

Biological:

Lady beetles, lacewings, predatory bugs and parasitic flies and wasps are all natural predators of corn earworm.

Cultural Controls:

Early seeding may result in the harvesting of sweet corn before the arrival of corn earworm.

Resistant varieties:

Any corn variety with long, tight husks is physically safer from earworms. Some Bt corn hybrids offers some control of corn earworm.

FOURSPOTTED SAP BEETLE (*GLISCHROCHILUS QUADRISIGNATUS*)

In years when they are abundant, adults of the fourspotted sap beetle can be quite noticeable on corn plants late in the season. Moist, fermenting pollen on the corn silks may possibly attract the beetles to the ears of corn. The beetles may bore into kernels of corn initially injured by other insects or birds. Sound ears of corn may occasionally be fed on when the beetles are numerous.

Larvae develop on various types of decomposing plant materials such as spilled grain, corn ears, waste onion piles, etc. The food of the larvae must be moist and either buried in the soil or in contact with it. They will not occur on corn ears still on the standing plant.

They overwinter as adults, and ears of corn left in the field are often a main source of decaying vegetation that they lay eggs into in the spring. Adults are capable of locating ears buried under 7.5 to 15 cm of soil.

Fourspotted sap beetles are also attracted to the fermenting frass of European corn borer, and have been known to congregate in the tunnels of the corn borers and reduce populations. This reduction in corn borers is believed to be caused by mechanical injury with subsequent direct attack on weakened or dying larvae.

Fourspotted sap beetle is not considered a major economic concern in field corn, but can be quite noticeable in years when they are abundant.

FIGURE 62. Fourspotted sap beetle.
Photo credit: John Gavloski, Manitoba Agriculture

Defoliators

Defoliators on corn include armyworms and grasshoppers. Cereal leaf beetle (*Oulema melanopus*) will feed on corn, but is more of a concern on small grain cereals than corn.

ARMYWORMS (*MYTHIMNA UNIPUNCTA*)

Armyworms do not overwinter in Manitoba, but in some years they move in from the South.

Armyworms are only sporadically an economic concern of corn in Manitoba.

Identification:

Newly hatched armyworm larvae are mostly pale green, and in daylight hours they can be found in the folded leaves of the whorl of the corn plant. Once grown to 19 mm - 25 mm, the larvae turn brown with colour variations among individuals. Mature larvae reach up to 38 mm with a thin white stripe down the centre, and stripes along each side of the body.

FIGURE 63. Armyworm adult.
Photo credit: John Gavloski, Manitoba Agriculture

FIGURE 64. Armyworm larva on oats.
Photo credit: Morgan Cott, MCGA

The adult moths are pale brown with a noticeable white dot in the centre of the front wings, and a wingspan of about 38 mm. The moths are active at night and hide in grass and trash during the day.

Armyworm eggs are mainly white with a light green hue, and are laid in clusters on lower leaves of grass and corn plants.

Damage

Early instar larvae skeletonize the surface of the leaf blades or the inner surface of the sheath, and later feed from the margins of the leaves, consuming all the tissues. Larger larvae may also feed on corn ears or tassels.

Sampling and Thresholds

Sampling Techniques:

Adults:

Influxes of moths from the south, during May and June, can be monitored using pheromone traps.

Larvae:

Examine 20 plants in 5 areas of the field and determine the percentage of damaged plants.

Also note the number of larvae found and their size. During the day, larvae may be found under plant residue on the soil, or in the whorl of the plant.

Early symptoms in corn may include ragged feeding on the top leaves, and wet, brown pellets (feces) in the area.

Economic Thresholds:

For corn past the 6-leaf stage, if 50% of the plants are showing damage and have larvae smaller than 25 mm, insecticide treatment may be warranted. As long as the growing point of the plant is not damaged, the corn plant is usually able to recover from moderate feeding.

With early-season feeding, insecticide may be warranted in seedling corn if there are two or more unparasitized larvae per seedling and feeding damage exceeds 10%.

Control

Cultural Controls:

Since barnyard grass and some other wild and cultivated grasses are common hosts of armyworms, weed control may help.

Insecticides:

If economic threshold levels are exceeded, insecticides are most effective when applied to small larvae. Spraying should be done in the evening when armyworms are feeding on the plants. Only infested areas of the field may need to be treated. Levels may vary between locations in a field, so assess how widespread the higher levels are.

SECTION 9

DIAGNOSTICS

MANITOBA
CORN GROWERS
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Diagnostics

Regular field scouting is important in order to spot problems or potential problems. In addition to disease and insect damage, there are a number of abnormalities that producers may observe as they scout their fields. Producers may need to consult an agrologist for the cause and remedy, if any, for some forms of crop damage. Some of the more common types of issues observed in corn include:

POOR SEEDLING EMERGENCE

Causes include variability in soil moisture and temperature, uneven planting depths, poor seed bed preparation, feeding by insects or birds, or root diseases.

> SCOUTING TIP: Look for patterns in the field; is the stand uniformly poor or are there areas with skips or stunted plants?

Dig up seed in a few spots with uneven emergence and compare placement and seed bed conditions to areas with good emergence to diagnose issue. If no seed is present, this may be due to planter malfunction, or bird or rodent damage.

Poor stands can also result from poor seed bed conditions such as surface crusting. In this case, a germinated seed may be unable to emerge, resulting in a malformed seedling. If seedlings emerge but later die or are in poor condition, the cause may be root damage from insects or diseases. See insect and disease sections for more information.

FERTILIZER DAMAGE

Seedling Damage

Placement of fertilizer, especially phosphorus, beside or with the seed is most efficient from the standpoint of nutrient uptake. However, excessive rates of fertilizer applied with the seed may cause damage from ammonia toxicity or salt injury. Fertilizer burn results in reduced root growth and blackened areas on the roots. Damage is more severe on sandy soils that are dry and remain dry after seeding.

FIGURE 65. Stand loss due to preplant band urea intersecting corn rows.
Photo Credit: John Heard, Manitoba Agriculture

Ammonia toxicity from ammonium-based nitrogen sources (i.e. urea, UAN solution, ammonium sulphate, or diammonium phosphate) can result in delayed emergence and reduced stands. Embryos may turn brown and die soon after emerging from the seed or seedling leaves may turn yellow with brown necrotic tips. Roots may be brown and short. Reduced stands can also be observed if corn rows are inadvertently seeded directly over bands of preplant-applied anhydrous ammonia. Ammonia should be applied on a slight diagonal direction to minimize seedling damage.

Salt injury occurs when fertilizer applied too close to the seed draws water out of the germinating and emerging plant. Salt-damaged seeds may be slow to emerge. Salt-damaged roots are injured by desiccation, and will result in slow growing, wilting, or dried out above-ground tissue. Fertilizers with high salt index and greater seedling risk are potash (KCl), ammonium nitrate, and urea.

More information on safe rates, forms, and placement of fertilizer can be found in the Nutrient Management section on page 34.

Excess Fertilizer

Excess rates of fertilizer placed close to the seed may also cause the problems described above. At later growth stages, excess nitrogen will give lush green foliar development but delayed maturity. Excess nitrogen availability later in the season may lead to nitrate accumulation in silage corn, resulting in nitrous oxide or “silo gas” release during the ensiling process. Caution must be used after silo filling to prevent silo gas poisoning.

Excess phosphorus will generally not create problems but can induce or intensify zinc deficiency. Similarly, excess sulphur or potassium will generally not adversely affect growth unless placed with the seed.

Foliar Application

Foliar applications of UAN solutions and other liquid fertilizers will frequently scorch leaf tips, edges, and other plant parts directly contacted by the solution. The tissue dies and may serve as a source of infection for diseases.

FIGURE 66. Recovery from UAN solution dribble into the whorl.
Photo credit: Manitoba Agriculture

FIGURE 67. Nitrogen deficient corn (L) versus non-deficient corn (R).
Photo credit: John Heard, Manitoba Agriculture

NUTRIENT DEFICIENCIES

Visual nutrient deficiency symptoms may be mistaken for similar symptoms caused by adverse weather, diseases, insects, soil compaction, herbicide damage or other factors. Visual symptoms are most reliable when they cover broad areas and are related to a soil or management pattern. Field diagnosis should be verified by reliable soil tests or plant analysis.

The part of the plant affected and the type of discolouration or distortion characterizes the nutrient deficiency symptom. Nutrients that are mobile within the plant (N, P, K and Mg) will move from older leaves to newer growth, so symptoms appear in older growth. Other nutrients are less mobile within the plant so deficiency symptoms tend to appear in the newest growth.

Nitrogen

Nitrogen deficiencies cause stunted, spindly, yellow plants, reduced yield and delayed maturity. Older leaves will show a V-shaped yellowing of the inner leaves with margins remaining green. Old leaves show deficiencies first.

Phosphorus

Deficient seedlings appear stunted and weakened. Leaves and stems will often show purpling or reddening. Ears may have irregular rows and twisted ends with underdeveloped kernels and grain will have higher moisture content at harvest.

FIGURE 68. Non-deficient corn (top) versus stunted, phosphorus deficient corn (bottom).
Photo credit: John Heard, Manitoba Agriculture

FIGURE 69. Phosphorus deficient corn following canola in the crop rotation.
Photo credit: Morgan Cott, MCGA

Potassium

Yellowing and drying of leaf margins, especially on older leaves; stunted plants with short inter-nodes; delayed maturity and plants may frequently lodge late in the season.

FIGURE 70. Potassium deficient corn.
Photo credit: John Heard, Manitoba Agriculture

Sulphur

General stunting, delayed maturity, and yellowing of new foliage. Deficiencies are most likely to occur in well-drained soils, and soils with low organic matter.

FIGURE 71. Sulphur deficient corn.
Photo credit: John Heard, Manitoba Agriculture

Zinc

Deficiency results in interveinal chlorosis on new corn leaves. Pale white bands between the leaf margin and mid-vein in the basal part of leaf, and under severe deficiencies, new leaves may be completely white.

FIGURE 72. Zinc deficient corn.
Photo credit: Morgan Cott, MCGA

DIAGNOSTIC SOIL AND TISSUE SAMPLING

Since visual deficiency symptoms may be similar for various nutrients, proper diagnosis is often dependent upon both tissue and soil testing. Tissue sampling can be done in two ways—at a specific growth stage in order to compare to textbook values, or at the time symptoms occur to compare suspect vs. healthy plants.

To compare nutrient levels to established values, the leaf opposite the cob (called the ear-leaf) should be collected at tasseling from 20-25 plants. Contact your local agronomist or laboratory for instructions on sampling, handling and shipping.

If symptoms are apparent in the young plant, sample 20-25 whole plants in both affected and adjacent unaffected areas. Soil samples can also be collected from affected and unaffected areas. If deficiencies are identified early enough, foliar fertilizer applications may be successful.

HERBICIDE DAMAGE

Pre-seed and post-emergent herbicide damage may be caused by misapplication, off-target movement, excessive application rates, application outside of recommended staging, or carryover from the previous year. The environmental conditions and hybrid can also impact on the whether injury symptoms appear and to what level. For those herbicides to which corn has a low tolerance, herbicide injury may cause abnormal colour, twisted or thickened shoots and roots, and symptoms similar to drought stress.

Group 1 –Quizalofop (Assure II, Yuma), Sethoxydim (Poast Ultra), Pinoxaden (Axial)

These post emergent herbicides are not registered on corn. Corn tissue that is exposed to this type of chemistry will start to yellow (chlorosis), especially in the newly formed leaves and eventually the growing point will turn brown. A sublethal dose can result in pale white or yellow streaks interveinal streaks on the newer leaves.

FIGURE 73. Quizalofop injury on corn.
Photo credit: Peter Sikkema, University of Guelph

FIGURE 74. Sulfonyurea (Ultim) injury on corn.
Photo credit: Peter Sikkema, University of Guelph

Group 2 – Sulfonylurea (Accent, Ultim)

Early application of post-emergent sulfonylurea herbicides is encouraged to minimize the risk of crop injury. Good growing conditions are important for reducing the risk of injury as this allows for rapid herbicide breakdown within the corn plant. Healthy corn plants can metabolize the herbicide more quickly and reduce the risk of injury. If plants are under stress from injury, or adverse growing conditions they are more susceptible to herbicide damage. Injury symptoms include stunted plants, yellow translucent leaves, dead growing point, and bottle-brush roots.

Group 3 – Trifluralin (Treflan, Bonanza, Rival), Ethafluralin (Edge)

Residues in the soil will result in a thin and uneven stand. Those seedlings that emerge frequently have a dark blue-green hue similar to plants suffering from moisture stress. Shoots occasionally rupture the coleoptile sheath and emerge from just above the base of the stem and under the soil. This results in crinkled leaves. Usually, the roots are pruned with a large number of stubby adventitious buds.

FIGURE 75. Group 3 damage (L) vs a healthy plant (R).
Photo credit: Manitoba Agriculture

Group 4 - 2,4-D

Excess application of 2,4-D, as can occur with spray overlaps, or application to corn that is beyond the six-leaf stage may cause injury. Corn leaves may have a greyish-green colour and bumpy texture, and may show 'onion leaf' symptoms where the leaves remain wrapped in a spike. Upcurling of the brace roots and twisting of other roots may occur, sometimes resulting in the plants falling over ('brittle snap'). The amine formulation is less volatile and less likely to drift compared to the ester formulations of 2,4-D.

FIGURE 76. Onion leaf symptoms of 2,4-D injury on corn.
Photo credit: Peter Sikkema, University of Guelph

FIGURE 77. 2,4-D brace root injury.
Photo credit: Peter Sikkema, University of Guelph

Dicamba (Banvel II, Oracle, Engenia)

This herbicide can also affect the brace root system and can cause brittleness at the lower nodes so that a strong wind can cause plants to fall over. This will only occur within a few days of application, since dicamba is rapidly metabolized. Avoid spraying when the crop is stressed, due to drought, cold soils or wind damage.

FIGURE 78. Dicamba injury resulting in "rootless corn".
Photo credit: Peter Sikkema, University of Guelph

FIGURE 79. Dicamba injury resulting in "rootless corn".
Photo credit: Peter Sikkema, University of Guelph

HERBICIDE CARRYOVER/ RESIDUAL

Plantback or re-cropping restrictions for residual or extended control herbicides are an important crop rotation consideration. Soil moisture plays a significant role in herbicide breakdown. In addition, soil texture, organic matter and pH can influence the degradation of any herbicide. Re-cropping intervals are also impacted by use rates and time of application, so always read the label for specific re-cropping instructions. Check Manitoba Agriculture's current Guide to Field Crop Protection for detailed information on re-cropping restrictions. Rainfall records are a good tool for each field in order to determine localized risk. Herbicide residues can be managed, but it requires good record keeping, planning and knowing which herbicides leave residues.

ANIMAL DAMAGE

Birds can damage emerging seedlings, however; the more serious damage occurs in August and September when cobs have formed. Birds eat the kernels off the cob causing direct yield loss. Kernel damage as a result of feeding may result in mould growth. Feeding usually starts on exposed ear tips but with continued feeding, the birds may shred the husks and damage several inches of the ear. Red-winged blackbirds cause the most destruction, but grackles and starlings may also cause damage. Bird-scaring devices such as bangers may be successful deterrents.

Deer and raccoons have also been known to feed on un-harvested corn ears and cause damage to the corn crop.

ENVIRONMENTAL FACTORS

Drought

Lack of water will cause corn leaves to roll and turn a dull greyish-green. In older plants, nitrogen deficiency symptoms may develop. Severe stunting and irregular brown patches of dead leaf tissue may occur.

FIGURE 80. Fomesafen (Reflex) herbicide carryover damage on corn.
Photo credit: Morgan Cott, MCGA

FIGURE 81. Corn ear damage caused by birds.
Photo credit: Morgan Cott, MCGA

High Temperatures

Drought symptoms that disappear as the temperature drops are caused by high temperatures. These conditions are most common early in the growing season when root development is inadequate. Permanent bleaching and scalding of leaf tissue is uncommon; however, high temperature and drought during pollination can cause sterility and barren ears.

Low Temperatures

Imbibitional chilling of corn occurs when ungerminated kernels absorb (imbibe) water in order to germinate, but the water is colder than 10˚C. The absorption of cold water can disrupt the reorganization of cells during rehydration and can result in the loss of seed vigor or seed death.

Non-imbibitional chilling injury in corn occurs following germination, when cold water is absorbed during the emergence process. The result is damaged outer cell tissues, inhibiting elongation of those cells, creating weak plants with very poor emergence and possibly whole-plant death. Chilling injury to only part of the circumference of the mesocotyl (the area between the seed and the growing point) results in the "corkscrew" symptom as the undamaged sections of the mesocotyl continue to elongate.

Low temperatures (5-10 ˚C) can also cause "cold banding" on young corn plants. The most common symptom is the appearance of yellow bands across one or more leaves.

Excess Moisture

Waterlogging will cause young plants to turn yellow and eventually die within a few days. Older plants can tolerate water-logged conditions for a longer period, but they will also become yellow, weak and susceptible to disease after one week.

Frost

Early season frost events often kill exposed leaves, but not the whole plant since the growing point remains below the soil surface until V6 growth stage.

FIGURE 82. Frost damage on seedling corn.
Photo credit: Manitoba Agriculture

Maturity will be delayed, and there may be a slight yield impact as a result.

Fall frost before physiological maturity (black layer or R6) can have a negative impact on both grain yield and quality. Severity depends on growth stage, minimum temperature reached, relative humidity and duration of low temperatures. A killing frost (at least -2˚C) any time prior to R6 will kill the entire plant, which will stop kernel development. However, if the frost is not a killing frost and the leaves/stalks and husks are still green 2 – 5 days following the frost, grain filling will continue until maturity. The crop will still need the necessary heat units to aid in maturity following the delay. If necessary heat units aren't achieved, a premature black layer may form, ending grain fill, impacting quality and potentially yield.

Wind

Blowing soil particles can cause abrasions on leaves and stems and can uproot or break off young plants. Dead or damaged tissue will turn brown and dry up. Shredding of young leaves is frequent. Strong winds following a period of rapid vegetative growth may snap off corn plants at the lower nodes, which is known as "green snap". If the plant is severed, grain yield will be drastically reduced. Strong winds during grain fill may result in root and stalk lodging.

Hail

Damage by hail is easily recognizable by shredded leaves and/or bruised stalks. Early season hail occurring when the growing point is still below the soil surface will result in very little yield loss. However, if hail occurs later in the vegetative growth stages or during pollination and grain filling periods, yield loss may be significant.

Determining % leaf defoliation is subjective, but required when estimating yield loss as a result of hail damage. Leaf area removed and leaf necrosis need to be considered, while damaged green leaf tissue should not be considered as leaf area destroyed. It is best practice to delay assessment by 7 – 10 days following a hail event, so that living and dead tissue are more easily distinguished.

TABLE 11. Estimated percentage corn grain yield loss due to defoliation at various growth stages.
Adapted from: National Crop Insurance Services Corn Loss Instructions, 1984.

Growth Stage[2]	% Leaf Defoliation / % Yield Loss																		
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
7 Leaf	0	0	0	0	0	0	1	1	2	3	4	4	5	5	6	7	8	9	9
9 Leaf	0	0	0	1	1	2	2	3	4	5	6	6	7	7	9	10	11	12	13
11 Leaf	0	0	1	1	2	3	5	6	7	8	9	10	11	12	14	16	18	20	22
13 Leaf	0	1	1	2	3	4	6	8	10	11	13	15	17	19	22	25	28	31	34
Tassel	3	5	7	9	13	17	21	26	31	36	42	48	55	62	68	75	83	91	100
Silked	3	5	7	9	12	16	20	24	29	34	39	45	51	58	65	72	80	88	97
Silks Brown	2	4	6	8	11	15	18	22	27	31	36	41	47	54	60	66	74	81	90
Pre-blister	2	3	5	7	10	13	16	20	24	28	32	37	43	49	54	60	66	73	81
Blister	2	3	5	7	10	13	16	19	22	26	30	34	39	45	50	55	60	66	73
Early Milk	2	3	4	6	8	11	14	17	20	24	28	32	36	41	45	50	55	60	66
Milk	1	2	3	5	7	9	12	15	18	21	24	28	32	37	41	45	49	54	59
Late Milk	1	2	3	4	6	8	10	12	15	18	21	24	28	32	35	38	2	46	50
Soft Dough	1	1	2	2	4	6	8	10	12	14	17	20	23	26	29	32	35	38	41
Early Dent	0	0	1	1	2	3	5	7	9	11	13	15	18	21	23	25	27	29	32
Dent	0	0	0	1	2	3	4	6	7	8	10	12	14	15	17	19	20	21	23
Late Dent	0	0	0	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Nearly Mature	0	0	0	0	0	0	0	0	1	2	3	4	5	5	6	6	7	7	8
Mature	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

[2] As determined by counting leaves using the leaf over method (i.e., those with 40% – 50% of leaf exposed from whorl and whose tip points below the horizontal).

Saline Soils

Plant stands in saline soils will be extremely poor, especially in low-lying areas. Seedlings that do emerge will have a generally weak appearance with considerable tip burning and necrosis of lower leaves. Plants will show drought symptoms before those in non-saline parts of the field.

Floppy Corn Syndrome

Excessively dry conditions in the upper soil profile when corn is developing its nodal or brace roots can result in the development of rootless or floppy corn syndrome. If nodal roots are unable to reach adequate soil moisture before the root tip desiccates, then the entire nodal root often dies. Rootless plants are anchored in the ground only by the mesocotyl. Aboveground, rootless corn may appear fairly normal until a windy day results in plants laying on their side, broken over at the mesocotyl.

Floppy corn syndrome is typically associated with hot and dry surface soil, and develops more easily when corn is planted at extremely shallow depths. Shallow planting results in nodal root development beginning closer to the soil surface, where hot and dry conditions are most common. To reduce the risk of floppy corn syndrome plant at the recommended depth of 1.5 - 2". If the planter is improperly set, the symptoms may appear over the entire field but are more common where there is a rough, uneven seedbed, cloddy soil or compaction. Inter-row cultivation may assist in encouraging root development.

FIGURE 83. Corn with poorly developed nodal roots (left) compared to corn with a well developed nodal root system (right).
Photo credit: John Heard, Manitoba Agriculture

Purpling Corn

Most commonly occurring as a result of an environmental stress that inhibits the translocation of simple sugars in the plant, leading to anthocyanin production (purpling). The pigment change is an indication of reduced phosphorus uptake, which can be a result of several conditions, not just a lack of P fertilizer. Other causes could be reduced root efficiency due to lack of mycorrhizae, root injury by toxic fertilizer banding, cold soil temperatures, dry soils, saturated soil, compaction, herbicide injury or insect feeding.

NON-ENVIRONMENTAL FACTORS

Tall Corn–Short Corn Syndrome

Soil compaction may cause this uneven pattern of crop growth due to impairment of root growth. This may be caused by working the soil when it is too wet, using heavy machinery and seeding into well trafficked areas. Plants may be stunted and purple in colour.

FIGURE 84. Tall corn – short corn in compacted, waterlogged area of field.
Photo credit: John Heard, Manitoba Agriculture

Excessive Tillering

Tillers are determined by plant population, plant spacing, soil fertility, early season growing conditions and hybrid genetics. Plants are most likely to tiller in locations with less than optimal populations and spacing, commonly field edges and near field access, where compaction and other conditions yield poor stand density. Fields that have been generously fertilized commonly produce corn plants that readily develop tillers to take advantage of the resources. Hail, frost and flooding injury that destroy or damage the growing point early can also result in tiller development as a mode of survival. Some hybrids have a high tendency towards tillering as well, which can bring a yield benefit if the adaptation is predetermined.

Corn Cob in the Tassel

Occurring when the upper flower, that becomes a tassel, instead forms a combination of male and female parts on the same reproductive structure. The physiological basis for the survival of the female floral parts on the tassel is likely hormonal, however it could be linked to genetics. Ear development in the tassel may also occur when the plant sustains hail or mechanical damage early in its development. Yields should not be affected, unless there is no development of a regular corn cob.

REFERENCES

Corn loss instructions. National Crop Insurance Service. Revised 1984.

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SECTION 10

HARVESTING AND STORAGE OF CORN GRAIN

Harvesting and Storage of Grain Corn

DRY DOWN

Corn reaches physiological maturity at about the time a black layer develops at the base of the kernel. At this point the kernel stops receiving nutrients and water from the plant, and dry down begins. At the time of physiological maturity moisture content is approximately 30 - 35%. The rate of dry down depends on corn maturity, variety, and moisture content, as well as environmental factors such as temperature, humidity, solar radiation, and wind speed. Rates of dry down can be less than 0.3 percent per day with cool, wet weather, and as high as 1.0 percent moisture per day with excellent drying weather. Research conducted at NDSU estimated corn dry down per month based on environmental conditions and found that corn will dry approximately 18% in September, 11 - 12% in October, and just 4 - 5% in November (Hellevang, 2009).

ESTIMATING YIELD

Estimate yield prior to harvest with the following formula:

$$\text{Yield Estimate} = \frac{(\text{Ears/Acre})*(\text{Kernel Rows/Ear})*(\text{Kernels/Row})}{90{,}000 \text{ kernels/bushel}}$$

Yield can be estimated given four factors:

1) Ears per acre
   - Determine row width
   - Using the table below measure the corresponding row length in the field
   - Count the ears within that row length and multiply by 1,000 to determine ears per acre

2) Kernel rows per ear
   - Randomly choose 5 - 10 cobs in one row length
   - Count the number of kernel rows per ear, average results

3) Kernels per row

- Randomly choose 5 - 10 cobs in one row length
- Count the number of kernels per row, average results

4) Kernel weight

- Kernel weight isn't often know until after harvest, so an assumption can be made that the crop is 56 lb bushel weight, which is 90,000 kernels per bushel.

For more accurate results, repeat this same process up to 10 times in a field.

Row Width	1/1,000th acre
20"	26'1"
22"	23'8"
30"	17'5"
36"	14'6"

HARVEST TIMING

Grain corn harvest can begin when the kernel moisture reaches 30%. Most producers aim to harvest grain corn between 20 and 27% moisture. Harvest timing is a trade-off between the increased drying costs associated with harvesting higher moisture grain, and the increased harvest losses associated with low moisture content.

If the moisture content is too high at harvest time, many of the kernels will rupture before breaking away from the cob and longitudinal cob breakage may increase. If the moisture content is too low, field losses due to lodging and dropped ears will be increased, and more kernels will be damaged when the cylinder bar strikes them.

HARVEST LOSSES

Harvest losses can be a major problem in corn production, and limiting losses is a good way to improve profitability. Total harvest loss includes pre-harvest loss and machine loss. Pre-harvest losses typically result from broken or bent stalks, due to high winds, hail, and disease or insect pressure. Machine losses can be broken up into header losses and threshing losses, with the majority of losses occurring at the header. Harvest losses ranging from 1 - 20 bu/acre have been observed in Manitoba, but normal loss is considered to be approximately 2 - 4 bu/acre.

Adjustments to the combine should keep losses to a minimum. Information on the appropriate combine settings can be obtained from the dealer or by consulting the operation manual. In order to reduce harvest losses it is important to know where they are occurring and how much yield is being lost.

Calculating total harvest losses:

1) Intact ears left on the stalk or on the ground

- Count the number of intact ears left on the stalk or ground in 1/1000 of an acre
    - Determine row width
    - Using the table in the estimating yield section measure the corresponding row length in the field
- Multiply the ears left on the stalk or ground by 1,000 to determine ears per acre
- One hundred cobs per acre is approximately 1 bu/acre loss
- To differentiate between pre and post-harvest losses count ears on the ground in harvested and non-harvest areas of the field

2) Incompletely threshed cobs

- Count incompletely threshed cobs as above
- When harvest moisture is appropriate, kernels remaining on the cob are due to cylinder and rotary settings. Loss can be reduced by adjusting combine settings.

3) Loose kernels on the ground

- Count the number of loose kernels in one square foot in multiple locations behind the combine
- Average counts for average loss/ft^2
- Two kernels/ft^2 = approximately 1 bu/acre loss

DRYING GRAIN CORN

Moisture content of grain corn should be reduced to 14 - 15% for safe storage. In many cases natural air drying may not dry corn fast enough to bring it to a safe moisture content before winter, and heated drying systems are required. The amount of time that grain can be stored prior to drying without risk of losing grade is dependent on the temperature and moisture content of the grain. The cooler and drier the grain, the longer it can be safely stored.

At the start of the drying process, the heated air removes the moisture located near the kernel surface. The first few percentage points of moisture can be removed quickly and with relatively little use of energy. As the kernel dries, moisture must be drawn from progressively greater depths within the kernel. In high-temperature dryers, moisture cannot move from the interior of the kernel to the surface as quickly as it is being evaporated. The outer layers of the kernel become extremely dry while the centre remains wet. Once the outer part of the kernel becomes dry, the hot air flowing through the corn collects only a small fraction of the moisture that it could otherwise remove. Thus, fuel is used inefficiently in the final stages of drying in a high temperature unit (i.e. after the corn has been dried to 18 - 20% moisture).

High drying temperatures, fast drying, and fast cooling can result in stress cracks, increased susceptibility to breakage, and lower test weights. Lower drying temperatures reduce the rate of drying, but may be necessary to maintain quality.

Stress cracks develop from rapid cooling of hot corn. Stress-cracked kernels are broken kernels held together by only a thin pericarp or skin surrounding the kernel. When hot grain is cooled rapidly, which happens in most continuous-flow dyers, the outer layers of the kernel become cool while the centre remains hot. The resulting stresses cause the kernel to break during handling. Stress cracked kernels are more susceptible to insect damage and mould growth during storage, and can also lead to issues during processing. Severe stress cracking can make corn unsuitable for industrial users and may limit the export opportunities for corn. If corn is intended for industrial or export markets, consideration should be given to systems which reduce stress cracking. These include dryeration, low-temperature drying and combination high-low temperature systems.

Low Temperature Drying

In low temperature drying, the corn is dried with unheated, or slightly heated air until it is dry and cool enough for long-term storage. This drying takes place over a period of several weeks or months. In some cases, the corn may not be dried enough to store safely beyond the winter. Additional aeration in the spring may be necessary to complete the drying process unless the corn can be sold or fed before the weather warms up.

Low temperature drying is a race between the rate of drying and the rate of grain deterioration due to mould growth. Low temperature drying completely eliminates damage from over-heating and stress cracks. It seems well suited for economically producing quality corn where 400 tonnes (16,000 bushels) or less are to be dried, although it has been used for much larger quantities. The major drawback is that most farms do not have the electrical power to handle large low temperature dryers.

Careful management is essential to ensure that drying is completed before mould damage occurs. The grain must be clean and free from damage to ensure uniform movement of air.

Over-Drying

Corn is considered dry on the basis of a moisture content of 15.5% although certain markets will require lower moisture contents. Because there is no price adjustment for corn at lower moistures, the marketing of over-dried corn creates a loss of potential income to the producer. Corn should be dried no more than is necessary to ensure safe storage and meet the market requirements for moisture.

GRAIN CORN STORAGE

Corn must be stored in a manner that will preserve its quality regardless of whether it is kept for livestock feed or for sale to industrial users. Corn can be sold immediately after harvest and drying, but storage of the corn for later marketing can be advantageous. Storage allows the corn grower to take advantage of price changes throughout the year. On-farm storage also offers greater flexibility in the choice of markets. However, storage adds to the cost of corn production through increased overhead or capital costs, drying and handling costs and interest charges.

Aeration

One of the biggest problems in stored grain is the migration of moisture through the grain mass because of temperature differences within the grain. This occurs most often when the difference in temperature between the grain mass and the outside air is greater than 10° to 12°C. Moisture migration results in condensation of moisture and spoilage in pockets of corn. Grain masses under 25T (1000 bushels) usually cool uniformly, but larger amounts require aeration.

Aeration should begin as soon as the corn is put into storage and continue periodically until the grain has reached a safe storage temperature. This cooling should be done in stages of 3° to 5°C as outside temperatures fall. For each stage, aerate until the air coming out of the grain is the same temperature as the outside air. This will ensure that all of the grain has been cooled.

During the winter, corn should be checked weekly for temperature changes and the presence of hot spots. Run the fan briefly and record the temperature of the air coming out of the bin. Note any unusual odours. Compare the results against previous readings to see if any problems are developing. Under some conditions, it may be necessary to aerate during the winter to re-establish a uniform temperature within the corn.

In the spring, the corn should be aerated to warm it up slowly. This should also be done in stages, keeping the grain temperature within 10 °C of the average outside temperature. Warming the grain should begin in March. Aerate on cool, dry days to reduce condensation. Never draw warm, moist air through cold grain because the resulting condensation will cause spoilage.

Prevention of Grain Spoilage

Damage from moulds can be prevented by proper drying and aeration of the corn as outlined above. However, considerable damage can also be caused by insect infestations which can occur in dry corn. Insects are present in most grain-handling systems and it is almost impossible to eliminate them completely. However, loss from insect damage can be kept to a minimum by using the following program:

1) Remove all dust and old grain from bin walls, ceilings, floor and aeration ducts before refilling the bin.
2) Repair cracks where insects might enter.
3) Clean equipment used to move grain.
4) Never store new corn on top of old since insects will move from the old grain into the new.

5) Cool and dry grain as quickly as possible. At 15°C stored grain insects stop laying eggs and development stops.

6) Check stored grain regularly to detect hot spots.

7) If insects are detected in stored corn, first determine whether the insect is a species that feeds primarily on the grain, or fungi that grows in moist spots in the grain. Fungus feeding insects can be managed by drying the grain. Grain feeding insects can be killed by cooling the grain to lethal temperatures (by using aeration or turning the grain), or insecticides such as diatomaceous earth, or the fumigant aluminum phosphide (Phostoxin). The use of aluminum phosphide is restricted to licensed pesticide applicators possessing a stored agricultural products license.

CAUTION*: Refer to product labels for application details. Some commodities, such as canola, flax, and sunflowers, should not be stored in facilities recently treated with malathion.*

OVER-WINTERING CORN

If weather conditions make it difficult to harvest corn in the fall, it may be more economical to leave corn in the field and let it dry down naturally over winter. Field drying is extremely slow in the winter, and corn will only dry to about 20 to 21% moisture content. While corn is expected to dry approximately 4 to 5% in November, in December and January corn will dry approximately 2% per month (Hellevang, 2009).

Heavy snowfall during the winter can cause significant amounts of lodging resulting in yield losses. Root and stalk strength should be taken into consideration when deciding if a field should be overwintered. Standing corn may result in more snow catch and slow soil drying in the spring, which could delay planting.

Corn can be harvested throughout the winter if conditions are cool and there isn't much snow. If stalks stay standing throughout the winter, and ear drop and wildlife damage are limited, corn can get through the winter without much yield loss. Yield loss throughout the winter will vary by hybrid and environmental conditions.

REFERENCES

Hellevang, K. 2009. Post-harvest tips for later maturing corn. NDSU Extension Service.

SECTION 11

CORN FOR SILAGE

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Corn for Silage

Corn is a highly suitable crop for silage production in Manitoba. It is a high yielding and relatively low maintenance crop that is very popular on beef and dairy farms due to the high energy content and digestibility, and also because it is very palatable.

HYBRID SELECTION

When choosing a silage hybrid, take into consideration many of the same things as for a grain corn crop. Most seed companies have specific hybrids that may grow taller or have bigger leaves, and are bred for silage production with regards to nutrient content.

Yield, maturity, and lodging resistance are also important considerations in choosing a hybrid for silage. Corn makes the best silage once it has reached the dent stage (R5). At this stage, the whole plants contain 65 - 70% moisture. Choose the highest yielding hybrid that generally reaches this stage before frost damage. It is a common error to choose late-maturing hybrids that look attractive because of their vigorous growth. In this case, a hard frost can cause lodging in plants with over 75% moisture and poor silage may also result because of low dry matter content, high sugar content, and low silage pH. Also, there will be less trouble with freezing and spoilage in piles or bunkers of silage made at the proper moisture level.

Experience has demonstrated that hybrids producing high grain yields also produce good silage yields. When choosing hybrids specifically for whole-plant silage, a yield advantage can usually be obtained by selecting hybrids rated 100 to 200 heat units later than those selected for grain.

Since it is unlikely that one hybrid will excel in all of the desired characteristics for a particular farm, judgement is still necessary in making a selection. The producer growing corn for the first year should choose two or three hybrids on the basis of test information and grow them to find out which one is best for that farm and the management practices used by the producer. The producer who grows corn regularly and has established preferences should review hybrid selection every year, because new hybrids are continually coming on the market.

PLANTING DATES

For silage, planting late also has a negative impact on yield, as it does for grain corn. The amount of grain in the silage is dependent on silking and pollination occurring with minimal moisture stress. Early planting produces the best quality silage. When planting earlier than the first week in May, a 5% increase in plant population would be advised to allow for losses due to frost injury.

PLANTING RATES

Planting rates for silage production are usually 2,000 – 4,000 plants per acre higher than for grain production. The higher plant populations will also affect the hybrid choices because bushier plants won't produce as well as narrow, erect hybrids in high populations. High plant populations will also help with weed control, which is an important factor in corn production.

HARVEST TIMING

Harvest of corn silage crops typically occurs at 65 – 70% plant moisture in Manitoba, depending on storage method. At this stage, dry matter yields, crude protein, neutral detergent fiber (NDF) and digestibility have been proven to be highest and losses during feeding and harvest are measured to be at the lowest. This stage can be identified by early dent to ½ milkline and kernels appear glazed and well-dented.

STORAGE

Before deciding which storage technique to use, consider volume that is needed, investment costs, structure durability, and ease of loading/unloading. To reduce the cost of producing silage, use storage techniques available that minimize silage dry matter losses due to air/silage interactions.

If storage is damaged during the feeding period, it is best practice to repair the area as soon as possible to minimize the amount of oxygen entering the silage. If excessive spoilage has occurred, it is recommended that you test your feed for toxins before feeding.

FIGURE 85. Milkline levels.

ADVANTAGES AND DISADVANTAGES OF CORN SILAGE

Advantages

- Silage can be harvested in almost any weather conditions
- Higher output of nutrients per acre than grain
- Can salvage crops damaged by hail, frost and high weed competition
- Large quantities of uniform quality feed can be stored
- Handling is mechanized from the field to feed trough

Disadvantages

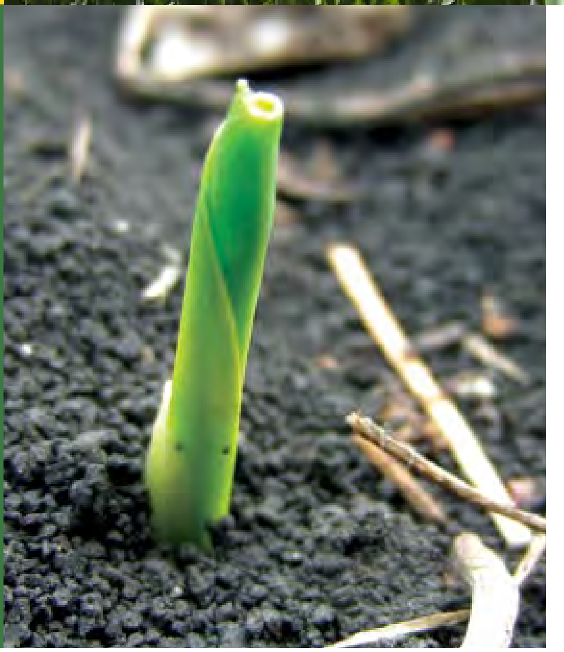
- Requires more labour and time than hay
- Has an odour that may be offensive if stored near populated areas
- Capital investment required for storage facilities, forage harvester
- Has limited market potential. Long distance transportation is inefficient because silage is heavy and deteriorates with exposure to air

FEED QUALITY

The protein and digestible energy content of whole plant corn silage varies with the stage at which the corn is harvested. Protein content decreases while energy content of the dry matter and the silage increases as the corn matures. Corn grown with high levels of nitrogen fertilizer will usually have a higher protein content, perhaps by 1 – 2 percentage points. However, it is usually more profitable and economical to feed a protein supplement with the silage than to apply more nitrogen fertilizer. Corn harvested from a field with a very high population will likely have a higher protein content and a lower energy content than corn from a lower population. This is a result of delayed maturity and less ear development. Since the energy contained in corn silage increases as the plant matures, the more mature silage has a greater feeding value, assuming that the silage is properly fermented.

Notes

Notes



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