Publication 30

# Guide to Forage Production

Ministry of Agriculture,
Food and Rural Affairs

Ontario

**Front Cover:** Round bales of hay in the field
**Back Cover:** Windrows of cut hay drying in the field



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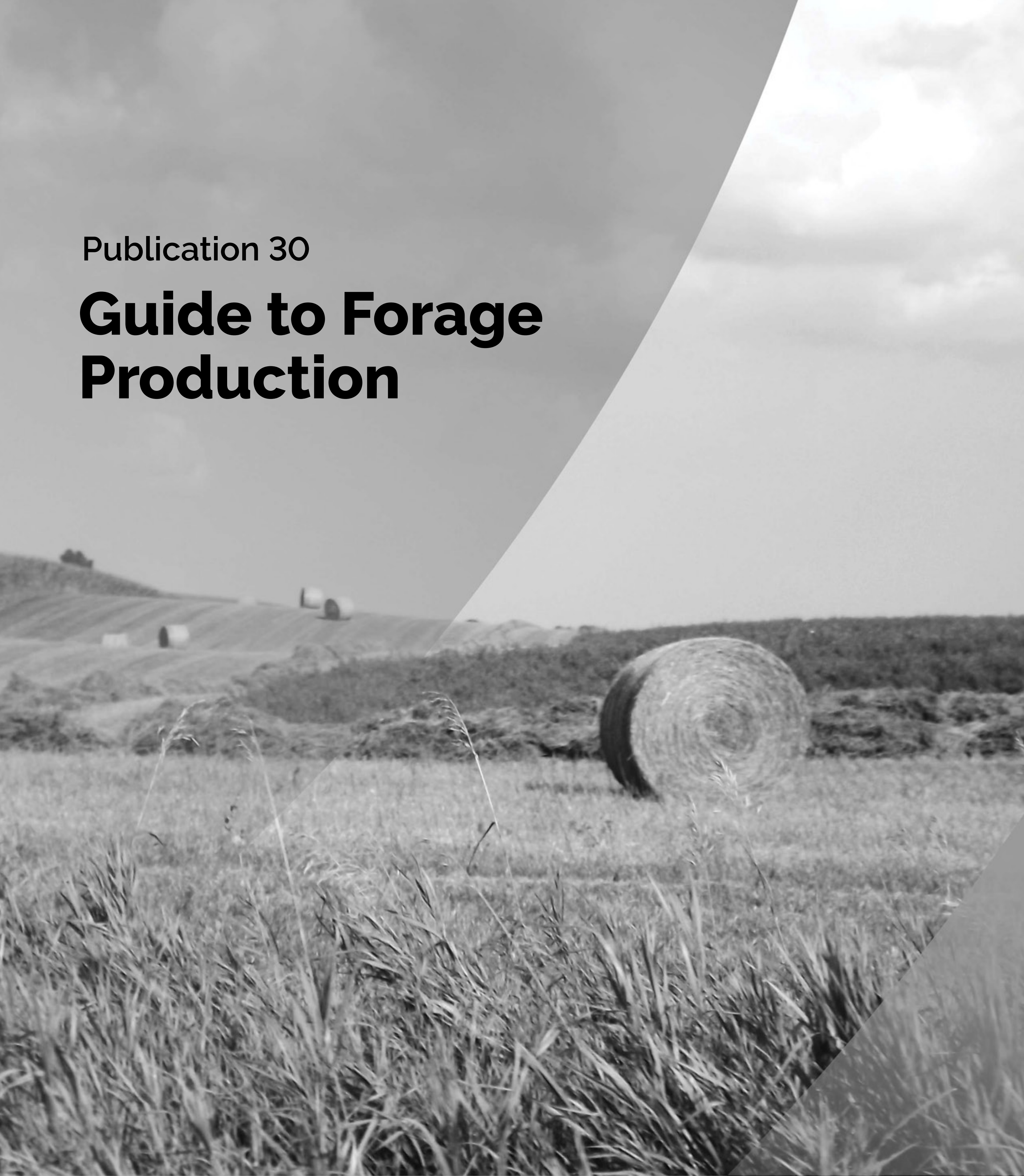
# Guide to Forage Production



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Food and Rural Affairs

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**Guide to Forage Production**
Publication 30

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# Preface

## Forage (noun)

- Plants or plant parts fed to, or grazed by, domestic animals. Forage may be fresh, dry or ensiled (e.g., pasture, green chop, hay, haylage) — Wright and Lackey, 2008
- Edible parts of plants, other than separated grain, that can provide feed for grazing animals, or that can be harvested for feeding — Allan, 1991
- Food for animals, especially when taken by browsing or grazing — Merriam-Webster Dictionary
- Food grown for horses or farm animals — Cambridge Advanced Learner's Dictionary and Thesaurus

Forages form the foundation of ruminant and equine diets. These animals require a minimum amount of forage in their diets to remain healthy and productive. As the above definitions suggest, forage is not one plant species — it's the purpose of the crop. Many species can be grown as forage. Some of these are only cultivated for forage, while others are also used in grain and oilseed production in Ontario.

Forage production differs from grain and oilseed production in that the crop is not grown to physiological maturity. This difference often influences agronomy and other management decisions, which in turn affect yield and quality. High-quality forages can find a buyer in local, regional or international markets.

In addition to their role as a critical feed ingredient and saleable crop, forages also provide valuable environmental goods and services. Grasslands and flowering forage crops provide habitat and food sources to wildlife, which promotes biodiversity in the landscape. Below ground, perennial root systems improve soil health and sequester atmospheric carbon into the soil.

The focus of this guide is twofold: forage crop agronomy, and the preservation and storage of mechanically harvested forage crops. For more information on grazing and pasture management, refer to OMAFRA Publication 19, *Pasture Production*.

Whether you are a farmer, advisor, researcher or student, I hope that you find the information contained within this guide both practical and useful.

Christine O'Reilly, Editor
OMAFRA Forage and Grazing Specialist

CHAPTER 1

# Planning and Establishment

## Understanding a Farm's Forage Needs

Forage crops form the foundation of ruminant and equine diets. Forage grown on the farm where it will be consumed is almost always the cheapest source of feed for livestock operations.

Ideally, the producer, agronomist and livestock nutritionist will work together to develop a forage crop plan for the farm. This plan should consider good agronomic practices, such as manure management and crop rotation, to meet the farm's yield goals. The plan must also account for appropriate quality in the forage crops to meet animal nutrient requirements and reduce the need for supplemental feed. Harvest timing has the greatest effect on forage quality. An overview of nutritional analyses for forages can be found in Chapter 16, *Forage Analysis and Grading*.

To determine the farm's yield goals for forage production to meet animal demands, the producer and agronomist should start with the farm's carrying capacity estimates and stocking rate.

## Carrying Capacity

Carrying capacity is an estimate of the maximum number of animals that could be sustainably fed based on the production potential of an area of land. The time period for forage production must be specified but is typically one growing season or one calendar year. While carrying capacity is most often associated with pasture production, it is a fundamental concept for planning any forage production system, including systems that rely solely on stored forage.

Carrying capacity differs between farms due to differences in soil texture, topography, drainage, soil health, climate and management. Carrying capacity also varies somewhat year-to-year on the same farm due to weather. Good management practices that improve soil health, reduce crop pest and disease pressure, and contribute to better forage yield and quality can increase a farm's carrying capacity.

Forage quality is not factored into the carrying capacity calculation; it is assumed to be appropriate for the class(es) of livestock being fed. In situations where forage quality is not adequate, the carrying capacity will be lower than predicted.

The accuracy of this calculation depends on the quality of information available. There are two steps to calculate carrying capacity.

## Step 1. Calculate forage supply

The forage supply is the amount of dry matter (DM) yield available per hectare (or acre). This value can be extremely variable between forage crop species, fields or paddocks, and years, and thus should be calculated separately for each field and paddock, or area of similar vegetation production. The forage supply for each field and paddock are then added together to determine the farm's forage supply.

Stored forage crops can be weighed and moisture tested at harvest to determine the DM yield. Refer to Chapter 14, *Harvest*, for methods of moisture-testing and DM calculations. Remember to subtract storage losses from the yield to increase the accuracy of the calculation (see Chapter 15, *Storage*, for typical losses from different storage systems). Table 1-1 outlines the formula to calculate stored forage supply.

For grazed crops, the amount of forage available in the paddock before each grazing event can be added together, then multiplied by the average utilization (%). Utilization is the amount of available forage dry matter the animals actually eat. The most accurate way to determine utilization is to measure the pasture before and after grazing and calculate the percentage consumed. Grazing management has the biggest influence on utilization. Table 1-2 outlines the formula to calculate grazed forage supply.

**Table 1-1. Stored Forage Supply Formula**

| | **Sample Calculation**<br>Alfalfa Silage in an Oxygen-limiting Tower Silo | | |
|---|---|---|---|
| | **Metric** | **Imperial** | **Your Calculation** |
| Annual forage yield | 6,200 kg DM/ha | 5530 lb DM/acre | |
| Field size | × 20 ha | × 50 acres | × |
| **Field forage production** | **= 124,000 kg DM** | **= 276,500 lb DM** | = |
| Storage losses from Table 15-1 or 15-2 (%)[1] | 7% | 7% | |
| Proportion remaining after storage losses ((100 – storage losses) ÷ 100) | 0.93 | 0.93 | |
| **Field forage supply**<br>= field production × proportion remaining after losses | **= 115,320 kg DM** | **= 257,145 lb DM** | = |

[1] Typical losses for different storage systems can be found in Chapter 15. Hay loss estimates can be found in Table 15-1, while losses in silage and baleage is estimated in Table 15-2.

**Table 1-2. Grazed Forage Supply Formula**

| | Sample Calculation<br>Perennial Pasture | | |
|---|---|---|---|
| | **Metric** | **Imperial** | **Your Calculation** |
| Annual paddock yield<br>= sum of available forage before each grazing event | 5,580 kg DM/ha | 4,980 lb DM/acre | |
| Paddock size (ha) | × 4 ha | × 10 acres | × |
| **Paddock forage production (kg DM)** | **= 22,320 kg DM** | **= 49,800 lb DM** | **=** |
| Utilization (%)<br>= percent of available forage the animals ate<br>(divide by 100 to convert to decimal) | × 0.60 | × 0.60 | × |
| **Paddock forage supply (kg DM)**<br>= paddock production × utilization (decimal) | **= 13,392 kg DM** | **= 29,880 lb DM** | **=** |

Repeat the above calculations for each field and paddock on the farm. Add up the supply from each field and paddock to get a **total annual forage supply** for the farm.

## Step 2. Calculate the carrying capacity

Different classes of livestock vary hugely in their dry matter intakes. Therefore, it is easiest to benchmark carrying capacity by using standard animal units rather than real livestock. One animal unit is equivalent to 12 kg (26 lb) forage dry matter intake per day. Table 1-3 outlines the formula to calculate carrying capacity.

**Table 1-3. Carrying Capacity Formula**

| | Sample Calculation | | |
|---|---|---|---|
| | **Metric** | **Imperial** | **Your Calculation** |
| Total annual forage supply (Step 1) | 905,784 kg DM | 1,996,912 lb DM | |
| Animal unit (AU) demand | ÷ 12 kg DM/day | ÷ 26 lb DM/day | ÷ 12 kg or 26 lb |
| **Number of AU-days of forage** | **= 75,482 AU-days** | **= 76,804 AU-days** | **=** |
| Number of days animals are on feed per year | ÷ 365 days | ÷ 365 days | ÷ |
| **Maximum number of AUs that can be fed on forage supply** | **= 206.8 AUs** | **= 210.4 AUs** | **=** |
| Size of total forage production area | ÷ 94 ha | ÷ 232 acres | ÷ |
| **Carrying capacity (AU/ha)** | **= 2.2 AU/ha** | **= 0.9 AU/acre** | = |

## Stocking Rate

Stocking rate is the average annual number of animals kept on an area of land. Like carrying capacity, stocking rate is most commonly used in pasture situations but is a fundamental concept in planning whole-farm forage production.

Stocking rate, like carrying capacity, is easiest to benchmark when it is calculated using a standardized animal unit. One animal unit is the equivalent of a 454-kg (1,000-lb) beef cow consuming 2.6% of her body weight in forage dry matter each day. This means one animal unit represents 12 kg (26 lb) of forage dry matter intake per day. Keep in mind that the typical size of beef cattle has increased since the animal unit was first developed, and that a mature beef cow in Ontario is usually larger than the standard animal unit (Table 1-4). Table 1-5 outlines the formula to calculate stocking rate.

**Table 1-4. Animal Units per Head, Based on Typical Body Weight and Estimated Dry Matter Intake**

| Livestock Class | Animal Unit Equivalent |
|---|---|
| Beef cow | 1.30 |
| Backgrounder | 0.79 |
| Finishing cattle | 1.19 |
| Replacement beef heifer | 0.92 |
| Dairy cow, large frame | 2.23 |
| Dairy cow, medium frame | 1.69 |
| Dairy cow, small frame | 1.46 |
| Dairy heifer | 0.75 |
| Bull | 2.30 |
| Dairy doe | 0.26 |
| Meat breed doe | 0.15 |
| Kids | 0.05 |
| Horse, large frame | 1.44 |
| Horse, medium frame | 0.96 |
| Horse, small frame | 0.48 |
| Dairy ewe | 0.32 |
| Meat breed ewe | 0.17 |
| Lambs | 0.08 |

**Table 1-5. Stocking Rate Formula**

| | **Sample Calculation** Replacement Beef Heifers | | |
|---|---|---|---|
| | **Metric** | **Imperial** | **Your Calculation** |
| Number of animals in class | 105 | 105 | |
| Animal unit equivalent (Table 1-4) | × 0.92 | × 0.92 | × |
| **Animal units (AU)** | **= 96.6** | **= 96.6** | = |
| If there are different classes of livestock on the farm, repeat this calculation to represent each class. Add up the classes to get **total animal units** for the farm. | | | |
| Total animal units on farm | 96.6 | 96.6 | |
| Size of total forage production area | ÷ 94 ha | ÷ 232 acres | ÷ |
| **Stocking rate (AU/ha)** | **= 1.03 AU/ha** | **= 0.42 AU/acre** | = |

## CAUTION!

Do not confuse animal units with nutrient units. Animal units are a standardized method of estimating forage intakes. Nutrient units, under the *Nutrient Management Act, 2002*, are the amount of nutrients that give the fertilizer replacement value of the lower of 43 kg (95 lb) of nitrogen or 55 kg (121 lb) of phosphate. Some reference material will equate the manure produced by a number of livestock in a class to a nutrient unit, but this is unrelated to animal units.

Stocking rate is a management decision. Most farms strive to match their stocking rate to their carrying capacity. Since home-grown forage is the cheapest source of feed, this approach maximizes the number of animals on the operation while minimizing feed purchases.

However, the stocking rate does not have to equal carrying capacity. For example, operations that rely on purchased forage for some or all of their needs typically have a stocking rate above the farm's carrying capacity. While the most common examples of this are stables, having a stocking rate greater than the carrying capacity is not unique to horses. Operations intentionally stocking above carrying capacity should carefully plan and budget for their additional feed purchases to manage their production costs and profit margins.

On the other hand, the opportunity cost of having other enterprises on the farm may motivate producers to choose a stocking rate below what the farm could carry. The farm's land base can produce enough forage to feed many more animals, but to have a hay or grain enterprise, there must be a surplus of land available that is not required to feed livestock. The stocking rate is below the farm's carrying capacity.

When calculating carrying capacity to inform feed budgets and forage crop plans, remember to include only the acreage dedicated to growing feed for the livestock enterprise.

Regularly reviewing an operation's stocking rate and carrying capacity can help management make informed decisions about the forage production system. Completing these calculations annually helps prevent surprises resulting from a mismatch between the farm's goals and the relationship between its carrying capacity and stocking rate.

# Types of Forage Crops

Plants from different families can be grown as forage. Understanding their characteristics and the roles they can fill in a forage production system is the first step in planning which crops to grow.

## Legumes

As a family, legumes are higher in protein than grasses. Their seeds form in a pod. Most legumes grown for forages have taproots and broad, compound leaves (composed of several leaflets) that are arranged alternately on the stem. New shoots originate from the crown of the plant, and the growing point of each shoot is located at the top of the shoot.

If properly inoculated, legumes have the capacity to use atmospheric nitrogen, eliminating the need to apply nitrogen as commercial fertilizer. Legumes also supply a considerable amount of nitrogen to the grasses associated with them in the mixture.

### Inoculation

For normal growth, all legumes must have nitrogen-producing nodules on their root systems. These nodules are created by an infection of *Rhizobium* bacteria. When a legume species has routinely been grown in a field as part of the rotation, these bacteria are present in the soil and will usually result in good nodulation.

If a legume is being planted for the first time in a field, the seed must be inoculated with the proper strain of *Rhizobium* bacteria before planting. Each legume species requires a specific strain of rhizobia (Table 1-6). The cost of rhizobia is low in comparison to the cost of seed. Thus, if you are in doubt about the presence of rhizobia in the soil, inoculate the seed. Since inoculant must be alive, check the expiry date on inoculant and follow handling instructions.

**Table 1-6. Inoculant for Forage Legume Species**

| Legume | Inoculant Group | ***Rhizobium* Species** |
|---|---|---|
| Alfalfa<br>Sweet clover | A | *Synorhizobium meliloti* |
| Alsike clover<br>Red clover<br>White clover | B | *Rhizobium trifolii* |
| Common vetch | C | *Rhizobium leguminosarum* |
| Austrian winter pea | EL | *Rhizobium leguminosarum biovar viciae* |
| Birdsfoot trefoil | K | *Rhizobium loti* |
| Crown vetch | M | *Rhizobium* spp. |
| Berseem clover<br>Crimson clover | R | Possibly *Rhizobium trifolii* |
| Soybeans | S | *Bradyrhizobium japonicum* |
| Kura clover | not assigned | *Rhizobium ambiguum* |

*Note:* Inoculants are often sold by group letter rather than by species name.
*Source:* Adapted from USDA – Natural Resources Conservation Service, 2015.[1]

Pre-inoculated seed (with or without coating) is satisfactory, provided that the inoculant is applied in the current season. Good seed coverage is required for maximum efficacy of any inoculant. When applying on farm, apply inoculants at the base of a brush auger when loading the seeder. Kits that hang on the side of a truck, tote or gravity wagon are available from dealers. Occasionally, some producers have experienced bridging or build-up in planters and augers from over-application of liquid seed treatments or inoculants. Simultaneous application of a low rate of peat is one option to reduce bridging, as peat will suck up some excess moisture.

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

Sourcing inoculants for “minor-use” legumes can be difficult. In some cases, these are unavailable in Canada because they have not been registered with the Canadian Food Inspection Agency. Others are approved for sale in Canada but are not offered commercially. Where inoculants are unavailable, and the field has no history of growing that species, legumes require applied nitrogen.

# Grasses

Grasses have many long slender leaves that are borne on a stem. They have very fibrous roots that help bind the soil together, thereby reducing erosion. Some grasses have rhizomes or underground stems that produce new shoots at each node. Grasses with rhizomes can thicken up a stand. Grasses that do not have rhizomes are known as bunch grasses.

Grass species differ in their competitiveness with legumes, which will influence the grass-legume ratio of an established stand.

Grasses such as orchard and the ryegrasses tend to be more competitive with alfalfa than timothy or bromegrass are.

Grasses are lower in protein than legumes when cut at a similar stage of development.

Timing of forage production activities — grazing, cutting and fertility applications, for example — depends on crop stage rather than height, yield or calendar date. Many scales exist to describe the physiological development of grasses. The Zadoks scale is shown in Figure 1-1. It is commonly used in Ontario to describe the stage of development in cereal grains but can be applied to all grasses.

For more detailed information and identification of cereal and grass growth stages, do an internet search for “Bayer Cereal Staging Guide”.

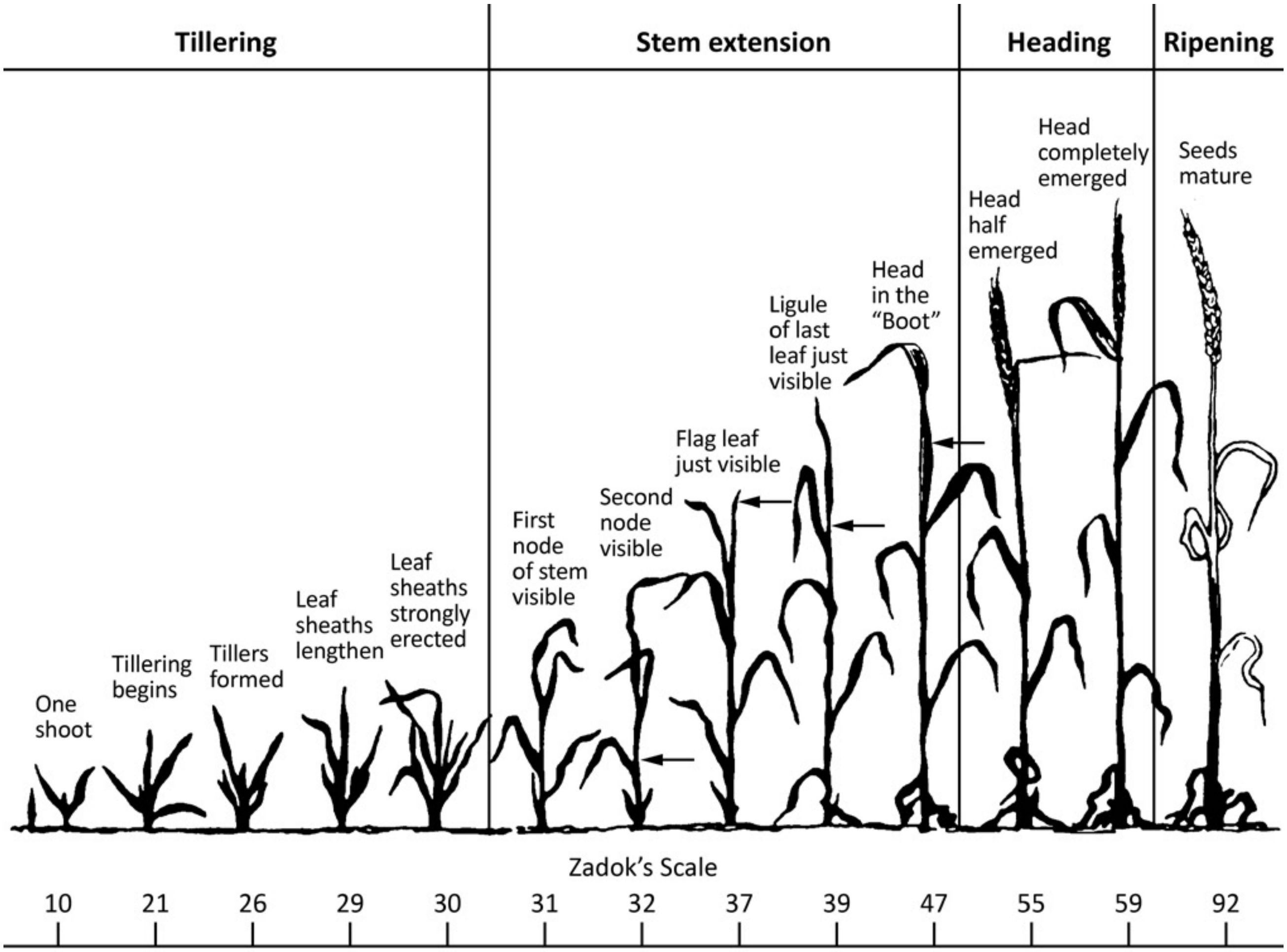



**Figure 1-1.** Development stages of grasses.

## Identifying Grass Species

Grasses can easily be identified by looking at the leaves, stems and inflorescences (seed heads). The drawings on the following pages show common differences in grass anatomy that can be used to identify different species (Figure 1-2).

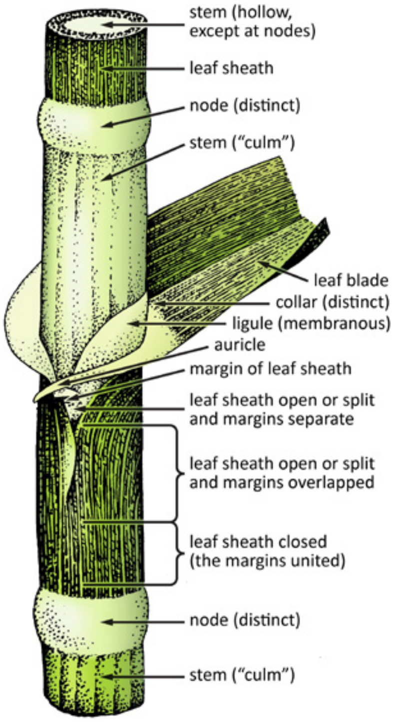



**Figure 1-2.** Grass leaf and stem anatomy is used to identify plants in vegetative growth stages.

A leaf consists of 2 parts — the sheath and the blade. The sheath is the tubular portion that surrounds the stem or younger growing leaves. The sheath can be:

- split, with margins separate
- split, with margins overlapping
- closed, forming a tube around the stem, with only a small notch on the side opposite to the leaf blade (Figure 1-3).

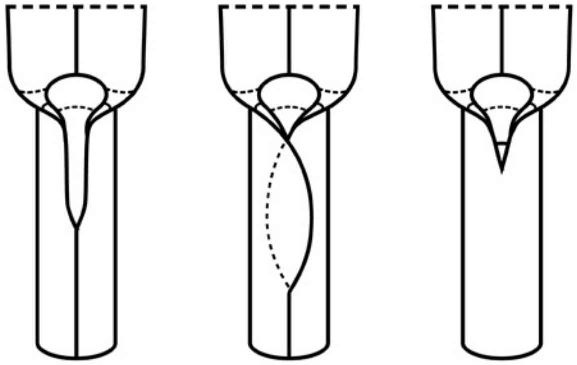


**Figure 1-3.** Sheath types: Split, split with overlapping margins, and closed.

The blade is the upper, non-clasping part of the leaf. It is usually long and flat but may be slightly folded or rolled lengthwise, and bristle-like (Figure 1-4).

**Figure 1-4.** View of the cross-section of a blade: flat, folded (or keeled), and rolled.

The tip of the blade can be boat-shaped, or tapered and flat (Figure 1-5).

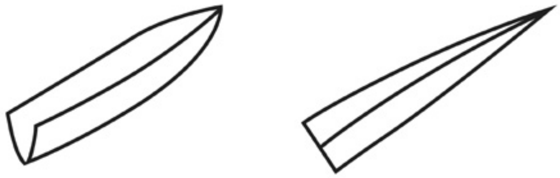


**Figure 1-5.** Leaf shapes: boat-shaped and tapered.

The area that divides the sheath and the blade is called the collar (Figure 1-2). It can also offer clues to a grass's identity. The collar may be broad or narrow, have a conspicuous midrib or be continuous from one edge of the leaf to the other (Figure 1-6).

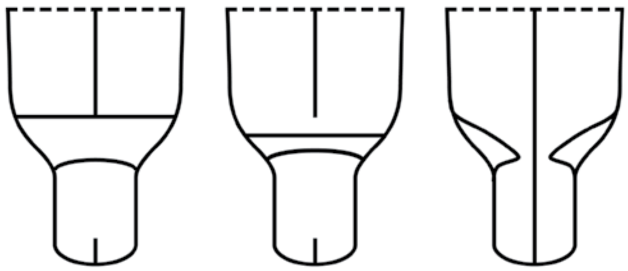


**Figure 1-6.** Collar types (seen from the back of the leaf blade): broad, narrow, and divided by the midrib.

Two types of appendages may be found on the collar. Auricles are claw-like and project from the sides of the collar. They are often absent, but when present they may vary from being large and clasping to small and slender (Figure 1-7).

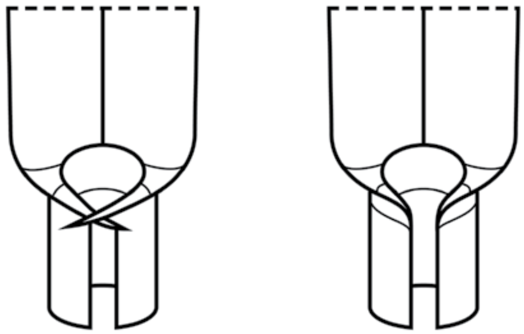


**Figure 1-7** Auricle types: clasping and very short.

The ligule is a very thin, tongue-like appendage growing upward from the inner surface of the collar between the leaf blade and the stem. If present, it may be just a fringe of hair or a thin membrane (Figure 1-8).

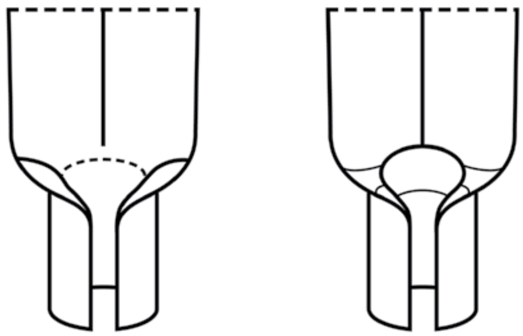


**Figure 1-8.** Ligule types.

The flowering stems of grasses are usually hollow and are either round or flat (Figure 1-9).

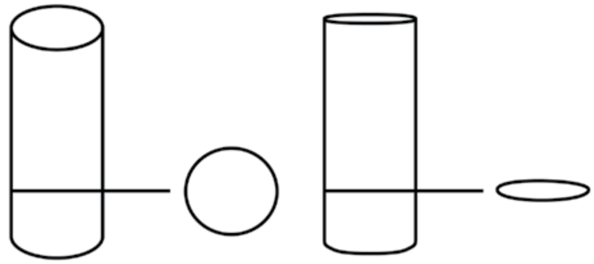


**Figure 1-9.** Stem types: round and flat.

There are three forms of seed heads (Figure 1-10): panicle (branching), spike (unbranched, with uniformly spaced spikelets) and spike-like panicle (unbranched, with uniformly spaced spikelets).

**Figure 1-10.** Types of inflorescence: panicle (or branching), spike (or unbranched), and spike-like panicle.

## Non-legume Forbs

The word "forb" is used to describe plants that are not woody and not grasses. These plants are often called "broadleaved" in field crop situations, particularly when they are viewed as weeds. Technically, legumes are a type of forb, but their ability to fix nitrogen means they are generally more familiar to producers as forage crops than non-legume forbs. For example, brassicas are the most commonly used non-legume forbs for forage in Ontario, while dandelions are the most common weedy forb species in hay fields.

Non-legume forbs can be a valuable addition to a forage production system. It is difficult to generalize about them because they are not a single plant family. Management of non-legume forbs as forage crops depends on the species in question.

# Species Selection

Most hay and pasture fields in Ontario are mixtures of forage species. Livestock are very adaptable in what they can eat, so selecting crops that thrive under the farm's growing conditions and management is the best way to grow a high-yielding crop.

Choosing productive species does not need to be difficult. A "process of elimination" approach can simplify deciding which species to include.

1. **How does this forage crop fit into the farm's forage production system?** There is no forage crop that can do everything, so identifying the farm's overall forage needs is the first step in planning how to fill them. Assigning a goal to each crop narrows down what types of plants are most appropriate.

    - Perennial forage crops are usually the cheapest per tonne to grow because the establishment costs can be amortized over several years.
    - Annual crops may have higher yields than perennials but must be planted every year, which costs more and increases the weather risk at planting time. They excel at filling gaps in perennial crop production.
    - Cool-season crops grow fastest in spring and fall, while warm-season crops thrive in the summer heat.
    - Legumes generally have a higher protein content, while grasses contain more energy as digestible fibre, sugars, and starches.

*The answer to this question can be a guide to the appropriate chapter(s) in this book when assessing forage crop options. Mixing crops from different chapters into one stand may create challenges in managing forage quality, as crops are grouped in chapters based on their lifespan and the timing of their peak growth rate. Note that alfalfa is a cool-season perennial and silage corn is a warm-season annual.*

2. **What soil properties might affect production?** Topography and texture are impractical to change, and these affect how water moves over and through the soil. Unless a major drainage project is planned, drainage is a soil characteristic that should affect species selection. Eliminate species that will not thrive in the field's drainage conditions from the list of potentials.

    Crop nutrients are most available at a soil pH around 7.0. Acidic soils have fewer available nutrients, which may limit crop production. If the seed mixture is for a new seeding and the field will be tilled, there is an opportunity to incorporate lime to correct low soil pH (see Chapter 2, *Soil Fertility and Nutrient Use*). However, other establishment methods may not provide an opportunity to lime. In these situations, discount species that will not thrive at the pH level in the field.

    Generally, legumes are more sensitive to pH than grasses. When planting a legume/grass mix, decide on the legume component first, then select complementary grasses.

*There are figures at the beginning of each crop chapter summarizing the drainage and pH tolerances of the forage crops described in the chapter.*

3. **Is the forage for cutting or grazing?** The intended harvest management for the field should also be considered when selecting a mixture. Even though both harvesting methods

cause defoliation, forage plants do not respond the same way to cutting and grazing. Choose species and varieties selected for the method and frequency of harvest to maintain the desired species in the stand.

*There are tables at the beginning of each crop chapter summarizing the suitability of different harvest management for the forage species described in the chapter.*

4. **How long will the stand be kept?** Research by Dr. Yousef Papadopoulous and colleagues at Agriculture and Agri-Food Canada (AAFC Kentville) on perennial cool-season crops shows that simple mixtures of two or three species tend to have lower seed costs, are easier to manage within a crop rotation and potentially have higher short-term yields. However, complex mixtures of four or more species usually have higher resilience to adverse weather conditions and higher long-term yields.

5. **What animals will eat this forage?** Ruminants can consume a wide variety of feedstuffs and thrive, so long as their diet is changed slowly to give the rumen microbes time to adapt. Horses are hindgut fermenters, and this different digestive strategy can make them more sensitive to what they eat than ruminants; some of the forage species described in this publication are not suitable for horses, and this will be noted. Choice of a pasture mix is more influenced by livestock species than choice of a hay mix, as animal behaviour and physiology will affect crop production and management in a pasture. For more information, see OMAFRA Publication 19, *Pasture Production*.

   Studies on cover crop (annual forage) grazing suggest that young stock have higher average daily gains when grazing a single species, but complex mixtures tend to have higher yields. This translates to more grazing days, therefore complex mixtures may be a better fit for carrying mature animals than a single crop species.

# Seeding Rates and Quality

## Pure Live Seed

Forage crop seeding rates are often given as a weight of pure live seed (PLS) over an area — kg/ha or lb/acre. PLS measures the amount of viable seed in a lot. The tag on the seed bag has the information needed to calculate PLS.

A laboratory germination test is used to determine what percentage of the seeds are viable.

The number of weed and other crop seeds in a 25-g (0.9-oz) sample are counted to determine the purity of the lot.

To calculate the percent of pure live seed, multiply percent germination by percent purity, then divide by 100.

**Example:**

The tag on a bag of seed lists germination as 80% and purity (or pure seed) as 94%.

Percent germination × percent purity ÷ 100 = percent pure live seed

**80 × 94 ÷ 100 = 75.2% PLS**

Seeding rates listed in this guide are in PLS, unless otherwise stated.

## Seed Grades

Certified seed is the highest grade available for forage production in Canada. It is graded by a licensed third party. To be graded as certified seed, a lot must meet minimum germination and purity standards. This ensures a high proportion of pure live seed in each lot. The minimum thresholds vary depending on species.

Certified seed is usually sold under a variety name. This is the crop equivalent of buying registered purebred livestock. The plants in each variety have known and recorded genetics, and consistently express certain traits that are different from other populations within that species.

Common seed has lower minimum germination and purity standards than certified seed. Common seed can be graded by the seller. It cannot be sold under a variety name, so there is no guarantee that common seed will have the improved genetic traits of certified seed. Buying common seed is the crop equivalent of buying commercial crosses of livestock — while the species is known, the genetic potential or traits of the plants may be uncertain. While common seed cannot be sold as a variety, sellers may brand their common seed to differentiate it from their competitors. Branded common seed must include the word "Brand" or "TM" or ® to help differentiate from registered (certified) varieties.[2]

For details on the purity and germination standards for different grades of each species of forage seed, see Schedule I of the Seeds Regulations (Consolidated Regulations of Canada, c. 1400), which are available online through the Government of Canada.

# Establishment Methods

There are several different types of seeding equipment available and being successfully used by farmers. The most important aspect is ensuring the chosen equipment will create good seed-to-soil contact, which enhances germination. Equipment that is well-maintained and properly calibrated will always do a better job of establishing forages. Renting good-quality equipment, or hiring someone with the right equipment and experience, can ensure that seeding is done correctly. Different methods of establishing forage crops are described on the following pages.

## Direct Seeding

Direct seeding means planting a seed into the soil where the crop will be grown. Under good management, direct-seeded forage stands are often thicker and more uniform than other establishment methods. This is particularly true for forage species such as birdsfoot trefoil, alfalfa and reed canarygrass, which do not tolerate heavy shade.

Direct seedings have not met with success on all farms. Weed competition is a greater problem with direct seeding than with under-seeding; this problem is most likely to limit success of direct seedings (see Chapter 11, *Weed Management*).

Direct-seeded forages are useful when harvested forage acreage must be increased on short notice to compensate for winterkill or increased forage requirements. Direct seedings have been most popular in Ontario on silt loam, loam and sandy loam soils, as tillage is important to create a fine, crumbly seed bed unless a no-till drill or sod-seeder is used.

Direct seedings on heavier clay loam soils require more skillful seedbed preparation and seeding. Clay soils, particularly where the seedbed is somewhat lumpy, are more vulnerable to dry conditions during germination, thereby reducing establishment. They are also more vulnerable to crusting and seedling emergence problems if heavy rains follow seeding.

## Sod Seeding

When a crop is direct-seeded into an established perennial forage, it is called sod seeding. The established stand may be alive or terminated by a herbicide. Living stands will compete with the new seedlings for light and moisture. To reduce competition, the established stand should be cut or grazed closely just prior to seeding.

Sod seeding can be done with a no-till drill or sod-seeder. Broadcasting is not a reliable sod seeding method, as it is difficult to achieve good seed-to-soil contact, even with packing.

Sod seeding has several advantages over conventional seeding. Reseeding can be done in areas not suitable for plowing, with a minimum loss of time (spent doing tillage) and forage production. As most of the soil surface remains undisturbed, few annual weeds germinate, and moisture loss from the ground is kept to a minimum.

A no-till drill can be used to place seed into the soil of an existing sod. This method of renovation has the highest chance of success, as the seed can be placed at the proper depth in close contact with soil particles and can readily absorb soil moisture for germination.

Modify the drill by rerouting the seed tubes of the legume seed box so the seed falls into the disc openers. Adjust the discs to place the seed and fertilizer 0.5–1.5 cm (¼–⅝ in.) deep.

Sod seeders, designed for seeding into sod, normally do a better job of establishing new stands than modified grain drills. There are various models of sod seeders built to handle different sod conditions, different degrees of stoniness and roughness of terrain. Before renting or buying a sod seeder, confirm that it will handle the conditions presented by the field to be renovated.

The type of groove opener on the sod seeder affects the rate of success. There are three basic slot shapes: the “V”, the “U” and an inverted “T”. The seedling emergence from the V-shape slot created by double disc openers and the torn or shattered U-shape made by hoe openers is improved by press wheels operating directly on the seeds at the base of the groves before covering. This brings the seeds into good contact with the soil. It is important that the grooves be closed to prevent the slot from drying out.

A chisel opener creates an inverted “T” slot in the soil. In dry conditions, this slot design is superior to the other two. Under good moisture conditions, few differences in seedling emergence are seen. Closure of the “T” groove is improved by using either a bar harrow behind the drill or press wheels.

## Under-seeding

Under-seeding refers to establishing a perennial forage with an annual companion (nurse) crop — typically a cereal. The companion crop competes with the forages for moisture, light and fertility, and if any of these items are deficient, the forage seeding will suffer before the companion crop does. Under-seeding is most effective in spring, when soil moisture is typically not limiting. It is not recommended for summer establishment of forages. Some of the perennial species described in this publication are not suitable for under-seeding, and this will be noted in the crop chapters.

The companion crop typically establishes faster than the perennial forage. Its faster canopy closure helps reduce soil erosion. It also provides an opportunity to harvest silage while the perennial forage establishes. Using a companion crop can help maintain forage production during an establishment year. In this situation, both the seeding rate for cereals and the nitrogen application may be the normal rate in order to increase the silage yield. With reasonable soil moisture following harvest, it is quite possible to also obtain a cut of forage in late August in areas with 2,800 crop heat units or more. See Chapter 7, *Cool-Season Annuals*, for more information on timing silage cereal harvest.

Oats are the best companion crop followed, in order of compatibility, by mixed grain, 6-row barley, spring wheat, 2-row barley, winter wheat and winter rye. Alfalfa or trefoil mixtures seeded under winter wheat or winter rye are often failures. Generally, select the strongest strawed, shortest and earliest grain variety in any species for the least competition.

## Cross-seeding

Cross-seeding (or cross-drilling) is an establishment method that uses two passes of a drill to establish the forage crop. Half of the total seed rate is seeded on the first pass, and a second pass is made at a 45° or 90° angle to sow the rest of the seed.

Cross-seeding is recommended for establishing forages on soils that are at risk of erosion (Figure 1-11). Changing the plant distribution from rows to a grid enables the crop canopy to close earlier. This protects the soil and helps suppress weeds. The drawback to cross-seeding is the increased time and fuel required to establish the crop.

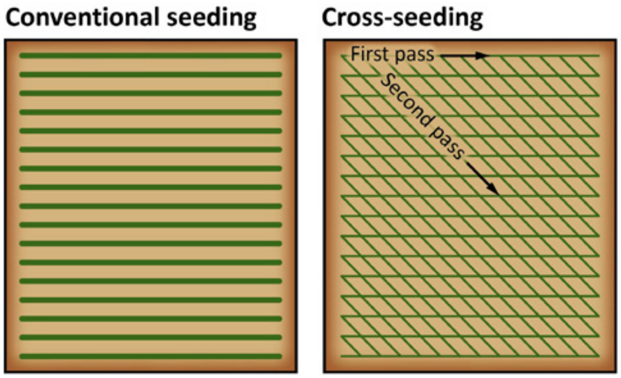



**Figure 1-11:** Cross-seeding.

## Frost Seeding

Frost seeding is a method of establishing forages into a light frost in the early spring. After the snow has melted and the frost is out of the ground, there are often several cold nights with below-zero temperatures. Seeding into this light frost avoids compaction or rutting, as the frost will support the weight of the tractor. Forage legumes tend to have very small seeds and can achieve good seed-to-soil contact when broadcast on bare ground that is still going through freeze-thaw cycles.

Grasses and cereals have larger seeds that do not establish well when broadcast. Therefore, a no-till drill should be used to establish grasses and spring cereals at air temperatures above -8°C. It is not essential for the seed trench to close when frost seeding, as the trench will close as the frost leaves the ground.

The window of opportunity for this method of seeding is short. Best results are generally achieved when seeding as the frost is just beginning to firm the soil, about -3°C to -4°C, often near midnight. It is critical to stop as soon as frost begins to soften in the morning sun, as thawed soil will stick and plug a drill in as little as 15 m (50 ft) of travel. Frost seeding is not suitable for establishing warm-season crops.

# References

1. Unknown. February 2015. *Legume Seed Inoculation – Plant Materials Technical Note*. USDA – Natural Resources Conservation Service. Technical Note TX-PM-15-01.

2. Canadian Seed Growers Association. *Understanding Variety Names in the Seed and Grain Sector.* Retrieved from: seedgrowers.ca/resources/variety-names/

## Additional Sources

This chapter includes excerpts from the following OMAFRA sources:

Publication 811, *Agronomy Guide for Field Crops.* 2017.

*Pasture Grasses Identified,* Factsheet 06-095. 2006.

Van Schaik, M. *Taking Stock: Understanding Feed Inventories Now for Strategic Winter Feeding*. OMAFRA Virtual Beef newsletter. 2019. Retrieved from: www.omafra.gov.on.ca/english/livestock/beef/news/vbn0919a1.htm

CHAPTER 2

# Soil Fertility and Nutrient Use

Just like livestock, forage crops need proper nutrition to be healthy and productive. Typically, the most limiting nutrients for crop production are nitrogen (N), phosphorus (P) and potassium (K). Sulphur (S) deficiency is becoming more common in Ontario. Plant nutrients are generally most available when soil pH is moderate (e.g., between 6.0 and 7.5).

For more detailed information about crop nutrition, refer to OMAFRA Publication 611, *Soil Fertility Handbook*.

## Soil Testing

A soil test provides information on the pH, phosphorus, potassium and other nutrient levels in a field. Equipment for soil sampling includes an auger or sampling probe. Ensure the tube is stainless steel if micronutrients will be analyzed. A thick permanent marker, wooden dowel or screwdriver is handy for removing the soil core from the sampling tube into a container such as a clean plastic pail. Sample depth should be 15 cm (6 in.), with the exception of nitrate-nitrogen samples and pH samples taken in continuous no-till systems. Nitrate-nitrogen samples should represent 30 cm (12 in.) depth. Sampling in continuous no-till fields, with a history of broadcast N, and where lime will be surface applied, should be sampled for soil pH to a 5-cm (2-in.) depth.

A soil sample is a composite of individual cores mixed together, that is representative of a given area. Take at least 20 cores per composite soil sample; one sample should represent no more than 10 ha (25 acres). To collect the individual cores, traverse the area to be represented in a zigzag pattern (see Figure 2-1). Avoid taking cores adjacent to gravel roads or where lime, manure, compost or crop residues have been piled. Sample separately if areas are large enough to manage separately (e.g., site-specific management zones, eroded knolls, etc.) Avoid collecting cores from recently applied fertilizer bands.

Where a soil probe or auger is not available, a spade can be used to collect a soil sample for analysis. Before digging, remove any plant material from the soil surface. Dig a small, square hole about 5 cm (2 in.) deeper than the sampling depth:

- 20 cm (8 in.) deep for general nutrient and pH analysis (sample will be 15 cm (6 in.))
- 35 cm (14 in.) deep for nitrate-nitrogen (sample will be 30 cm (12 in.))

**Note:** Where nitrogen is surface-applied with no tillage over many years, a shallow layer of acidic soil may develop. A separate, shallow sample (5 cm (2 in.)) can be taken to check for this. Adjust for the shallow depth of sample when using Ontario liming recommendations.

From one side of the hole, carefully dig out a 5-cm (2-in.) thick slice of soil with the spade. Remove soil from either side of the slice until only a 5-cm (2-in.) wide column of soil remains. This column is the “core” being collected as part of the sample. The guidelines for sample depth, number and location of cores collected still apply when using a spade. Greater care must be taken during collection to ensure a good-quality sample because the spade is not specifically designed for this purpose.[1]

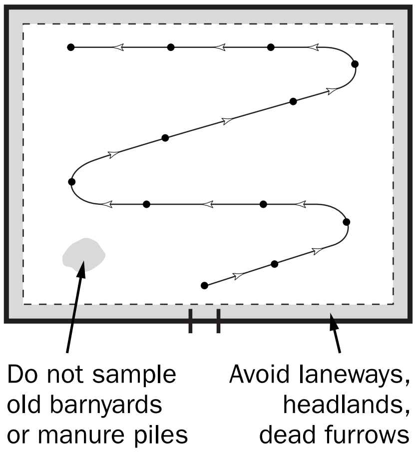



**Figure 2-1.** Composite soil sampling

Thoroughly mix the soil sample: break up lumps, discard stones and crop residue. Heavy-textured soil (e.g., clays) may require some drying to allow mixing and subsampling, if necessary. Place the sample or subsample — about 400 g (1 lb) — into a labelled bag and forward to the lab.

Sample fields frequently enough to detect changes in the soil test before they become large enough to significantly affect crop yields or fertilizer requirements. For most farms, once every 3 years is adequate for this purpose. This often works out to once in the rotation, at the same point in the rotation. Where large amounts of K are removed (e.g. high-yielding alfalfa, corn silage) levels can change quickly. Under these conditions, take samples more frequently.

To allow time for transport and analysis, take soil samples in the previous fall, from fields to be fertilized for spring-seeded crops. Harvest rush and the frequency of poor weather in late fall may make summer a more convenient time. Sampling at the same time each year allows better precision if trends are tracked over time.

Soil sample boxes, information sheets and details on the cost of various tests are available from any of the accredited labs, or from many fertilizer and farm supply outlets. A list of accredited soil testing laboratories in Ontario can be found online.

# Soil pH and Lime

The pH scale ranging from 0–14 is used to indicate acidity and alkalinity. A pH value of 7.0 is neutral. Values below 7.0 are acidic, and those above 7.0 are alkaline. Most field crops grow well in a soil pH range from 6.0–8.0. Alfalfa and other legumes prefer pH above 6.5, as nodulation is much better in neutral soils. pH guidelines for forage crops are presented in the crop chapters of this guide.

Where lime is required to raise soil pH, it must be mixed uniformly with the soil to be effective, as agricultural limestone does not dissolve quickly. Tillage implements that mix the soil, such as the disc (offset disc-harrow), do the best job.

In no-till soils, correcting pH is a challenge. If the entire plow layer (15 cm (6 in.)) is acidic, then tillage to incorporate limestone is the only practical option. This does not mean that liming and no-till are completely incompatible. In no-till soils where nitrogen fertilizers have been surface-applied, a shallow layer of acid soil can develop. Sample the top 5 cm (2 in.) layer to check the surface pH. Frequent applications of low rates of limestone can neutralize the acidity in this zone.

Many farmers apply and incorporate a fraction of the total lime recommended over several years. This helps ensure the lime will be more uniformly distributed and mixed by tillage. This is an excellent preventive measure but will not correct severe acidity.

# Phosphorus and Potassium

Plants need phosphorus for healthy root development and metabolic functions. Potassium is critical for regulating water in the plant and forming enzymes, and is required during the "hardening-off" process perennials undergo to survive winter.

Phosphate ($P_2O_5$) and potash ($K_2O$) guidelines are based on OMAFRA-accredited soil tests. More information on crop-specific requirements of these nutrients are presented in each crop chapter. Only use these tables with OMAFRA-accredited soil tests. Non-accredited tests may use extractants that pull out different amounts of nutrient and will not give correct values if used with the published OMAFRA tables. A list of accredited labs can be found at ontario.ca/crops.

# Nitrogen and Sulphur

Nitrogen is essential for plants to form chlorophyll (for photosynthesis) and protein. In non-legumes it is often the most yield-limiting nutrient. Sulphur in plants helps form important enzymes and proteins.

Plant-available forms of nitrogen and sulphur are mobile in the soil. Recommendations for nitrogen and sulphur fertility are not based on soil tests. Nitrogen guidelines are based on researched response curves for each crop that maximizes yield and minimizes the economic costs of nitrogen. Legumes do not need added nitrogen, provided nodulation is successful. Nitrogen requirements differ between non-legume forage species. Recommendations are provided in the crop chapters of this guide.

In forage crops that have high sulphur demands, deficiencies can be diagnosed using a plant tissue test. Plant tissue analysis measures the nutrient concentration in plant tissue. It is most useful when combined with visual inspection of the crop and soil conditions, and knowledge of past field management.

## Plant Tissue Analysis

Timing and stage of growth when a sample is collected affect the results of plant analysis. Concentrations of some nutrients vary considerably with the age of the sampled tissue and the date of sampling. Results are difficult to interpret if samples are taken at times other than what is optimal for the crop.

Collect a large enough quantity to have a fresh sample weighing about 200 g (0.44 lb). A few leaves are not enough material to test and are not representative of the crop.

- Collect tissue samples into labelled paper bags. Sample the top 15 cm (6 in.) of plant material. Avoid sampling areas where there is disease, insect, mechanical or spray injury. Plant tissues will rot if stored in plastic bags.
- Sample plant tissue separately from variable areas that are large enough to sample soil and fertilize separately.
- Avoid contamination of the sample with soil. Even a small amount of soil will cause the results to be invalid, especially for micronutrients.
- Sample plants suspected of nutrient deficiency as soon as a problem appears. Take tissue samples from a problem area and submit a separate sample from an adjacent, non-affected part of the field. Also collect and submit a soil sample from both affected and non-affected areas to aid diagnosis.

Fresh plant samples should be delivered directly to the laboratory. If they cannot be delivered immediately, they should be dried to prevent spoilage. Samples may be dried in the sun or in an oven at 65°C or less. Hotter temperatures could negatively affect the accuracy of forage quality analysis (see Chapter 16, *Forage Analysis and Grading*, for more information on nutritional analyses).

Plant analyses may be obtained from several laboratories in Ontario. Refer to the list of accredited soil-testing laboratories in Ontario online. Tissue analysis is not part of the OMAFRA accreditation program. However, OMAFRA-accredited labs have the necessary skills and equipment to perform accurate tissue analysis.

Tissue analysis has limitations and expert help is sometimes needed to interpret the results. Tissue analysis does not indicate how much fertilizer is required to correct a deficiency or even whether a deficiency is related to soil fertility problems. Tissue test results in the deficiency range may also be due to factors such as weather, pest pressure or disease, and therefore should be used in conjunction with a soil-testing program.

# Manure as a Nutrient Source

Manure can be an excellent source of nutrients for forage crops, as it is readily available on livestock farms. The value of manure in crop production is often underestimated. Manure contains all the nutrients needed by crops but not necessarily in the proportions needed for specific soil and crop conditions. In addition to nitrogen, phosphorus and potassium, manure contains many secondary nutrients and micronutrients, as well as organic matter that helps build and maintain soil structure.

Research in Ontario done on perennial cool-season forages shows that manure applications can increase the yield of the crop over fertilizer alone when the rate of macronutrients (N, P and K) applied is the same from either source (Table 2-1).

**Table 2-1. Yield and Quality of Alfalfa/Grass Mixtures Following Nutrient Applications**

| | Yield (DM basis) | | | Quality[1] | | | Yield + Quality (DM basis) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Treatment** | **tonnes/ha** | **tons/acre** | **% change** | **kg milk/tonne** | **lb milk/ton** | **% change** | **kg milk/ha** | **lb milk/acre** | **% change** |
| No added nutrients | 5.58 | 2.49 | – | 1,518 | 3,035 | – | 8,470 | 7,557 | – |
| Fertilizer | 5.72 | 2.55 | 2.4 | 1,535 | 3,069 | 1.1 | 8,772 | 7,826 | 3.4 |
| Splash plate | 5.92 | 2.64 | 5.7 | 1,519 | 3,038 | 0.1 | 8,989 | 8,020 | 5.8 |
| Surface band | 5.92 | 2.64 | 5.7 | 1,520 | 3,040 | 0.2 | 8,996 | 8,026 | 5.8 |
| Injected | 6.32 | 2.82 | 11.7 | 1,526 | 3,052 | 0.6 | 9,647 | 8,607 | 12.2 |

[1] *MILK2006* is an Excel spreadsheet that uses the forage analysis (CP, ADF, NDF and NDFd; see Chapter 16, *Forage Analysis and Grading* for definitions) to calculate an approximation of a balanced ration using the U.S. National Research Council values. *MILK2006* was used with all preset defaults except forage quality parameters.

*Notes:* Represents Oxford Centre, Salford, and Brooksdale locations – 2nd, 3rd and 4th cuts in 2012.

*Source:* Ontario Ministry of Agriculture, Food and Rural Affairs. C. Brown. Unpublished.

# Manure Analysis

Manure analysis is necessary because the quantities of nutrients contained in manure, especially the phosphorus and potash components, will vary from farm to farm. Type of livestock, ration, bedding, added liquids and storage system all affect the final nutrient analysis. Using average values for a livestock class is useful as a last resort, but the range of nutrient values within the same manure type can vary greatly. Phosphorus tends to be concentrated in the solids, while potassium levels tend to be higher in the liquid portion, therefore the level of agitation will affect nutrient levels being applied to a field. Fertilizer adjustments based on a manure analysis will be more accurate than those based on average values, however average values can be fine-tuned for future fertilizer application where analysis results are available after application.

Above-average levels of nitrogen, phosphorus or trace elements in manure may be an indication that dietary levels are higher than required. Amino acid-balancing for nitrogen, reducing the amount of phosphorus in the mineral supplements or adding phytase (an enzyme that increases phosphorus efficiency in the animal) may help reduce these nutrients in manure. Consult a livestock nutritionist before making ration changes.

Manure analysis is available from several laboratories in Ontario. Sample after complete agitation (liquid) or thorough mixing (solid) each time the storage is emptied and send the sample for analysis. After several analyses, a trend in results should become evident. As well, sampling should occur when there are changes in ration or other management factors.

When sending a sample to the lab, fill a plastic jar about half-full, secure the top, place in a plastic bag and store in a cool place until shipping. Most labs have manure sample jars available upon request. Glass jars pose a safety risk as they may break during transit, and therefore should not be used. Clean plastic peanut butter jars are a good option because they will not shatter and they have screw-on lids.

Analysis should include total nitrogen, ammonium-nitrogen ($NH_4$-N), phosphorus, potassium and dry matter. Micronutrients, including sulphur, pH, organic matter and C:N ratio (for solid manure) analysis can provide valuable data for fertilizer application. Labs accredited for OMAFRA soil test return analysis results with “as-applied” percentages for nitrogen, phosphorus, potassium and dry matter, as well as mg/kg (or ppm) of ammonium nitrogen and micronutrients. On most reports, percentages of phosphorus, potassium and significant micronutrients from manure are converted to commercial fertilizer equivalents and potential commercial fertilizer reductions are often reported.

The best way of determining the amount of each nutrient from manure is to analyze a sample. Unfortunately, this is not always possible, as in the case of a new barn. In this case, average values will provide an estimate of the nutrients available to the crop.

Refer to OMAFRA factsheet *Available Nutrients and Value for Manure from Various Livestock Types* for estimates. It is based on the average results from manure analyses from the accredited labs in Ontario. Nitrogen is reported as available N under various application systems. Phosphate and potash values are reported as nutrients available to replace fertilizer nutrients. Use these values as the starting point in crediting nutrients from manure application.

To prevent burning the crop, applications of liquid manure should not exceed 55 kg/ha (50 lb/acre) of ammonia ($NH_3$). While the ammonia concentration will depend on the type of manure and how it is stored, typically this limit is equivalent to 33,600–45,000 L/ha (3,000–4,000 gal/acre).

## Applying Manure on Forages

Manure should be applied on forages as soon as possible after harvest. Once regrowth starts — typically within 5 days after cutting — equipment traffic can damage active growing points. The trampled crop must start growing all over, which reduces yield and sometimes delays maturity in the tracked areas compared to the rest of the field (see Table 2-2). Applying manure within 5 days of cutting will avoid a yield penalty in trafficked areas on the next cut. This is much easier to achieve in a haylage system than with dry hay.

**Table 2-2. Tire Track Impact of Manure Application 9–11 Days After Cutting**

**Legend**: CP = crude protein ADF = acid detergent fibre NDF = neutral detergent fibre
$TDN_w$ = total digestible nutrients calculated with the Weiss equation

| Treatment | Yield | | Difference (%) | CP (%) | ADF (%) | NDF (%) | Lignin (%) | K (%) | Ca (%) | TDNw |
|---|---|---|---|---|---|---|---|---|---|---|
| | kg DM/ha | lbs DM/acre | | | | | | | | |
| Manure 1 | 2,084 | 2,502 | – | 22.7 | 30.8 | 42.2 | 5.01 | 2.43 | 1.46 | 63.4 |
| Tire track 1 | 1,435 | 1,280 | (32) | 23.7 | 26.8 | 33.7 | 6.12 | 2.50 | 1.52 | 67.2 |
| Manure 2 | 2,780 | 2,480 | – | 20.7 | 42.5 | 52.5 | 9.12 | 2.65 | 1.64 | 56.0 |
| Tire track 2 | 1,636 | 1,460 | (41) | 24.5 | 32.9 | 38.9 | 7.32 | 2.69 | 1.69 | 60.8 |

*Source:* Ontario Ministry of Agriculture, Food and Rural Affairs. C. Brown. Unpublished.

Injection is the best way to reduce ammonia losses from manure; however, care must be taken in alfalfa stands to minimize crown damage. Research has shown that shallow injection depths of 1.25–2.5 cm (½–1 in.) do not have negative impacts on alfalfa yield. Grass stands are much more tolerant of injection equipment than alfalfa. Injection may not be appropriate on hilly fields, as the manure will run down the trench and pool at the bottom of the slope.

Solid manure can be challenging to spread on a living forage crop. Large chunks of manure can smother the plants. When manure ends up in baleage, bacterial contamination can make livestock sick. For these reasons, solid manure should only be applied to standing forage if it is very fine; solid manure the consistency of corn silage is easy to spread in a thin layer.

## Manure Applications and Johne's Disease

Application of manure from animals infected with pathogens is a potential method for spreading infection. This becomes a higher risk when the manure is applied to crops used for animal consumption.

Johne's (yo-nees) disease is a persistent and debilitating bacterial disease that affects the intestines of ruminant animals, including cattle, goats and sheep. The disease is especially problematic in dairy herds, where many cattle can be infected, but only a small percentage of animals (<5%) show the clinical signs of chronic diarrhea and extreme weight loss. These cows also experience decreased milk production. Infected animals, even those not showing sickness, may shed the bacteria in the manure. Johne's is most often introduced onto farms by the purchase of infected animals.

Johne's disease is caused by *Mycobacterium avium* subsp. *paratuberculosis* (MAP). Calves, especially those under 6 months of age, are most susceptible to infection. Animals under stress are also more susceptible than healthy cattle. The common routes of infection are via ingestion of colostrum or milk contaminated by infected cows. For this reason, Johne's prevention strategies revolve around calf management and herd testing (refer to *Healthy Cows for a Healthy Industry* at www.johnes.org). Infection can also occur when feed contaminated with manure containing the MAP pathogen is eaten, particularly by young stock. For this reason, manure application to forages is a potential source of infection.

MAP can survive in manure and water for up to 1 year and on pastures and hay fields for up to 6 months. Exposure to sunlight, drying, high pH, liming and low iron, as well as the processes of fermentation and composting, appear to reduce the survival of MAP. Factors that reduce the survival of the bacteria can also help in better managing manure applied to forages to prevent the spread of MAP.

The following management strategies are suggested for manure management in herds where Johne's disease has been identified:

- Manure should not be applied to forages in pastures for young stock during the grazing season.
- Top-dress the liquid manure as soon as possible following harvest. This allows the sunlight and desiccation to kill the MAP bacteria.
- Apply manure to fields that will be ensiled or harvested for haylage. Proper fermentation appears to kill the bacteria. Use good ensiling techniques, including proper dry matter content, use of silage inoculant if required, rapid filling, adequate packing and covering as soon as the storage is filled.
- Avoid application of manure to fields that will be harvested for dry hay, especially calf and heifer hay. Where manure is applied, it should be done before any re-growth occurs. A 30-day interval between manure application and harvest should reduce MAP bacteria numbers. However, year-to-year variations in environmental conditions (weather) cannot guarantee complete elimination.
- When choosing a field for manure application, those with a high pH or those that have recently had lime applied are preferred.

Management strategies that help to control Johne's Disease will also help to control other common pathogens such as *Salmonella*, *E. coli*, *Cryptosporidium* and several viral diseases that affect young calves and cattle.

# References

1. Cornell Soil Health Laboratory. Date Unknown. Sample Collection. Cornell College of Agriculture and Life Sciences. Retrieved from: soilhealth.cals.cornell.edu/testing-services/collecting-samples/

## Additional Sources

This chapter contains excerpts from the following OMAFRA sources:

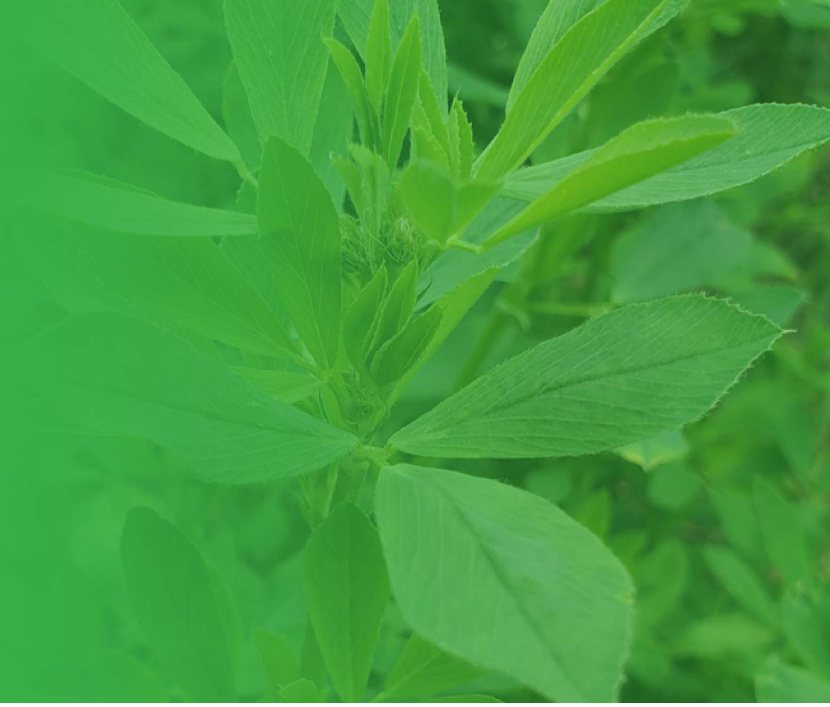
*Johne's Disease: Should Manure Be Applied to Forages?* Field Crop News Blog. May 24, 2012. fieldcropnews.com/2012/05/johne%e2%80%99s-disease-should-manure-be-applied-to-forages/

Publication 811, *Agronomy Guide for Field Crops.* 2017.

Publication 611, *Soil Fertility Handbook*. 2018.

CHAPTER 3

# Alfalfa



## Alfalfa

***Medicago sativa***
Alfalfa is a tall-growing plant, 60–100 cm (24–40 in.), with hollow or solid stems. Leaves consist of three leaflets that are two to three times longer than wide, with serrated tips. The flowers are usually blue or purple but may be yellow or white (Figure 3-1).

Alfalfa's tolerances to drainage, soil pH, and harvest suitability are included in the tables in Chapter 5, *Cool-season Perennials*.

Alfalfa is highly palatable to livestock and makes excellent hay and silage. It does not persist well under grazing and has a high bloat risk in pasture.

**Figure 3-1.** Alfalfa leaflets are two or three times longer than they are wide.
*Source:* Undersander and Cosgrove, University of Wisconsin, 1992.

## Soil Texture, Drainage and pH Considerations

When growing conditions are good, alfalfa is the most productive of the legumes. It requires well-drained (or tiled) soils with a pH of 6.2 or above, plus good fertility. Under less-than-ideal conditions, it is susceptible to root diseases and winterkill. Alfalfa is productive for the entire growing season but should not be harvested during the fall rest period (see the section *Fall Rest Period* later in this chapter).

## Variety Selection

The use of certified seed, rather than common seed, is strongly recommended. Only by planting varieties is it possible to know in advance whether the seed will provide the yield, persistence, disease resistance and maturity that is required for each specific field and farm operation.

Careful consideration of varietal traits will help match the right variety to environmental and management conditions in each field. There are no longer third-party alfalfa variety trials conducted in Ontario, so producers are encouraged to check results from neighbouring provinces and states.

# Fall Dormancy and Winter Hardiness

Alfalfa varieties are assessed on how much growth occurs after a fall cutting and given a score from 1 to 11. The higher the number, the more aggressively the variety grows late in the fall and early in the spring. This faster regrowth contributes to higher yield. However, high fall dormancy scores (5 and greater) also translate into poor winter survival. These varieties may break dormancy too early in the spring and be injured by a late frost, and often do not start acclimating for winter early enough in the fall.

In most of Ontario, varieties rated fall dormancy (FD) 4 are best suited to growing conditions. However, growers should consider an FD 3 variety if winterkill is an ongoing issue and the following apply:

- before winterkill, stand establishment is uniform and plant populations are good
- a current soil test indicates fertility is adequate for alfalfa production
- pest and disease pressures have been minimal
- the field has not been cut during the fall rest period

Winter hardiness has been somewhat disconnected from fall dormancy in varieties with FD ratings between 1 and 4. Many varieties are given a separate score for winter hardiness. These range from 1–6, with lower values indicating more tolerance to cold conditions. A winter hardiness value of 2 will suit most of Ontario.

# Insect and Disease Resistance

## Disease Resistance Index

Diseases reduce the yield, quality and persistence of alfalfa. Alfalfa varieties are assessed for their resistance to the following diseases:

- bacterial wilt
- verticillium wilt
- fusarium wilt
- anthracnose
- phytophthora root rot
- aphanomyces root rot (race 1)
- aphanomyces root rot (race 2)

The disease resistance index (DRI) combines the resistance ratings of all these diseases (Table 3-1) into one number. Some trials do not test for aphanomyces root rot (race 2), so a perfect DRI rating without this test sums to 30 rather than 35. A variety that is susceptible to all the tested diseases would receive a DRI of 7/35, while a variety that was highly resistant to everything in the index would rate 35/35.

**Table 3-1. Alfalfa Variety Disease Resistance Ratings**

| Resistance Class | % Resistant Plants | DRI Resistance Rating |
|---|---|---|
| Susceptible (S) | 0%–5% | 1 |
| Low resistance (LR) | 6%–14% | 2 |
| Moderate resistance (MR) | 15%–30% | 3 |
| Resistant (R) | 31%–50% | 4 |
| Highly resistant (HR) | >50% | 5 |

For more information on the diseases assessed in the DRI, including life cycle, scouting methods and control options, see Chapter 13, *Diseases*.

## Potato Leafhopper Resistance

Varieties resistant to potato leafhopper have tiny glandular hairs on leaves and stems. However, the glandular hairs are not fully expressed during the establishment year, so while resistant varieties can dramatically reduce the potato leafhopper damage, yield reductions can still occur. Treatment thresholds for highly resistant (HR) varieties after the establishment year can be increased by 4 times those for conventional varieties. See Chapter 12, *Insects and Pests,* for thresholds. New seedings of potato leafhopper–resistant varieties should be monitored. Use conventional variety thresholds for potato leafhopper during the establishment year.

Potato leafhopper–resistant varieties are particularly useful for farmers that do not scout or spray to control potato leafhopper. These producers may find the use of potato leafhopper–resistant varieties to be an easy and practical method to help manage the risk.

For more information on potato leafhoppers, including life cycle, scouting methods and control options, see Chapter 12, *Insects and Pests*.

## Root Morphology

Alfalfa roots can be tap, branching tap or rhizomatous (creeping-root), but most varieties grown in Ontario have taproots.

Varieties with branching roots were selected to be more tolerant of imperfect drainage than taproot varieties. Branch-rooted varieties have several taproots coming off the crown, but do not tend to root as deeply as conventional tap-rooted varieties.

Rhizomatous or creeping-root varieties have very wide crowns and develop lateral roots called rhizomes from which new alfalfa plants can develop. Creeping-rooted varieties have sunken crowns to withstand grazing pressure better than conventional tap-rooted varieties. Standard alfalfa normally requires a rest period of 30–35 days between grazing events, whereas creeping-rooted alfalfas may require a 45–50-day rest period.

## Genetically Engineered Traits

Varieties of alfalfa with genetically engineered traits are available in Eastern Canada. Crops with these traits are not eligible for export outside North America. In addition, organic regulations do not accept any genetically engineered materials in Canadian certified organic crop production.

### Glyphosate Resistance

Glyphosate-resistant alfalfa is marketed under the trade name RoundUp Ready. Alfalfa with glyphosate resistance will not be killed by label-rate applications of the herbicide glyphosate. This trait can be useful in situations with serious broadleaf weed challenges that require chemical control. The drawback is that planting a mixed stand is not an option. Some producers have planted glyphosate-resistant alfalfa in the spring, waited for weeds to emerge in the stand, sprayed the field with glyphosate, then planted grasses into the alfalfa in the fall. Otherwise, the trait is intended for managing pure stands of alfalfa.

### Reduced Lignin

Genetically engineered reduced-lignin alfalfa was developed by Forage Genetics International and is marketed under the trade name HarvXtra. Lignin is a structural fibre in the plant that enables it to stand upright. Ruminants cannot digest lignin, so lowering the overall lignin content of alfalfa at a given stage of development makes the forage more digestible than normal. Higher digestibility in forage improves ruminant performance. Independent research in the U.S. has shown that the reduced lignin trait offers flexibility in alfalfa harvest schedules, as growers can choose to harvest higher-quality forage on their normal schedule or to delay harvest by 7–10 days to achieve higher yields of the same quality as their conventional production system. In some cases, this has resulted in the need for one less cut per year than under a conventional system.[1]

Reduced-lignin alfalfa should be grown and stored separately from conventional varieties, as animal performance will differ, and ration formulation should take this into account.

# Establishment

In a pure stand, seed alfalfa at a rate of 13–22 kg/ha (12–20 lb/acre) of pure live seed (see Chapter 1, *Planning and Establishment*, for more on pure live seed). Under excellent management and favourable conditions for establishment, these rates may be reduced up to 25%. When coated seed is used, do not reduce these rates, because coated seed contains fewer seeds per unit weight. Do not expect very high seeding rates to compensate for poor conditions (e.g., a rough seedbed, a heavy companion crop).

Seeding depth should be 5–12.5 mm (¼–½ in.) on clay and loam soils, and 12.5–20 mm (½–¾ in.) on sandy soils. Emergence declines rapidly if alfalfa seeds are planted more than 20 mm (¾ in.) deep.

Well-nodulated alfalfa can fix 170–225 kg of nitrogen/ha/year (150–200 lb/acre/year). To fix nitrogen effectively, alfalfa must be inoculated with *Sinorhizobium meliloti* bacteria (Inoculant Group A). For more information on inoculants, see Chapter 1, *Planning and Establishment*. If purchasing pre-inoculated seed, ask how the seed was handled and stored prior to purchase to determine whether it is likely the inoculant is still viable.

## Spring Seeding

The most reliable time to seed alfalfa is early spring, regardless of whether the crop is direct-seeded or seeded with a companion crop. With a spring seeding, moisture is usually adequate, and the plants are well established for winter survival. Plant as early as a favourable seedbed can be prepared to increase the chances of adequate moisture during the critical germination and early growth period.

## Summer Seeding

Summer seeding can be a viable alternative to spring seeding. It has the advantage of providing a full yield the following year. A summer seeding can typically follow winter or spring cereal harvest. Companion crops are not recommended in summer seedings because they compete too strongly for available soil moisture.

Seeding too early in the summer increases the risk of hot, dry conditions, affecting germination and seedling development. Seeding too late increases the chance of receiving a killing frost before legume seedlings are adequately established to accumulate enough root reserves to survive the winter. Legumes seeded after early September rarely survive the winter, since small legume plants are more susceptible to heaving.

The optimal time to summer seed alfalfa mixes depends on the length of the growing season:

- more than 3,100 CHUs — August 10–20
- 2,700 to 3,100 CHUs — August 1–10
- less than 2,700 CHUs — July 20–August 1

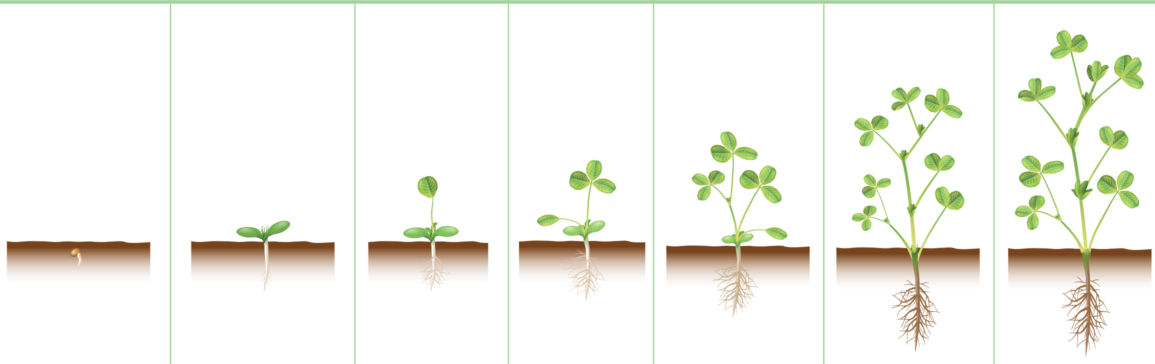
# Crop Development

Figure 3-2 and Figure 3-3 show the growth stages of the alfalfa plant from germination to full maturity. The first leaf of the alfalfa plant is unifoliate (a single leaf) occurring above the cotyledons. Subsequent leaves are trifoliate (three leaflets per stem) or multifoliate (more than three leaflets per stem), depending on the variety. These leaves are on alternate sides along the stem. Stems produced after the first (primary) stem are called secondary stems.

Crown development, also called contractile growth, begins about 1 week after emergence. This growth process may last up to 16 weeks. The cells in the stem below the cotyledonary node become shorter and thicker to form the crown. This process sometimes pulls the cotyledon and unifoliate below ground. Varieties with lower fall dormancy rating tend to express more contractile growth.

Root nodulation occurs within 4 weeks of germination, provided enough viable rhizobia are present around the seed.

**Figure 3-2.** Vegetative Growth Stages of Alfalfa

| | 0 | | | | | 1 | 2 |
|---|---|---|---|---|---|---|---|
| | Early Vegetative Growth | | | | | | |
| **Stage** | **Germination** | **Cotyledon** | **Unifoliate** | **First Trifoliate** | **Third Trifoliate** | **Mid-Vegetative Growth** | **Late Vegetative Growth** |
| Images |  | | | | | | |
| *Notes* | | Crown development begins; may last up to 16 weeks. | | | Stem length less than 15 cm (6 in.). No visible buds, flowers or seed pods. | Stem length 15-30 cm (6-12 in.). No visible buds, flowers or seed pods. | Stem length greater than 30 cm (12 in.). No visible buds, flowers, or seed pods. |

Adapted from Mueller and Tueber, 2007.[2]

**Figure 3-3.** Reproductive Growth Stages of Alfalfa

| | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|
| **Stage** | **Early Bud** | **Late Bud** | **Early Flower** | **Late Flower** | **Early Seed Pod** | **Late Seed Pod** | **Ripe Seed Pod (Full Maturity)** |
| Images |  | | | | | | |
| *Notes* | 1-2 nodes with visible buds. No flowers or seed pods. | 3 or more nodes with visible buds. No flowers or seed pods. | 1 node with open flowers. No seed pods. | 2 or more nodes with open flowers. No seed pods. | 1-3 nodes with green seed pods. | 4 or more nodes with green seed pods. | Nodes with mostly brown, mature seed pods. |

Adapted from Mueller and Tueber, 2007.[3]

Not all alfalfa plants in a field, or stems on a plant, reach the same stage of maturity at the same time. Two methods are used to determine the developmental stage of the crop: mean stage by count and mean stage by weight.

## Mean Stage by Count

Sample at least 40 stems from five or six locations in the field that are representative of growing conditions across the field. Reference Figure 3-2 and Figure 3-3 to sort stems by developmental stage. Count the number of stems at each stage. The Mean Stage by Count method relies on a weighted average, so multiply the number of stems at each stage by the stage number. Add these up and divide by the number of stems (Mueller and Teuber, 2007).

**Example:**

If an alfalfa sample had:

- 5 stems in stage 0
- 3 stems in stage 1
- 8 stems in stage 2
- 9 stems in stage 3
- 7 stems in stage 4
- 6 stems in stage 5
- 2 stems in stage 6

Mean Stage by Count is calculated as:

$$\frac{(5 \times 0) + (3 \times 1) + (8 \times 2) + (9 \times 3) + (7 \times 4) + (6 \times 5) + (2 \times 6)}{(5 + 3 + 8 + 9 + 7 + 6 + 2)}$$

Which equals:

$$\frac{0 + 3 + 16 + 27 + 28 + 30 + 12}{40}$$

Or:

$116 \div 40 = 2.9$

Therefore, in this example, the Mean Stage by Count is 2.9.

## Mean Stage by Weight

Sample at least 40 stems from five or six locations in the field that are representative of growing conditions across the field. Reference Figure 3-2 and Figure 3-3 above to sort stems by developmental stage. Dry the stems in an oven at 60°C and weigh them. Mean Stage by Weight is calculated the same way as Mean Stage by Count, except that the weight of stems at each stage is used instead of the number of stems (Mueller and Teuber, 2007).

# Fertility

Alfalfa has high fertility requirements (Table 3-2). For more information on the nitrogen, phosphorus and potassium requirements of alfalfa, see the fertility section of Chapter 5, *Cool-season Perennials*.

## Sulphur

Sulphur (S) deficiency is being observed more frequently on alfalfa in Ontario with significant reductions in yield. The appearance of sulphur deficiency is similar to nitrogen deficiency with general yellowing of the plants. Sulphur availability varies from year to year according to temperature and rainfall. Sulphur, like nitrogen, can be leached below the root zone. Sulphur in manure is in the elemental form, which is more slowly available than sulphate fertilizers. Sulphur deficiencies are more likely to occur in Northwestern Ontario, (where soil is upwind of major industrial centres) on low organic matter soils, and soils that have not had a manure application for several years. Tissue sampling of alfalfa is a diagnostic tool used to predict whether there will be a response to applying S (see Table 3-3). If required, apply 6 kg/ha of S per tonne (5 lb/acre of S/ton) of expected dry matter yield. Sulphur must be in the sulphate form to be utilized by plants, so application of sulphate-S provides a more immediate yield response. Applying elemental-S bulk, blended with other fertilizer, is a cost-effective long-term method of providing S.

**Table 3-2. Nutrient Removal of Alfalfa**

| | One Production Year (3 cuts) | | Lifetime (10 cuts) | |
|---|---|---|---|---|
| | Metric | Imperial | Metric | Imperial |
| Yield | 7.78 tonnes DM/ha | 3.47 tons DM/acre | 25.34 tonnes DM/ha | 11.30 tons DM/acre |
| Nitrogen removal[1] | 244 kg/ha | 218 lb/acre | 793 kg/ha | 708 lb/acre |
| Phosphate removal | 50 kg/ha | 45 lb/acre | 164 kg/ha | 146 lb/acre |
| Potash removal | 233 kg/ha | 208 lb/acre | 758 kg/ha | 676 lb/acre |

[1] Assuming nodulation was successful, alfalfa will fix its own nitrogen to meet crop needs.
*Source*: AgriSuite, Ontario Ministry of Agriculture, Food and Rural Affairs.

# Boron

Boron (B) is important for alfalfa, but application is not required on all soils. A deficiency shows up mainly on high-pH, sandy soils. Boron applications are often advised on sandy soils and, in particular, the sandy loam and loam soils in the area east of the Niagara Escarpment up to and including Frontenac County. Boron deficiency is seen most frequently on droughty soils under dry conditions.

As boron deficiency becomes more visual, the youngest upper leaves of the plant become yellow to red in different plants (Figure 3-4). Growth can be severely stunted and winter hardiness reduced.

Boron deficiency can usually be corrected or prevented by an application of 1.0–2.0 kg/ha (0.9–1.8 lb/acre) of boron broadcast with the other fertilizer (e.g., potash). Boron should not be banded at seeding.

**Figure 3-4.** Visible boron deficiency symptoms show in the newest leaves (upper canopy) turning yellow or red.

# Plant Tissue Analysis

Take plant tissue samples by cutting the plant at normal mowing height at the late bud stage (see Table 3-3). Plants suspected of nutrient deficiency, however, should be sampled as soon as the problem appears. For sampling at times other than heading, and for species other than alfalfa, samples should be taken from both deficient and healthy areas of the field for comparative purposes. A soil sample should be taken from the same area and at the same time as the plant sample.

**Table 3-3. Interpretation of Plant Tissue Analysis for Alfalfa**

**Legend:** – = no data available

| Nutrient | Critical Concentration[1] | Maximum Normal Concentration[2] |
|---|---|---|
| Nitrogen (N) | – | 5.5% |
| Phosphorus (P) | 0.2% | 0.5% |
| Potassium (K) | 1.7% | 3.5% |
| Calcium (Ca) | – | 4.0% |
| Magnesium (Mg) | 0.2% | 1.0% |
| Sulphur (S) | 0.22% | – |
| Boron (B) | 20 ppm | 90 ppm |
| Copper (Cu) | 5 ppm | 30 ppm |
| Manganese (Mn) | 20 ppm | 100 ppm |
| Molybdenum (Mo) | 0.5 ppm | 5 ppm |
| Zinc (Zn) | 10 ppm | 70 ppm |

[1] Yield loss due to nutrient deficiency is expected with nutrient concentrations at or below the "critical" level.
[2] Maximum normal concentrations are more than adequate but do not necessarily cause toxicities.
*Notes:* Values apply to the plant cut at normal mowing height at the late bud stage.

# Harvest Timing

When to begin cutting is always difficult to decide. Methods used to determine when to cut include the calendar date, stage of development, growing degree days (GDD), scissors cut data and predictive equations for alfalfa quality (PEAQ).

In mixed stands, be sure to consider the maturity of the grasses when making cutting decisions. Grasses have higher NDF, but also higher NDFd levels than alfalfa. Forage quality of grasses declines faster with maturity than alfalfa. A late break in alfalfa dormancy and cool spring weather often results in mixed stands that have a greater proportion of grass, and grass that is relatively more mature than the alfalfa.

## Growing Degree Days (GDD)

Alfalfa uses GDD Base 5°C. For more information on calculating and using GDDs for harvest timing, see Chapter 14, *Harvest*. Be aware when referring to U.S. sources that they calculate GDDs for alfalfa development in Base 41°F, so the number of growing degree days required for crop development appears much higher.

## Scissors-cut Sampling and Analysis

Plant samples are taken once or twice a week (Monday to Thursday) in the morning at a normal cutting height. Multiple samples are “grabbed” at random at various places in a field to get a representative sample. Avoid field edges and smaller damaged areas. Samples should be about 225 g (0.5 lb). Remove excess moisture from the sample with a towel and place in a paper bag. Deliver to the lab with overnight express delivery. Samples should not be taken on Friday or over the weekend to prevent them spoiling before they get to the lab. Labs typically use near infrared reflectance spectroscopy (NIRS) and they should be calibrated to accurately do this with fresh samples.

Results should be available from the lab by fax or e-mail the following day. Courier and lab costs are low relative to feed bills.

## Predictive Equations of Alfalfa Quality (PEAQ)

The PEAQ method was developed at the University of Wisconsin. It uses the longest stem and the most mature stem to estimate the NDF of the alfalfa in a standing crop.

**Technique:**

1. Walk through the field and choose a representative 0.2-square-metre (2 square-foot) area. Determine the growth stage of the most mature stem in the sampling area. The most mature stem will be in either vegetative (no visible buds), bud (buds visible on at least one node) or flower stage (at least one open flower on the stem).
2. Measure the length of the longest stem in the 0.2-square-metre (2-square-foot) area. Measure it from the soil surface (next to the plant crown) to the tip of the stem (not to the tip of the highest leaf blade). Straighten the stem for an accurate measure of its length. The longest stem may not be the most mature stem. Make sure to measure the longest stem, not an average length stem.
3. Based on the growth stage of the most mature stem and length of the longest stem, use the accompanying chart (Table 3-4) to determine estimated NDF of the standing alfalfa forage.
4. Repeat these steps in four or five representative areas across the field. Sample more times for fields larger than 12 ha (30 acres). Average all estimates for a field average.

**Table 3-4. Percentage Neutral Detergent Fibre (NDF) Estimates in Alfalfa**

| Length of Longest Stem from Soil to Stem Tip (cm (in.)) | Stage of Most Mature Stem | | |
|---|---|---|---|
| | Late Vegetative (Stage 2) | Bud Stage (Stage 3-4) | Flower Stage (Stage 5-6) |
| 41 (16) | 28.5 | 29.7 | 31.4 |
| 43 (17) | 29.2 | 30.4 | 32.0 |
| 46 (18) | 29.9 | 31.1 | 32.7 |
| 48 (19) | 30.6 | 31.8 | 33.4 |
| 51 (20) | 31.3 | 32.5 | 34.1 |
| 53 (21) | 32.0 | 33.2 | 34.8 |
| 56 (22) | 32.7 | 33.9 | 35.5 |
| 58 (23) | 33.4 | 34.6 | 36.2 |
| 61 (24) | 34.0 | 35.3 | 36.9 |
| 64 (25) | 34.7 | 35.9 | 37.6 |
| 66 (26) | 35.4 | 36.6 | 38.3 |
| 69 (27) | 36.1 | 37.3 | 38.9 |
| 71 (28) | 36.8 | 38.0 | 39.6 |
| 74 (29) | 37.5 | 38.7 | 40.3 |
| 76 (30) | 38.2 | 39.4 | 41.0 |
| 79 (31) | 38.9 | 40.1 | 41.7 |
| 81 (32) | 39.6 | 40.8 | 42.4 |
| 84 (33) | 40.3 | 41.5 | 43.1 |
| 86 (34) | 40.9 | 42.2 | 43.8 |
| 89 (35) | 41.6 | 42.8 | 44.5 |
| 91 (36) | 42.3 | 43.5 | 45.2 |
| 94 (37) | 43.0 | 44.2 | 45.8 |
| 97 (38) | 43.7 | 44.9 | 46.5 |
| 99 (39) | 44.4 | 45.6 | 47.2 |
| 102 (40) | 45.1 | 43.6 | 47.9 |

**Example:** if the most mature stem is in the bud stage, and the longest stem is 71 cm (28 in.), the NDF is estimated to be 38.0%.

PEAQ estimates the quality of the standing crop and does not account for changes in quality due to wilting (respiration), harvesting (leaf loss) and storage (fermentation). These factors may increase the final NDF content by from 2% (haylage) to up to 6% (hay), assuming good wilting and harvesting conditions. This procedure is most accurate for good stands of pure alfalfa with normal growth.

The NDF of the grasses in mixed stands will be higher than the alfalfa, so stands with significant grass must be cut earlier.

Similar charts are also available for ADF and relative feed value (RFV). A PEAQ stick has been developed that incorporates the NDF estimates onto an easy-to-read measuring stick, which can be used in the field.

PEAQ is intended to be used as a tool in making cutting decisions and is not to replace forage analysis and ration balancing. Studies have shown that NDF can be estimated using PEAQ with reasonable accuracy compared to GDD or scissors cutting. PEAQ is not perfect, but it is likely more accurate than using calendar date or growth stage alone.

PEAQ was designed for pure alfalfa stands. Recently, le Centre de référence en agriculture et agroalimentaire du Québec (CRAAQ) developed Nutri-Fourrager for mixed alfalfa/grass stands. While the tool was only developed in French, the web browser translation makes it usable in English as well. Nutri-Fourrager is available at https://nutrifourrager.craaq.qc.ca/

## Fall Rest Period

The fall rest period (sometimes called "critical fall harvest period") for alfalfa is 450 growing degree days, base 5°C — or approximately 6-weeks — before the average date of the first killing frost (-4°C for several hours), when alfalfa stops growing. Not cutting during this period allows alfalfa plants to grow and build up sufficient root reserves to survive the winter and grow more aggressively in the spring. When cut early in the period, the alfalfa will use the existing root reserves for regrowth, "emptying the tank." Later in the period, the alfalfa uses photosynthesis to produce carbohydrates and stores them as root reserves, "refilling the tank." Cutting in the middle of the fall rest period (3rd or 4th week), when root reserves will be depleted and there may not be time to replenish them, is usually higher risk than cutting at either the beginning or the end of the period.

The fall rest period begins around August 15th in Northern Ontario, August 30th in Eastern and Central Ontario, and September 4th in Southwestern Ontario (Figure 3-5). However, it is difficult to predict when that killing frost will occur. The actual date seldom occurs on the average date, so the beginning of the fall rest period is a guideline only.

Even when winterkill does not occur, the extra yield harvested during the fall rest period is typically offset by reduced vigour and lower 1st-cut yields the following spring. It can sometimes be difficult to observe, but can still be significant. Research shows that the yield sacrificed by not harvesting during the fall rest period is usually regained in first-cut yield the following year. The decision to cut in the fall should always be weighed against the immediate need for forage. If you do decide to cut, consider leaving some check strips that you can use for comparison next year.

Fields with older stands, a history of winterkill, low potassium soil tests, low pH, poor drainage, or insect and disease pressure are at increased risk of winterkill and are poor candidates for fall harvesting. Fall harvest of new seedings is generally not recommended. Aggressive cutting schedules with cutting intervals of less than 30 days between cuts increases the risk of winterkill, while intervals over 40 days (allowing flowering) reduce the risk. Frequently, first cut yields are poor in fields where a cut was taken the preceding fall.

Some areas of the province, such as the Ottawa Valley, have a higher historical risk of winterkill. In situations where forage inventories are adequate, increasing the risk of winterkill by fall cutting is far less acceptable.

If fall harvest must be done, risk of winterkill can be reduced (but not eliminated) by cutting towards the end of alfalfa growth, close to a killing frost. Little root reserves will be depleted by regrowth, but lack of stubble to hold snow to insulate the alfalfa crowns against damage during cold weather may be a problem. Increasing cutting height to 15 cm (6 in.) of stubble will help. Try to limit late cuttings to fields that are otherwise lower risk — well-drained, good fertility, healthy crowns and roots, etc. A killing frost occurs when temperatures reach about -4°C for several hours. After a killing frost, alfalfa feed value will quickly decline, as leaf loss occurs and rain leaches nutrients quickly.

Insufficient top growth and snow-holding capacity can contribute to alfalfa frost heaving. If winter ice sheeting occurs, stubble will protrude through, allowing air to get under the ice. Cut alfalfa initiates regrowth from crown buds and axillary buds, not the cut end of the stem, so cutting higher does not reduce usage of root reserves. However, cutting higher does allow for holding more snow as insulation.


**Figure 3-5.** Start of the six-week alfalfa fall rest period.

## Smothering

There is always the concern of smothering in heavy forage stands that are left unharvested. Heavy stands of grasses or red clover can sometimes smother over the winter because the top growth forms a dense mat. In contrast, alfalfa loses most of its leaves as soon as there is a hard frost, and the remaining stems remain upright and seldom pose any risk of smothering. While smothering may be a risk in mixed stands, it is not a risk in straight alfalfa.

# Termination

Cutting places stress on an alfalfa plant. Consider terminating healthy stands after 9-12 cuts, as they become very susceptible to disease and winterkill. Maintaining alfalfa past this point may not be as economical as terminating the stand, rotating the field into a different crop and establishing a new alfalfa stand elsewhere. Harvest is the most expensive part of growing a forage crop; planned termination keeps yield potential high enough to justify running the harvesting equipment through the field.

Other stressors, such as adverse weather, pests and diseases, may reduce the life of a stand before the target number of harvests is reached. Alfalfa stands should be assessed regularly to ensure they are healthy and productive enough to keep. These assessments include plant counts, root health checks and stem counts.

## Plant Counts and Root Health Checks

When the crop has broken dormancy and is putting out new stems, it is time to do a plant count and root health assessment to determine how well the alfalfa overwintered. This first scouting acts as an early warning system, revealing any serious problems before field work starts.

The target number of healthy alfalfa plants per area varies depending on the age of the stand. Alfalfa stands thin naturally over time but can compensate because the crown of older plants is larger and sends up more shoots. Table 3-5 shows how many healthy plants should be present in the field. Where there are ranges, pure stands should be near the high end, while alfalfa/grass mixtures can be at the low end of the range.

**Table 3-5. Target Alfalfa Stand Plant Count**

| Age of Stand | Healthy Plants |
|---|---:|
| New seeding | 215+ plants/m$^2$ (20+ plants/ft$^2$) |
| Year 1 | 129-215 plants/m$^2$ (12-20 plants/ft$^2$) |
| Year 2 | 86-129 plants/m$^2$ (8-12 plants/ft$^2$) |
| Year 3 or older | 54 plants/m$^2$ (5 plants/ft$^2$) |

Plants that have heaved are not healthy. Their crowns are exposed to drying winds, and their tap roots may be broken. These plants will not survive for very long.

Dig up some plants and cut open their roots. Healthy alfalfa taproots are white or cream-coloured, and firm like a potato. Unhealthy roots may be yellow or brown in the centre of the root, ropey or stringy, and may smell like rot. Plants with unhealthy roots are unlikely to survive.

If the number of healthy plants per area is lower than the targets in Table 3-5, producers have options and time to address their forage production needs. Fields could be patched with red clover (for protein) or grasses (for yield). Since patched fields should not be kept for another winter, this is a good opportunity to use Italian ryegrass for some very palatable haylage or baleage. Other grasses offer more summer growth. Another option is to terminate the stand and rotate it into something else. Alfalfa is autotoxic; it cannot follow itself in a rotation because seedlings will not germinate very well (see *Other Crop Production Issues, Autotoxicity,* in this chapter).

A plant count can also be done in the fall to assess the stand before winter. This can be used to make a termination decision after a tough growing year or can provide context for the spring plant count when assessing winter damage.

## Stem Counts

While plant counts will alert producers to a serious problem early in the season, stem counts are a better way to assess the yield potential of alfalfa. Stem counts cannot be done until there is at least 15 cm (6 in.) of growth. However, because this is much later in the spring than a plant count, there may be fewer options available to address issues.

Each alfalfa plant sends up multiple stems. Figure 3-6 outlines how the number of stems per square foot relates to yield potential.

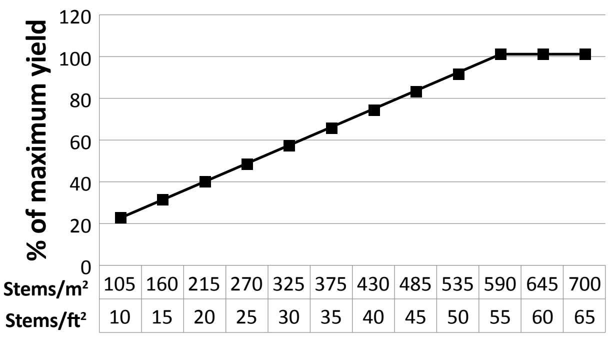



**Figure 3-6.** Alfalfa yield potential at various stem count densities.

Harvest is the most expensive part of growing a hay crop. In addition, there is very little difference in the per acre cost to harvest a low-yielding hay crop or a high-yielding hay crop. This means that a high-yielding hay crop is cheaper to grow per tonne of forage. If the yield potential is less than 75%, it is generally too expensive to keep harvesting that low-yielding crop. Consider replacing the stand if there are less than 430 stems/$m^2$ (40 stems/$ft^2$) and the crown and root health are poor.

By the time there is enough growth to do a stem count, patching is not an option. The alfalfa will out-compete any new seeds for light and moisture. Most producers in this situation harvest first cut, terminate the stand and rotate it into something else.

## Managing Alfalfa in Crop Rotations

Autumn is the best time to terminate an old stand of alfalfa so that a suitable seedbed exists in the spring and volunteer alfalfa is minimized. A mouldboard plow is the most effective tillage implement. Information on how to chemically terminate alfalfa can be found at the Ontario Crop Protection Hub at ontario.ca/cropprotection.

# Other Crop Production Issues

## Autotoxicity

Reseeding alfalfa following alfalfa is not a recommended crop rotation practice because of autotoxicity, seedling diseases and insect pests that can build up in the old stand. Alfalfa autotoxicity occurs when established alfalfa plants produce toxins that reduce establishment and growth of new alfalfa plants. Autotoxicity can occur when alfalfa is reseeded into an old alfalfa field rather than being rotated, or when alfalfa is seeded into an existing alfalfa stand in an attempt to thicken it.

While seed germination and plant density are reduced by alfalfa autotoxicity, effects on root growth are even more severe. Roots are swollen, curled, discoloured and lack root hairs. Mature plants appear to be more "branch-rooted," rather than "tap-rooted." The effects on root growth can significantly impact yields.

Responses to alfalfa autotoxicity are variable, depending on many factors. Water-soluble autotoxicity chemicals are more concentrated in leaves and stems than in the roots. Removing top growth before plowing, and tillage can help reduce the autotoxicity effect. Higher temperatures break down the toxic compound more rapidly, while rains can move them from the root zone. Autotoxicity may initially be more severe on light soils but lasts longer on heavier soils.

The concept of alfalfa autotoxicity is generally accepted. However, there is some disagreement on the minimum time required between killing the old stand (either by plowing or glyphosate application) and reseeding. Time is required for the toxins to degrade or move out of the root zone. Research has shown that while an interval of only 2 or 3 weeks is required to eliminate the adverse effects on germination and plants per area, the potential effects on root development and forage yields can persist much longer.

Impacts on root growth have significant effects on yield. Studies have shown that yields are reduced when alfalfa is seeded after alfalfa, regardless of the waiting period. This yield reduction appears to persist every year for the life of the stand. Stands affected by autotoxicity appear to regrow more slowly after each cutting. Even when alfalfa was killed in the fall and reseeded in the spring, yields were reduced when compared to alfalfa following corn. At the farm level, yield reductions from autotoxicity can be more difficult to recognize than plant density and are often attributed to other causes. For maximum yield, if the alfalfa is 2 or more years old, an intervening year of an alternate crop is required before reseeding to alfalfa.

The toxins are not present the first year in new seedings, so seeding failures or new seeds that were winterkilled can be reseeded without an autotoxicity effect. This would include a summer seeding after an unsuccessful spring seeding, or a spring seeding after an unsuccessful summer seeding.

It is not recommended that inter-seeding be done to thicken an established alfalfa stand as this is rarely successful. New seedlings often germinate, look acceptable initially, then die out over the summer. Research shows the area of autotoxicity influence is a 40-cm (16-in.) radius from established plants. This means that a field with plant density of less than 2 plants/$m^2$ (0.2 plants/$ft^2$) — almost nonexistent — would be required before inter-seeding could avoid autotoxicity. A stand with greater than 14 plants/$m^2$ (1.3 plants/$ft^2$) will have excessive zone overlapping and a high risk of failure. In an emergency, thin spots can be inter-seeded with red clover instead. Of course, inter-seeding a stand that is less than 1 year old is acceptable, because there is no alfalfa autotoxicity effect.

# References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2. Mueller and Teuber, 2007. *Alfalfa Growth and Development* [Chapter]. In *Irrigated Alfalfa Management for Mediterranean and Desert Zones.*

3. Mueller and Teuber, 2007. *Alfalfa Growth and Development* [Chapter]. In *Irrigated Alfalfa Management for Mediterranean and Desert Zones.*


# Additional Sources

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CHAPTER 4

# Silage Corn

## Corn

***Zea mays***
Corn is a large, annual, warm-season grass. It often has brace roots (Figure 4-1). The leaves are broad, smooth and glossy, with smooth leaf margins. Corn has both male and female flowers, called the tassel and the ear.

**Figure 4-1.** Nodal or brace roots on corn distinguish it from other warm-season annual grasses in the vegetative stage.

Corn's tolerances to drainage, soil pH, and harvest suitability are included in the tables in Chapter 8, *Warm-season Annuals.*

Corn is highly palatable to livestock and makes excellent silage. As a forage crop, corn can deliver good yield, starch content and digestible fibre, though it is a poor source of protein. Producers looking to extend their grazing season will sometimes graze standing corn, but this takes careful management to prevent grain overload.

## Soil Texture, Drainage and pH Considerations

In Ontario, coarse-textured soils (e.g., sand, loam or sandy loam) that have good internal drainage characteristics show little yield response to tillage (drainage classification: rapid or well). Even for crops that leave large amounts of residue cover, such as grain corn or cereals, there is often little response to tillage. On heavy-textured soils (e.g., clay, clay loam) with relatively slow internal drainage, tillage can significantly increase the rate of soil drying and warming. This increases the possibility for timely planting and rapid uniform emergence.

Soils experience slower spring drying rates in no-till systems due to the lack of soil loosening and residue incorporation associated with tillage. This can delay planting and possibly decrease the number of days available for timely planting. Effective tile drainage is necessary for many Ontario soils to ensure a reasonable opportunity for timely no-till corn planting. Good drainage also helps to provide a favourable seedbed environment for rapid, deep root growth. Producers on fine-textured soils often discover that successful no-till is very difficult on fields that are not systematically tile drained. These fine-textured fields with inadequate tile drainage will often require some type of fall tillage to maximize yield potential.

Most field crops grow well in a soil pH range of 6.0–8.0. Relative to other crops, corn is moderately tolerant to lower pH soils. Compared to other forage crops, it is more tolerant of low pH than alfalfa, but may be less tolerant than some perennial grasses. Lime is beneficial on coarse (sand)-textured soils below pH of 6.1 and on fine (clay)-textured soils below 5.1. For full lime recommendations, see Chapter 9, *Soil and Fertility Use*, in OMAFRA Publication 811, *Agronomy Guide for Field Crops*. pH above 8.0 does not generally impact crop growth directly but can impact nutrient availability. There are no practical methods for reducing soil pH.

Silage corn production is generally not suited to steep slopes or soils prone to erosion, as row spacing is wide and leaves a lot of bare soil for much of the year. Harvest typically occurs in early fall, and very little residue remains after harvest to protect or hold the soil in place. Cover crops can be a good fit in a silage corn system, especially when corn is grown in the same field for more than 1 year. Cover crops can protect soil after harvest when there is little crop residue left, can be planted in early fall when temperatures are still reasonable for establishment and, depending on species, could serve as an additional forage source. For example, cereal rye can grow well in cool conditions, has good winter survival to provide living ground cover all fall, winter and early spring, and grows and matures earlier in spring than other winter cereals for timely harvest before planting a silage corn crop. If silage corn must be grown on slopes or soils prone to erosion, ensure cover crops are in place after harvest.

With silage corn there are three timing options for cover crop establishment — early in season (V4–V6), late-season broadcast and post-harvest. Because the corn canopy is removed in early fall, a cover crop has a better chance of establishing successfully under a silage corn crop than under a grain corn crop, regardless of timing. Including a cover crop in silage corn production provides an opportunity to apply manure. The cover crop usually creates better soil conditions to carry equipment, which reduces soil compaction.

# Hybrid Selection

The goal in choosing silage corn hybrids is to optimize yield, digestible fibre and starch content.

## Maturity Ratings

Corn development is driven primarily by temperature, especially during the planting-to-silking period. Unlike soybeans, day length has very little effect on the rate at which corn develops. The Ontario crop heat unit system has been developed to calculate the impact of temperature on corn development. Ontario crop heat units (CHUs) are calculated based on daily maximum and minimum temperatures and allow for a numerical rating of growing seasons, geographical locations and corn hybrids. This system allows producers to select hybrids that have a high probability of reaching maturity before a killing frost occurs. The CHU map for Ontario is found in Chapter 1 of OMAFRA Publication 811, *Agronomy Guide for Field Crops*.

Because grain maturity and dry down are less of a concern when choosing hybrids specifically for whole-plant silage, a yield advantage can usually be obtained by selecting hybrids rated 100–200 heat units higher than those selected for grain.

Unlike for grain corn, there are no public Ontario corn silage hybrid performance trials. Work with your seed suppliers to select high-performing hybrids that have demonstrated consistency across a range of environments (soil types, precipitation, farm practices) and years (weather). Ideally look for performance data that has been replicated. This will increase the probability of selecting a hybrid that will perform well on your farm.

In the absence of silage yield data, a traditional selection approach for corn silage hybrids has been to plant a hybrid with high grain-yield potential under the assumption that grain yields are well related to whole plant yield. While this may serve as a general guide, hybrid trials in other jurisdictions suggest there is variability in grain:stover ratios, and that the highest grain-yielding hybrid may not be the highest silage-yielding hybrid.

### Switching to Shorter-season Hybrids

Field conditions may delay planting and necessitate switching to less than full-season hybrids. While hybrid switching in grain corn is an attempt to ensure the plant reaches maturity without sacrificing too much grain yield, the goal of growing silage corn is different: to balance energy content and total yield. This different goal changes the criteria for hybrid switching.

Research from Wisconsin shows that full-season silage corn has the highest forage yields when it is planted early. Once we pass the switch dates for grain corn, the total forage yield of full-season and shorter-season hybrids do not differ significantly. However, shorter-season hybrids have higher starch content than full-season hybrids, regardless of planting date. This additional starch makes a difference in the feed quality of the crop: as planting is delayed further, milk per acre from the shorter-season hybrid is higher than from the full-season hybrid. Therefore, the switch date for silage corn in Ontario is about a week later than for grain corn (Table 4-1).

## Silage Traits

Dual-purpose corn hybrids offer good grain yields and good silage yields. The advantage of growing a dual-purpose hybrid is the flexibility to change the crop’s end use depending on how growing conditions affect other forage crops and the grain markets. However, dual-purpose hybrids may not be as digestible as silage hybrids: there is a greater need for a grain crop to resist lodging, so lignin content in dual-purpose hybrids may be higher. These hybrids may also have a “stay green” trait that causes the moisture content of the grain and the stalk to diverge during dry-down. This makes correctly timing silage harvest difficult. Because it is difficult to predict yields and actual amount of silage acres required at planting, it can be helpful to have some portion of silage acres planted to a hybrid that can also be harvested as grain, for flexibility. Some silage-specific hybrids do not lend themselves for dry grain corn harvest (poor standability, poor kernel dry down or integrity for combining) and, if left over, may be better suited for high-moisture corn.

Brown mid-rib (BMR) hybrids have 20%–30% less lignin in their stalks than non-BMR silage corn hybrids. This increases the digestibility of the corn silage and increases livestock intakes. BMR hybrids are typically lower yielding than non-BMR hybrids, although breeders are making improvements in

**Table 4-1. Recommended Dates to Switch from Full Season Hybrids Across Various Heat Unit Zones**

| Heat Unit Zone (CHU-M1) | Grain Switch Date | Silage Switch Date |
|---|---|---|
| >3,200 | May 30–early June | June 6–mid June |
| 2,800–3,200 | May 20–25 | May 27–June 1 |
| <2,800 | May 15–20 | May 22–27 |

*Source:* Publication 811, *Agronomy Guide for Field Crops*, Ontario Ministry of Agriculture, Food and Rural Affairs and adapted from Lauer, 2013.[1]

yield potential. Higher animal intakes and lower yield potential mean that producers may have to grow more acres of BMR hybrids than they would grow of conventional hybrids to meet livestock demands. Due to their lower lignin content, the risk of lodging is higher for BMR hybrids. To help prevent lodging, ensure adequate potassium fertility based on a current soil test. BMR hybrids should be grown and stored separately from non-BMR hybrids. Their higher digestible fibre will have a large impact on animal performance. Keeping BMR hybrids separate from non-BMR hybrids gives nutritionists greater ability to correctly balance a ration.

Leafy hybrids have eight or more leaves above the ear and a lower ear position than dual-purpose hybrids. These physical characteristics increase the leaf area that produces sugar for the ear, while reducing the amount of highly lignified stalk needed to hold it up. Silage yields are generally comparable to those of dual-purpose hybrids. Leafy hybrids were selected under low plant populations — typically 70,000–75,000 plants per hectare (28,000–30,000 plants per acre) — and may lose feed quality if planted at higher rates, particularly if stressed. In research trials, leafy hybrids planted at 86,450 plants per hectare (35,000 plants per acre) had lower starch and higher lignin than dual-purpose varieties. Producers considering leafy silage corn must be able to adjust their planting rate to suit these hybrids.

# Planting

Soil temperature must be at least 10°C for corn to germinate evenly.

## Population

Corn silage plant populations are often promoted as having to be higher (10%) than grain corn. Research from Cornell University disputes this, showing no advantage to having plant stands of more than 86,500 plants/ha (35,000 plants/acre) for any of the hybrids tested. The research predicted that as hybrid populations increased, silage digestibility declined. Optimum plant populations may be very hybrid-specific due to the genetic diversity among silage hybrids. Seed suppliers may have more information on ideal populations for the hybrids they carry.

## Depth

The first rule of corn planting is to plant into moisture (25%–50% or near field capacity). However, a few other considerations allow for some fine-tuning of planting depth. Shallow planting of corn (less than 2.5 cm (1 in.) deep), even into moisture, may lead to less favourable positioning of the growing point and first nodal roots (Figure 4-2). This may lead to rootless corn syndrome in some cases and predisposes the seed to greater injury from herbicides. Coarse-textured soils that dry rapidly at the surface will also be more prone to poor root establishment with shallow plantings.

**Figure 4-2.** Uneven planting depth. Uniform seeding depth is critical to achieving uniform emergence.

In contrast, planting deeper at 5.5–8 cm (2 ¼–3 ¼ in.), especially when soils are cold early in the planting season, can delay emergence compared to planting at depths of 3.75–5 cm (1 ½–2 in.). Delayed emergence can lead to increased risk of insect feeding or seedling diseases. As the planting season progresses and as soils warm and dry, ensure that the corn seed is placed firmly into moisture and planted at a target depth of 5 cm (2 in.). When planting is extended and soils warm, planting at depths of 7.5 cm (3 in.) in order to find moisture is often less risky than planting at shallower depths and hoping for rain.

Physiologically speaking, a corn seed that is placed into moisture at 3.75 cm (1 ½ in.) deep will have excellent performance. The challenge comes when a corn planter is set to deliver seeds at 3.75 cm (1 ½ in.) deep and due to planter row-unit bounce or some areas of the field with a seedbed that is rough, uneven or compacted, will have some seed planted too shallow for good emergence. Therefore, it is often advisable to set the planter slightly deeper to avoid having any seeds that are less than 3.75 cm (1 ½ in.) deep.

Planting depth can be evaluated well into the growing season by carefully excavating the plant, removing the nodal roots and identifying the mesocotyl. The mesocotyl is generally a white, mostly hairless structure that runs from the seed to the crown. Measuring the length of the mesocotyl and adding 2 cm (¾ in.) usually results in an accurate assessment of planting depth.

## Corn Planting Following Early Hay Harvests

Producers looking for an opportunity to replace a declining hay field may consider planting corn following a first harvest of hay. With time and heat unit accumulation being the limiting factors, this corn crop needs to be planted as quickly as possible following hay harvest. For this reason, the option of no-tilling the corn crop into the hay stubble is very attractive. In addition, many of the soil structural and erosion control benefits fostered by the previous forage crop will be enhanced and/or prolonged by using a no-till system.

Research in Ontario, conducted by the University of Guelph, examined corn silage yields from several different cropping systems in a study conducted near Woodstock in 1988 and 1989. In this work, a 5-year-old sod (75% alfalfa) was converted to corn production using both conventional tillage and no-till systems following the removal of a hay crop (as haylage) in early June. Yields obtained from these two tillage systems are outlined in Table 4-2. Silage yields were equivalent between conventional and no-till in 1989 but no-till yielded dramatically less than conventional tillage in 1988. Rainfall was 7% of normal during June of 1988, and this resulted in no-till planting conditions that caused low plant stands and poor early growth. Success of the no-till corn planting following hay harvest in 1989 was attributed to adequate soil moisture during and after the planting operation.

Similar studies to those in Ontario were conducted by the University of Wisconsin (M. Smith, P. Carter and A. Imholte) during 1985 to 1987 and had somewhat similar results. In their study, no-till corn grain yields following an early-season hay harvest were comparable with yields obtained in tilled fields in only 1 out of the 3 years. The successful no-tilling occurred in the year that had June rainfall that was above average. In the other 2 years of the experiment, no-till corn yields averaged 2,887 kg/ha (46 bu/acre) less than those obtained with conventional tillage.

**Table 4-2. Effect of Corn Planting Systems Following Early June Hay Harvest on Corn Silage**

| | Corn Silage Yields @ 65% Moisture (tonnes/acre) | |
|---|---|---|
| **Corn Planting System** | **1988** | **1989** |
| Conventional tillage (following hay harvest) | 17.0 | 16.6 |
| No-till (following hay harvest) | 8.9 | 16.8 |
| Planting date | June 2 | June 8 |

*Source:* G.K.S. Aflakpui, T. Vyn, G. Anderson, D. Clements, M. Hall and C. Swanton. University of Guelph. Research conducted at Woodstock, Ontario.

If you are determined to plant corn following a hay harvest in early June and rain has been limiting, the lower risk alternative would include some tillage prior to planting. This tillage does nothing to conserve moisture or soil structure, but it may be essential for good seed-to-soil contact and early corn root exploration in these relatively hard, dry soils. This is a common phenomenon in Ontario. We can measure higher soil moisture in no-till soils compared to plowed ground, but if dry weather comes early, the corn plants cannot get a root system established. In these cases, no-till performs more poorly than plowed ground. Even though the no-till ground has conserved more moisture, the roots cannot get at it.

However, in years where soil moisture is adequate, it appears that no-till corn can do well in sod fields providing it is given a strong start. Here are some suggestions:

- This operation will require above-average planter unit down pressure and planter mass. No light-weights recommended.
- Some tight sods, especially those with a lot of grass in them, cannot be suitably worked with a three-coulter system common to many no-till planters. The resulting strip is clumpy, air filled and not conducive to germination or early plant growth. A single coulter along with trash removing wheels may result in a firmer, cleaner seedbed.
- If the root mat is extreme (i.e., long-term pasture), rubber closing wheels may not be enough to close the seed trench. Cast closing wheels with maximum down pressure may be required.
- Chemical control of the sod and other weeds is critical. Apply a recommended pre-harvest treatment to the hay crop and/or herbicides during pre-emerge or post-emerge windows of the corn crop.
- Select a hybrid with a heat unit rating suitable for the delayed planting date. Late-planted corn may be at greater risk of corn rootworm laying eggs in the soil. Scout these fields in August and determine the risk of rootworm for the next year's corn crop. If fewer than 1 beetle per plant is found then risk is low and rootworm management tools including Bt-RW hybrids (below-ground protection) are not necessary.

# Crop Development

The vegetative and reproductive growth stages in corn are described in Figure 4-3 and Table 4-3.

## Corn Leaf Stages

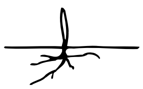
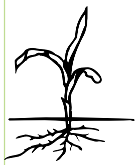
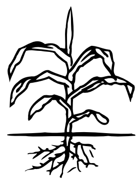
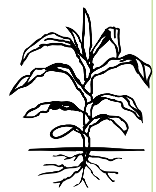
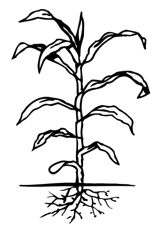
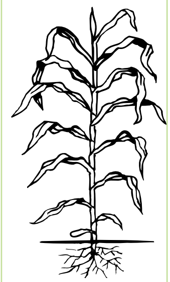
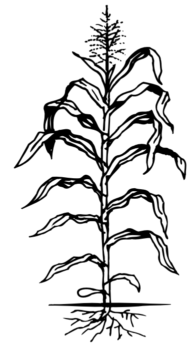
Counting the leaves on a corn plant sounds like an easy task, but there are a few complications that can cause mistakes. It is important to know which leaf-counting method is being referred to on pesticide labels or in other production information.

There are several methods used to count corn leaves:

- The leaf-tip method counts all leaves, including any leaf tip that has emerged from the whorl at the top of the plant.
- The leaf-over method only counts those leaves that are fully emerged and are arched over with the next leaf visible in the whorl but standing straight up.
- The leaf-collar method, used extensively in the U.S., refers to the leaf collar being visible. The leaf collar is the light green-to-whitish band that separates the leaf blade from the leaf sheath, which wraps around the stem. The stages for corn are referred to as V1, V2, V3, etc., where V3 stage is a plant with three collars visible.

Figure 4-3 shows comparative growth stages using different methods of counting leaves.

**Figure 4-3.** Vegetative Growth Stages in Corn

| **Stage** | **VE** | **V1** | **V4** | **V6** | **V8** | **V12** | **VT** |
|---|---|---|---|---|---|---|---|
| Images |  |  |  |  |  |  |  |
| Leaf collars | 0 | 1 | 4 | 6 | 8 | 12 | (varies) |
| Leaf tips | 1 | 3 | 7 | 10 | 11 | 15 | (varies) |
| Leaf over | 0 | 2 | 6 | 8 | 10 | 14 | (varies) |
| CHUs required[1] | 180 | 330 | 630 | 780 | 930 | 1,170 | 1,130 |
| Target date[2] | May 16 | May 25 | June 11 | June 18 | June 26 | June 31 | July 18 |
| *Notes* | ◦ Emergence.<br>◦ Days to emerge most often ranges from 6–21 days.<br>◦ Uniform emergence essential to high yields.<br>◦ Look for poor germination caused by chafer, wireworms, seedcorn maggot, seed corn beetle, slugs, black cutworm. | ◦ Start of critical weed-free period.<br>◦ Growing point below the ground.<br>◦ Ensure herbicide selection is safe for crop stage and forage use. | ◦ Ear initiation.<br>◦ Growing point below ground.<br>◦ Expansion of nodal root system will soon completely replace seminal root system.<br>◦ Risk from cutworm and flea beetle damage has passed. | ◦ End of critical weed-free period.<br>◦ Lower leaves (1–4) dry up, may not be visible.<br>◦ Growing point at or above ground; more susceptible to frost injury.<br>◦ Initiated ears and tassel now visible upon plant dissection. | ◦ Side-dressing nitrogen and inter-row cultivation beyond this point pose threat of root pruning.<br>◦ Beginning rapid stem elongation.<br>◦ Risk from slug damage has passed. | ◦ Crop becomes increasingly sensitive to yield reduction by heat or drought.<br>◦ Size of ear and number of potential kernels being established. | ◦ Tassel emerges.<br>◦ Pollen shed begins 2–3 days prior to silk emergence.<br>◦ Pollen viability reduced by drought and high temperatures.<br>◦ Scout for corn leaf aphids, corn rootworm adults and goosenecking caused by rootworm larvae. |

[1] Approximate CHUs required to reach various stages of corn development.
[2] Estimated date to reach various stages of development based on long-term heat unit accumulations for an average 2,800 CHU region and anticipating a May 5 planting date.

**Table 4-3. Reproductive Growth Stages in Corn**

| Stage | R1 Silking | R2 Blister | R3 Milk | R4 Dough | R5 Dent | R6 Maturity |
|---|---|---|---|---|---|---|
| Description | Silks emerge from husks at tip of ear. | Kernels are white, filled with clear fluid and distinct from surrounding cob material. | Kernels begin to have yellow colour. Inner fluid is milky white. | Milky inner fluid becomes thicker and pasty. Outer edge of kernels become firmer. Some dents appear. | Majority of kernels are dented. Hard white layer of starch evident at top of kernel (milkline). | Hard starch layer evident from top to bottom of kernel. Black layer forms at base of kernel. |
| CHU Required[1] | 1,480 | 1,825 | 2,000 | 2,165 | 2,475 | 2,800 |
| Target Date[2] | July 20 | Aug. 3 | Aug. 11 | Aug. 18 | Sept. 1 | Sept. 18 |
| *Notes* | ◦ Pollination requires 3–7 days.<br>◦ Silks continue to elongate until fertilized.<br>◦ Environmental stresses very detrimental to kernel yield.<br>◦ Begin scouting for ear insect pests (corn earworm, fall armyworm). | ◦ Kernels beginning dry matter accumulation.<br>◦ Relocation of nutrients from the leaves and the stem to the ear begins.<br>◦ Firing of lower leaves may become evident. | ◦ Rapid grain filling period.<br>◦ Good plant health, clear skies and active photosynthesis add to kernel size and test weight. | ◦ Top of kernel begins to firm up.<br>◦ Killing frost may cause yield losses of 25%–40%.<br>◦ Begin to assess ear rot incidence. | ◦ Milk line advances toward tip as crop matures.<br>◦ Whole plant moistures suitable for silage harvest.<br>◦ 90% of grain yield reached by one-half milkline.<br>◦ Examine fields for lodging, ear drop and stalk rots. If high, consider harvesting early. | ◦ Physiological maturity.<br>◦ Kernels have achieved maximum dry weight. |

[1] Approximate CHU required to reach various stages of corn development.
[2] Estimated date to reach various stages of development based on long-term heat unit accumulations for an average 2,800 CHU region, and anticipating a May 5 planting date.

# Fertility

Fertility responses and recommendations for silage corn are expected to be similar to grain corn production. Refer to Chapter 1, *Corn,* of OMAFRA Publication 811, *Agronomy Guide for Field Crops,* for full corn nutrient recommendations.

When growing corn on a livestock operation, it is important to credit nitrogen from non-fertilizer sources (legume forages or manure applications). For fertility budgeting, it is also important to remember that much larger quantities of phosphate and potash are removed with a corn silage crop than with grain corn or dry stover removal (see Table 4-4 for an example). Larger inputs of phosphorus and potassium will be required over the rotation to maintain soil test levels compared to grain-only rotations.

# Harvest

## Timing

The silking date can be used as an indicator to give an estimate of timing for silage corn harvest, usually 42–47 days after silking. Of course, the optimum harvest time will be affected by crop heat units (CHUs) during that period and may come earlier or later, depending on temperatures. It can be useful to predict which fields are ahead of others.

### Moisture Content at Harvest

Corn silage quality and animal performance are significantly affected by the whole plant moisture and maturity of the corn at harvest. Not only is it important to minimize fermentation dry matter losses and spoilage, it is difficult to compensate for poor forage quality with ration balancing.

Ensiling at the correct whole-plant moisture level and optimum stage of maturity is critical. Corn maturity is very dynamic. As corn matures from dent to black layer, yield increases, starch increases, starch digestibility decreases, and fibre and fibre digestibility decrease.

The best silage fermentation usually occurs when whole plant moisture is 65%–70%, producing optimum feed for livestock performance. This corresponds well to horizontal and bag silos, but silage may have to be a bit drier in tall tower silos to prevent seepage. Variability between fields and within fields can make this even more complex. Recommended moisture contents for silage corn are in Chapter 15, *Storage,* Table 15-6.

Harvesting silage corn at moisture levels above 70% will not only yield less but will result in seepage and a very undesirable clostridial fermentation. Clostridia bacteria are very inefficient and convert forage sugars and organic acids into butyric acid, carbon dioxide and ammonia. This silage will have high dry matter losses, high levels of foul-smelling butyric acid, with a higher pH, and poor feed quality, palatability and intake potential.

**Table 4-4. Nutrient Removal of Corn When Harvested for Grain or Silage**

| | Grain Corn | | Silage Corn | |
|---|---|---|---|---|
| | Metric | Imperial | Metric | Imperial |
| Yield[1] | 7.5 tonnes/ha | 3.3 tons/acre | 15 tonnes DM/ha (50 tonnes/ha @ 70% moisture) | 6.7 tons DM/acre (22.3 tons/acre @ 70% moisture) |
| Nitrogen removal | 110 kg/ha | 98 lb/acre | 285 kg/ha | 254 lb/acre |
| Phosphate removal | 56 kg/ha | 50 lb/acre | 127 kg/ha | 113 lb/acre |
| Potash removal | 39 kg/ha | 35 lb/acre | 266 kg/ha | 237 lb/acre |

[1] Assuming a Harvest Index of 0.5, the above grain and silage corn crops are yielding the same.
*Source:* AgriSuite, Ontario Ministry of Agriculture, Food and Rural Affairs.

Harvesting silage corn at moistures that are too low will result in poor packing, inadequate air exclusion, poor fermentation and heating. This will mean higher dry matter losses, greater spoilage and poor bunk life.

Kernel processors can be used to increase starch digestibility. Low-moisture silage corn that is not harvested using a kernel processor can be lower in starch digestibility. Kernels that are too dry will become hard and pass through cattle undigested. Fibre digestibility has been found to decrease by over 10% as moisture decreases from 70% to 58%.

Nutritionists have described the "new corn silage slump" where cows do not milk according to the expected results of the balanced ration when being fed newly fermented corn silage in the fall. This is attributed to the reduced starch digestibility of hard-textured, dry kernels in newly fermented, unprocessed corn silage. This can be very frustrating for milk producers trying to fill fall quota. This problem is usually reduced after 3 months, when the kernels have a chance to absorb silage moisture, become softer and fracture more easily.

## Moisture Testing

The most accurate method for determining when to harvest is to measure the moisture content.

Sample at least 10 plants from the field, avoiding the headlands. Watch for moisture variability within fields. Chop a sample using a harvester or yard chipper. Use a Koster Tester, microwave or laboratory to determine percent dry matter. Refer to Chapter 14, *Harvest,* for the method.

The current recommendation is to determine a whole-plant moisture shortly after denting when the milkline is about 20%. This can be done by sampling, chopping, drying and measuring as described above. Experience shows that in a typical year, silage corn at this stage dries approximately 0.5% per day. Therefore, if the sample was 70% moisture, and 65% moisture is the target, harvest about 10 days after the corn was sampled. In dry years, the drying rate will be more rapid. During wetter years, the drying rate will be slower. Check moistures again, closer to harvest.

## Kernel Milkline

The kernel milkline has often been used to determine when to harvest corn silage. This is done by breaking a cob in half and looking at the kernels. After denting (which shows as 0% milkline), a whitish line can be seen on the kernels. This line is where the solid and liquid parts of the kernel are separated while maturing and drying. This line will progress from the outer dent end of the kernel towards the cob. When this milkline has reached the cob (100% milkline), a black layer is visible (Figure 4-4). The traditional recommendation has been to harvest when the milkline is between one-half and two-thirds.

☐ Soft/milky starch ■ Solid/dry starch

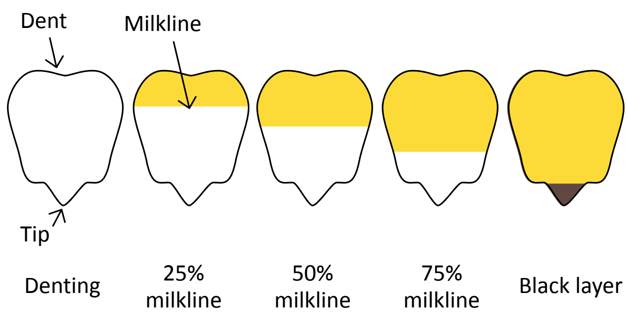



**Figure 4-4** Kernel milkline development

There is considerable variation in the percent kernel milkline and the moisture percent of the whole plant. University of Wisconsin data over many years show a range in whole plant moisture at one-half milkline of 52%–72%, with an average of 63%. This will be too wet for some and much too dry for others. The two most significant causes of the variation are weather and hybrid differences.

When extended dry weather results in abnormal corn plant development, percent moisture estimates based on the kernel milkline are not very accurate. Corn plants severely stressed by dry weather without cobs do not have kernel milklines to use as estimates, but plants are typically much higher moisture than they appear. Similarly, it can sometimes be difficult to accurately estimate whole-plant moisture from kernel milklines in frost-damaged corn.

Hybrid differences also affect the accuracy of using kernel milkline to estimate moisture level. Corn hybrids have varying degrees of "stay-green" characteristic. More stay-green means there is faster grain dry-down relative to stover dry-down. This is desired in a grain hybrid, because, as the grain dries, the stalk stays green and healthy, and is less likely to have broken stalks and lodge in late season.

Some hybrids are designed only for use in silage and have less stay-green, so that the grain will have higher moisture relative to the whole plant. In other words, hybrids with higher stay-green ratings will have milklines that are more advanced relative to whole plant moistures. Silage-only hybrids that have less stay-green characteristic will likely be ready to harvest at a less advanced milkline.

Because whole-plant moisture, not milkline, is critical for silage quality, one suggestion is to use milkline as a guide for when to start monitoring moisture content, rather than as a harvest guide (Table 4-5). Dr. Joe Lauer, from the University of Wisconsin, suggests milkline trigger points where whole-plant moistures will usually still be too wet for storage, but suitable to start monitoring whole-plant moisture for optimum storage.[2]

# Kernel Processing

## Laboratory Assessments

### *Kernel Processing Score*

The standard method for determining if kernel processing is adequate is by using a Ro-Tap Sieve Shaker. A sample of silage is dried and then sieved through several screens with progressively smaller mesh. The percentage of kernels that can pass through a 4.75-mm screen determines the Kernel Processing Score (KPS):

- 70% or greater is optimum
- 50%–69% is adequate
- less than 50% is an inadequately processed silage

KPS is a useful measurement for nutritionists as they balance a ration, however, it cannot be done in time to improve kernel processing during harvest.

## On-farm Assessments

### *Pioneer Corn Silage Processing Monitoring Cup*

The Pioneer Corn Silage Processing Monitoring Cup is a method developed by DuPont Pioneer, the U.S. Dairy Forage Research Centre and Dairyland Laboratories to assess whether kernel processing is adequate during silage corn harvest.

**Table 4-5. Using Kernel Milkline as a Trigger for Checking Corn Whole Plant Moisture for Silage Harvest**

| Silo Structure | Recommended Moisture Content | Kernel Milkline Trigger |
|---|---|---|
| Horizontal silo | 65%–75% | 20% |
| Bag silo | 60%–70% | 20% |
| Upright conventional silo | 60%–65% | 35% |
| Upright oxygen-limiting silo | 50%–60% | 60% |

*Notes:*

Whole plant silage corn moisture decreases at an average rate of 0.5% per day.

The milkline is the boundary between solid/dry and soft/milky starch in an immature corn kernel. Milkline movement starts with kernel denting and moves towards the kernel tip at the cob. It takes about 12 days to go from early dent to 50% kernel milkline, and about 13 days to go from 50% kernel milkline to black layer.

"**trigger**" = kernel milkline stage to begin checking whole plant moisture

To use, scoop silage into a 1-L (32-ounce) cup. Spread the silage out, and count how many whole or half kernels are present in the sample:

- 2 or less is ideal
- 2–4 is adequate
- more than 4 indicates a need to adjust equipment to increase kernel damage

Samples should be taken from at least three loads per hour to ensure processing is sufficient throughout the harvest.[3]

### *SilageSnap App*

The SilageSnap app was developed by the University of Wisconsin – Madison, University of Wisconsin Extension Services and the Midwest Forage Association to visually estimate the Kernel Processing Score during corn harvest. It is available for Android and iOS/Apple smartphones. To use it, the camera on a smartphone must be calibrated with a coin. The calibration process enables the phone to accurately measure the kernel pieces and count how many would pass through a 4.75-mm screen.

**Sample Preparation:**

1. Collect a representative forage sample, mix it and pull 1–2 handfuls for scoring.
2. Fill a dishpan or similarly sized container about three-quarters full of water.
3. Place the handful(s) of forage sample in the container.
4. Gently stir the material for about a minute to separate the stover from the kernel. The stover will float while the kernels will sink.
5. Skim the stover from the surface using your hands or a strainer.
6. Slowly pour the water from the dishpan, leaving the kernels behind. Remove any remaining stover from the kernels by hand.

**Image Capture:**

1. Use a dark, matte background. Black construction paper works well.
2. Spread the kernels in a single layer so they don't touch each other. It may require several pieces of paper to hold all the kernel fragments. A paintbrush may help spread out the kernel pieces.
3. Hold the camera level with the background, at the height determined by the calibration process.
4. Avoid cutting off kernels at the edge of the image and avoid bright lights that cause glare.[4]

More detailed information and examples can be found at: wimachineryextension.bse.wisc.edu/precision-agriculture/silagesnap/

# Other Crop Production Issues

## Bt-resistant Pests

Corn hybrids with traits that produce Bt proteins have been widely adopted to manage insect pests. Over-reliance on this mode of action for crop protection has led to populations of insects developing resistance to one or more of the Bt proteins that used to work against them. Resistance develops faster in continuous corn situations where Bt products are used repeatedly. This type of production is more common in silage corn than in grain, making Bt-resistance an important issue in silage production. Unexpected damage in Bt corn by the target pests should be reported to your seed provider and the OMAFRA field crops entomologist.

More detailed information on these pests (i.e. life cycle, management options) can be found in OMAFRA Publication 811, *Agronomy Guide for Field Crops*.

## Bt-resistant European Corn Borer

Significant infestations of European corn borer larvae may cause stalk lodging and ear droppage, which directly affect the quality and quantity of silage corn at harvest. This pest can carry both stalk rots and ear rots into the plant and is associated with fusarium infection, which could result in mycotoxins in the silage.

Vegetative corn is more attractive to European corn borer moths than more mature fields. Since there is a tendency to grow hybrids rated 100–200 CHUs longer than "full-season" grain corn in an area, silage fields may be among the least mature fields in their geography. Fields established after a first cut of hay are likely to draw in large numbers of European corn borer moths for egg-laying.

In 2018, European corn borer was confirmed to be resistant to the Cry1F protein in Bt corn in Nova Scotia. All corn growers across Canada should monitor for any signs of ECB damage showing up on any Bt corn hybrid. This especially applies to those regions that have shorter growing seasons with limited selection of Bt hybrids to choose from. Avoid using Bt hybrids that contain only one protein for European corn borer (i.e., only Cry1F or Cry1Ab proteins), to reduce the risk of resistance. Pyramid hybrids containing more than one effective Bt protein against European corn borer are recommended.

## Bt-resistant Western Bean Cutworm

Young western bean cutworm larvae feed on corn tassels and silks until they are large enough to tunnel into the ear and feed extensively on the kernels. Additional impact to quality can be expected from ear mould infection and accumulation of mycotoxins such as deoxynivalenol (DON, vomitoxin) and fumonisins, as well as secondary pests that may come in and feed on the damaged ears.

Western bean cutworm has developed resistance to the Cry1F Bt protein across North America. This leaves only one effective Bt protein — Vip3A — to protect against western bean cutworm. As a result, growers should not solely rely on Bt hybrids that contain Vip3A as their management tool against this pest. Rotate all effective tools, including foliar insecticides and Vip3A hybrids to reduce the risk of resistance. Scout for any signs of resistance to any management tool used and report them to the OMAFRA field crops entomologist.

## Bt-resistant Corn Rootworm

Corn rootworm is a significant pest of corn. Rootworm larval feeding has a larger impact on silage yield and quality than on grain. Significant yield loss can occur well before the classic signs of rootworm damage (lodging, goose-necking) are visible. Corn rootworm populations are highest in fields of continuous corn.

In fields where Bt rootworm corn hybrids have been used for more than 3 consecutive years, resistance to these traits among corn rootworm populations is suspected. Growers can no longer rely solely on Bt rootworm hybrids for protection against rootworm injury. The best management practice to reduce the resistant rootworm population is to rotate out of corn for at least 1 year. When first transitioning out of continuous corn, producers are encouraged to replace corn for a minimum of 1 year, but ideally for 2–3 years.

Crop rotation is the only way to reduce corn rootworm populations. Rootworm larvae present in the soil in late spring to early summer require corn roots during that time to survive. Planting a non-corn crop results in the larvae starving in the absence of their food source. Once a continuous corn field has been rotated, implementing a good forage crop rotation that avoids growing corn-on-corn will help keep corn rootworm populations low. Dicotyledonous crops, including legumes like alfalfa, are not corn rootworm hosts and are the best choice for crop rotation. Sorghum species are non-hosts for corn rootworm due to toxins they exude from their roots. These species may be a better replacement for corn silage in a ration than a legume crop. Many grass species are alternate, though not ideal, hosts for corn rootworm, so check with the OMAFRA field crops entomologist or forage specialist to see whether rootworm populations are likely to survive on a grass or cereal species being considered for crop rotation.

In situations where it is difficult to rotate silage corn fields, corn rootworm Bt hybrids can be used in combination with other crop protection tools to manage corn rootworm pressure as follows:

- **Year 1:** non-rootworm Bt hybrid corn. Scout for root damage and adult beetle populations.
- **Year 2:** non-rootworm Bt hybrid corn. If Year 1 damage or beetle thresholds (one beetle per plant during August) are met, use an insecticide to protect the crop.
- **Year 3:** rootworm Bt hybrid corn. Do not use insecticides against corn rootworms.
- **Year 4:** rotate out of corn to a non-host crop. Dicot species (such as alfalfa) are not hosts; neither are sorghum, sudangrass or their hybrids. Other grass species, such as Italian ryegrass, may act as an alternate host and enable corn rootworm populations to "bridge" between Year 3 and Year 1 corn. To prevent this, grass or spring cereals should be grown for 3 consecutive years (i.e., Years 4–6) before the field is rotated back to corn.

# References

1. Lauer, J. 23 May 2013. *Switch Dates for Corn Silage.* University of Wisconsin — Agronomy Department, Madison, WI, U.S. Available from: http://corn.agronomy.wisc.edu/AA/A113.aspx

2. Lauer, J. 1999. *Kernel Milkline: How Should We Use It for Harvesting Silage?* University of Wisconsin – Agronomy Department, Madison, WI, U.S. Available from: http://corn.agronomy.wisc.edu/WCM/W041.aspx

3. Mahanna, B., ed. 2014. *Silage Zone Manual.* DuPont Pioneer, Johnston, IA, U.S.

4. University of Wisconsin — Madison Shared Apps. 18 September 2018. SilageSnap [Smartphone application]. Version 1.0.180907. Available for Android and iOS/Apple devices. More information: wimachineryextension.bse.wisc.edu/precision-agriculture/silagesnap/

## Additional Sources

This chapter contains excerpts from the following OMAFRA sources:

Buchneri Inoculants to Improve Corn Silage Bunk Life. Last modified: July 29, 2003. www.omafra.gov.on.ca/english/crops/facts/info_buchneri.htm

*Harvesting Corn Silage at the Correct Moisture Content,* Factsheet 13-051. 2013.

Publication 811, *Agronomy Guide for Field Crops.* 2017.

*Corn Planting Following Early Hay Harvests*. Last modified: June 25, 2004. www.omafra.gov.on.ca/english/crops/field/forages/corn_earlyhay.htm

CHAPTER 5

# Cool-season Perennials

Cool-season perennials are the most widely used group of forage crops in Ontario. Perennials usually cost less per tonne to produce than annuals because the establishment costs can be amortized over a few years. Cool-season crops typically grow best under mild weather conditions, but each species has different tolerance to various soil drainage (Figure 5-1), soil pH (Figure 5-2), and harvest management (Table 5-1), as well as different tolerance to adverse weather (Chapter 10, *Weather Stress*).

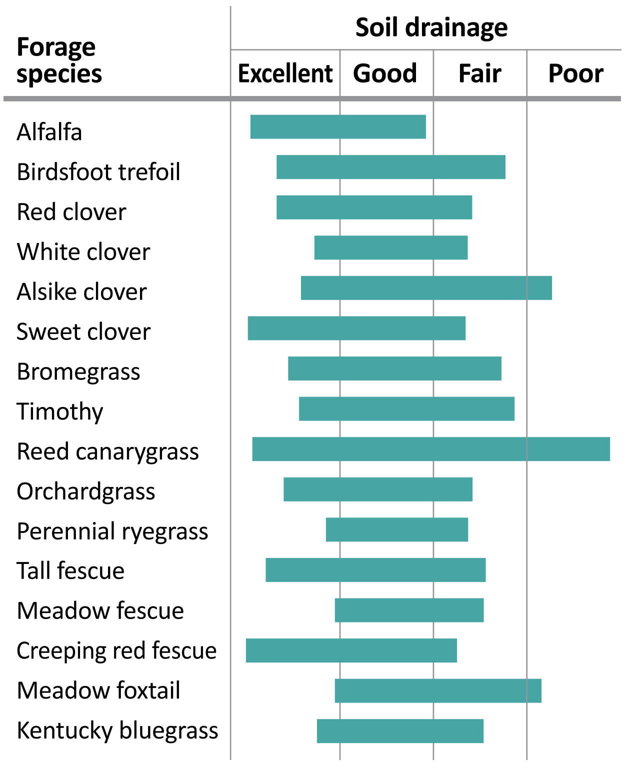



**Figure 5-1.** Soil drainage requirements of perennial cool-season forage species.

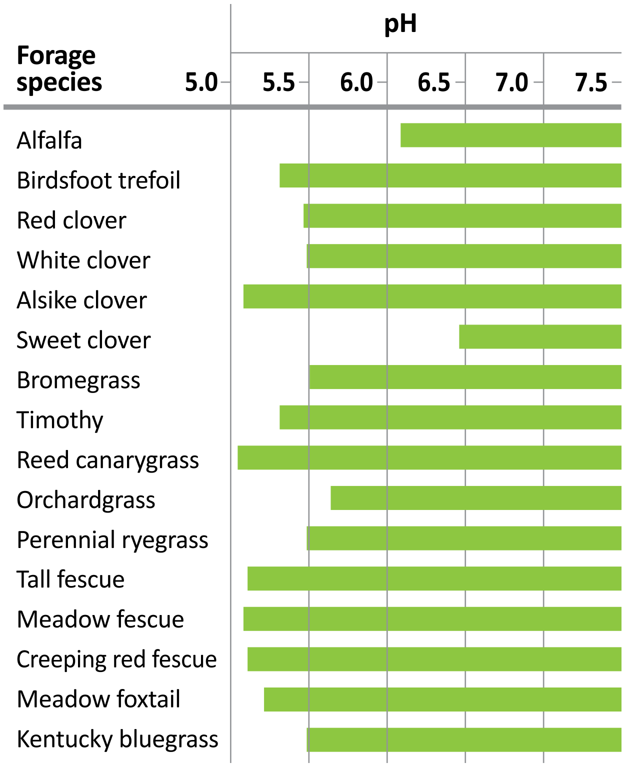



**Figure 5-2.** pH range for perennial cool-season forage species.

**Table 5-1. Suitability of Cool-Season Perennial Forage Species to Different Types of Harvest Management**

**Legend:** H = Highly suitable S = Suitable N = Not suitable

| Forage Species | Frequent, Close Grazing | Rotational Grazing | Hay | Baleage | Silage |
|---|---|---|---|---|---|
| Alfalfa | N | S | H | H | H |
| Alsike clover | N | S | S | S | S |
| Birdsfoot trefoil | N | H | H | S | S |
| Crown vetch | S | H | S | N | N |
| Kura clover | H | H | N | S | S |
| Red clover | N | S | S | H | H |
| Sweet clover | N | S | S | N | N |
| White clover | H | H | S | S | S |
| Bluegrasses | H | H | N | N | N |
| Smooth bromegrass | N | S | H | H | H |
| Creeping red fescue | H | H | N | N | N |
| Tall fescue | N | S | H | H | H |
| Meadow fescue | N | S | H | H | H |
| Meadow foxtail | N | S | N | N | N |
| Orchardgrass | S | H | H | H | H |
| Perennial ryegrass | H | H | N | H | H |
| Reed canarygrass | N | H | H | H | H |
| Timothy | N | S | H | H | H |

It is important to consider how early in the season the area to be seeded is usually accessible and workable.

- Orchardgrass, meadow foxtail or meadow bromegrass are ideal for fields that dry quickly and are accessible early in the season. These fast-starting grasses can advance the normal grazing season, but the first two become unpalatable and of poor feed quality if allowed to mature. Once ready to be grazed, the animals must have access to them.
- Mixtures based on reed canarygrass are also ideal for early land. However, palatability and quality decline quickly as reed canarygrass matures, so an early grazing or harvest is necessary.
- A trefoil-based mixture with a grass such as tall fescue, bromegrass or timothy is suitable for fields that are slow to dry.

# Legumes

## Alsike Clover

### *Trifolium hybridum*

Alsike leaves have three stalkless leaflets with fine serrations on the edge borne on smooth slender stalks. The stems may be upright, up to 50 cm (20 in.), or prostrate, bearing distinctive white and pink flowers. The roots consist of a shallow, branching taproot. It grows 38–75 cm (15–30 in.) in height with a small 1-cm (⅜-in.) diameter pink flower, which forms at the ends of secondary branches from the main stem. It should be differentiated from red clover, which has a larger flower, hairy stems and leaves, and a white inverted "V" on the leaf similar to the white clovers (Figure 5-3).

**Figure 5-3.** Alsike clover has smooth stems, serrated leaves, and pink or white flowers.
*Source:* Shutterstock.com.

Alsike is a perennial, though it is often treated as a biennial. It produces only one cut of hay per year.

## CAUTION!

Alsike can cause photosensitivity and liver damage in horses, as well as bloat in ruminants. It is not normally recommended for pasture mixtures. Limit alsike clover to less than 5% of a horse's diet to prevent toxicity.

Alsike clover is adapted to a wide range of soil drainage conditions, including heavy, wet soils. It also has the widest tolerance to pH of the perennial forage legumes and will grow in soils with a pH between 5.1 and 7.5. For a pure stand, seed at 3 kg/ha (3 lb/acre); in mixtures, use 0.8 kg/ha (0.75 lb/acre). Seeding depth should be 3–6 mm. Spring seeding is recommended, but summer seedings can be successful, provided there is adequate moisture for germination.[1]

Alsike produces most of its growth in June. Performance is not consistent from year to year, and adding alsike to a mixture usually lowers yields.

# Birdsfoot Trefoil

*Lotus corniculatus*

Birdsfoot trefoil has leaves composed of five small leaflets on fine stems, 60–90 cm (24–36 in.) tall. The leaves are distinct, consisting of two leaflets close to the stem, separated from the other three by a definite stalk. Trefoil flowers from June to September, producing clusters of bright yellow to orange-yellow flowers (Figure 5-4). The roots consist of one deep taproot with many branching side roots near the surface. The name "birdsfoot trefoil" comes from the shape and arrangement of the plant's seed pods, which resemble the many toes of a bird.

**Figure 5-4.** Birdsfoot trefoil has compound leaves with five leaflets and clusters of bright yellow flowers.

Trefoil is well adapted to steep or stony land that should not be worked and is also adapted to soil where drainage is marginal for other legumes. It is a non-bloating legume and is best suited for permanent pasture situations. It has a lower yield and is harder to dry than alfalfa, which limits its usefulness as a hay crop. Although individual plants live only for a few years, stands of trefoil have remained productive for 10 or more years when allowed to go to seed. Trefoil has a wider pH tolerance than most perennial forage legumes and will grow in soils with a pH as low as 5.3.

Seed trefoil at a rate of up to 2–9 kg/ha (2–8 lb/acre) as the legume component of a forage mixture. Seeding depth should be 5–12.5 mm (¼–½ in.). Birdsfoot trefoil will not establish well under a companion crop and is not suitable for summer seeding. Trefoil seedlings are not competitive, making them slow to establish. Trefoil may be thin in first-year stands but thickens with time. Spring growth is also slow, but mid-summer yields are good if it is not overgrazed early in the season. It retains feed quality well and is therefore suited for fall stockpile grazing. Trefoil does quite well when established by frost seeding.

Trefoil seed contains a higher percentage of hard seeds (seeds that are slow to germinate), resulting in the germination of the seeds being staggered over a long time and many plants escaping late-spring killing frosts. Trefoil cannot be established into stands that already contain Kentucky bluegrass. Evidence indicates bluegrass produces a chemical toxic to trefoil seedlings.

Trefoil has a fall rest period that is about 10 days earlier than alfalfa's at any given location.

Research from Agriculture and Agri-Food Canada has shown that cattle have higher average daily gains on pastures that contain trefoil as the legume compared to alfalfa-based mixes. This may be due to the higher sugar:crude protein ratio in trefoil, which may improve the digestive efficiency of rumen bacteria. It is also possible that higher gains were achieved due to the condensed tannins found in trefoil, which increase the amount of rumen undegradable protein in the forage.[2]

Many horses do not like the taste of birdsfoot trefoil and will avoid eating it. There are no toxicities associated with trefoil for horses, but since few horses will eat it trefoil is not generally recommended for horse hay or pasture.

## Kura Clover

### *Trifolium ambiguum*

Kura clover has stems that may be up to 45 cm (18 in.) long. Leaves are smooth and frequently have a watermark (Figure 5-5). Kura clover is similar in growth habit to white clover, except that kura clover spreads underground by means of rhizomes while white clover spreads on the surface by means of stolons.

**Figure 5-5.** Kura clover looks similar to white clover but is generally larger.

Kura clover is best suited for pastures, as it is very tolerant of grazing. It is difficult to dry and therefore is not a good hay crop. Kura clover is very winter hardy and fairly tolerant of acidic (pH between 5.1 and 7.3) and droughty soils.

Kura clover can be slow to establish, so weed management is very important during the establishment year. It will not establish well under a companion crop. Seed at 8–12 kg/ha (7–11 lb/acre) at 3–5 mm (⅛–¼ in.) depth.

As with other forage legumes, proper seedbed preparation, seeding depth and soil firming are critical in establishing kura clover. It seems unlikely that this species will frost seed successfully, although it has not been tried to date. The species of *Rhizobium* bacteria required for kura clover does not occur naturally in Ontario soils. Proper inoculation procedures are therefore very important in achieving successful stands.

In Ontario trials, white clover out-yielded kura clover in the establishment year, but kura clover yielded higher than white clover in production years. Because of its rhizomes, kura clover stands will thicken over time and will often fill in gaps where other species in the mixture winterkill.

Kura clover can cause bloat like other clovers.

## Red Clover

### *Trifolium pratense*

Red clover has leaves consisting of three stalkless leaflets on tall plants, 15–60 cm (6–24 in.), with large rose-purple to magenta flowers. Stems and leaves are hairy (Figure 5-6). Red clover has a weak taproot with many fibrous, side-branching roots. Like white clover, red clover leaves have a V-shaped watermark.

**Figure 5-6.** Red clover has hairy stems and leaves, with a V-shaped watermark, and red to purple flowers. *Source:* Shutterstock.com.

Red clover is a short-lived perennial. Yields are good the year after establishment, but are often quite low the following year, especially in Southern Ontario. It can be grown in fields that are too wet or acid for alfalfa. It is hard to dry, often resulting in "dusty or mouldy" hay. This limits its usefulness as hay, however, it can be stored as silage.

There are two general types of red clover grown in Ontario: double-cut or "medium" red clover, and single-cut or "mammoth" red clover. Double-cut will flower in the seeding year, and regrowth after cutting is strong and vigorous. Single-cut is slower growing, has large stems and matures about 2 weeks later than double-cut. Single-cut does not flower in the seeding year, or after the first cut in succeeding years.

Red clover tolerates imperfect drainage and lower pH levels (5.5). It is productive in the first year but tends to thin over winter, resulting in lower yields in succeeding years. Red clover has traditionally been thought of as a short-lived perennial, with the older varieties and plants from common seed living just 2–3 years beyond the seeding year. Newer varieties are promising to be longer-lived. Red clover is very competitive and easy to add to a stand by frost seeding. When seeded in mixtures, red clover can suppress the establishment of other legumes because of its competitive nature. In a pure stand, seed at a rate of 12–15 kg/ha (11–13 lb/acre); reduce this rate when mixed with grasses.

**CAUTION!**

Red clover can cause bloat. Use pastures and hay aftermath with more than 50% red clover carefully. Red clover can contain compounds with an estrogenic effect on the reproductive cycle of sheep.

## Sweet Clover

*Melilotus officinalis*

Sweet clover is a tall (up to 2 m (6.5 ft)), branched, coarse plant that is not a true clover. Its leaves have three oblong leaflets with serrated edges. Both stems and leaves have a distinctive sweet odour when crushed. The flowers, white or yellow, are in numerous long, loose flower arrangements called racemes (Figure 5-7). Sweet clover's main advantage is its deep taproot. It is ideal on land that needs a deep taproot to break up a hardpan. It grows on infertile soils, provided the pH is near neutral or higher. Sweet clover can be used for grazing or hay.

**Figure 5-7.** Sweet clover has a tall, coarse appearance. Leaflets are rounded and serrated. Crushed stems and leaves produce a sweet odour.
*Source:* Shutterstock.com.

Sweet clover should be planted in early spring when field conditions are able to carry equipment. The hard seeds may need to be scarified to enable germination. A companion crop should not be used. Seed at a rate of 9–14 kg/ha (8–15 lb/acre) at 1.25 cm (½ in.) depth. Sweet clover is a relatively drought-tolerant legume due to its deep taproot.[3]

Sweet clover is a biennial, which grows slowly in the year of establishment and doesn't flower that year. In the spring of the second year it grows quickly to become a tall, coarse-stemmed plant. There are two types: white-flowered and yellow-flowered. White sweet clover is deeper rooted, taller and coarser, which makes it more suitable for a cover crop than for forage. The yellow type is more palatable to livestock and attractive to bees.

### CAUTION!

Mouldy sweet clover hay may contain dicoumarol, which can prevent normal blood clotting and result in the death of livestock from bleeding.

## White Clover

*Trifolium repens*

White clover is a short-lived perennial that is used mainly in pastures. White clover has stems that creep on the ground with erect or upward-slanting branches. Leaves consist of three rounded, stalkless leaflets with shiny undersides and leaf edges that may have a few shallow teeth. The flowers form a spherical head and are usually white but may be pink-tinged (Figure 5-8). Roots are shallow and fibrous and develop from the nodes of the creeping stems (stolons). Three types of white clover are used in Ontario. They look similar but differ in size.

- Wild white clover is the smallest, ranging from 5–17.5 cm (2–7 in.) tall.
- Intermediate white clover (also called Dutch or New Zealand White) grows to 40 cm (16 in.).
- Ladino clover can grow up to 60 cm (24 in.).

The intermediate types are more suited for pastures than the ladino and tend to have more stolons per square metre than the ladino varieties.

**Figure 5-8.** White clover has smooth stems and leaves, and a V-shaped watermark.
*Source:* Shutterstock.com.

White clover is adapted to soils that range from well-drained to those with some drainage problems. Its shallow root system limits production on excessively drained soils and during droughty periods. White clover roots generally grow to the same depth as roots of commonly used grasses, creating intense competition between white clover and the grasses for soil nutrients and moisture. White clover often disappears from pastures because it cannot compete with the grasses for nutrients present at low levels. Grasses growing with white clover receive approximately 200 kg/ha (180 lb/acre) nitrogen over the grazing season. The amount of nitrogen available to grasses from white clover is higher than from other legumes because white clover sloughs off root nodules after each harvest. White clover will grow in soils with a pH above 5.5.

White clover is a short-lived perennial that will reseed if not grazed severely. It can be frost seeded or no-till drilled in to maintain its presence in the stand. For a pure stand, seed at 4.5 kg/ha (4 lb/acre); in a mixture, seed at 1–2 kg/ha (1–2 lb/acre). Target a seeding depth of 3–5 mm (⅛ – ¼ in.).[4]

# Grasses

In an established stand, grass plants are not made up of a single stem but have many tillers. One grass plant may have dozens of tillers that arise from growing points at the base of the plant. Having the growing point at the base of the plant is an evolutionary adaptation because it protects the grass from grazing, since most animals cannot graze so close to the ground as to damage this growing point.

During vegetative growth, leaves are pushed upward from the base of the tillers. Then all grasses begin stem elongation in preparation to flower and set seed. The stem, or culm, consists of nodes separated by internodes. Each node with its associated internode is a stem segment, commonly called a joint. Technically, all grass species are jointing species because they all put up flowering stems by lengthening the internodal spaces. The designation of "jointing" or "non-jointing" refers to how the grass regrows once the seed head is removed.

When jointing grass species regrow after flowering, they go through stem elongation again. Jointing grasses have their growing point above the newest completed joint, which means that as stem elongation progresses, the growing point rises. Jointing grasses are easily damaged if the growth point is cut or grazed off at the wrong time. Defoliation will be least damaging to jointing species if it occurs either during tillering when the growth point is low, or between boot and early heading. If the grass is harvested during stem elongation, new regrowth must start from the crown of the plant and use energy reserves from the roots — just like when the plant breaks dormancy in the spring. This is a significant stress on the grass. By waiting until boot stage, the crown has time to develop additional tillers that will provide regrowth. So long as the timing is correct, jointing grasses can be cut as low as 5–7.5 cm (2–3 in.) without reducing yield potential or persistence. Jointing grass species include timothy, smooth brome, reed canarygrass and Italian (annual) ryegrass.

When non-jointing species are cut after flowering, the regrowth remains in the vegetative state, and very few tillers attempt stem elongation again during the growing season. The growing points of non-jointing grasses remain close to the ground. It is more difficult to cut or graze off these growing points and leaf regrowth can occur faster compared to jointing species. Keeping the cut height or target grazing residual above the stem base protects the growing points and productivity of non-jointing grasses. Non-jointing grass species include orchardgrass, tall fescue, meadow fescue, Kentucky bluegrass and perennial ryegrass. While meadow fescue, Kentucky bluegrass and perennial ryegrass will tolerate defoliation down to 5 cm (2 in.), orchardgrass is more productive if 7.5–10 cm (3–4 in.) of residual is left.

Mixing jointing and non-jointing species together makes management more complicated. Non-jointing grasses are better suited for pastures, as the growth point is better protected, and the vegetative regrowth is more palatable to grazing animals. Either jointing or non-jointing species can be harvested for stored forage. There may not be a time when all jointing species in a mixture are at the same optimal stage for harvest, so grass managers should closely monitor the growth stage of each species and decide which to favour. Repeated cutting at a susceptible growth stage will push a grass species out of the stand.

# Bluegrasses

In Ontario, two common bluegrasses, Canada and Kentucky, grow on about 1 million hectares (2,471,000 acres) of permanent pasture land. In Southern Ontario, the shallow-rooted bluegrasses produce lush, palatable growth during the spring, but are unproductive during the dry, hot summer. Early growth is palatable, but total production is limited.

When properly fertilized and managed, bluegrass production can be markedly improved, especially in the cooler climate of Northern Ontario. In pastures, they serve as a bottom grass that controls weed invasion, withstands close grazing and trampling, and fills in when other species thin out.

Bluegrass withstands animal traffic and can be added to a mixture for areas where high resistance to trampling damage is needed or as a bottom grass in horse pastures. The dense root system and thatch from bluegrasses provides a good cushion for horse’s hooves and legs.

## Canada Bluegrass

*Poa compressa*

Canada bluegrass is a bluish-green grass with shorter leaves with boat-shaped tips. The plant is shorter than Kentucky bluegrass with a similar open, fine panicle (Figure 5-9). Canada bluegrass forms an open sod and is found on less fertile soils. The sheath is split. The blade is 2–5 mm wide, 2–10 cm (1–4 in.) long, and flat to V-shaped with a boat-shaped tip. The light-green collar is narrow and divided by the midrib. There are no auricles. The ligule is a short membrane (Figure 5-10). The stems are flat, and 50–75 cm (20–30 in.) tall. The inflorescence is a slender, fine panicle with two branches at each node of the central axis. Its most distinguishing features are the pale bluish-green colour and dullness of leaves, which taper gradually from the collar to their boat-shaped tips. The leaf blade, when held up to light, looks as if it has a fine transparent line on each side of the midrib.

**Figure 5-9.** Canada bluegrass inflorescence.

Canada bluegrass is often considered a "pioneer species" because it is adapted to acidic, low-fertility soils. It does not yield as well as Kentucky bluegrass. Seed in mixtures at a rate of 1–2 kg/ha (1–2 lb/acre) at 5 mm (¼ in.) depth.[5]

## Kentucky Bluegrass

*Poa pratensis*

Kentucky bluegrass is a dark-green grass with long narrow leaves. It grows 30–100 cm (12–40 in.) tall with an open, fine panicle. Kentucky bluegrass forms a dense sod on fertile soils. The sheath is closed when the plant is young but later splits. The blade is 2–5 mm wide, 5–40 cm (2–16 in.) long and V-shaped with a boat-shaped tip. It is shiny on the under-surface. The yellowish-green collar is broad and slightly divided by the midrib. There are no auricles. The ligule is a very short membrane (Figure 5-11). The inflorescence is an open, fine panicle with five branches at each node of the central axis (Figure 5-12). The most distinguishing feature is the dark green colour and the shininess of the underside of leaves plus the boat-shaped leaf tips. The leaf blade, when held up to the light, looks as if it has two transparent lines on each side of the midrib. Kentucky bluegrass is a non-jointing species.

**Figure 5-10.** Canada bluegrass collar. No auricles, short ligule.

**Figure 5-11.** Kentucky bluegrass collar. No auricles, short ligule.

**Figure 5-12.** Kentucky bluegrass inflorescence.

In a pure stand, seed Kentucky bluegrass at rates of 11–17 kg/ha (10–15 lb/acre); reduce rates in mixtures. Target a seeding depth of 5–12.5 mm (¼– ½ in.). Kentucky bluegrass may be frost-seeded (see Chapter 1, *Planning and Establishment*). It does not establish well under a companion crop.

# Bromegrasses

Brome is palatable and tends to retain nutritional value with increasing maturity better than most grasses.

## Meadow Bromegrass

*Bromus riparius*

Meadow bromegrass is a reduced creeping type of bromegrass that regrows quickly after being grazed. It has more basal leaves than smooth bromegrass. Leaves are light green in colour, slightly hairy and narrower than leaves of smooth bromegrass. With better frost resistance than the smooth type, meadow bromegrass is a better choice for late fall grazing. The inflorescence of meadow bromegrass is similar in appearance to smooth bromegrass. However, seeds are larger, with longer awns, and are slightly hairy (Figure 5-13). The seeding problems associated with smooth bromegrass can be worse with meadow bromegrass.

The sheath is closed near the top and is hairy. The blade is 2–5 mm wide, 10–30 cm (4–12 in.) long and is flat with a sharp pointed tip. It is also hairy on both upper and lower surfaces. The collar is narrow and divided at the midrib. There are no auricles. The ligule is a short, white membrane not unlike the smooth brome species (Figure 5-14). The stems are round and 60–90 cm (24–36 in.) tall. The inflorescence is a large panicle with branches in all directions. It is a bit smaller than smooth bromegrass and has short awns. Its most distinguishing features are the hairy blades and sheaths, and the many, drooping basal leaves distinguish this grass from smooth bromegrass.

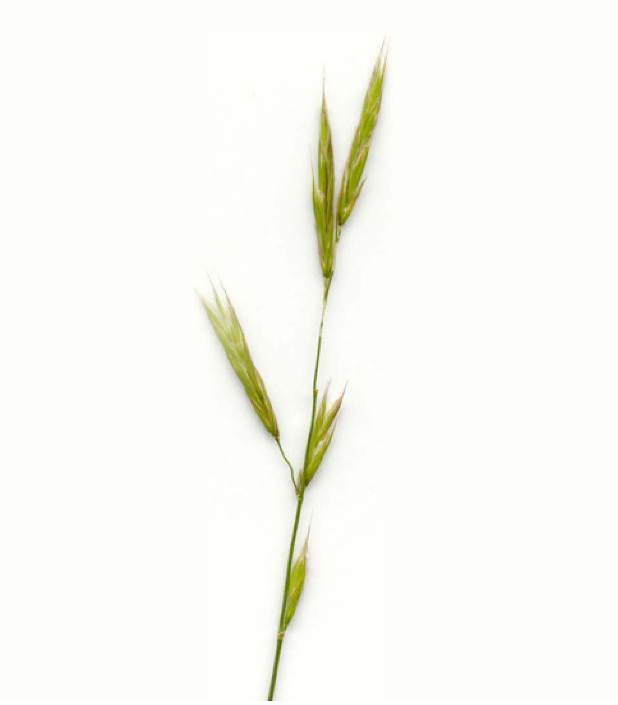


**Figure 5-13.** Meadow bromegrass inflorescence.

**Figure 5-14.** Meadow bromegrass collar. No auricles, ligule is a short membrane.

Meadow bromegrass can be used wherever smooth bromegrass can be grown. Substitute meadow bromegrass for smooth bromegrass in the recommended mixtures. Adjust the seeding rate for meadow bromegrass upwards to take into account its larger seed size. It does not establish well under a companion crop.

Meadow bromegrass is attractive as a pasture species for several reasons. It is a palatable grass that starts growth earlier in the spring than smooth bromegrass, remains productive during the entire grazing season and can extend the grazing season into late fall. It has faster recovery rates after grazing, with its regrowth coming from existing tiller bases, a trait similar to orchardgrass, whereas the regrowth for smooth bromegrass is initiated from crowns and the rhizomes. Meadow bromegrass remains in a vegetative state after first grazing, producing a nice leafy mass for grazing animals.

## Smooth Bromegrass
### *Bromus inermis*

Smooth bromegrass is a tall grass, varying in colour from light to dark green. Leaves are long, wide and flat with a pointed tip and a "W" marking on the leaf. Roots have blunt, brownish rhizomes that allow the plant to spread to form an open sod. The inflorescence is a large spreading panicle, similar to oats, giving rise to the older name of "oatgrass." The sheath is closed. The blade is 4–12 mm wide, 15–40 cm (6–16 in.) long and flat with a sharp, pointed tip. The collar is narrow and divided by the mid-rib. There are no auricles. The ligule is a very short membrane (Figure 5-15). The stems are round and 60–120 cm (24–48 in.) tall. The inflorescence is a large panicle with the branches spreading in all directions. When top heavy, the branches shift over to one side (Figure 5-16). It spreads by rhizomes, and the stand can thicken over time. Smooth bromegrass is a jointing species.

**Figure 5-15.** Smooth bromegrass collar. No auricles, ligule is a very short membrane.

**Figure 5-16.** Smooth bromegrass inflorescence.

With deep fibrous roots, smooth bromegrass adapts to well-drained or droughty soils. Seed a pure stand at 10–14 kg/ha (9–12.5 lb/acre); reduce the seed rate in a mixture. Its major drawback tends to be its large fluffy seed, which makes it difficult to seed through the small seed-box of drills. It does not establish well if it is either surface seeded or seeded deeper than 5 cm. Less than 2 cm (¾ in.) depth is ideal when planting smooth bromegrass. Once established, bromegrass is a good competitor that can compete with legumes on low-potash soils.

Smooth bromegrass is most productive during spring and fall, with mediocre-to-good mid-season production. Bromegrass is an earlier, more aggressive grass than timothy. It has more regrowth in the second cut because of its improved drought tolerance. Bromegrass is palatable and keeps its nutritional value better than most grasses, giving pasture managers more flexibility in grazing schedules. Late June production could be stockpiled for use in August. Smooth bromegrass's quality at later maturity also makes it a good fit for hay production systems with long cutting intervals.

# Fescues

## Creeping Red Fescue

*Festuca rubra*

Creeping red fescue is a short plant with narrow, bristly, dark-green leaves. The roots are rhizomatous and form a dense sod. The inflorescence is a fine, open panicle (Figure 5-17). The sheath is split part way and covered with fine hairs. The blade is 1.5–3 mm wide, 5–15 cm (2–6 in.) long, thick and rolled or folded lengthwise. The upper surface is deeply ridged, and the undersurface is shiny. The collar is narrow and continuous. There are no auricles. The ligule is a very short membrane. The stems are nearly round (Figure 5-18). Its most distinguishing features are dark-green, very slender and bristle-like leaves; old, dead basal leaf sheaths are reddish brown (hence the common name).

**Figure 5-17.** Creeping red fescue leaves and inflorescence.

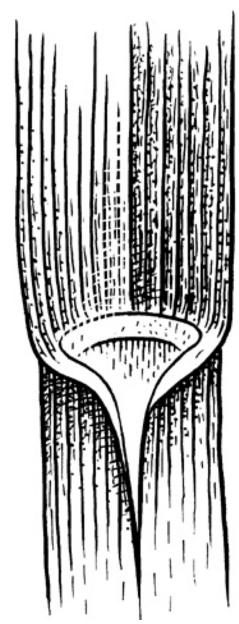


**Figure 5-18.** Creeping red fescue collar. No auricles, the ligule is a very short membrane.

Creeping red fescue grows and spreads on most soils, including fertilized subsoils. It grows throughout the entire season and retains good nutritional value in the fall. Productivity is limited, as the grass is short and most varieties were developed for turf or soil conservation purposes. It will tolerate droughty soils and a wide range of soil pH.

Seed at up to 4 kg/ha (4 lb/acre) in a pasture mix, or 9 kg/ha (8 lb/acre) in a pure stand for erosion control. Seeding depth should not exceed 5 mm (¼ in.).[6]

Creeping red fescue is best used for streambank or grassed waterway protection, as the roots hold the soil while the thatch of top growth slows water movement and protects the soil surface. These characteristics also make it a good "bottom" grass — a species added to the mixture to give turf qualities to the forage. As such, add it to mixtures for exercise yards, laneways and wet fields damaged by animal traffic in rainy periods.

## Meadow Fescue

*Festuca pratensis*

Meadow fescue has bright green leaves with narrow, long (up to 50-cm (20-in.)) blades and sharp-pointed tips. Meadow fescue is a bunchgrass with short rhizomes that give it a weakly creeping habit. The sheath is split with the margins overlapping at the bottom. The blade is 3–8 mm wide and 10–50 cm (4–20 in.) long, the upper side is dull and the lower side shiny (Figure 5-19). The edges are rough, and the tip is sharp-pointed. The collar is broad and continuous. The auricles are 0.5–1.5 mm long and usually blunt but sometimes claw-like. The ligule is a very short membrane (Figure 5-20). The stems are round and 60–125 cm (24–50 in.) tall. The inflorescence is a slender panicle. Its most distinguishing features are rough leaf edges, short ligules and claw-like auricles. Meadow fescue is a non-jointing grass.

**Figure 5-19.** Meadow fescue leaves and inflorescence.

**Figure 5-20.** Meadow fescue collar and auricles. The ligule is a very short membrane.

Meadow fescue grows best on deep, fertile soils but will tolerate variable drainage and low fertility. It has a shallower root system, is shorter lived and is not as tolerant of poor conditions as tall fescue. Meadow fescue is most productive in summer and fall and maintains feed quality into the cooler fall months. It fits well with trefoil to give summer and fall grazing. This allows it to be used on fields that tend to be wet in spring and cannot be grazed until later in the season. Seed a pure stand at a rate of 20–25 kg/ha (18–22 lb/acre) and a depth of 1 cm (⅜ in.). In a mixed stand, reduce the seeding rate.

## Tall Fescue

*Festuca arundinacea*

The leaves of tall fescue are dark green and ribbed with wide, long blades and sharp, pointed tips. This deep-rooted, tall, coarse-growing plant forms tussocks if it is not grazed or cut after several years. It is basically a bunchgrass, but frequent grazing will produce a tough sod resistant to trampling damage. This deep green grass forms large 10–40-cm (4–16-in.) diameter, dense bunches, even though it has short rhizomes. The sheath is split, with the margins overlapping. The sheaths are smooth, thick and leathery, and the lower ones are very slow to decay. The blade is 4–12 mm (3⁄16–½ in.) wide, 20–70 cm (8–28 in.) long and flat with a sharp-pointed tip. It is thick and leathery, very smooth and shiny on the under-surface but dull and deeply ridged on the upper surface. The edges are rough. The yellowish collar is broad and wrinkled on the edges. The yellowish auricles are soft and wavy and have a few fine hairs along their margins. The ligule is a small membrane (Figure 5-21). The stems are round and 90–150 cm (36–60 in.) tall. The inflorescence is a spreading panicle (Figure 5-22). Its most distinguishing features are its tall, coarse growth, the prominently ribbed leathery dark green leaves and the thick tussocks formed by the accumulation of old dead leaf sheaths for several years. Tall fescue is a non-jointing grass.

**Figure 5-21.** Tall fescue collar. Soft auricles, small ligule.

**Figure 5-22.** Tall fescue inflorescence.

Tall fescue is adapted to most soils, including those with imperfect drainage. Spring growth is slow, followed by steady production throughout the season. It fits well into a rotational grazing system and is an ideal partner with birdsfoot trefoil for providing season-long forage. It can be rotationally grazed up until late June–early July and then left to stockpile in late summer for fall grazing. Research at the New Liskeard Agricultural Research Station has consistently shown that the fibre levels of tall fescue are lower than all other grasses in the fall (see Table 5-2). In a simple mixture, seed tall fescue at a rate of 10 kg/ha (9 lb/acre) at 12.5 mm (½ in.) depth.

Tall fescue is useful for erosion control and protection of fragile lands. Its deep roots, long-lived perennial nature and tolerance to marginal conditions allow it to establish and survive on most areas where permanent cover is required.

**Table 5-2. Total Digestible Nutrient Content of Five Grass Species**

**Legend:** – = no data available

| Grass Species | Total Digestible Nutrients (%) | | |
|---|---|---|---|
| | **1994** | **1995** | **1996** |
| Tall fescue | 61.4 | 61.5 | 59.2 |
| Reed canarygrass | 56.7 | 57.2 | 54.1 |
| Smooth bromegrass | 58.4 | 58.0 | 55.9 |
| Meadow bromegrass | 54.5 | 57.3 | 55.1 |
| Orchardgrass | 56.2 | – | – |
| Average | 57.4 | 58.5 | 56.1 |

*Notes:* Harvested in early November at New Liskeard.
*Source:* Alternative Forages for Hay, Silage and Pasture. Jim Johnston. Forage Feeds Profit — 1997 Ontario Forage Council Conference.

## Festuloliums

### Hybrid *Festuca* sp. x *Lolium* sp.

Festuloliums are hybrid grasses: a cross between a ryegrass (either perennial or Italian) and a fescue (either tall or meadow). The name "festulolium" comes from the Latin genus of each parent species in the hybrid, *Festuca* and *Lolium.*

Ryegrasses are used almost exclusively in temperate climates because they are very palatable. These grasses have high sugar content and, when fertilized well, have much higher protein content than is normally found in grasses. However, their tendency to winterkill has limited their adoption in Ontario and elsewhere. Recognizing the need for palatable, digestible and high-yielding forage grasses in continental climates, forage breeders have started crossing ryegrasses with fescues to achieve better persistence and winter hardiness.

Some festuloliums favour their ryegrass parent, while others have more fescue-like traits. The parent species used in the cross will affect yield and persistence; for example, a festulolium from an Italian ryegrass parent will likely yield better but have a shorter productive life than one from a perennial ryegrass parent. In addition, the cultivars used as parent lines will influence the traits of the festulolium hybrid, such as heading date.

When choosing a festulolium, be sure to write down the hybrid name for future reference. Ask questions of the seed dealer about which parent species were used in the cross, and which parent the hybrid favours. Consider how the field will be managed when selecting a hybrid to match its traits to the type of harvest (i.e., grazing or cutting) and the frequency. Not all festulolium hybrids will thrive under all conditions, so thorough research helps ensure a good match.

## Meadow Foxtail

### *Alopecurus pratensis*

Meadow foxtail resembles timothy but has smaller, ribbed leaves. It is a shorter plant and heads out much earlier than timothy. Roots are shallow and fibrous. The sheath is split with the margins overlapping. The blade is 3–8 mm wide, 10–15 cm (4–6 in.) long and flat with a sharp-pointed tip; the edges are rough. The upper surface is prominently ribbed. The light-green or yellow, medium-broad collar is divided by the midrib. There are no auricles. The ligule is a coarse membrane that is slightly hairy and striated (Figure 5-23). The stems are round and 50–100 cm (20–40 in.) tall. The inflorescence is a dense, spike-like panicle and looks like timothy, but with a blackish tinge. The short, soft awns along the sides of the seed head give the appearance of a fox's tail (Figure 5-24). Its most distinguishing features are the rough leaf edges, the type of ligule and the collar divided by the midribs distinguishing meadow foxtail from timothy.

**Figure 5-23.** Meadow foxtail collar. No auricles, coarse hairy ligule.

**Figure 5-24.** Meadow foxtail inflorescence sometimes has a blackish tinge.

Meadow foxtail tolerates poor drainage and low pH. It is extremely early, with most fields heading out by early May. Once headed out, it is very unpalatable. Meadow foxtail is the earliest pasture species but is often seeded on fields too wet to carry animals at the time grazing should start. The shallow roots contribute to low production during periods of high temperatures and drought. It is best used mixed with species that produce through the summer.

Meadow foxtail seed is light, fluffy and hairy, making it difficult to seed. Use coated seed to avoid problems at seeding. In a pure stand, seed at 9–13 kg/ha (8–11 lb/acre); in mixtures, 2.5–4.5 kg/ha (3–5 lb/acre) at 5–12.5 mm (¼–½ in.) depth.[7]

## Orchardgrass

### *Dactylis glomerata*

Orchardgrass is an aggressive, bluish-green bunchgrass. It has long, wide leaf blades and a coarsely tufted panicle. The cross-section of the stems is oval-shaped. The sheath is split part way and is green on the top and pale green or white on the lower part. The blade is 5–12.5 mm (¼–½ in.) wide and 7.5–40 cm (3–16 in.) long. It is V-shaped near the base, but flat towards the sharp, pointed tip. The yellow-green collar is broad and divided by a midrib. There are no auricles. The ligule is a white membrane that usually has an awn-like point at the top (Figure 5-25). The stems are flat and 90–150 cm (36–60 in.) tall. The inflorescence is a panicle made up of several short, thick tufts (Figure 5-26). Orchardgrass is a bunch-type grass that has profuse tiller formation at the base of the plant. This tiller formation begins early in the spring and continues through the growing season. When orchardgrass seed heads are removed by cutting or grazing, the new growth is nearly all leaves. Orchardgrass is a non-jointing grass.

**Figure 5-25.** Orchardgrass collar. No auricles, ligule comes to an awn-like point.

**Figure 5-26.** Orchardgrass inflorescence.

Orchardgrass requires well-drained soils with good surface drainage. In simple mixtures with alfalfa, 7–9 kg/ha (6–8 lb/acre) is required. In more complex mixtures, 3.5–4.5 kg/ha (3–4 lb/acre) is sufficient. Its aggressive seedlings make orchardgrass easy to establish.

Orchardgrass can be very productive, particularly in pastures and hay fields with aggressive harvest schedules. However, because it heads so very early in the spring and then declines quickly in digestible energy and protein, it has not been as widely used for stored forage in Ontario compared to other forage grasses. This is changing more recently, as plant breeders are researching and developing newer orchardgrass varieties with later maturity. There is a tremendous range in heading dates, from May 16 to June 11 from the earliest to the latest variety (26 days).

Orchardgrass is not as winter hardy as either timothy or brome and will not persist on wet soil. Graze or cut orchardgrass lightly in the fall to remove thick growth that could lodge and cause winterkill. Orchardgrass will winterkill, on average, one year out of four.

Orchardgrass responds very well to high rates of nitrogen fertilizer. Take caution because orchardgrass accumulates nitrates easily, which can lead to nitrate poisoning. To reduce risk, limit mid- or late-season nitrogen applications to 85 kg/ha (76 lb/acre). See Chapter 10, *Weather Stress* and Chapter 16, *Forage Analysis and Grading*, for more details.

## CAUTION!

Grass tetany/staggers is a concern for livestock grazing on early pastures dominated by orchardgrass, as the grasses may not have sufficient levels of magnesium to meet animal needs.

Orchardgrass can be thought of as being both high performance and high risk. It can yield well and be palatable if managed properly but may winterkill or cause nutritional issues that can challenge a forage production system.

## Perennial Ryegrass

### *Lolium perenne*

Perennial ryegrass is a soft, fine, dark-green grass. Leaves are narrow and short, with ribbed tops and smooth, shiny undersides. It produces a lot of tillers and is 30–60 cm (12–24 in.) tall. The pale-green sheath can be either closed or split. The blade is 2–6 mm (3⁄32–¼ in.) wide, 5–15 cm (2–6 in.) long and V-shaped, with a sharp-pointed tip. The collar is narrow. The auricles are small, soft and claw-like. The ligule is a thin membrane that is toothed at the top. The inflorescence is a slender, stiff spike with each spikelet edgewise on the central axis (Figure 5-27). Perennial ryegrass leaves are usually narrower than Italian ryegrass, and new perennial ryegrass leaves are generally folded in the bud, while Italian ryegrass leaves are rolled. Italian ryegrass seeds have awns, whereas perennial ryegrass is awnless. Do not confuse cereal rye (Secale cereale) with ryegrass (Lolium multiflorum or L. perenne), which are totally different grass species with quite different characteristics. Perennial ryegrass is a non-jointing grass.

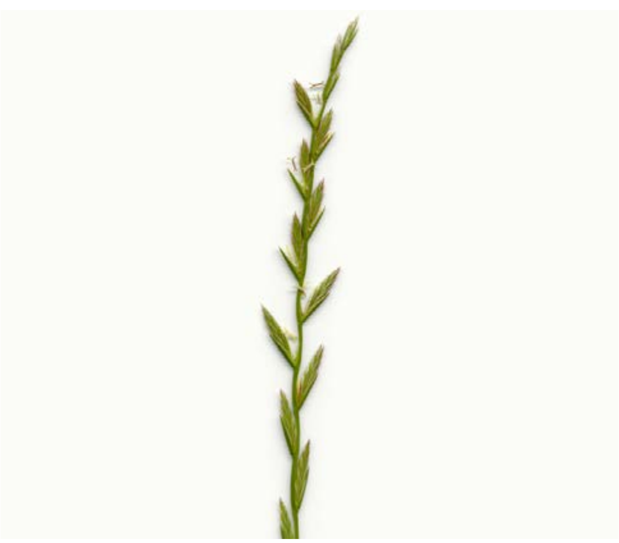


**Figure 5-27.** Perennial ryegrass inflorescence.

Perennial ryegrass requires well-drained, fertile soils. It is easy to establish and competitive in mixtures. Seed pure stands at 22–44 kg/ha (20–40 lb/acre) or include 5.5–11 kg/ha (5–10 lb/acre) in a mixture. Seeding depth should be 1.25–2.5 cm (½–1 in.).

Perennial ryegrass is a short-lived perennial that comes in turf-, pasture- and hay-adapted varieties. The pasture-adapted varieties tend to have finer leaves, smaller and more numerous tillers, and later maturity than the hay varieties.

Management of perennial ryegrass is different from that of timothy or brome. It is early and vigorous in the spring, and grows well in the fall, but is unproductive during the hot, dry summer months. Winterkilling is promoted by excessive top growth going into the winter. Thus, ryegrass may kill in alfalfa mixtures not cut after the end of August.

If irrigation is possible, consider pure stands of perennial ryegrass. Ryegrass responds well to nitrogen fertility, and the resulting yields could warrant the cost of irrigating. Do not apply nitrogen after July on the forage types of perennial ryegrass. This appears to lower their overwintering ability — a problem associated with perennial ryegrass in Ontario. Graze or cut off any fall growth before winter to lessen the likelihood of snow moulds developing and damaging the ryegrass.

## Redtop

### *Agrostis gigantea*

Redtop has dark green leaves with a purplish inflorescence that turns red as it opens. It has fine leaves and stems that are both upright and creeping. Redtop forms a loose sod. The sheath is split, with the margins overlapping. The blade is 2–7 mm wide, 5–20 cm (2–8 in.) long and flat with a sharp, pointed tip. It is prominently ridged on the upper surface, and the midrib is distinct on the bottom side. The pale green collar is large and V-shaped. There are no auricles. The ligule is a thin, pointed membrane that is very tall (Figure 5-28). The inflorescence is a fine panicle that is a rusty-red colour at maturity (Figure 5-29). Its most distinguishing features are the prominently ridged upper surface of the blade, the tall ligule and the absence of auricles.

**Figure 5-28.** Redtop collar. No auricles, tall ligule.

Redtop is tolerant of very low fertility, low pH and poor drainage but does not yield well. It is not competitive on fertile soils and often disappears if soil conditions are improved. Productivity and feed quality are lower than with timothy. Redtop can be used on ditch banks or grassed waterways where its tolerance to wet soils and sod-forming habits reduce erosion. The presence of red top is a symptom of wet, acidic soils with low fertility.

**Figure 5-29.** Redtop inflorescence.

## Reed Canarygrass

### *Phalaris arundinacea*

Reed canarygrass is a tall, up to 2.5 m (100 in.), coarse grass with rhizomatous roots that form a loose sod. It is easily distinguished by its wide leaves. The inflorescence is a panicle similar to orchardgrass but with finer tufts (Figure 5-30). The sheath is split with overlapping margins. The blade is 6–15 mm wide, 10–30 cm (4–12 in.) long and flat with a sharp-pointed tip. The pale green or yellow collar is narrow and continuous. There are no auricles. The ligule is a white membrane that sometimes tears at the top with maturity (Figure 5-31). Stems are round. Its most distinguishing features are wide leaf blades and edges of the blade constricted 5 cm (2 in.) from either the tip or the collar. Reed canarygrass is a jointing grass.

It is best known for its ability to tolerate poorly drained soils and prolonged flooding. Because of its deep-root system, reed canarygrass is more drought resistant than other grasses and can provide high yields on well-drained or even droughty soils. Reed canarygrass has excellent winterhardiness, persistence and disease resistance.

**Figure 5-30.** Reed canarygrass inflorescence.

**Figure 5-31.** Reed canarygrass collar. No auricles.

In the past, livestock have performed poorly on reed canarygrass pastures because it contained unpalatable alkaloids. Recommended reed canarygrass varieties are free of the tryptomine and carboline alkaloids, which cause scours and poor performance. Some varieties (Marathon, Palaton and Venture) are also lower in the gramine alkaloids that reduce palatability. The newer varieties are less aggressive and invasive than the older varieties. "Common" reed canarygrass seed should be considered high in alkaloids and should be avoided.

Reed canarygrass is slower and more difficult to establish than other grasses. It will not establish under a companion crop. It is not very competitive in the year of seeding, but once established, reed canarygrass is very aggressive. In legume mixtures, a strong reed canarygrass presence may not occur until the third year but will eventually predominate. This slow establishment means reed canarygrass is not well suited to short, 3-year alfalfa mixture rotations, but it can work well in longer rotations. Seedling vigour is poor, so frost seeding, inter-seeding into established stands, and fall seeding are usually not recommended. Seeding is most successful with conventional tillage but can work in no-till systems as well. A firm, well-prepared, packed seedbed is important. Seeding depth should be 5–12.5 mm (¼–½ in.). Seeding rates are usually 10–12 kg/ha (9–11 lb/acre) in a pure stand, or at least 4.5–7 kg/ha (4–6 lb/acre) if included with a legume. Weed control is important to minimize competition. It will tolerate soil pH as low as 5.1.

Because it has a sod-forming habit and is not a bunchgrass, it will fill in gaps in hay stands (unlike orchardgrass, ryegrass and timothy). Reed canarygrass responds well to adequate fertility, particularly nitrogen, and can be a useful tool in nutrient management. Pure stands respond well to split nitrogen applications, resulting in increased yield and protein.

Prior to the full head stage, feed quality, including crude protein and digestibility, is similar to other grasses at the same stage of maturity. Regrowth is excellent and occurs faster than most other grass species. Normally, regrowth will be leafy and result in stem elongation, but with no inflorescence (seed heads). If kept vegetative, reed canarygrass remains productive throughout the growing season.

## Timothy

### *Phleum pratense*

Timothy has soft, grey-green leaves with wide, medium length blades. The head is a distinctive, very dense, spike-like panicle. It has an onion-like bulb or corm at the base of the stems and a shallow root system. It is a non-aggressive bunchgrass with limited tillering ability. The sheath is split with overlapping margins. The blade is 4–12 mm wide, 7–25 cm (2 ¾–10 in.) long and flat with a sharp-pointed tip. The collar is broad and continuous. There are no auricles. The ligule is a white membrane with a distinct notch and tooth on each side (Figure 5-32). The stems are round and 50–100 cm (20–40 in.) tall. The inflorescence is a very dense, spike-like panicle (Figure 5-33). Timothy is the most widely sown forage grass in Ontario but is better suited for mechanical harvesting than pasture as it is a jointing grass.

**Figure 5-32.** Timothy collar. No auricles, notched ligule.

**Figure 5-33.** Timothy inflorescence.

Timothy is widely adapted to heavier soils, variable drainage, fertility and pH. It is most productive in the spring, followed by lower mid-season productivity and little fall growth. Earlier varieties produce slightly more regrowth than later maturing varieties. The shallow root system makes it very susceptible to drought and high temperatures. Prolonged flooding for 2 or 3 weeks may kill it.

In pure stands, seed at rates up to 17 kg/ha (15 lb/acre), as higher seeding rates increase the risk of leaf and stem diseases. When mixed with alfalfa, timothy can be seeded at rates up to 7 kg/ha (6 lb/acre). In more complex mixtures, 2–4.5 kg/ha (2–4 lb/acre) is generally sufficient. Timothy should be planted into a firm seedbed at 5 mm (¼ in.) depth. It is easy to establish in early spring or late summer. Growers in southwestern Ontario have had success planting timothy after winter wheat or a short-season soybean crop.

Historically, timothy was paired with alfalfa because it was not aggressive enough to push the alfalfa out of the stand. This meant that the first cut was a grass/alfalfa mix, and the remaining cuts were predominantly alfalfa. Modern alfalfa varieties have been selected for greater persistence and are able to compete with more aggressive grasses that are productive across the growing season, providing mixed hay in all cuts. Timothy/alfalfa mixtures are still in demand as horse hay: timothy's soft leaves, attractive colour and distinctive panicle are desirable features in that market. International buyers also value these traits in timothy but prefer pure timothy hay rather than mixed hay crops.

Timothy cut at the heads-emerged stage is high in digestible energy. The ideal harvest timing is at full head elongation but before bloom.

# Fertility

## Nitrogen

Forage stands that are less than 50% legume have a yield response to nitrogen (N) fertilizers. For nitrogen guidelines see Table 5-3.

Grass stands containing less than one-third legumes require nitrogen to optimize yield. Where conditions permit, it is generally more economical to grow mixtures containing legumes. It can be profitable to fertilize grass stands consisting of productive forage grass species. Improved grass stands that are well managed will respond well to additional nitrogen. Suggested nitrogen rates for grass stands (less than one-third legume) are 23 kg/t (45 lb/ton) of expected forage dry matter yield.

The use of nitrogen also increases the protein level in the grass. Make the first application for hay or pasture as early as possible in the spring at green-up, followed by a second application after the first cut and a third application after the second cut. To avoid the danger of nitrate toxicity, apply no more than 170 kg/ha (150 lb/acre) of nitrogen at any one time.

Nitrogen deficiency in forages shows up as a general yellowing and stunting of the plants. It may appear in the lower parts of the plants first. In legumes, a nitrogen deficiency usually indicates poor nodulation and/or low soil pH.

**Table 5-3. General Nitrogen Guidelines — Perennial Cool-Season Forages**

| Crop | Suggested Nitrogen |
|---|---|
| **Legume or legume/grass at seeding** | |
| Without a companion crop[1] | 0 kg/ha |
| With a companion crop[1] | 15 kg/ha (13 lb/acre) |
| Unimproved pasture | 50 kg/ha (45 lb/acre) |
| Grass for seed | 90 kg/ha (80 lb/acre) |
| **Hay or pasture** | |
| Half or more legumes | 0 kg/ha |
| One-third to one-half legumes | 60 kg/ha (54 lb/acre) |
| Grass (less than one-third legumes) | 23 kg/t (45 lb/ton) of expected dry matter yield |

[1] A companion (nurse) crop is an annual crop, typically a cereal, seeded with a perennial forage. See Under-seeding in Chapter 1, *Planning and Establishment*.

# Phosphate and Potash

Phosphate ($P_2O_5$) and potash ($K_2O$) guidelines are given in Table 5-4 and Table 5-5. These guidelines are based on OMAFRA-accredited soil tests using the sufficiency approach, which applies the most economic rate of nutrients for a given crop year. For information on the use of these tables or if an OMAFRA-accredited soil test is unavailable, see OMAFRA Publication 811, *Agronomy Guide for Field Crops*.

When direct-seeding on soils that require phosphate fertilizer, establishment may be improved by the placement of a high phosphate fertilizer 5 cm (2 in.) directly below the seed. Using a grain drill with fertilizer and grass seed attachments, this placement may be accomplished by drilling the fertilizer through the furrow opener and dropping the forage seed on a firm soil surface directly behind the furrow opener. Usually it is advisable to firm the soil surface immediately after seeding.

Potash may be more effective in promoting persistence if it is applied within the 6 weeks before the start of the fall rest period. Potash deficiency is visible in alfalfa with symptoms of small, light dots on the leaflets. These dots can be on any part of the leaflet but are usually concentrated near the margins (Figure 5-34). Potash deficiency symptoms in grasses and clovers are less distinctive but result in overall slow growth and poor yield.

High soil potassium levels can result in luxury consumption of potassium by forages and subsequent nutritional problems when fed to dairy cows prior to calving. Potassium applications on soils testing over 150 ppm will not significantly increase winter hardiness and are not recommended.

**Figure 5-34.** Potash deficiency symptoms in alfalfa. Symptoms are less distinctive in grasses and clovers, but still result in overall slow growth and poor yield.

Phosphate, if required, may be applied with the potash or at other times of the year. Phosphate deficiency symptoms are rare and non-specific in forages, but a shortage of phosphate may manifest itself as stunting and poor winter survival of legumes.

**Table 5-4. Phosphate ($P_2O_5$) Guidelines for Perennial Cool-Season Forages**

**Legend:** HR = high response MR = medium response LR = low response RR = rare response NR = no response

| Sodium Bicarbonate Phosphorus Soil Test | At Seeding, With or Without a Nurse Crop | Band Seeded Without a Nurse Crop[1] | Established Stands | Unimproved Pasture |
|---|---|---|---|---|
| 0–3 ppm | 130 kg/ha (HR)<br>116 lb/acre (HR) | 130 kg/ha (HR)<br>116 lb/acre (HR) | 180 kg/ha (HR)<br>161 lb/acre (HR) | 70 kg/ha (HR)<br>62 lb/acre (HR) |
| 4–5 ppm | 110 kg/ha (HR)<br>98 lb /acre (HR) | 110 kg/ha (HR)<br>98 lb/acre (HR) | 120 kg/ha (HR)<br>107 lb/acre (HR) | 60 kg/ha (HR)<br>54 lb/acre (HR) |
| 6–7 ppm | 90 kg/ha (HR)<br>80 lb/acre (HR) | 90 kg/ha (HR)<br>80 lb/acre (HR) | 90 kg/ha (HR)<br>80 lb/acre (HR) | 50 kg/ha (HR)<br>45 lb/acre (HR) |
| 8–9 ppm | 70 kg/ha (HR)<br>62 lb/acre (HR) | 70 kg/ha (HR)<br>62 lb/acre (HR) | 60 kg/ha (HR)<br>54 lb/acre (HR) | 30 kg/ha (HR)<br>27 lb/acre (HR) |
| 10–12 ppm | 50 kg/ha (MR)<br>45 lb/acre (MR) | 50 kg/ha (MR)<br>45 lb/acre (MR) | 30 kg/ha (MR)<br>27 lb/acre (MR) | 20 kg/ha (MR)<br>18 lb/acre (MR) |
| 13–15 ppm | 30 kg/ha (MR)<br>27 lb/acre (MR) | 40 kg/ha (MR)<br>36 lb/acre (MR) | 20 kg/ha (MR)<br>18 lb/acre (MR) | 20 kg/ha (MR)<br>18 lb/acre (MR) |
| 16–20 ppm | 20 kg/ha (MR)<br>18 lb/acre (MR) | 30 kg/ha (MR)<br>27 lb/acre (MR) | 0 (LR) | 0 (LR) |
| 21–25 ppm | 20 kg/ha (MR)<br>18 lb/acre (MR) | 20 kg/ha (MR)<br>18 lb/acre (MR) | 0 (LR) | 0 (LR) |
| 26–30 ppm | 0 (LR) | 20 kg/ha (LR)<br>18 lb/acre (LR) | 0 (RR) | 0 (LR) |
| 31–40 ppm | 0 (LR) | 20 kg/ha (LR)<br>18 lb/acre (LR) | 0 (RR) | 0 (RR) |
| 41–50 ppm | 0 (RR) | 20 kg/ha (LR)<br>18 lb/acre (LR) | 0 (RR) | 0 (RR) |
| 51–60 ppm | 0 (RR) | 0 (RR) | 0 (RR) | 0 (RR) |
| 61 ppm + | 0 (NR)[2] | 0 (NR)[2] | 0 (NR)[2] | 0 (NR)[2] |
| **100 kg/ha = 90 lb/acre** | | | | |

[1] For use only where seed is banded directly above the drilled fertilizer.

[2] When the response rating for a nutrient is "NR," application of phosphorus in fertilizer or manure may reduce forage yield or quality and may increase the risk of magnesium deficiency.

*Notes:*

Based on OMAFRA-accredited soil tests.

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

Where manure is applied, reduce the fertilizer application according to the amount and quality of manure (see Chapter 2, *Soil Fertility and Nutrient Use*, *Manure* section).

**Table 5-5. Potash ($K_2O$) Guidelines for Perennial Cool-Season Forages**

**Legend:** HR = high response MR = medium response LR = low response RR = rare response NR = no response

| Ammonium Acetate Potassium Soil Test | At Seeding, With or Without a Nurse Crop | Summer or Fall Applications, New Seedings and Established Stands |
|---|---|---|
| 0–5 ppm | 90 kg/ha (HR)<br>80 lb/acre (HR) | 480 kg/ha (HR)<br>428 lb/acre (HR) |
| 16–30 ppm | 80 kg/ha (HR)<br>71 lb/acre (HR) | 400 kg/ha (HR)<br>357 lb/acre (HR) |
| 31–45 ppm | 70 kg/ha (HR)<br>62 lb/acre (HR) | 320 kg/ha (HR)<br>285 lb/acre (HR) |
| 46–60 ppm | 50 kg/ha (HR)<br>45 lb/acre (HR) | 270 kg/ha (HR)<br>241 lb/acre (HR) |
| 61–80 ppm | 40 kg/ha (HR)<br>36 lb/acre (HR) | 200 kg/ha (HR)<br>178 lb/acre (HR) |
| 81–100 ppm | 30 kg/ha (MR)<br>27 lb/acre (MR) | 130 kg/ha (HR)<br>116 lb/acre (HR) |
| 101–120 ppm | 20 kg/ha (MR)<br>18 lb/acre (MR) | 70 kg/ha (MR)<br>62 lb/acre (MR) |
| 121–150 ppm | 20 kg/ha (MR)<br>18 lb/acre (MR) | 20 kg/ha (MR)<br>18 lb/acre (MR) |
| 151–180 ppm | 0 (LR) | 0 (LR) |
| 180–250 ppm | 0 (RR) | 0 (RR) |
| 251 ppm + | 0 (NR)[1] | 0 (NR)[1] |

**100 kg/ha = 90 lb/acre**

[1] When the response rating for a nutrient is "NR," application of potash in fertilizer or manure may reduce forage yield or quality and could increase the risk of milk fever in dry dairy cows. For example, potash application on soils low in magnesium may induce magnesium deficiency.

*Notes:*

Based on OMAFRA-accredited soil tests.

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

Where manure is applied, reduce the fertilizer application according to the amount and quality of manure (see Chapter 2, *Soil Fertility and Nutrient Use Manure* section).

# References


1. St. John, L., and D. Ogle. 2008. *Plant Guide for Alsike Clover (Trifolium hybridum L.).* USDA — Natural Resources Conservation Service, Idaho Plant Materials Center, Aberdeen, Idaho 83210.

2. Bélanger, G., G.F. Tremblay, Y.A. Papadopoulos, J. Duynisveld, J. Lajeunesse, C. Lafrenière and S.A.E. Fillmore. 2017. *Yield and Nutritive Value of Binary Legume-Grass Mixtures Under Grazing or Frequent Cutting.* Canadian Journal of Plant Science. 98(2):395-407.

3. Verhallen, A., A. Hayes and T. Taylor. June 2001. *Cover Crops: Sweet Clover.* Ontario Ministry of Agriculture, Food and Rural Affairs. Retrieved from: www.omafra.gov.on.ca/english/crops/facts/cover_crops01/sweetclover.htm#start

4. Ogle, D., and L. St. John. 2008. *Plant Guide for White Clover (Trifolium repens L.).* USDA-Natural Resources Conservation Service, Idaho Plant Materials Center, Aberdeen, Idaho 83210.

5. St. John, L., D. Tilley and S. Winslow. 2012. *Plant Guide for Canada Bluegrass (Poa compressa).* USDA-Natural Resources Conservation Service, Plant Materials Center, Aberdeen, Idaho 83210

6. St. John, L., D. Tilley, P. Hunt and S. Wright. 2012. *Plant Guide for Red Fescue (Festuca rubra).* USDA — Natural Resources Conservation Service, Plant Materials Center, Aberdeen, Idaho 83210.

7. Kline, P., K. Broersma, S.B.M. Wright and L.M. Rode. 1993. *Meadow Foxtail: A Production Guide.* Agriculture Canada, Ottawa, ON, Canada.


# Additional Sources

This chapter contains excerpts from the following OMAFRA sources: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*Rethinking Orchardgrass.* Last modified: April 11, 2011. www.omafra.gov.on.ca/english/crops/field/forages/rethinking.htm

*Information for Extension Personnel: Orchardgrass in Ontario.* December 1967.

*Kura Clover: A New Pasture Legume for Ontario?* Factsheet 98-049. 1998.

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*Managing Jointing and Non-Jointing Grasses.* Field Crop News Blog. September 2019. fieldcropnews.com/2020/09/managing-jointing-and-non-jointing-grasses/

*Pasture Legumes Identified,* Factsheet 04-057. 2004.

*Pasture Grasses Identified,* Factsheet 06-095. 2006.

*Alsike Poisoning, Photosensitization and Photodermatitis in Horses.* Last modified: January 15, 2016. www.omafra.gov.on.ca/english/livestock/horses/facts/info_alsike_clover.htm

CHAPTER 6

# Warm-season Perennials

## Grasses

While warm-season perennial grasses have the potential to be more widely used as forage on Ontario farms, experience to date is limited.

### Switchgrass

*Panicum virgatum*

Switchgrass is a tall grass species native to North America. A key feature of switchgrass plants is the white hairs at the point where the leaf blade attaches to the stem. During the first 5–6 weeks of growth, stems have a reddish-purplish tint and are round (Figure 6-1). Weedy grass seedlings like crabgrass or foxtail are often lighter green colour, with short wide leaves, and multi-stemmed.

Switchgrass is suitable for grazing, hay or silage. Switchgrass can produce relatively good yields in the 2,100–2,700 corn heat units (CHU) areas and will perform better in longer-season regions.

**Figure 6-1.** Switchgrass headed out.

## CAUTION!

Switchgrass makes excellent feed for cattle; however, green plant material contains saponins that can cause photosensitivity and liver damage in sheep, goats and horses. Do not feed switchgrass to small ruminants or equines. Switchgrass straw is safe for use as bedding, as saponin levels are low.

Switchgrass is suited to most soil types. Yields are lower on extremely heavy or light soils. Ideally, soil pH should be between 6.0 and 6.8. Switchgrass production is highest on fertile soils but is also well-suited to marginal lands where annual crops are less productive. Establishment has been most successful on well-drained, medium-textured soils that warm quickly and where weed competition is low. A light packing prior to planting will improve uniform seeding depth and again following seeding will improve the seed-to-soil contact. Seeding switchgrass following soybeans in the rotation has provided a low-residue, firm seedbed well adapted for no-till seeding.

There are two main ecotypes of switchgrass. The lowland ecotypes are most adapted for floodplain conditions in the Southern and Central U.S. Upland ecotypes are adapted to drier upland conditions and grow in more northerly areas. Upland switchgrass also has superior forage quality as it has a lower fibrous stem content. In Ontario, the native switchgrass found in the province is of the upland type, as the lowland ecotypes are less winter hardy.

Late-maturing switchgrass cultivars yield higher over early-maturing cultivars as they make more efficient use of sunlight for photosynthesis. New varieties have lower seed dormancy, bigger seed size for good stand establishment in the first year, less lodging and higher biomass yields.

Good site preparation is key for establishing a successful switchgrass field. Field preparation should typically include one or two secondary tillage passes followed by packing or cultipacking. Packing the soil before and after planting is highly recommended on all soil types. Switchgrass seed is small and requires planting equipment that can place the seed at a uniform and shallow depth. Seeding can be done using a grain drill equipped with a forage seed box. In conventionally tilled fields, seeding is best performed with a packer seeder in 17.5–19-cm (7–7 ½-in.) row width at a depth of 0.5–1.25 cm (¼–½ in.). It is best to seed when soils are relatively warm. Seeding usually takes place when the risk of frost has passed, generally between May 10 and June 10, depending on the region. Seed will germinate above 10°C. For successful establishment, a seeding rate of 8–10 kg/ha (7–9 lb/acre) of pure live seed (PLS) is recommended. Use a higher rate of 12 kg PLS/ha (11 lb/acre) in more marginal fields.

Switchgrass can be fairly slow to form a canopy in the establishment year. There can be increased competition from aggressive cool-season perennial grasses (such as quackgrass, bromegrass and reed canarygrass). It is important to fully eliminate perennial weeds from the site prior to planting. Poor weed control in conventionally tilled fields is the most frequent cause of switchgrass stand failures. Weed pressure can be minimized in the establishment year by no-till seeding into soybean stubble, which provides an excellent seedbed and reduced annual grass pressure. Newer, improved switchgrass cultivars have better seedling vigour for early establishment in the first year, which helps minimize the weed pressure. Weed control is critical to establishment and production success. With new fast-establishing varieties, most farmers now direct seed and use a pre-emergent herbicide. Farmers wanting to use a nurse crop for forage would be advised to sow in 35.5 cm (14 in.) rows and harvest above the growing point of the young switchgrass seedlings.

Because it is currently a low-acreage crop, minor use label expansion registrations have been granted on some herbicides for use on labelled weeds. For current information on products registered for use on switchgrass, contact OMAFRA's provincial minor use coordinator, ag.info.omafra@ontario.ca.

Limited fertility guidelines exist for switchgrass. Nitrogen fertilizer should not be applied during the seeding year because it encourages weed competition. In most cases, the only operation required following harvest is the application of nitrogen (N) fertilizer. For a spring harvest regime, 60–70 kg of N/ha (50–60 lb N/acre) is sufficient to sustain production for an 8–10 t/ha (3.5–4.5 tons/acre) yield target. A general guideline is to apply 6 kg N/t (12 lb N/ton) of biomass removed from the field. Over-fertilization with nitrogen can result in crop lodging, yield reductions and harvesting difficulties. Fertilization is commonly done in mid-to-late May, when the crop is about 15–25 cm (6–10 in.) high and when switchgrass has resumed its growth. This timing helps to minimize N losses where urea is used. Earlier N applications tend to help support grass weed growth, especially annual grass weeds and quackgrass. These guidelines were developed based on experience producing biomass in Ontario; at the time of publication there is no Ontario research on fertility programs for forage or grazing systems.

Switchgrass has a large root system and can pull potassium and phosphorus from deeper layers of the soil profile. As a perennial crop, it has time to develop symbiotic relationships with beneficial mycorrhizal fungi in the root zone, which further improves phosphorus uptake. Phosphorus and potassium fertility should be at target soil test levels (12–18 ppm P and 100–130 ppm K). If soil phosphorus and potassium levels are below target ranges, incorporate these nutrients into the soil ahead of planting, at rates that meet crop removal rate plus an amount that will build up the soil test over time.

Switchgrass has been left unharvested in the establishment year until the following spring to improve winter hardiness. Expected yield in the establishment year is about one-third of full stand potential and the year after establishment is about two-thirds of full production potential. Once established and properly maintained, a switchgrass stand will remain productive for an indefinite period and can produce 8–12 t/ha (3.5–5.4 tons/acre) of dry fall harvest material.

If switchgrass is being used for livestock bedding, pasture or roughage in the diet, it can be grazed during the growing season or cut for hay in July or August with the possibility of two harvests. Harvesting switchgrass twice in the same year, or before natural senescence has occurred, could lead to stand degradation. To date, most Ontario experience with switchgrass is as a biomass crop on a one-cut system. In these cases, switchgrass is productive for a decade or more. It is unknown how grazing or multiple harvests will affect persistence in Ontario.

Switchgrass is a jointed grass, which means that its growth point rises throughout the growing season. An early cut of hay or grazing should leave behind 20 cm (8 in.) of residual to enable fast regrowth. It matures earlier than other warm-season grasses, so grazing may need to start on switchgrass paddocks before cool-season paddocks run out of forage to maintain switchgrass quality.[1]

# References

1. Mitchell, R.B., and B.E. Anderson. 2008. *Switchgrass, Big Bluestem and Indiangrass for Grazing and Hay* [Factsheet G1908]. University of Nebraska-Lincoln Extension, Institute of Agriculture and Natural Resources, NE, U.S.

## Additional Sources

This chapter contains excerpts from the following OMAFRA source:

Publication 811, *Agronomy Guide for Field Crops.* 2017.

CHAPTER 7

# Cool-season Annuals

Many cool-season annuals are grown for forage in Ontario. Annuals excel at filling the natural production gaps that occur with perennial forage crops. Cool-season crops typically grow best under mild weather conditions, but each species has different tolerance to various soil drainage (Figure 7-1), soil pH (Figure 7-2), and harvest management (Table 7-1), as well as different tolerance to adverse weather (Chapter 10, *Weather Stress*).

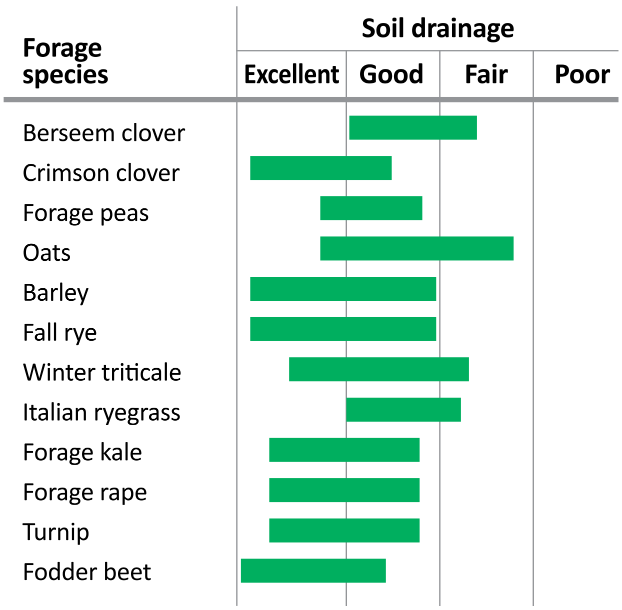


**Figure 7-1.** Soil drainage requirements of annual cool-season forage species.

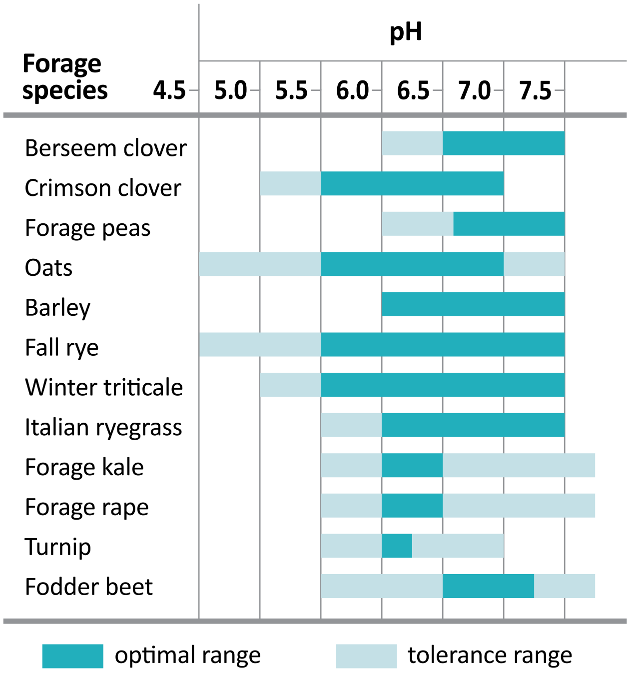


**Figure 7-2.** pH range for annual cool-season forage species.

**Table 7-1. Suitability of Cool-Season Annual Forage Species to Different Types of Harvest Management**

**Legend**: H = Highly suitable S = Suitable N = Not suitable

| Forage Species | One Close Grazing | Rotational Grazing | Hay | Baleage | Silage |
|---|---|---|---|---|---|
| Berseem clover | H | N | S | S | S |
| Crimson clover | S | S | N | S | S |
| Forage peas | S | N | S | S | S |
| Oats | H | S | N | H | H |
| Barley | S | N | N | H | H |
| Fall rye | S | H[1] | N | H | H |
| Winter triticale | S | H[1] | N | H | H |
| Italian ryegrass | N | H | N | H | H |
| Forage kale | H | N | N | N | N |
| Forage rape | H | N | N | N | N |
| Turnip | H | N | N | N | N |
| Fodder beet | H | N | N | N | S[2] |

[1] For winter cereals, interpret "rotational grazing" as one grazing event in the fall and another in the early spring.
[2] Fodder beets can be lifted from the ground, cleaned, chopped, mixed with straw, and ensiled, but few farms in Ontario have appropriate equipment to do this.

# Legumes

## Berseem Clover

*Trifolium alexandrinum*

Berseem clover will grow to 30–120 cm (12–48 in.) tall. It has a hollow stem and slightly hairy leaves. Flowers are yellowish-white (Figure 7-3). The tap root is short and generally does not grow deeper than 30 cm (12 in.). Berseem clover is a non-bloating legume that is suitable for hay or pasture.

**Figure 7-3.** Berseem clover in flower.

Berseem clover is not winter hardy but may survive inconsistently in mild regions of Southern Ontario and Niagara. It prefers loamy and clayey soils with high silt and very fine sand contents. Berseem clover has a soil pH range of 6.5–7.5 and tolerates poor drainage and drought better than crimson clover.

In a pure crop, seed at 20–22 kg/ha (18–20 lb/acre) at 5 mm (¼ in.) depth. First cut is typically 60 days after planting, subsequent cuts on a 25–30-day interval. Set cut height to 7–10 cm (3–4 in.). It can be frost seeded.[1]

Berseem clover can be used to patch an old or damaged alfalfa stand, as the growth habit and maturity of berseem clover usually align well with alfalfa. Like red clover, there are single-cut and multi-cut varieties of berseem clover. Choose a multi-cut variety when patching a perennial hay field.

## Crimson Clover

*Trifolium incarnatum*

Crimson clover is not winter hardy but may survive inconsistently in mild regions of Southern Ontario and Niagara. It prefers soils with a pH between 5.0 and 7.0 and will tolerate shade. It has hairy leaves and does not have a watermark (Figures 7-4a and 7-4b).

**Figure 7-4a.** Crimson clover in flower.

**Figure 7-4b.** Crimson clover leaves are hairy and do not have a watermark.

Crimson clover prefers well-drained soils. Plant in August at 20–22 kg/ha (18–20 lb/acre) at 5 mm (¼ in.) depth in clay soils, 12.5–20 mm (½–¾ in.) in sandy soils. Ideal harvest time is 4–6 weeks before seed set. Set cut height to 7–10 cm (3–4 in.).[2]

## Forage Peas

*Pisum sativum*

Peas have weak, vine-like stems that may reach a height (or length) of 1 m (40 in.). Flowers are in pairs and may be white, pink or purple. They have a shallow root system, which makes them susceptible to drought. Peas are susceptible to lodging, so they are usually mixed with a cereal crop for support (Figure 7-5).

**Figure 7-5.** A pea cover crop. Forage peas are normally grown with cereals to prevent lodging.

Peas grow best on well-drained loamy and clayey soils, and do not do well on poorly drained soils and droughty, sandy and gravelly soils. They prefer a soil pH range of 6.0 to 7.5 and fertile soils. Peas can withstand freezing temperatures (-12°C) but do not overwinter consistently, particularly in areas of low snowfall and extended cold temperatures.

Forage peas seeded in mixtures with cereals will enhance feed nutrient quality. Pea mixtures can increase protein levels and improve forage digestibility. When peas form at least 50% of the sown mixture (by weight), producers can expect crude protein in the harvested forage to be 2%–4% higher than with pure cereals. Pea protein is highly degradable, and rations may require a "bypass" protein supplement to properly balance the ration. Acid detergent fibre (ADF) content does not vary significantly between mixtures and pure cereals, but neutral detergent fibre (NDF) levels are 2%–4.5% lower in mixtures, resulting in a higher feed intake potential.

Adding peas will increase seed costs. Forage pea varieties are preferred. Cereal-pea mixtures may be used as a companion crop for seeding alfalfa but should be harvested for silage. Mixtures of triticale and peas usually have more peas in the harvested forage than mixtures of oats and peas. This tends to increase quality but makes wilting slower and increases the length of time the crop must cure before ensiling.

Cut when the cereal is heading out, as the peas will just be starting to pod. If seeded in late April, this growth stage will typically occur around the last week of June. Cereal-pea mixtures can be difficult to wilt, and heavy stands can lodge. When used as a companion crop, timely cutting, wilting and removal from the field is important for successful alfalfa establishment.

# Cereals and Grasses

Annual grasses tend to have aggressive seedlings that establish quickly. They can be a good choice when extra forage is needed. Cereals are annual grasses that have been selected for grain production. Cool-season annual grasses may or may not require vernalization to initiate seed production. These species also vary in their ability to overwinter in Ontario.

Any of the cereals, when grazed early enough in the vegetative state, will show some regrowth. In the vegetative state cereals are a good source of protein but have very low dry matter and fibre content.

Since cereals tend to be nitrate accumulators, if large amounts of nitrogen fertilizer are applied during cool growing conditions or cloudy periods, the plants may accumulate toxic levels of nitrates. To prevent this, limit nitrogen applications to 30–50 kg N/ha (27–45 lb N/acre). Cereals produce the maximum amount of forage when seeded and fertilized for good grain yields. Refer to Chapter 4, *Cereals,* in OMAFRA Publication 811, *Agronomy Guide for Field Crops,* for phosphate and potash recommendations for cereals. Italian and Westerwold ryegrasses produce multiple cuts, so the fertility guidelines for perennial forages are more appropriate (see Chapter 5, *Cool-season Perennials*).

## Spring Cereals

Spring cereals are very adaptable for forage production as haylage, baleage or pasture (Table 7-2). They are difficult to dry for hay in Ontario. Oats, barley and spring wheat are used extensively as companion crops for perennial forage seedings. They should be harvested as forage to improve the establishment of the perennial forage seeding by removing them as competition. As a double-crop option, spring cereals are sometimes seeded in August following winter wheat or a spring cereal for an early October harvest as silage or baleage.

**Table 7-2. Average Yield of Spring Cereal and Cereal-Pea Entries in Ontario Forage Crops Committee Trials from 1994–1997**

| | Kemptville | | Elora | | New Liskeard | |
|---|---|---|---|---|---|---|
| | kg/ha | lb/acre | kg/ha | lb/acre | kg/ha | lb/acre |
| Oats | 4,509 | 4,023 | 5,834 | 5,205 | 3,720 | 3,319 |
| Oats + peas | 4,814 | 4,295 | 6,189 | 5,522 | 4,199 | 3,746 |
| Triticale | 5,007 | 4,467 | 5,017 | 4,476 | 2,280 | 2,034 |
| Triticale + peas | 4,486 | 4,002 | 4,125 | 3,670 | 2,627 | 2,344 |

*Notes:*

Average of 5 oat, 7 oat-pea, 2 triticale and 2 triticale-pea entries.

Kemptville and Elora locations harvested at heads-emerged stage; New Liskeard harvested at early heading.

At the same stage of maturity, oats, barley and triticale have similar feed quality. If the cereal is mixed with field peas and/or seeded down to alfalfa, triticale will usually give higher protein and lower neutral detergent fibre (NDF) levels. This is because triticale is less competitive than other cereals, and the harvested forage will have greater amounts of peas and/or alfalfa present.

Cereal forage harvested in the boot stage has a higher protein level and about the same energy level as corn silage. When harvested at the milk stage, it has about 10% less energy than corn silage (similar to alfalfa) and about 4 percentage units more protein than corn silage. The highest quality is when the harvested forage is in the boot stage, but the maximum energy harvested per hectare occurs at the soft dough stage (Table 7-3).

**Table 7-3. Summary of cereal forage yield and quality (2-year average from New Liskeard)**

| | Boot | Headed | Milk | Dough |
|---|---|---|---|---|
| **Forage Yield** | | | | |
| Oats | 4,298 kg/ha<br>3,827 lb/acre | 5,389 kg/ha<br>4,808 lb/acre | 6,424 kg/ha<br>5,731 lb/acre | 8,504 kg/ha<br>7,587 lb/acre |
| Barley | 4,319 kg/ha<br>3,853 lb/acre | 5,664 kg/ha<br>5,053 lb/acre | 6,878 kg/ha<br>6,136 lb/acre | 7,676 kg/ha<br>6,848 lb/acre |
| Oats + Peas | 3,541 kg/ha<br>3,159 lb/acre<br>14% peas[1] | 4,689 kg/ha<br>4,183 lb/acre<br>15% peas | 6,997 kg/ha<br>6,243 lb/acre<br>28% peas | 7,270 kg/ha<br>6,486 lb/acre<br>35% peas |
| Barley + Peas | 3,532 kg/ha<br>3,151 lb/acre<br>24% peas | 4,633 kg/ha<br>4,133 lb/acre<br>28% peas | 5,925 kg/ha<br>5,286 lb/acre<br>38% peas | 8,080 kg/ha<br>7,209 lb/acre<br>42% peas |
| **Forage Crude Protein (% of DM)** | | | | |
| Oats | 16.4 | 13.5 | 10.1 | 8.4 |
| Barley | 16.6 | 13.3 | 10.0 | 6.9 |
| Oats + Peas | 18.2 | 15.4 | 12.2 | 10.3 |
| Barley + Peas | 18.6 | 15.9 | 14.0 | 11.3 |

| | Boot | Headed | Milk | Dough |
|---|---|---|---|---|
| **Forage ADF (% of DM)** | | | | |
| Oats | 35.2 | 40.9 | 43.5 | 43.3 |
| Barley | 35.5 | 39.8 | 40.1 | 45.8 |
| Oats + Peas | 37.2 | 41.0 | 42.1 | 43.5 |
| Barley + Peas | 36.4 | 38.9 | 38.7 | 42.5 |
| **Forage NDF (% of DM)** | | | | |
| Oats | 53.7 | 60.1 | 61.2 | 62.4 |
| Barley | 56.1 | 61.0 | 58.8 | 68.8 |
| Oats + Peas | 52.6 | 57.7 | 57.8 | 59.8 |
| Barley + Peas | 53.3 | 57.5 | 54.3 | 60.3 |

[1] Percent peas in the harvested forage.

Conditioning and wilting of early-cut cereal silage prior to ensiling is desirable. Whole plant peas are lush, often containing 5%–10% more moisture than cereals at harvest, which can result in an extra half day of drying time and increase the risk of weather damage. Because of this, cereals are rarely made into dry hay. As the crop matures, moisture content in the standing crop declines. At the soft dough stage, whole plant barley is approximately 60% moisture, while barley-pea mixtures are about 8%–10% higher in moisture. At the same stage of maturity, oats tend to be higher in moisture content than barley. For some storage systems that require very wet forage (i.e., bunker silo), the standing crop may be too dry to ensile properly if left to the dough stage. Additional practices to help assure good quality feed are chopping at the recommended length of cut, thorough packing of the silage and covering bunker silos rapidly after filling.

## Oats

### *Avena sativa*

Oats do not have auricles, and leaf-sheaths and blades are usually hairless. The ligules are of medium length. Oats are the only cereal whose leaves twist counter-clockwise when viewed from above.[3]

Oats prefer soil pH between 5.0 to 6.5, but can tolerate as low as 4.5. They are more tolerant of saturated soils than barley. As a pure stand, seed at 80–100 kg/ha (70–90 lb/acre). When used as a companion crop for a spring-seeded perennial forage, seed at 30–40 kg/ha (26–35 lb/acre).

Oats are ready to be pastured 6–8 weeks after being seeded and can be seeded anytime from spring to fall. Early spring seedings can be cut for haylage and the aftermath grazed until fall. Many find that oat forage is the most palatable of the cereals. Early spring planting promotes maximum yields. Nitrogen fertilizer enhances vegetative growth, yield and crude protein, and therefore 55 kg/ha (50 lb/acre) of nitrogen is suggested. Oats normally require about 60 days of growth following germination to reach the boot-stage. Forage quality drops quickly after heading, so harvesting at the boot- to early-heading stage will optimize feed value. Yield will increase as plants mature but feed quality drops dramatically. Under Ontario conditions, oats can yield 2.5–4.5 tonnes DM/ha (2,230–4,000 lb DM/acre) when harvested at late-boot to early head, or 5.5–8.5 tonnes DM/ha (4,900–7,500 lb DM/acre) when harvested at heads-emerged to soft-dough stage.

Forage oat varieties tend to have more aggressive regrowth than grain varieties. Rust–resistant varieties are preferred. Buckthorn acts as the alternate host for rust in oats. Remove buckthorn from field margins whenever possible. Growers in Southern Ontario should consider using a fungicide for crown rust control, as yield losses from this disease may be as high as 50%. See Ontario Crop Protection Hub at ontario.ca/cropprotection, for more information.

### Barley

*Hordeum vulgare*

In the vegetative stages, barley's most distinguishing feature is its long, hairless auricles. The ligules are of medium length. Barley's leaf sheaths and blades are usually hairless.[4]

Barley prefers cool, dry soils with a pH above 6.0. As a pure stand, seed at 80–100 kg/ha (70–90 lb/acre). When used as a companion crop for a spring-seeded perennial forage, seed at 30–40 kg/ha (26–35 lb/acre).

Barley tillers more than oats and has a less upright growth habit, which makes it more competitive against weeds than oats. Its fibrous roots are not as aggressive as cereal rye. Forage barley varieties do not have awns, which make them more palatable to livestock when the plant is in reproductive stages.

Under Ontario conditions, barley can yield 2.5–5.5 tonnes DM/ha (2,230–4,900 lb DM/acre) when harvested at late-boot to early head, or 5.5–9.5 tonnes DM/ha (4,900–8,475 lb DM/acre) when harvested at heads-emerged to soft-dough stage.

## Winter Cereals

Fall rye and winter triticale can provide a "double crop" forage option by planting after the harvest of many crops, including silage corn. Seeded in late summer or fall, they can provide haylage harvested in mid- to late May or can provide fall and early spring grazing. After the cereals are completely killed with glyphosate or tillage, they can be followed by late-planted crops, such as soybeans or sorghum-sudangrass. Nutritional quality, palatability and intake drop very quickly at the heading stage, so the harvest window is very narrow. Target harvest at the flag-leaf or early-boot stage for high nutrient quality. Rye will mature about 7–10 days earlier than triticale, which enables earlier seeding of the following crop. Apply 55 kg/ha (50 lb/acre) nitrogen in the spring at green-up to increase yield and crude protein.

Under Ontario conditions, fall rye and winter triticale can yield 5.0–9.0 tonnes DM/ha (4,460–8,000 lb DM/acre) when harvested at flag leaf or boot stage in May. When grazed 7 weeks after seeding or in early spring, yields may be 1.0–1.5 tonnes DM/ha (900–1,300 lb DM/acre).

### Fall rye

*Secale cereale*

Fall rye has very short, hairless auricles and short ligules. Leaves are flat and a blue-green colour, though new leaves are typically rolled in the bud. The leaf sheath and blade may be hairy.[5] Do not confuse cereal rye (*Secale cereale*) with ryegrass (*Lolium multiflorum* or *L. perenne*), which are totally different grass species with very different characteristics.

Fall rye grows well on lighter and low pH soils, but does not do well on poorly drained, heavier soils. Forage rye is higher yielding, but not as palatable as winter wheat. Rye matures rapidly at the flag-leaf, boot and early-heading stages, with significant reductions in forage quality. This can create the challenge of a very narrow harvest window, particularly if there are rain delays.

Fall rye is easy to establish and can be seeded from late summer to late fall. If harvest as silage the following May is planned, fall rye should be seeded in September, but later seedings can work on sandy soils. Early planting allows more time for tillering, higher forage yields and slightly earlier forage harvest dates. Some growth going into winter is required for early spring growth and good yields. Seed is relatively inexpensive. Under good conditions, fall rye can be seeded at 110 kg/ha (100 lb/acre), but the seeding rate can be increased up to 190 kg/ha (168 lb/acre) if the seed is broadcast rather than drilled, or if the seeding date is late. Seed at 2.5 cm (1 in.) depth, or into moisture.

Fall rye is best known as a cover crop that prevents erosion and gives good weed suppression. Rye is very cold tolerant, the hardiest and most disease resistant of the winter cereals. Fall rye has an extensive fibrous root system, can scavenge nitrogen very effectively and utilizes early spring moisture to grow rapidly. Fall rye is faster growing and earlier maturing in the spring than the other winter cereals, including wheat, barley and triticale. This enables an earlier forage harvest and more "double crop" options (i.e., the first crop is harvested early enough in the growing season to enable a second crop to be established, grown, and harvested in the same year).

Decreased moisture in the soil profile following forage rye harvest can potentially have a negative effect on the yield of the following crop. It is essential to completely kill the rye with glyphosate or tillage to minimize shading and competition for moisture.

Fall rye is best used to provide early-spring grazing but can also be grazed into late fall. It is ready to graze early in the spring, and growth is very rapid. To ensure that it does not get too mature, be prepared to move livestock frequently by strip grazing. Grazing rye on wet heavy clay soils in late fall or early spring is not recommended due to livestock "pugging" and compaction. If fall pasture is desired, fall rye should be seeded by August 15–30.

Nitrogen applied at 55–80 kg/ha (50–70 lb/acre) in the spring at green-up will stimulate tillering and increase forage yield. Fall rye can be made into good stored feed by making it into silage, either in tower or bunk silos, piles, bags or as baleage. Fall rye cut at the desired stage is extremely difficult to dry sufficiently to be made into dry hay.

The timing of cutting is critical. Quality, palatability and intake drop very quickly at the heading stage (faster than other cereals) so the optimum harvest window is very narrow. It is recommended to target harvesting forage rye at the flag-leaf or early-boot stage for high nutrient quality. Early-boot generally occurs May 10–20 in Southern Ontario. At this stage, a dry matter yield of 4.9 tonnes/ha (4,446 lbs/acre) or more is possible under good conditions.

There can be a very large range in forage quality with only a few days difference in harvest. At the early-boot stage (Zadok Stage 39 — ligule of the last leaf just visible), crude protein (CP) can approach up to 18% (depending on the amount of nitrogen applied), with neutral detergent fibre (NDF) under 50%.

At the head-emerged stage (Zadok Stage 55), CP drops to the 13%–14% range, while NDF increases to over 60%. This will likely be adequate for beef cows, heifers and dry cows, but will not be high-producing dairy cow or sheep quality. When rye is cut later, at the early-dough stage, the yield may approach 7.4 t/ha (6,600 lbs/acre), but the quality, palatability and intake will be much lower. Delaying forage rye harvest past the boot stage because of bad weather or competing field crop activities results in low quality forage.

Rye is sometimes noted for having an "allelopathic effect" that suppresses the germination and growth of weeds and other crops. With most of the rye residue removed, allelopathy is a low risk in most forage rye situations. The possible exception may be with no-till corn on heavier soil types.

## Winter Triticale

*x Triticosecale*

Winter triticale, a cross between rye and wheat, has been suggested by Tom Kilcer in New York State as being preferable in both forage yield and quality to either fall rye or winter wheat. His research indicates that winter triticale harvested at the flag-leaf stage (rather than boot-stage) can be very high-quality feed for dairy cows.

Triticale has blunt, hairy auricles and a medium-length ligule. Leaf-sheaths and blades are always hairy. It is very difficult to tell the difference between triticale and wheat at the vegetative stages. Triticale seeds are darker than wheat and are oblong rather than oval, so digging up seedlings to find the seed may help identify young plants.[6]

Triticale can be grown on a variety of soil types but, like fall rye, should not be sown on poorly drained soils (e.g., heavy clay). Seed early enough in the fall to provide time for the crop to establish itself. The date of seeding differs with location. See OMAFRA Publication 811, *Agronomy Guide for Field Crops* and use the seeding dates suggested for winter wheat. Seed winter triticale at a rate of 100–125 kg/ha (90–113 lb/acre). In the spring, as the triticale is starting to turn green, fertilize with 80 kg N/ha (72 lb N/acre). Seed at 2.5 cm (1 in.) depth, or into moisture.

Triticale is more drought tolerant than wheat or oats. It tolerates a wide range of soil conditions but does best in well-drained light soils — sand, loamy sand, sandy loam and gravel-based soils.

Seed can be difficult to source and more expensive than rye. Harvest of triticale will be slightly later than rye at the same stage of maturity, which may delay planting of the subsequent crop. While there is good potential for triticale as an Ontario forage crop, farmers interested in forage triticale may want to try rye as well and evaluate them in their own systems.

## Annual Ryegrass
*Lolium multiflorum*

Ryegrasses are rapidly growing bunchgrasses that are best adapted to cool, moist conditions and perform poorly in hot, dry weather. They are higher in nutrient quality than other cool-season grasses at the same maturity. Ryegrasses are best suited for silage, baleage or pasture, because their waxy leaves make them difficult to dry for hay.

Italian ryegrass is leafy and short growing — up to 40 cm (16 in.). Leaves are glossy, dark green and hairless. Italian ryegrass leaves are usually wider than perennial ryegrass, and new Italian ryegrass leaves are generally rolled in the bud, while perennial ryegrass leaves are folded. Italian ryegrass seeds have awns, whereas perennial ryegrass is awnless. Italian ryegrass has long, clasping auricles (Figure 7-6). Culms are often red at the base. Do not confuse cereal rye (*Secale cereale*) with ryegrass (*Lolium multiflorum* or *L. perenne*), which are totally different grass species with quite different characteristics.

**Figure 7-6.** Italian ryegrass collar. The ligules are long and clasping.

Although it is commonly called “annual” ryegrass in Ontario, Italian ryegrass may overwinter. Like winter cereals, it has a vernalization requirement (exposure to cold temperatures) for flowering. The year it is seeded, it remains vegetative without a seed-head, producing a lush, leafy growth with exceptionally high forage quality. When overwintered, it will form a seed-head the following year, therefore harvest timing will be important for forage quality. Italian ryegrass gained its nickname because it is more susceptible to winterkill than winter cereals; older varieties would winterkill consistently in Ontario. European plant breeders have been improving the winter hardiness of Italian ryegrass to expand its range as a forage crop.

There are annual ryegrass varieties without a vernalization requirement: Westerwolds (*Lolium multiflorum* ssp. *westerwoldicum*). Westerwold ryegrasses grow taller (40–80 cm (16–32 in.)), have more stems and will head out if left to mature. Graze or cut Westerwold ryegrasses before they head out to maintain high productivity and feed quality.

Italian ryegrass tolerates more standing water than perennial ryegrass. It grows best on medium-to-heavy soils and has high requirements for moisture and nutrients. Italian ryegrass tolerates soils with pH above 5.5.

Seed Italian ryegrass in early spring at a rate of 20–25 kg of seed/ha (18–22 lb/acre). Since highly fertile soil is needed to support the rapid, high production of forage, use a soil test to determine the phosphorus and potassium requirements, and apply high rates of nitrogen in split (at least three) applications. Because Italian ryegrass provides multiple harvests, growers should follow the fertility guidelines for perennial cool-season forages. Seed at 5–12.5 mm (¼–½ in.) depth.

Italian ryegrass can either be spring seeded or seeded in August. Although there is some risk of winterkill, August-seeded Italian ryegrass can provide a late fall harvest and some early-season forage the following spring. A single cut can be taken in May, after which the field is replanted to silage corn, soybeans, edible beans or sorghum-sudangrass. An alternative is to keep taking cuts every 4 weeks until the stand becomes unproductive. Harvested correctly, fibre digestibility (NDFd), palatability and intake are exceptionally high, enabling higher forage diets to be fed to high-producing dairy cows.

For maximum yields and quality, Italian ryegrass requires top management. Yields range from 8–12 tonnes DM/ha (7,140–10,700 lb DM/acre) when there is adequate rainfall (Table 7-4), but its need for a constant water supply limits its use in Ontario. The shallow root system makes it ill-equipped to access water reserves when rainfall is scarce, and during periods of little or no rain, the plants stop growing and may die.

**Table 7-4. First Cut and Total Dry Matter Yield of Westerwold Ryegrass "Marshall"**

| Location | 1993 | | 1994 | | 1995 | | Average | |
|---|---|---|---|---|---|---|---|---|
| | 1st cut | Total | 1st cut | Total | 1st cut | Total | 1st cut | Total |
| New Liskeard | 3,604 kg/ha<br>3,215 lb/acre | 11,089 kg/ha<br>9,893 lb/acre | 3,141 kg/ha<br>2,802 lb/acre | 12,051 kg/ha<br>10,752 lb/acre | 3,326 kg/ha<br>2,967 lb/acre | 6,694 kg/ha<br>5,972 lb/acre | 3,357 kg/ha<br>2,995 lb/acre | 10,045 kg/ha<br>8,962 lb/acre |
| Verner | – | – | 2,793 kg/ha<br>2,492 lb/acre | 8,800 kg/ha<br>7,851 kb/acre | 4,661 kg/ha<br>4,158 lb/acre | 5,889 kg/ha<br>5,254 lb/acre | 3,727 kg/ha<br>3,325 lb/acre | 7,345 kg/ha<br>6,553 lb/acre |
| Kemptville | – | – | 2,869 kg/ha<br>2,560 lb/acre | 7,331 kg/ha<br>6,541 lb/acre | 6,229 kg/ha<br>5,557 lb/acre | 6,229 kg/ha<br>5,557 lb/acre | 4,549 kg/ha<br>4,059 lb/acre | 6,814 kg/ha<br>6,079 lb/acre |

*Notes:* Seeded at 20 kg/ha (18 lb/acre). Three cuts were taken each year at New Liskeard, two cuts at Verner and Kemptville, except 1995 in Kemptville. First cut was harvested 55–60 days after planting, when the heads were fully emerged. Subsequent harvests were taken 30–40 days later.
*Source*: Johnston and Bowman, 1998.

# Non-legume Forbs

## Brassicas

Forage brassicas can provide good pastures from September to December. Forage rape, kale and stubble turnips are the three brassicas most commonly used for pasture. Brassicas are not suitable for hay, baleage or silage production.

**CAUTION!**

Brassicas should not be fed to horses.

Seed the brassicas in well-drained fields with a pH of at least 6 and adequate fertility according to soil test recommendations. For canola and forage rape, refer to Chapter 6, *Spring and Winter Canola,* in Publication 811, *Agronomy Guide for Field Crops*. Limited Ontario fertility guidelines exist for phosphorus and potassium in other forage brassica crops. Phosphorus and potassium fertility should be at target soil test levels (12–18 ppm P and 100–130 ppm K). If soil phosphorus and potassium levels are below target ranges, incorporate these nutrients into the soil ahead of planting, at rates that meet crop removal rate plus an amount that will build up the soil test over time. Nitrogen requirements vary somewhat depending on the type of forage brassica, so guidelines are provided with each crop description that follows. Brassicas have a higher sulphur requirement than most other field crops. Sulphur is an important component in protein. The current guideline is to apply up to 18 kg/ha (20 lb/acre) of sulphur as an insurance factor against sulphur deficiency.

Crops planted on poorly drained soils do not do well, and grazing losses are high. All species are small-seeded and produce maximum yields when precision drilled into rows no more than 1.5 cm deep (⅝ in.). However, good stands can also be established by broadcast seeding.

All forage brassicas should be planted in the summer, and seeding dates are important for all of these, as delays past the recommended dates cause large declines in yields. They will germinate and then not grow very much during hot dry weather. Once day and night temperatures cool and more rain falls, they grow quickly.

### Crop Development

Brassica development is aligned with growing degree days (GDD Base 0°C) and the amount of sunlight captured (Table 7-5). Brassicas grow best at temperatures between 10°C and 30°C, with an optimum of 18°C–25°C. Most forage brassicas are biennials or winter brassicas and will not set seed during the establishment year.

**Table 7-5. Growth Stages of Brassicas**

| Growth Stage (decimal code system) | Description | |
|---|---|---|
| 0–1.0 | Emergence | |
| 1.0 | Cotyledons unfolding | |
| 1.1–1.2 | 1- to 2-leaf stage | Rosette stage |
| 1.4–1.6 | 4- to 6-leaf stage | |
| 2.0–2.2 | Bolting – internode lengthening | |
| 3.0–3.9 | Bud development | |
| 4.0–4.9 | Flowering – 20% of all buds on main raceme flowering or flowered | |
| 5.1–5.9 | Pod development | |
| 6.0–7.9 | Seed development | |
| 8.1–8.4 | Ripening and maturity[1] | |

[1] Occurs when seed begins to mature, 10% seed colour change.
*Notes:* Decimal indicates number of leaves exposed.
*Source:* OMAFRA Publication 811, *Agronomy Guide for Field Crops.*

## Forage Kale

*Brassica oleracea*

Kale is a biennial that has been selected for leaf production. It has a short (75 cm–1.5 m (30–60 in.)), upright growth habit with highly digestible leaves and stems. It is frost-hardy and will continue to provide fresh forage after snowfall. Its crude protein level (on a dry-matter basis) ranges from 19% in September to 15% in late fall.

Kale grows well on soils ranging from light loam to clay. Good fertility and good drainage are essential. An alkaline soil is also preferred. In an environment of poor drainage, stunted yellow growth is obtained. Kale can withstand higher temperatures than rape, but grows best under relatively cool, moist conditions.

Kale should follow a good legume sod in the rotation. It fits into the same place in a crop rotation as a row crop. Kale requires earlier seeding than rape; at first it grows more slowly after seeding, and it does not compete well with weeds. It is important, therefore, that kale be seeded on fields with low weed pressure. A fine, firm seedbed is essential for the best establishment. Packing or rolling following seeding is beneficial.

Seed kale in early June. The best yields are obtained when kale is drilled in rows 15–70 cm (6–28 in.) wide at a rate of 2–4 kg/ha (2–4 lb/acre). Do not plant kale seed deeper than 1.5 cm (⅝ in.) deep. Kale can be broadcast-seeded at an increased seeding rate of 6 kg/ha (6 lb/acre). It requires approximately 80–120 kg N/ha (70–110 lb N/acre) and grows well if manure is used. A split application of nitrogen is preferred, with half applied up front, and half applied 3 weeks after planting.

The crop is typically ready to be grazed 10–15 weeks after seeding. Kale seeded by June 1 is ready to graze by mid-August. Where the crop is required during part of August and September, early seeding is essential. In Ontario conditions, forage kale can yield 9.0–12.0 tonnes DM/ha (8,000–10,000 lb DM/acre).

Although bloat is not as prevalent on kale as on rape pasture, precautions should be taken. See *Other Brassica Crop Issues* below.

## Canola and Forage Rape

*Brassica napus, Brassica rapa*

**CAUTION!**

**Do not confuse oilseed rape with canola or forage rape.** Oilseed rape is a brassica selected for oil production, which was originally used for fuel and then industrial lubrication. High levels of glucosinolates and erucic acid prevent rapeseed oil and meal from being used in human foods and animal feeds, as these compounds can be toxic.

Canola is a group of oilseed rape varieties that have been bred to have low levels of glucosinulates and erucic acid. Because canola has low levels of these toxic compounds, it can be used as a forage crop. Both annual ("spring") and biennial ("winter") canola varieties exist. The upper leaves of canola are waxy, dark-bluish green with shallow lobes (Figure 7-7).

**Figure 7-7.** Canola.

Forage rape is a biennial crop that requires vernalization before it will set seed. It has dark green leaves. Two main types of forage rape are used for pasture. The broadleaf or giant types are leafy and upright growing and are best pastured by cattle or sheep. Dwarf types are shorter and branching and may be used for fattening lambs. Rape is not recommended for dairy pasture because it causes off-flavours in milk. Rape is faster growing than kale and can provide forage sooner.

Rape is adapted to fertile, well-drained soils. On land where fertility is limiting or drainage is a problem, short, stunted growth may occur. It fits best after a good legume sod or on land too weedy for spring grain. In the latter case the land may be summer-fallowed until early July and then sown to rape. Rape may also be sown on land from which early pasture or hay has been taken, and which is then immediately plowed and worked. In all cases, thorough cultivation prior to seeding is essential and helps to eliminate weeds. A fine firm seedbed similar to that required when seeding hay and pasture crops is required for good rape stands.

As a fall pasture, fodder rape should be seeded in early July. The rape crop is also more effectively utilized where it is grown in rows rather than broadcast. Row seedings give high yields and considerably less wastage. For maximum yields, drill rape at 6–8 kg/ha (5–7 lb/acre). Rape can be broadcast seeded at 10 kg/ha (9 lb/acre), but yield will be lower. Packing or rolling after seeding is beneficial.

Rape requires 80–100 kg N/ha (72–90 lb N/acre). A split application of nitrogen is preferred, with half applied up front, and half applied 3 weeks after planting. The rape crop is a heavy user of nitrogen and phosphorus and responds well to fertilizer, particularly manure.

The crop is typically ready to be grazed 10–12 weeks after seeding. In Ontario conditions, forage rape can yield 7.0–9.0 tonnes DM/ha (6,000–8,000 lb DM/acre).

## CAUTION!

Rape can cause serious losses in livestock from bloat and rape poisoning. Bloat can usually be prevented by following the grazing management suggested. Rape poisoning may occur when stunted, low-growing, purple-coloured crops are pastured. Such crops are more prevalent in wet years, on poorly drained land and/or when adequate fertilizer has not been used. See *Other Brassica Crop Issues* below.

### Forage Turnip, Rutabagas and Swedes

*Brassica rapa, Brassica napus, Brassica napobrassica*

Forage turnips, also called stubble turnips, fall turnips, white turnips or Dutch turnips, produce a thick mass of bushy tops and large white roots (Figure 7-8). The animals will first graze the tops off the turnips and then graze the area a second time, feeding on the roots. The roots are high enough out of the ground that animals can get to them easily. Strip grazing is recommended to make best use of this crop. Plant turnips the same way as rape and fertilize with 80–100 kg N/ha (70–90 lb N/acre). Even though animals can use both roots and tops, turnips are still lower yielding than rape or kale crops. In Ontario conditions, forage turnip can yield 6.0–9.0 tonnes DM/ha (5,000–8,000 lb DM/acre).

**Figure 7-8.** Forage Turnip

Plant turnips from mid-June to mid-July at a rate of 2–6 kg/ha (2–5.5 lb/acre). The crop is typically ready to be grazed 10–12 weeks after seeding. If storing forage turnips, applications of boron might be necessary to prevent against water-core or brown heart resulting from B deficiency. Affected rutabagas develop soft, brown internal discolouration that can provide an entry point for other diseases and rots during storage.

### Other Brassica Crop Issues

Crop rotation is an excellent way to reduce build-up of diseases and insects. Rotations of 3–4 years between brassica crops (including canola for oilseed and brassica vegetables) are recommended.

Livestock can bloat on forage brassicas. Strip graze brassicas to avoid excessive wastage. Brassicas have a high moisture content, typically 85%–89%. To ensure enough fibre in their diet, either feed animals hay or give them access to permanent grass/legume pastures. When first turned out onto brassicas, livestock should be full, and then allowed free access to it. Bloat danger is more prevalent where farmers try to rotate livestock between brassicas and other grazing areas. Of equal importance is the necessity to provide some form of high-fibre feed to livestock grazing brassicas. Adjacent pastures, hay aftermaths, a stack of straw or feeding low-quality hay from racks placed in the brassica field are all satisfactory. Where such feed is present, livestock seldom gorge themselves on the crop and consequently rarely bloat.

In addition to causing bloat and nitrate poisoning, brassicas can also cause forage rape poisoning, anemia, goitre, rape scald and rape blindness.

#### *Forage Rape Poisoning*

Forage rape poisoning can occur if animals graze stunted, purple-coloured rape or canola plants. This type of plant is produced when rape growing in wet conditions or on soils deficient in phosphate is frosted. Animals affected take shallow, rapid breaths and suffer from digestive disturbances. **Death may follow.** When the affected animals recover, they often remain unthrifty.

#### *Anemia*

Brassicas contain a hemolytic factor that may cause grazing animals to suffer from anemia. Cattle are more susceptible to this disorder than sheep. Anemia only develops when the livestock are grazing brassicas for at least 1 week. It usually takes 3 weeks to occur. In extreme cases, hemoglobin appears in the urine, giving it a red colour. The amount of the hemolytic factor in brassicas increases with plant maturity.

#### *Goitre*

All brassica crops contain goitregenic substances. The goitregen affects the uptake of iodine by the thyroid gland, and goitre develops. Goitre can occur in all animals grazing brassicas but is more of a concern with sheep. Do not use brassica pastures during the mating season or for ewes late in their pregnancy. Lambs may be born dead or deformed.

#### *Rape Scald*

White-faced sheep grazing brassicas in August and September may suffer from "rape scald." Their light-coloured skin becomes susceptible to sunburn, and their heads may swell.

#### *Rape Blindness*

Rape blindness is the sudden appearance of blindness in cattle and sheep grazing rape. Complete recovery of sight normally occurs a few weeks after the livestock have had a change of diet.

**CAUTION!**

Do not allow animals to graze brassica crops for more than 6–8 weeks at a time to reduce the risk of health problems.

## Fodder and Sugar Beets

*Beta vulgaris*

Fodder beet is a subspecies, closely related to garden and sugar beets. Fodder beet is a biennial plant that is grown as an annual. It provides an alternative to brassicas in crop rotations. Fodder beets may contain up to 20% sugar and are an excellent energy source. Beets are low in protein and minerals.

Although beets can be ensiled in a 5:1 ratio with corn, few Ontario farms have appropriate lifting equipment to harvest a beet crop. For this reason, grazing is generally the intended use. Varieties with lower dry matter content tend to have bulbs that are raised out of the ground, which makes them better suited for grazing. Any fodder beet variety with a dry matter content below 13% is considered a mangel.

Sugar beets have higher sugar and dry matter content than fodder beets, which makes them easier to ensile. Chopped straw, hay or corn stalks can be used to bring the moisture content down to prevent seepage and encourage efficient fermentation. Sugar beets are typically 80% moisture (20% dry matter), which is well above the target moisture content for ensiling (Figure 7-9).

**Figure 7-9.** Sugar beets can be grown for forage, but their bulbs do not stick out of the ground as much as fodder beet varieties.

Beets grow best on well-drained soils. Fodder beets will not tolerate soils with pH below 5.5, and ideally pH should be between 6.5 and 7.2. Seed beets early, once soil temperatures are above 4˚C, as beets will germinate at 4.5°C. The target plant population is 75,000–80,000 beets/ha (30,300–32,400 beets/acre); typically sugar beet germination in Ontario is 60%, so seed at a rate of 125,000–133,000 seeds/ha (50,600–53,800 seeds/acre). Seed at a depth of 2–2.5 cm (¾–1 in.). Seeds are very sensitive to salt damage, so mixing fertilizer and seed at planting is not recommended. Fodder beets are typically established with a drill. Beet plates exist for planters, as table beets in Ontario are sown this way. Fulkerson (1983) attributed the higher total yields in the second year of his fodder beet trial to narrower row width[7], so beets that will be lifted should be planted in 53-cm (21-in.) rows (Table 7-6).

**Table 7-6. Dry Matter Yields of Fodder Beet Varieties at Elora, ON**

| Variety | Roots | | Tops | | Total | |
|---|---|---|---|---|---|---|
| | 1981 | 1982 | 1981 | 1982 | 1981 | 1982 |
| Monobamba | 7,948 kg/ha<br>7,091 lb/acre | 14,875 kg/ha<br>13,271 lb/acre | 5,779 kg/ha<br>5,156 lb/acre | 3,748 kg/ha<br>3,344 lb/acre | 14,191 kg/ha<br>12,661 lb/acre | 18,612 kg/ha<br>16,605 lb/acre |
| Triumf | 8,595 kg/ha<br>7,668 lb/acre | 15,338 kg/ha<br>13,684 lb/acre | 4,983 kg/ha<br>4,446 lb/acre | 2,727 kg/ha<br>2,433 lb/acre | 13,971 kg/ha<br>12,465 lb/acre | 18,065 kg/ha<br>16,117 lb/acre |
| Monoblanc | 7,869 kg/ha<br>7,021 lb/acre | 16,638 kg/ha<br>14,844 lb/acre | 5,611 kg/ha<br>5,006 lb/acre | 4,337 kg/ha<br>3,869 lb/acre | 14,087 kg/ha<br>12,567 lb/acre | 20,974 kg/ha<br>18,713 lb/acre |
| Brigadier | 6,893 kg/ha<br>6,150 lb/acre | 14,064 kg/ha<br>12,548 lb/acre | 3,984 kg/ha<br>3,554 lb/acre | 2,934 kg/ha<br>2,618 lb/acre | 10,876 kg/ha<br>9,703 lb/acre | 16,999 kg/ha<br>15,166 lb/acre |
| Barres | 11,593 kg/ha<br>10,343 lb/acre | 14,669 kg/ha<br>13,087 lb/acre | 4,142 kg/ha<br>3,695 lb/acre | 3,256 kg/ha<br>2,905 lb/acre | 15,154 kg/ha<br>13,520 lb/acre | 17,925 kg/ha<br>15,992 lb/acre |

*Notes:* May 15, 1981: seeded in 71-cm (28-in.) rows. May 15, 1982: seeded in 53-cm (21-in.) rows.
*Source:* R.S. Fulkerson, 1983.[8]

Beets have high fertility requirements. When grown after corn or wheat, apply 120–150 kg N/ha (110–130 lb N/acre); apply 100–130 kg N/ha (90–115 lb N/acre) when following other non-legume crops in rotation. Adjust for a nitrogen credit following a legume crop or manure application. Use a soil test and follow sugar beet guidelines for phosphorus and potassium in fodder beet production (see Table 7-7). Work on table beet and sugar beet varieties in Ontario suggests that beets are highly responsive to manganese and iron, show a moderately high response to boron, copper and molybdenum, and a moderate response to zinc.

**Table 7-7. Fertility Guidelines for Sugar Beets in Ontario**

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

| Sodium Bicarbonate Phosphorus Soil Test | Phosphate Required | Ammonium Acetate Potassium Soil Test | Potash Required |
|---|---|---|---|
| 0–3 ppm | 150 kg/ha (HR) | 0–15 ppm | 180 kg/ha (HR) |
| 4–7 ppm | 140 kg/ha (HR) | 16–30 ppm | 170 kg/ha (HR) |
| 8–9 ppm | 130 kg/ha (HR) | 31–45 ppm | 160 kg/ha (HR) |
| 10–12 ppm | 130 kg/ha (MR) | 45–60 ppm | 140 kg/ha (HR) |
| 13–15 ppm | 120 kg/ha (MR) | 61–80 ppm | 120 kg/ha (HR) |
| 16–20 ppm | 100 kg/ha (LR) | 81–100 ppm | 90 kg/ha (MR) |
| 21–25 ppm | 90 kg/ha (LR) | 101–120 ppm | 70 kg/ha (MR) |
| 26–30 ppm | 70 kg/ha (RR) | 121–150 ppm | 20 kg/ha (MR) |
| 31–40 ppm | 50 kg/ha (RR) | 151–180 ppm | 0 kg/ha (LR) |
| 41–50 ppm | 30 kg/ha (RR) | 181–210 ppm | 0 kg/ha (LR) |
| 51–80 ppm | 0 kg/ha (RR) | 211–250 ppm | 0 kg/ha (RR) |
| 80+ ppm | 0 kg/ha (NR) | 250+ ppm | 0 kg/ha (NR) |

*Source:* OMAFRA Publication 363, *Vegetable Production Recommendations.*

Young beets are not competitive, making weed control very important.[9] However, beets can be severely injured by herbicides, so careful planning of the crop rotation is important for success. Fodder beets will be ready to graze in the fall. Strip grazing is recommended.

Rumen acidosis is the most common animal health concern when grazing fodder beets. The transition process onto beets is critical to prevent acute rumen acidosis as well as a learned feed aversion (caused by subclinical acidosis). Contact the OMAFRA grazing specialist for more details on allocation and access for grazing livestock to successfully transition onto beet.

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CHAPTER 8

# Warm-season Annuals

The most commonly grown annual warm-season forage crop in Ontario is corn (see Chapter 4, *Silage Corn*), but other warm-season annuals can produce forage in the province. Annuals excel at filling the natural production gaps that occur with perennial forage crops. Warm-season crops typically grow best under hot weather conditions, but each species has different tolerance to various soil drainage (Figure 8-1), soil pH (Figure 8-2), and harvest management (Table 8-1), as well as different tolerance to adverse weather (Chapter 10, *Weather Stress*).

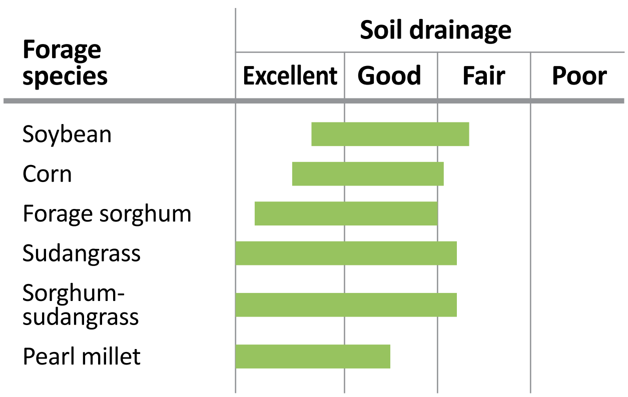


**Figure 8-1.** Soil drainage requirements of annual warm-season forage species.

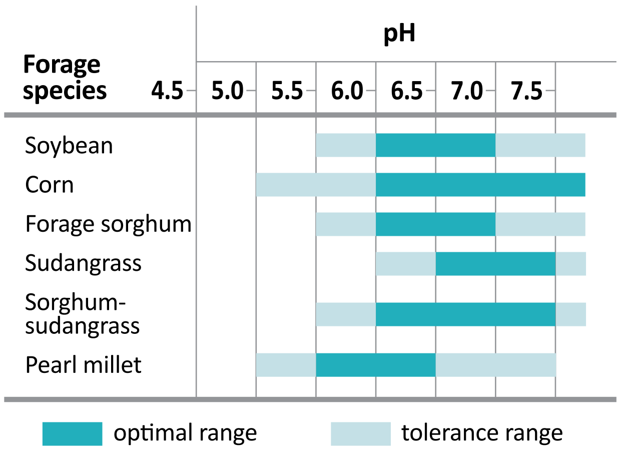


**Figure 8-2.** pH range for annual warm-season forage species.

**Table 8-1. Suitability of Warm-Season Annual Forage Species to Different Types of Harvest Management**

**Legend:** H = Highly suitable S = Suitable N = Not suitable

| Forage Species | One Close Grazing | Rotational Grazing | Hay | Baleage | Silage |
|---|---|---|---|---|---|
| Soybeans | S | N | S | N | S[1] |
| Corn | H | N | N | N | H |
| Forage sorghum | H | N | N | H | H |
| Sudangrass | S | H | N | H | H |
| Sorghum-sudangrass | S | H | N | H | H |
| Pearl millet | S | H | S | H | H |

[1] Soybeans can be ensiled, but because they buffer pH changes and are difficult to pack, chopping corn into the silo with the soybeans can make ensiling easier.

# Legumes

## Soybeans

### *Glycine max*

Soybeans are an annual legume crop. Once the cotyledons emerge from the soil, two single leaves emerge. All subsequent leaves are compound and made up of three leaflets called trifoliates. Soybeans will start to flower near the end of June and continue to put on new growth and flowers at the same time for about 4–6 weeks (Figure 8-3). Soybeans can grow to between 30–122 cm (1–4 ft) tall depending on soil type, variety and growing conditions.

**Figure 8-3**. Soybeans.

Soybeans were originally introduced to Ontario as a forage crop for cattle. The easiest way to harvest soybeans is by grazing (before R5). Ensiling soybeans is difficult because their high oil and low sugar contents buffer against efficient fermentation. Soybeans are typically high in protein and low in digestible fibre (NDFd).

Soils with good drainage are preferred, but so long as there is no root rot present and moisture continues through the growing season, soybeans can tolerate wet feet. Soybeans will tolerate soil pH between 5.5 and 8.0, but the optimal is between 6.5 and 7.5.

Later maturing varieties tend to have higher dry matter yields. In Canada, maturity groups (MG) range from MG 000 in the north to MG III in the south. With the use of decimals, each decimal unit is approximately equivalent to 1 day of maturity, that is, a cultivar rated MG 1.5 is about 5 days later maturing than a cultivar rated MG 1.0 in its region of adaptation. See OMAFRA Publication 811, *Agronomy Guide for Field Crops,* for the soybean maturity group map. Research from Wisconsin suggests that a soybean variety that matures 5–15 days later than a full-season oilseed soybean variety can increase yield up to 1,350 kg/ha (0.6 tons/acre). This strategy is an option for early-seeded beans. "Bushy" varieties are preferred to "straight" varieties for forage production.

Soybeans produced for forage are mostly grown with the same management considerations as for oilseed (see Chapter 2, *Soybeans,* in OMAFRA Publication 811, *Agronomy Guide for Field Crops*).

Planting forage soybeans in narrow rows – 17.5 cm (7 in.) — and high populations are preferred over wide rows (38 cm (15 in.)) and low populations. Plants grown at densities over 308,750 plants/ha (125,000 plants/acre) produce stems with smaller diameter. Coarse stems are not as digestible and are left uneaten by livestock. Typically, soybeans for oilseed are seeded in narrow rows at about 479,000 seeds/ha (194,000 seeds/acre). Soybeans may be planted with a drill, an air seeder or a narrow-row planter. Generally, May is the time to seed soybeans, but successful soybean crops have been seeded as late as the middle of July in Southwestern Ontario.

Inoculation is important to ensure good nodulation and is essential on fields that have never grown soybeans before.

Pesticides used for weed, insect, and disease control in soybeans may prevent the crop from being taken as forage. Check the label of any pesticides used, before harvesting and feeding the soybeans as a forage. Some will list a pre-harvest interval (PHI) for silage. Other products will clearly state that the formula is not safe for use on feed, fodder, forage or silage. There will be products that do not mention silage or feed on the label. These have not been tested for their effects on livestock, and crops treated with them should not be fed.

Maturity stage at time of harvest has the greatest effect on yield and quality. Dry matter yields increase with each advance in maturity stage. Crude protein levels decrease from late vegetative stage to late reproductive stage, but as the pods mature, crude protein increases. Soybeans take longer to dry for hay than alfalfa, so should be harvested between growth stages of beginning pod (R3) and beginning seed (R5) with a mower-conditioner, and tedded.

Soybean forage harvested between full seed (R6) and beginning maturity (R7) stage (when leaves begin to turn yellow, but before they begin to fall off the plant) is comparable to alfalfa hay harvested at an early bloom stage of development for crude protein, acid detergent fibre (ADF) and neutral detergent fibre (NDF). Since soybeans seeds have a higher oil content, the ether extract (EE) content of the soybean forage is significantly higher than for alfalfa forage. The nutritional impact at first would appear desirable, however feeding large amounts of vegetable fats to ruminant livestock has not always proven beneficial. Increasing the EE content of the ration of lactating cows can increase milk production but can also decrease intake and reduce fibre digestion. For this reason, it is recommended that the EE concentrations of rations should not exceed 5%, which means that soybean forage harvested at the R7 stage should be limited to no more than 50% of the total ration dry matter. Other sources suggest limiting soybean forage to 20% of the ration.

Table 8-2 gives an indication of whole plant nutrient analysis (dry matter (DM) basis) at 3 different stages of growth. This information comes from Southwestern Ontario harvest research where harvest occurred during the first week of September. The sample differences indicate differences in maturity.

**Table 8-2. Whole Plant Soybean Nutrient Analysis**

| Nutrient | Sample 1: 68 pods unfilled, flowering at top of plant | Sample 2: 14 pods, lower pods half filled, top pods flat | Sample 3: 18 pods, lower pods full sized and green, top pods rippled |
|---|---|---|---|
| Crude protein (%) | 15.4 | 12.8 | 21.1 |
| Calcium (%) | 1.25 | 1.28 | 1.27 |
| Phosphorus (%) | 0.37 | 0.33 | 0.35 |
| Potassium (%) | 2.01 | 1.99 | 2.07 |
| Magnesium (%) | 0.59 | 0.41 | 0.40 |
| Acid detergent fibre (%) | 29.8 | 20.2 | 28.0 |
| Neutral detergent fibre (%) | 42.5 | 43.2 | 41.3 |

*Notes:* All samples were 76 cm (30 in.) tall, green foliage.
*Source:* Gwen McBride, 1992.

One of the biggest challenges with harvesting soybeans is preventing soil and stones from being incorporated into the forage. Soil will raise the ash content and can introduce clostridial bacteria to the silage, resulting in butyric fermentation (see Chapter 16, *Forage Analysis and Grading*). Stones can damage the forage chopper.

Soybean silage has sometimes been mixed with corn silage, and feeding trials have indicated little difference in value between corn-soybean silage and corn silage. When mixed, it is recommended that about two or three parts corn and one part soybeans makes a well-balanced silage that keeps well and is readily eaten by cattle, and produces no negative effect on milk quality.

There are a few precautions to watch for with forage soybeans. When white mould is a problem, the palatability will be reduced. Some other moulds can lead to toxin production and should be tested before incorporation into a ration.[1,2]

**CAUTION!**

Raw soybean seeds can cause ammonia toxicity in livestock. Harvesting forage soybeans at the correct maturity is important to prevent animals from consuming unroasted beans. Soybean forage may cause bloat.

# Grasses

Members of the sorghum and millet families are semi-arid, tropical, warm-season annual grasses. They are very sensitive to frost in both spring and fall and are easily killed.

Annual warm-season grasses may be a better alternative to silage corn, depending on several factors:

- if a grower does not have the planting and harvesting equipment for silage corn, but has their own haying equipment
- the limited availability of custom operators
- fields with moderate or high erosion potential, from slope or other soil characteristics

# Sorghums

The genus *Sorghum* includes grain and forage sorghums, sudangrass and some weedy grass species. Sorghums are known for being drought resistant. They are more efficient in water absorption because they have twice as many secondary roots per unit of primary root as corn and have only half as much leaf area as corn for evaporation. Their water requirements are the same as corn, but they can go dormant during extended drought periods. Growth will begin when the rains come.

**CAUTION!**

Sorghum species should not be fed to horses as they can cause neurologic conditions including urinary incontinence, which can lead to cystitis.

Sorghums yield slightly lower than corn when harvested for silage, but most have the advantage that they can be cut 2–3 times during the season and can also be stored as either chopped silage or baleage, green chopped or pastured. Corn silage produces more tonnes per hectare, but it must be harvested in the fall with specialized forage harvesting equipment. The availability of harvesting equipment and the immediate need for forage will help producers to decide between sorghum-sudangrass and other annual forages.

Varieties with brown midrib (BMR) characteristics have been developed with significantly improved nutritional quality. BMR is a genetic mutation that reduces the amount of lignin, improving fibre digestibility, digestible energy and intake. However, there may be increased potential for less vigorous growth and lodging. Unlike BMR corn, there does not seem to be a reduced yield associated with this trait in sorghum species.

## Forage Sorghum

*Sorghum bicolor* ssp. *bicolor*

Forage sorghum has wide, glossy leaves with toothed edges. Unlike corn, sorghum does not have nodal roots. Forage sorghums have fine fibrous secondary roots and tillers, giving them good drought tolerance. Forage sorghum has a panicle at the top of the plant where seeds form.

Older forage sorghum varieties were adapted to a high-yield, lower forage-quality, single-cut harvest. Grain sorghums, also called milo, are not suggested for forage production due to low yields. Newer forage sorghums have been developed to be grown as short season, multiple-cut, high-quality forage. Forage sorghums will tolerate heavier soils better than pearl millet. Optimum growth of these plants occurs under hot, moist conditions.

Planting forage sorghums should occur after the risk of frost has passed and soil temperatures are above 12°C, typically the last week of May or early June. Seeding rates range from 22–44 kg/ha (20–40 lb/acre). Generally, higher seeding rates should be used in narrow row widths and under poorer seeding conditions. Planting depth should be 2–3.75 cm (¾–1 ½ in.). Fertilize with phosphorus and potash like corn according to soil test (refer to Chapter 1, *Corn,* of OMAFRA Publication 811, *Agronomy Guide for Field Crops,* for full corn nutrient recommendations). Suggested nitrogen rates for sorghums are 80–100 kg/ha (90–110 lb/acre) up front, and another 50 kg/ha (45 lb/acre) after cutting to encourage regrowth.

The stage of maturity is the most important factor influencing the quality and quantity of forage produced. Typically, forage sorghums are ready for harvesting 60–65 days after planting (late July or early August) and a second cut will be ready 30–35 days later. For faster regrowth, leave at least 10 cm (4 in.) of stubble when cutting or 15–20 cm (6–8 in.) when grazing. A one-cut silage system will greatly improve yields but at the expense of feed quality. Feed quality drops dramatically after heading.

Under growing conditions in Southern and Eastern Ontario, forage sorghum has a yield potential of 7.0–9.0 tonnes DM/ha (3.1–4 tons DM/acre).

## Sudangrass

*Sorghum bicolor* ssp. *drummondii*

Sudangrass has narrower leaves than forage sorghum, but otherwise appears similar. It is a fine-stemmed and leafy plant with very quick regrowth. It is best used for pasture or in multiple-cut systems. If used in a one-cut system, yields will be less than that of sorghum. Forage quality will be high due to low fibre content if cut frequently.

Sudangrass can be used for pasture. It has pencil-size stems and is palatable even after it heads out. Grazing should be delayed until the crop reaches 45 cm (18 in.). Under rotational grazing, the crop will remain productive and succulent throughout the season. Sudangrass can tolerate slightly wetter soils than the other sorghum species but grows best on medium-to-well-drained soils.

Sudangrass establishes well when drilled at 28 kg/ha (25 lb/acre). The seed should always be treated to protect the crop from seed rot and seedling blight. Planting depth should be 2–4 cm (¾–1½ in.). Fertility requirements are the same as forage sorghum. Since it grows rapidly, adequate nitrogen is essential.

Sudangrass makes palatable pasture and can be grazed even after heading, although it is preferable to start grazing when the crop is 60 cm (2 ft) high. This practice permits fast recovery of the aftermath and, when coupled with some form of rotational grazing, will keep the regrowth young and succulent throughout the season. For maximum feed value, sudangrass should be cut for haylage soon after heading. It compares favourably with good timothy hay in feeding value.

Under the growing conditions of Southern and Eastern Ontario, sudangrass has a yield potential of 5.0–7.0 tonnes DM/ha (2.2–3.1 tons DM/acre).

## Sorghum-Sudangrass

Hybrid *Sorghum x drummondii*

Sorghum-sudangrass hybrids are the most popular *Sorghum* grass for use in Ontario. They have larger stems and are less leafy than the sudangrass but perform best in our climate. Sorghum-sudangrass is intermediate in height and leaf width to its parent species (Figure 8-4). The resulting hybrid may favour either parent, so be sure to discuss what you want from the hybrid with your seed salesperson.

**Figure 8-4**. Sorghum-sudangrass.

Seeding method, fertility and cut height for sorghum-sudangrass is the same as for forage sorghum (see above).

Under growing conditions in Southern and Eastern Ontario, sorghum-sudangrass has a yield potential of 8.0–12.0 tonnes DM/ha (3.6–5.4 tons DM/acre).

## Other Issues with *Sorghum* Species

### *Prussic Acid Poisoning of Livestock*

**CAUTION!**

Members of the sorghum family contain dhurrin, a glucoside that breaks down to release hydrocyanic acid, also known as prussic acid (hydrogen cyanide, HCN). A sudden disruption of growth such as frost, drought or cutting causes prussic acid to be released inside the plant at a more rapid rate. High prussic acid levels may be lethal to ruminants. Prussic acid will break down in 1–2 weeks, so material made into silage is safe to use.

In general, sorghums are higher risk for prussic acid poisoning than sudangrass, and sorghum-sudangrass is intermediate. Some newer hybrid forage sorghums have been bred to have lower levels of prussic acid. Prussic acid poisoning is not a concern with millets. To reduce the risk of prussic acid poisoning:

- Do not pasture or green chop sorghum stands less than 45–60 cm (18–24 in.) tall. New regrowth typically has high prussic acid content, but more mature plants are generally safe unless stressed.
- Do not ensile or green chop sorghum over 76 cm (30 in.) tall for 3–5 days after a killing frost. Silage should be completely fermented before feeding (6–8 weeks). This will allow time for the prussic acid to dissipate.
- Immediately after a frost, remove the livestock from the sorghum pasture until it has dried out (usually 6–7 days). If new shoots develop, harvest the field as silage rather than pasture.
- After a drought-ending rain, do not graze animals on new sorghum growth.

### *Allelopathy*

When a plant is described as “allelopathic” it means that the plant has an impact on the germination and/or growth of other plants. The most significant allelopathic chemical produced by sorghum species is called sorgoleone. Sorgoleone interferes with seedlings’ photosynthesis. Sorgoleone production is linked to sorghum root hair development. Maximum secretions occur at temperatures of 25˚C–35˚C, especially with high humidity and plenty of available oxygen.

To increase palatability and digestibility in sorghum species, many producers have been increasing the seeding rates they use. Prior to 2010, sorghum species for forage use were commonly sown at 22–28 kg/ha (20–25 lb/acre). More recently, seeding rates have climbed, and sorghum species are frequently seeded at 33–44 kg/ha (30–40 lb/acre). The higher plant population decreases stem diameters and lignin content. While producers knowingly accept the increased risk of lodging, higher plant population also increases the risk of allelopathy.

Any mention of sorghum species and allelopathy in extension resources usually says that it is not an issue unless seeding rates are increased above that which is normally used for forage. But the publishing dates on those articles show that they were written before seeding rates started to climb. Awareness of allelopathy will help producers avoid issues from sorghum species in their forage production systems.

Plant population is likely to have the biggest effect on risk of allelopathy. The seed size of sorghum species varies hugely, from 24,200–99,000 seeds/kg (11,000–45,000 seeds/lb). Even varieties or hybrids within a species lack consistency in seed size. A seeding rate based only on weight can result in very inconsistent plant populations! As populations climb, so does the risk of accumulating allelopathic compounds to levels that might affect the next crop.

Most sources recommend a population of 197,600–247,000 plants/ha (80,000–100,000 plants/acre) for forage sorghum. Although seeding rates for sudangrass and sorghum-sudangrass are typically higher than forage sorghum, there is a lack of consensus as to an appropriate plant population. More research is needed in this area, as much of the ongoing sorghum allelopathy work is focused on organic methods of weed suppression rather than optimizing forage crop rotations.

To avoid an excessive plant population, producers can calculate the appropriate seeding rate. Seeds/kg (seeds/lb) should be stated on the seed tag or bag, along with the percent germination. See Chapter 1*, Planning and Establishment,* for calculating the amount of pure live seed.

Rather than increasing seeding rates, other strategies exist to help producers maximize quality. Timely harvest is critical to prevent the crop from becoming over-mature. Sudangrass has finer stems and more leaves than forage sorghum or sorghum-sudangrass, which may increase palatability to livestock. Brown mid-rib (BMR) varieties of sorghum species are available, which reduces the amount of lignin the plant produces.

# Millets

The name "millet" has been given to numerous grass species with small edible seeds. Most millet types, including Japanese, proso, foxtail, barnyard, Koda, finger and teff, have short (0.3–1.2 m (1–4 ft)), slim stalks. Pearl millet has thicker stalks that are over twice as long (1.5–3 m (5–10 ft)). The millets commonly used for forage in Ontario are pearl millet and Japanese millet. With proper management, millets can produce forage with very good quality. Millets have a smaller stem than sorghums and slightly higher total digestible nutrients (TDN) and protein levels.

## Pearl Millet

*Pennisetum glaucum*

Pearl millet has solid stems that are often hairy. Although yields are similar to sudangrass, pearl millet has slightly higher feeding value as compared to sudangrass or Japanese millet. Pearl millet tends to have a smaller stem than sorghum grasses (Figure 8-5). As with any forage, the stage at cutting will impact on the quality. It can be used for fresh fodder, pasture, silage and even hay, when properly conditioned. Unlike sorghums, pearl millet does not produce prussic acid.

**Figure 8-5**. Pearl millet.

Pearl millet grows with a mass of very fine fibrous secondary roots and tillers. It exhibits drought tolerance and prefers a lighter sand or sandy loam. Pearl millet does not tolerate heavy soils as well as forage sorghum.

Pearl millet can be planted when there is no risk of frost and when soil temperatures are 12°C or warmer. While the last week of May or early June is typically the best time to seed, planting can be delayed until the first of July. The recommended seeding rate is 8–10 kg/ha (7–9 lb/acre) at a 0.5–1 cm (¼–⅜ in.) planting depth. Growth habits are similar to sorghum-sudangrass hybrids. Row width should be 10–15 cm (4–6 in.). It takes about 5 days to germinate and emerge. It starts off yellow and stays this colour for 8–10 days. It will stay at 15 cm (6 in.) height for about 2 weeks, then begins growing rapidly. Pearl millet has a great ability to tiller, and 12–15 tillers per plant are common.

As a general guide, apply 70% of corn fertilizer recommended rates. The phosphorus (P) and potassium (K) and half the total nitrogen should be applied at planting. The other half of the nitrogen should be applied after the first cut.

Quality and quantity of forage produced will be determined by the stage of maturity when harvested. For high feed quality, first cut is usually ready about 55–60 days after planting, when it is still vegetative. Second-cut is ready about 30–35 days later. Leaving at least 10 cm (4 in.) of stubble will result in faster regrowth, however, when grazing, about 15–20 cm (6–8 in.) of stubble should be left for faster regrowth. In Southern and Eastern Ontario, the yield potential of pearl millet is 4.0–12.0 tonnes DM/ha (1.8-5.4 tons DM/acre).

Pearl millet has higher crude protein (CP) levels than corn silage, but it has lower energy content. Feeding trials of pearl millet were conducted at the University of Guelph, Kemptville College, by Dr. Paul Sharpe in 1996/97 using Holstein steers. A ration of pearl millet silage was compared to a control ration of grass haylage and corn silage plus some supplement. In general, the results show that pearl millet silage can be included in a ration as up to 60% of the dry matter to give optimum performance. This is partially due to the crude protein and/or total digestible nutrient (TDN) levels in the rations. As a precaution, it is recommended to do a forage analysis of the pearl millet silage and use it to balance the ration to meet the requirements of the animals.

Sweet pearl millet is commonly used as a biofuel crop, and the residues produced are often used in livestock feed. In addition to sweet pearl millet, regular midrib (RMR) and brown midrib (BMR) pearl millet varieties are also available. Although BMR millet shows improved quality through increased digestibility, BMR millet yield is lower, which offsets value so that both BMR and RMR millet are approximately equal in overall feed value per unit area grown. Sweet millet differs from regular pearl millet in that the plant has longer and narrower leaves, profuse nodal tillering with asynchronous maturity, short thin spikes and very small grains. Sweet millet has been found to have twice the amount of soluble sugar in comparison to regular pearl millet varieties, hence its name.[3]

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CHAPTER 9

# Managing for Healthy Soils and Ecosystems

## Soil Compaction

Soils are made up of minerals (sand, silt and clay particles), organic matter and pore spaces that contain water and air. Compaction in its purest sense can be defined as “an applied pressure/force exerted on a landscape that reduces pore space within the soil matrix” (Figure 9-1). Crops grown in compacted soils often have a restricted root system. This leads to poor nutrient uptake, stunted growth, a general lack of vigour and reduced yields. Compaction-affected plants are also more susceptible to disease and insect pressure.

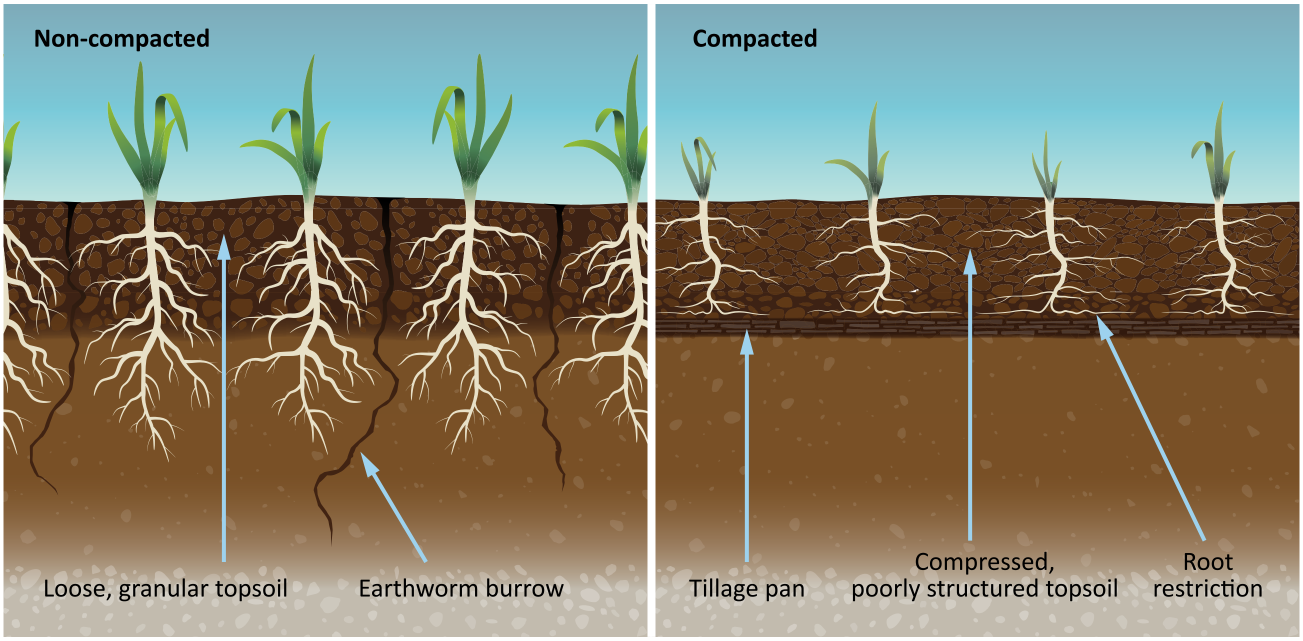


**Figure 9-1**. The difference in porosity between compacted and un-compacted soils.

The effects of soil compaction often go unnoticed in forage fields, but compaction can impact yield. Research has shown that compaction can cause between 6% and 74% yield loss in perennial forage stands.[1] Heavy equipment, high tire pressures and multiple passes create more severe compaction. One study reported grass yield losses increase from 5% to 15% as the pressure exerted by the tractor on the ground rose from 10 to 30 psi. The study also showed a 33% reduction in yield when comparing a 3-pass system to a single pass.[2]

Yield impacts from compaction are primarily the result of decreased pore space within and between soil aggregates or clods. This reduces water infiltration and drainage, aeration, root growth, and nutrient availability and uptake. Low aeration can decrease nitrogen availability because of denitrification, and a low-oxygen environment leads to reduced root respiration that can restrict potassium uptake. Phosphorus uptake can also be reduced by up to 40% if root growth is significantly impeded.[3]

The risk of causing soil compaction can be reduced by waiting until soils are dry enough to carry equipment. No-till and conservation tillage cropping systems maintain the soil's ability to carry equipment because the structure stays intact. Heavier equipment has a greater risk of causing compaction, so choosing the smallest tractor that can safely do a job will reduce the load on the soil. Adjustments can be made to agricultural equipment to further reduce compaction during field work.

Tire selection can help reduce soil compaction. Agricultural field tires exert less pressure on the soil than road tires. Increasing the number of axles and tires under equipment and wagons disperses the weight over a greater surface area, much like snowshoes distribute a person's weight across the snow. Inflation/deflation systems can be installed on tractors with lines to implements; when paired with appropriate tires, these systems can quickly pay for themselves in reduced soil compaction through higher forage yields.

The front tires on front end loaders are not big enough to support the weight of a bale. Where possible, plan traffic through the field and use bale loaders or gatherers.

It is not always possible to fix soil compaction after the fact. Deep compaction (caused by equipment) is harder to fix. Shallow compaction (caused by equipment or livestock) will over time fix itself because it occurs where roots grow, microbes live, and frost enters and leaves the soil. These processes help break up mild-to-moderate shallow compaction.

# Pollinators

There are many species that pollinate plants: bees (both managed honey bee colonies and the over 400 species of wild or native bees in Ontario), flies, butterflies, beetles, wasps, moths, ants and hummingbirds. All animals specialized for pollination rely on flowering plants for pollen and nectar food sources, and the plants rely on pollinators to move pollen within and between flowers, which enables the plants to set seed and, in some cases, can increase yield.

Wild or native pollinators are part of the natural landscape; most are solitary (no colony) and nest in the soil or vegetation. Honey bee (one species — *Apis mellifera*) colonies, on the other hand, are a managed part of agricultural production in Ontario, with approximately 3,000 beekeepers managing 90,000–110,000 honey bee colonies through the province in any given year. In many cases, beekeepers will actively seek out areas where there is a high proportion of forage (especially alfalfa and clovers), and provide custom pollination services to produce forage seed in Ontario and other regions of North America. Honey bee colonies each contain 10,000–60,000 individuals and are managed by beekeepers in box-like units (hives) that can be easily transported, where required. A hobbyist beekeeper may only have one colony at a location, while a commercial beekeeper may have 30 or more colonies per location.

Pollinators are essential for agricultural (pollination of field crops, horticulture, seed production, etc.) and ecosystem (food and habitat for wildlife) services. At the same time, habitat and feed sources have been in decline, which affects the populations of native pollinators and the honey crops of beekeepers, and which in turn impacts the available pollination services within the landscape.

While many conservation programs prefer native species be planted to establish new habitat, managed forage species provide quality feed sources to native pollinators. Any flowers that can bloom at different times and provide diversity within an environment are a bonus. Forage crops that provide pollen or nectar that can benefit native pollinators and managed honey bee colonies include:

- alfalfa
- canola/forage rape
- clovers (alsike, crimson, red, white)
- peas
- birdsfoot trefoil
- sweet clover
- vetches

These crops only benefit pollinators in situations where they are allowed to flower, and the bloom is available for a sufficient period of time (minimum 1–2 weeks). In most cases, blooming clover and alfalfa constitute the main honey crop for beekeepers.

Wild bees will forage within about 750 m (0.5 miles) of their nests, although many solitary bee species will only fly up to 350 m (0.2 miles) from their nests. To create good habitat for these insects, a mixture of species with blooms in spring, summer and fall is necessary to ensure a reliable food source. In the case of honey bees, the thousands of foraging honey bees from a typical honey bee colony will forage within a 3-km radius and up to 10 km if required.

Field borders, buffer strips or in-field strips planted with flowering species (both wildflowers and the listed forage crops) can create needed pollinator habitat. In addition, pastures containing at least 30% legumes can be excellent habitat, provided it is not overgrazed.

Diversity of flowering plants (timing and species) will also benefit pollinators. Many wild or native pollinators specialize on a certain type of flower, either due to preference or the structure of their body. While honey bees are generalists that will pollinate most types of flowering plants, a diversity of plants provides their nests with a variety of pollen sources, which is good for the nutritional requirements of the colony.

Different pollinator species have different habitat preferences. Ground-nesting bees like undisturbed bare ground that is well-drained. Some ground-nesting bees will nest under bunch grasses. Wood- and cavity-nesting bees like dead wood and shrubs, so there are opportunities to create habitat for these species in fencerows and farm woodlots. Honey bee colonies are managed in artificial boxes that can be placed within a well-drained and accessible area, as a result of agreements between landowners and beekeepers. Even if a property does not contain honey bee colonies, it is very likely that honey bees are foraging from a nearby property (within 3 km).

Limiting mowing to one-third of the field per year provides undisturbed habitat for pollinators. Rotational grazing with a low stocking density for short periods of time also can maintain good pollinator habitat. Including different legume species and varieties in the forage mix that have different maturity dates will increase the amount of time that blooms are available to pollinators. Stockpiling these fields for grazing after seed set can naturally reseed the field while providing a future feed source to pollinators.[4]

# Grassland Birds

Birds that breed and nest in grasslands have experienced the sharpest population declines of all types of birds in North America. In Ontario, hay fields and pastures provide most of the habitat for grassland birds. Among the several grassland bird species at risk in the province, bobolink (*Dolychonyx oryzivous*) and eastern meadowlark (*Sturnella magna*) are two threatened species with rapidly declining populations. Many conservation efforts are focused on bobolinks and eastern meadowlarks, and actions that benefit these species will have benefits for other grassland birds as well.

Bobolink and eastern meadowlark both prefer to nest in grass over 30 cm (12 in.) tall, away from the edges of the field. Many conservation programs prefer native grass species be planted to establish new habitat, but tame forage species can provide quality nesting areas if the mixture meets the following criteria:

- 60%–80% grasses, with a minimum of three grass species of varying heights (see sidebar for guidance on heights)
- 20%–40% forbs or legumes. Alfalfa cannot be more than 25% of the mixture.

### Tame Forage Grasses Categorized by Height

**Short**

- Canada bluegrass
- Creeping red fescue
- Kentucky bluegrass

**Medium**

- Meadow bromegrass
- Meadow fescue
- Meadow foxtail
- Perennial ryegrass

**Tall**

- Orchardgrass
- Reed canarygrass
- Smooth bromegrass
- Tall fescue
- Timothy

Fields that attract these birds are usually at least 200 m (650 ft) wide, and a minimum area of 4 ha (10 acres). Bobolinks are more sensitive to edge effects than eastern meadowlark and are less likely to use fields bordered by a windbreak or woodlot than fields bordered by row crops or forages. Bobolinks and eastern meadowlarks nest from May through July, and usually return to the same field each year to nest.[5]

For more detailed information on ways farmers can provide good-quality habitat to grassland birds, refer to the *Farming With Grassland Birds* guide from the Ontario Soil and Crop Improvement Association at www.ontariosoilcrop.org/wp-content/uploads/2015/08/GrasslandBirdsWorkbook.pdf

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CHAPTER 10

# Weather Stress

Adverse weather conditions can negatively impact forage production. Different species vary in their tolerance to stressful growing conditions.

## Winterkill

Many different causes of stand loss are frequently grouped under the term “winterkill”: cold injury, ice damage and heaving typically occur over winter, but frost injury and drowning are sometimes also included when they occur in early spring. Diseases and insect pest pressure that cause stand losses are often mistaken for winterkill when the effects are noticed in the spring; refer to Chapter 12, *Insects and Pests,* and Chapter 13, *Diseases,* for more information.

## Cold and Frost Injury

Cold injury over winter is most likely to occur when there is not a layer of snow to insulate the soil and forage plants (Table 10-1). Frost injury tends to occur in spring or fall when the crop is actively growing. In either case, the severity depends on both the temperature and the duration of the cold event.

**Table 10-1. Snow Cover Effects on Temperature 6 cm Below the Surface**

| | Soil Temperature (°C) | | | |
|---|---|---|---|---|
| | | Snow | | |
| Average Daily Air Temperature (°C) | Bare Soil | Compacted | Uncompacted | Uncompacted Snow and Stubble |
| -2.2 | -1.1 | -0.5 | 0.0 | 1.7 |
| -8.3 | -3.9 | -1.7 | -0.5 | 1.1 |
| -10.5 | -5.6 | -4.4 | -1.1 | 0.6 |
| -16.7 | -8.9 | -7.8 | -2.2 | 0.6 |

*Notes:* 3-year means from Elora, ON.
*Source:* Bowley and Wright, 1991.[1]

Temperatures in the plant canopy level are usually "layered" and higher than reported air temperatures (Table 10-2). Soil temperatures, slope, wind and the microclimate within a field can all have an effect.

**Table 10-2. Critical Lower Temperatures of Perennial Cool-Season Forage Grasses**

| Species | $LT_{50}$ (°C) |
|---|---|
| Reed canarygrass | -5.7 |
| Orchardgrass | -9.0 |
| Meadow fescue | -10.9 |
| Meadow foxtail | -11.3 |
| Creeping red fescue | -12.2 |
| Kentucky bluegrass | -13.6 |
| Timothy | -14.4 |

*Notes:* $LT_{50}$ is the temperature at which 50% of the plants die after an hour of exposure (roots and shoots). *Source:* Adapted from Gudleifsson et al, 1986.[2]

## Alfalfa

The survival of alfalfa is conditional upon many controllable management factors and uncontrollable environmental factors. The uncontrollable factors include snow cover, temperature and temperature fluctuations. Controllable management factors include variety used, soil fertility (potassium level), soil drainage and harvest timing. Management will greatly offset the risk of alfalfa winter injury. Table 10-3 outlines a method to estimate your risk of alfalfa winter injury. Enter the scores for answers that describe your management and field situation to assess your risk of winter injury to alfalfa.

Alfalfa frost damage can sometimes occur in the spring after growth has started, resulting in damaged growing points. Some wilting can be visible about 24 hours after frost or some yellowish or brownish discolouration 3 or 4 days later. The top of the alfalfa stems will typically bend over with a shepherd's hook shape. Damage is often minimal, and plants will grow out of it, but some yield loss and development delay can result. Thin alfalfa stands are more susceptible to frost damage.

In mild cases, leaves at the tops of the plants become wilted and discoloured, but plants should completely recover. If the "shepherd's hook" straightens, normal growth resumes. Frosts as low as -3°C can freeze leaf margins (resulting in white spots on leaves), but not damage stems or growing points.

In more severe cases, alfalfa stems freeze to various degrees and growing points are destroyed. Growth of alfalfa is from the tip of the stem where the growing point is located within a dense cluster of unfolded leaves. Temperatures below -4°C for 4 hours or more will damage growing points and stems will die. However, it would take a lot of hard frost to kill an entire alfalfa crown, and this very rarely occurs. Mature alfalfa crowns can tolerate soil temperatures as low as -12°C.

Frost-damaged alfalfa plants usually recover and regrow from:

- axillary buds on lower parts of the plant (if lower stems are not damaged), and/or
- newly formed crown buds

In most cases, axillary buds will become the main growing point if the terminal buds are damaged. It is a good idea to dig up a few plants to check crowns and roots before making termination decisions following a hard frost. If the roots are healthy, the crop will come back, although the first cut may be delayed.

**Table 10-3. Risk of Alfalfa Winter Injury**

Risk of winter injury:

- 7 points or less – low risk
- 8–12 points – medium risk
- 13–16 points – high risk
- 17 points or more – very high risk

| | Points | Your field |
|---|---|---|
| **Years harvested for forage** | | |
| First production year | 1 | |
| Second production year | 2 | |
| Third production year or older | 3 | |
| **Disease resistance** | | |
| Resistant (R) or highly resistant (HR) to all diseases | 2 | |
| R or HR to both verticillium and bacterial wilt | 3 | |
| R or HR to only bacterial wilt | 4 | |
| **Potassium soil test** | | |
| High (above 150 ppm) | 1 | |
| Medium (80-150 ppm) | 2 | |
| Low (less than 80 ppm) | 3 | |
| **Soil drainage** | | |
| Excellent | 1 | |
| Good | 2 | |
| Fair | 4 | |
| Poor | 6 | |
| **Cutting schedule**<br>The following applies to western, central and eastern Ontario.<br>For southern Ontario, add 1 cut. For northern Ontario, subtract 1 cut. | | |
| 2 cuts, last cut prior to fall rest period | 1 | |
| 2 cuts, last cut during fall rest period | 2 | |
| 3 cuts, last cut prior to fall rest period | 2 | |
| 3 cuts, last cut after the fall rest period | 3 | |
| 3 cuts, last cut during the fall rest period | 4 | |
| 4 cuts, last cut 5-6 weeks after the fall rest period | 4 | |
| 4 cuts, last cut during the fall rest period | 5 | |
| **Total** | | |

Damage to new seedings of alfalfa is usually minimal. Companion crops protect new alfalfa seedlings somewhat against frost damage. Alfalfa generally has excellent frost tolerance up to the cotyledon and unifoliate stage. Some frost damage can occur starting in the first-trifoliate stage. Only a few hours of temperatures below -4°C can kill alfalfa seedlings at the beginning of the second-trifoliate stage. After contractile growth, where the cotyledons are pulled below the soil surface to form a crown, alfalfa becomes more frost tolerant again. Observe new seedings for 3–5 days after frost. Plants will initially wilt back. If the entire plant dies back to the ground, it is dead. To survive and recover, one set of leaves must survive. Reseeding may be required if less than 40–54 viable plants per 0.25 $m^2$ (15–20 viable plants per square foot) survive.

There is usually no benefit to cutting frosted alfalfa plants. Cutting will not enhance recovery and forage quality drops rapidly. Severe frost kills the growing points, the same as cutting does. Regrowth would have to come from new crown buds and may further weaken the stand. Yield will be extremely low with poor quality. In extreme cases, frozen alfalfa that is harvested can be at increased risk for high nitrate levels.

## Sorghum Species

Members of the sorghum family — sorghum, sudangrass and hybrid sorghum-sudangrass — are warm-season annual grasses with little tolerance to frost. Even a light frost can disrupt their growth and cause prussic acid (also called hydrocyanic acid, hydrogen cyanide or HCN) to be released inside the plant at a rapid rate (Figure 10-1).

**CAUTION!**

High prussic acid levels may be lethal to ruminants; death often occurs within 20 minutes of ingesting sorghum forage with elevated prussic acid concentrations.

**Figure 10-1.** Sorghum species often look dead after a light frost, but regrowth may occur. Even after the frost-induced prussic acid has dissipated, new regrowth is high in prussic acid.

Early fall, between the first frost and the first killing frost, is the riskiest time of year for prussic acid production. There are no visual symptoms of prussic acid levels in the plants. New regrowth contains the highest concentrations of prussic acid, so waiting until after a killing frost to be sure the crop is dead is the safest approach to manage a fall sorghum harvest. A killing frost for sorghum species is -2°C.

After a killing frost, wait 3–5 days for the crop to wilt somewhat before making silage or baleage. Prussic acid levels will decrease with fermentation. The crop should be completely fermented before feeding; this takes 6–8 weeks.

There is not much information on how to manage sorghum that was cut but still in the field when frost occurred. However, cellular processes, like respiration and photosynthesis, continue after cutting so long as the leaves have enough water and oxygen to keep going. While information on this specific situation is scarce, the safest option is to respect the same wait times (3–5 days) as if the crop was hit by frost just before cutting.

Where sorghum species are being grazed, it is generally easiest to remove livestock from the sorghum pasture when there is frost in the forecast, before it occurs. Prussic acid levels are highest in the plant just after the frost event, and since these often occur very early in the morning it may not be practical to move livestock then.

Sometimes frost comes as a surprise. Immediately after a frost, remove the livestock from the pasture until it has dried out (usually 6–7 days). If new shoots develop, harvest the field as silage rather than pasture.

Prussic acid concentration is always higher in leaves than in stems. Because livestock preferentially graze leaves, they are more likely to be poisoned by prussic acid in a pasture situation. Lightly grazing a field will not reduce risk.

# Ice Damage

Ice restricts the amount of oxygen available to plant roots, and ice sheeting or encasement can smother a forage crop. However, wide-scale stand losses are uncommon. Usually enough stems will stick out of the ice sheet to allow some oxygen to reach the crowns of the plants. Stand losses where there is severe icing generally shows up in patches (Table 10-4). These patches occur where the plants were already under stress, or where the ice was deep enough to completely seal the area. Generally, those areas are depressions where water collects, and the ice is deeper and stays for over 1–2 weeks.

**Table 10-4. Ice Tolerance of Some Perennial Cool-Season Forage Grasses**

| Species | $LI_{50}$ (days) |
|---|---|
| Orchardgrass | 9 |
| Meadow fescue | 13 |
| Meadow foxtail | 18 |
| Creeping red fescue | 22 |
| Reed canarygrass | 26 |
| Kentucky bluegrass | 27 |
| Timothy | 37 |

*Notes:* $LI_{50}$ is the average number of days it takes for half the population to die when encased in ice.
*Source:* Adapted from Gudleifsson et al, 1986.[2]

Ontario research by Bowley and McKersie (1990) suggests that when alfalfa crowns are encased in ice, more than 50% of the population will die in less than 10 days.[3]

# Heaving

In soils that are wet going into winter, repeated freezing and thawing can cause overwintering forage crops to heave. As the soil water expands and contracts, it “jacks” plants out of the soil (similar to fence posts). Heaved plants have their crown moved above the soil level, where it is at greater risk of drying out and dying. Severe heaving can break the taproot of legume crops, and the chance of survival in these cases is small.

Factors that increase the risk of frost heaving include:

- heavy-textured soils (clays)
- soils that were saturated going into winter
- soils with limited sub-surface drainage
- fields that lack insulating and snow-holding residue because a fall harvest was taken
- late seeded summer-seedings that did not form sufficient root systems before winter

In addition, alfalfa brings some of its own unique risk factors:

- older stands have larger tap roots and crowns, and are at higher risk of heaving
- straight alfalfa (as opposed to alfalfa-grass mixtures) is at higher risk of heaving

**Do not cultipack or roll** heaved fields, as this does more harm than good by damaging and breaking crowns. Raise the cutter bar at harvest to avoid crown damage.

Stands that are only slightly heaved will likely reseat themselves over the season by natural settling and secondary root growth. If crowns are still elevated by the following winter, exposed crowns will be more susceptible to desiccation, freezing, mechanical damage and disease, and plants are more likely to winterkill.

For alfalfa specifically, if the crowns are heaved less than 2.5 cm (1 in.), the taproot is probably not broken, and the stand is salvageable. If crowns are heaved more than 3.75 cm (1 ½ in.), the taproot is likely broken. Heaving can sometimes elevate crowns 15–20 cm (6–8 in.) out of the soil (Figure 10-2). Obviously, broken taproots cannot heal. Broken plants will green up, but then die, depending on how deep the break is, so digging some plants will help in assessment. Plants with taproots broken 7.5–10 cm (3–4 in.) below ground will likely die soon. Part of a first-cut might be salvageable if roots are broken below 15–20 cm (6–8 in.). Depending on how elevated the crowns are, these fields can be difficult to harvest without further damaging crowns. If possible, rotate these fields to corn and take advantage of the nitrogen credit.

**Figure 10-2.** Frost heaving of alfalfa.

# Excess Water

## Saturated Soils

Roots need both water and oxygen in the soil to thrive. When soils are saturated, the pore spaces in the soil are full of water, and there is no room for air. If the soil remains saturated for too long, plant roots will die. This can create an opportunity for secondary infection of root rot diseases (see Chapter 13, *Diseases*).

Plants are more tolerant of saturated soil conditions when they are dormant or growing slowly (Table 10-5). As the weather warms and growth rates increase, the roots require more oxygen, so tolerance to saturated soils is less.

**Table 10-5. Tolerance of Some Perennial Cool-Season Species to Saturated Soils in Springtime**

| Species | Duration |
|---|---|
| Alfalfa | 1–2 weeks |
| Alsike clover | 2–3 weeks |
| Red clover | 3–4 weeks |
| Bromegrasses | 3+ weeks |
| Meadow fescue | 6+ weeks |
| Meadow foxtail | 6+ weeks |
| Timothy | 6+ weeks |

Adapted from Manitoba Agriculture, Food, and Rural Initiatives, 2012.[4]

## Flooding

Flooding prevents oxygen from reaching the crown of the plant. Flowing water tends to have more oxygen in it than stagnant water, so forages generally can survive longer if the flood water is moving. In general, perennials have greater flood tolerance than annual crops. Growing plants have much higher oxygen demands than dormant ones, so the time of year will also affect how well a forage stand comes through a flood. For example, dormant alfalfa can survive flooding for up to 7–10 days; if it is actively growing, it will only tolerate submersion for 3–4 days.

Excess water can increase the risk of plant diseases by creating an environment for fungi and bacteria to thrive. Flooding may introduce pathogens to the crop that could make livestock sick. In addition to carrying pathogens, silt deposits left by flood water may smother a forage stand. Alfalfa is more tolerant of silting than white clover. Many perennial species will grow through silt deposits up to 5 cm (2 in.) so long as soil surface crusting is not an issue.

Wait 2–3 weeks after the flood water has receded to assess crop survival. Dig up roots to check whether they are healthy and look specifically for root diseases that may limit future productivity of the stand.

Silt deposits will raise the ash content of a forage, so an analysis will help ensure enough nutrients are supplied in the ration. Refer to Chapter 16, *Forage Analysis and Grading,* for more on ash.[5]

# Insufficient Water

Perennial cool-season grasses cope with prolonged low-moisture conditions by going dormant. The leaf material turns brown and appears dead, but the crown of the plant is still alive. Just like breaking dormancy after winter, grasses breaking dormancy after a drought rely on energy reserves in their roots and lower stems to fuel regrowth. Grazing or cutting these stands before they have a chance to restore their reserves will weaken the plants, reducing yield and potentially increasing the risk of issues over winter. Waiting until grass plants have 3–4 fully developed new leaves will ensure that they have had time to refill their energy stores and can withstand the stress of defoliation.

Moderate stress from dry weather can cause alfalfa plants to continue growth but with reduced stem numbers and stem elongation. The alfalfa plant produces carbohydrates, which are stored in the root system and are available as energy for regrowth after cutting and when moisture returns. Cut in dry weather if there is adequate alfalfa growth to economically justify cutting, and the planned harvest interval can be maintained. Severe moisture stress will temporarily stop plant growth. When rains return, cutting alfalfa (particularly at the flower stage) will stimulate regrowth by encouraging the growth of new crown buds.

Cutting red clover during extreme dry conditions can cause stand reductions. Birdsfoot trefoil also maintains lower levels of root carbohydrates during the summer, so cutting at a more mature stage with a longer stubble will improve regrowth potential.

Tremendous variation can occur in corn fields stressed by dry conditions. Some fields will have short plant height with more normal ears. Yields will be reduced, but forage quality may be close to normal. Other fields will be more normal in height but have very small ears or no ears. Growers attempting to salvage dry weather–damaged grain corn fields by harvesting for forage should be aware of some of the harvesting and nutrition implications. Ensiling at the correct whole plant moisture is critical, but often more difficult to determine.

Be aware of the potential for nitrate poisoning (see Chapter 16, *Forage Analysis and Grading* for more details on nitrate poisoning in livestock). Nitrates accumulate in corn plants and grasses when there is a large amount of soil nitrates and a lack of moisture that interferes with normal plant growth. The risk of nitrate accumulation is often greatest following a rain that ends a dry period (see below). The increased nitrate potential also increases the risk of silo gas. Refer to Chapter 15, *Storage,* for more information on the hazards associated with silo gas.

# Hail

Hail damage reduces leaf area and therefore has a negative effect on forage yield. Despite this, the long-term impact to grasses is small because the growth points of most grass plants are low. The reduced leaf area caused by hail damage may also contribute to nitrate accumulation in some fast-growing species (see below).

## Alfalfa and Red Clover

The growing points on alfalfa and red clover are at the tips of the stems. If hail removes these growth points, any regrowth must occur from the crown. When less than 50% of the stem tips are removed, producers are encouraged to wait until their planned harvest maturity to cut but expect reduced yields. Cutting after minor hail damage will not increase yield.

If more than 50% of stem tips are removed by hail in predominantly alfalfa or red clover stands, there are more variables to consider for management. Fields being harvested as baleage or silage risk the damaged crop becoming mouldy if left standing, which could negatively impact fermentation and feed quality. These fields should be flail chopped or mowed at 10–15 cm (4–6 in.) and left in the field. The regrowth can be harvested when it reaches the target maturity. Fields being harvested as dry hay can be harvested immediately following the hail damage if the yield justifies harvest. Waiting will not improve yield in this situation as too many growth points have been removed. If the yield is insufficient to justify harvesting the hay, wait for the regrowth to reach harvest maturity before cutting. Cutting the damaged crop will not improve regrowth or yield, and the spoilage concerns for silage are not as big an issue in dry hay for ruminants.

New seedlings are at greater risk from hail damage than established stands. If the young plants have not yet developed crowns, the growth point at the tip of the stem is their only growth point. If hail damage removes this growth point, the plant will die. Crowns typically develop when alfalfa and red clover seedlings are about 7.5–10 cm (3–4 in.) tall. The crown can be felt as a ridge between the roots and top growth. If the seedling has a crown, it will typically recover even if hail removes the growth point at the tip of the stem because it can send up a new stem. Count the number of plants that are likely to survive. If this is over 67 plants per 0.25 $m^2$ (25 plants per $ft^2$), keep the stand. If the number of plants is below this threshold, the stand should be reseeded.[6]

## Corn

Yield impacts of hail damage at different growth stages have been studied in grain corn (see Chapter 1 in OMAFRA Publication 811, *Agronomy Guide for Field Crops*) but limited hail damage information is available for silage corn. There is an interaction between leaf loss and growth stage on grain yield in corn. For grain yield, losses increase through vegetative stages, peak at flowering and decline through grain fill stages. For forage crops generally, leaf loss is yield loss. Whether these two types of yield loss are additive and/or proportional to one another likely also depends on the growth stage of the corn when the hail damage occurs. Since this has not been studied to the same extent as hail damage in grain corn, estimating yield loss from hail in silage corn is difficult. Weighing and moisture testing the crop during harvest is the best way to determine the yield.

Hail damage creates entry points for some types of leaf and stem diseases. Trials have evaluated whether there is an enhanced yield response to foliar fungicides following mechanical damage simulating hail and have generally shown there is no greater response to fungicides following damage than where there was no damage.[7,8] This may reflect the fact that foliar fungicides are protecting against fungal diseases (northern corn leaf blight, common rust, grey leaf spot, eyespot) that do not require wounds to initiate infection.

Opportunistic diseases that do take advantage of plant wounds include bacterial wilts, smuts and stalk or ear rots. Most modern grain corn hybrids generally have good resistance against smuts, and to date Goss's wilt has not been found in Ontario. Most hybrids have good protection against Stewart's wilt, but infection primarily requires flea beetle feeding. Foliar fungicides do not protect against these diseases.

Certain fungicides are labelled for suppression of ear and stalk rots, risks of which may increase with hail damage, but research investigating suppression in regards to hail events is limited.[7,8]

# Nitrate Accumulation

Fast-growing plants can accumulate nitrates under stressful weather conditions. Corn, sorghums, sudangrass, millets, cereals, Italian ryegrass and fast-growing weeds like lambsquarters and pigweeds, can all accumulate high levels of nitrates. When fed, high nitrate concentrations in forages can cause nitrate poisoning in livestock.

There are several factors that are known to increase the risk of high nitrates in fast-growing plants:

- **High soil nitrogen fertility.** This could be from fertilizers, manure applications, legume cover crops or winter-killed alfalfa.
- **Hail, frost or prolonged cloudy weather.** Under these conditions, plant roots are taking up nitrates, but the leaves are unable to turn those nitrates into amino acids fast enough to prevent accumulation.
- **Periods of dry weather followed by rain.** Nitrates move with water into the roots, so a rain after a dry spell will move lots of nitrogen into the plant. It takes 5–7 days for the crop to metabolize high levels of nitrate, so concentrations are highest during the first week after the rain event.

Proper fermentation can reduce nitrate levels by 25%–65%. It is important that the crop is at the correct moisture level for the silo being used (see Chapter 14, *Harvest,* and Chapter 15, *Storage*). If the crop is too wet or too dry it will not ferment properly, and the nitrate concentration will remain high. Baleage is generally too dry to ferment completely, so do not expect baleage to reduce nitrate levels as much as ensiling. Nitrate levels are stable in dry hay; if they are high at harvest, they will always be high.

Nitrates accumulate the most in lower parts of the plant, so raising the cut height is commonly recommended to lower nitrate levels in the feed. However, if forage inventories are a concern, a better approach is to harvest at the normal cut height, allow the crop to ferment for at least 3–5 weeks, and then conduct a lab test for feed nitrates so the forage can be diluted if needed before feeding. Refer to Chapter 16, *Forage Analysis and Grading,* for guidance on interpreting nitrate test results and feeding high nitrate forages.

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# Additional Sources

This chapter contains excerpts from the following OMAFRA sources:


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*Managing Forages in Dry Years.* Last modified: 2003. www.omafra.gov.on.ca/english/crops/facts/info_fordry.htm

*Alfalfa Stand Assessment*. Last modified: 2000. www.omafra.gov.on.ca/english/crops/facts/info_alfalfa_stand00.htm

*Risk of Alfalfa Winterkill*, Factsheet 91-072. 1991.

*Hail, Hail, Go Away!,* Field Crop News Blog. Last modified: 2018. fieldcropnews.com/2018/09/hail-hail-go-away/

CHAPTER 11

# Weed Management

Weeds compete with forage crops for water, sunlight and nutrients. High weed populations can reduce the yield, quality and persistence of a forage stand. When considering the impact weeds have on forage quality, it is important to differentiate between low quality and anti-quality. Ruminant forage quality is mostly defined by the concentration of nutrients in the feed. Weeds may reduce forage quality because they are a poor source of nutrients; they may have high lignin content, or low protein or digestible fibre. Enough of these weeds would cause a forage analysis to measure low quality in some way. Some weeds may reduce quality by contributing anti-quality components (toxins) that affect animal health and production; see *Poisonous Weeds* below for more information. Poisonous weeds may have low or high concentrations of nutrients, so a standard forage analysis would not necessarily indicate a problem.

Managing weed populations is very important in the establishment year for perennial forage stands. Many perennial forages, particularly legumes, are slow to establish. Weeds often have faster early growth than these species. Fields with an existing perennial weed problem are not good candidates for a new perennial forage seeding. Controlling weeds before establishing a forage crop is the best way to prevent problems during the establishment year and first production year.

According to the 2007 Forage Weed Survey, the most common weeds in Ontario hay fields are:

- Dandelion
- Lambsquarters
- Common ragweed
- Chickweed
- Broad-leaved plantain
- Shepherd's purse
- Quackgrass
- Tufted vetch
- Mouse-eared chickweed
- Redroot pigweed

## Soil Fertility

An established perennial forage crop can often out-compete weeds, provided the stand is thick and the field has appropriate soil fertility. See Chapter 2, *Soil Fertility and Nutrient Use,* and the fertility sections in the crop chapters of this guide for more information on soil sampling and providing crop nutrients to forages. Soil fertility alone does not reduce weed pressure, but it is an important part of maintaining a productive forage stand where weeds are less likely to encroach.

# Mowing

Mowing is a strategy that can be used to prevent weeds from setting seed. Often mowing is most effective on annual weeds if it occurs during flowering but before seed set. This timing reduces the ability of the plant to regrow, while preventing new seeds from being dispersed in the field. Mowing is an important weed management technique during the establishment year for a perennial forage. Not only does mowing reduce the amount of weed seed produced, it also encourages forage grasses to tiller, which will thicken the stand and help further suppress weeds in future years.

Repeated mowing is sometimes used to deplete the root reserves of perennial weeds. Like perennial forages, perennial weeds typically have large roots systems that store energy reserves to fuel regrowth. However, most perennial weeds are not as well adapted to repeated defoliation as tame forage species. Persistence is required, but repeated mowing can help push perennial weeds out of a stand.

# Tillage

Another mechanical option to manage weeds is tillage.

## Mouldboard Plow

Using a mouldboard plow in the fall prior to seeding is necessary when planting into fields that have high populations of biennial or perennial weeds, like wild carrot, common burdock, scentless chamomile, wild parsnip, curled dock, tansy ragwort, etc. It is also the most effective way to deal with deep rooted winter annual species that cannot be controlled once a legume forage field is established. Canada fleabane, which is also resistant to glyphosate, is a good example of a weed that is best controlled with a mouldboard plow.

## Stale Seedbed

The stale seedbed technique is an effective approach to preparing a field before planting, so that the crop emerges ahead of weeds, giving the crop a competitive advantage. The approach to prepare a stale seedbed is simple:

**Step #1:** Prepare a seedbed using shallow tillage several weeks before planting.

**Step #2:** Weed seeds germinate and seedlings emerge in the days following.

**Step #3:** The emerged weeds are killed off with as little soil disturbance as possible so that more seedling weed emergence is not stimulated. This is typically done with an application of glyphosate, as it can control a wide range of species at different sizes. However, flame weeders or shallow cultivation tools could be used in organic systems.

**Step #4:** Plant the crop into the stale seed bed as soon as possible after Step #3.

# Herbicides

Herbicides can sometimes be used to control problem weeds. Selective herbicides are effective on either grasses or broad-leaved forbs (including legumes). Herbicide use in mixed stands often involves reseeding productive species after treatment.

Herbicide labels include a pre-harvest interval (PHI) that provides information on how much time is required between application and cutting or grazing. Not all herbicides are appropriate for use on forages, despite being labelled for use on forage crop species — especially species that are commonly grown for grain. Some products clearly state that the formula is not safe for use on feed, fodder, forage or silage. There will be products that do not mention silage or feed on the label. These have not been tested for their effects on livestock, and crops treated with them should not be fed.

Perennial weeds are often most susceptible to herbicides in the fall, before a killing frost. The weeds are actively moving carbohydrates down into their roots for storage, and more readily translocate systemic herbicides at the same time.

Refer to Ontario Crop Protection Hub at ontario.ca/cropprotection for information on chemical weed control options, including options for specific weeds and crops.

# Poisonous Weeds

Some plants contain compounds that can make livestock sick. In Ontario, incidents of livestock being poisoned by toxic weeds are unusual. Animals naturally avoid eating unfamiliar foods if they can. Because of this tendency to be wary of eating things that are not a normal part of their diet, plant poisonings are most likely when animals are forced to consume a poisonous plant. In a grazing situation, this might occur if the animals run out of pasture and are not promptly provided with supplemental feed.

The risk of poisoning from toxic weeds is lower when stored forage is fed. The weeds would have to go unnoticed during growth, harvest, storage and feed-out. Livestock would have to be in a situation where they could not sort their feed, such as a total mixed ration (TMR) feeding system. Even then, the formulated ration would consist of many ingredients, which dilute the toxin and further reduce the risk. Because the risk of poisoning from weeds is low, it is generally only considered in situations involving multiple animals whose symptoms cannot be explained by more probable causes.

In addition to the low probability of an animal eating a potentially poisonous plant, the risk of poisoning depends on the concentration of the toxic compound (which is influenced by what the chemical is, the stage of plant maturity and growing conditions), the susceptibility of the animal and how much plant material the animal ate.

The 2007 Forage Weed Survey identified the most common poisonous weeds in Ontario hay fields. These were found in less than 5% of fields surveyed.

## Eastern Black Nightshade
### *Solanum ptycanthum*

Eastern black nightshade is an annual, reproducing only by seed. It occurs throughout Southern Ontario in open dry woods, edges of pastures, waste places and in cultivated land, especially in row crops.

In seedlings, the hypocotyls (stem below cotyledon) are hairy and can be green or maroon. The cotyledon is oval, smooth and green on the upper surface, maroon on the lower surface (Figures 11-1 and 11-2). Eastern black nightshade stems are erect, 5–100 cm (2–40 in.) high, mostly hairless, and branched in the upper part of the stem. The leaves alternate (1 per node), are oval or diamond shaped, pale green, soft and nearly translucent (Figure 11-3). The flowers are small and usually grouped together in a small umbel of 2–5 flowers. Eastern black nightshade flowers extend from a short stalk from the side of the stem. Petals are white and may or may not be tinged with purple. The flowers resemble potato flowers but are smaller at 9–15 mm in diameter. Fruits are black berries that are first green and contain many flat seeds; berries are reputed to be poisonous (Figure 11-4). Eastern black nightshade flowers from June until late autumn. Eastern black nightshade has a slender taproot with branched fibrous root system. It is often mistaken for pigweed seedlings.

**Figure 11-1.** The leaves of Eastern black nightshade seedlings are green on the upper side.

**Figure 11-2.** The leaves of Eastern black nightshade seedlings are maroon on the lower side.

**Figure 11-3.** Eastern black nightshade plant.

**Figure 11-4.** Eastern black nightshade berries start off green, but turn black when mature.

## CAUTION!

Plant species from the nightshade family often contain glycoalkaloids, which are bitter tasting and poorly absorbed from the gastrointestinal tract, causing gastric irritation and symptoms that range from "tummy rumbling" to vomiting (or colic in horses) and diarrhea. Very high doses can affect the animal's nervous system, causing a loss of coordination, weakness, muscle tremors, paralysis, respiratory challenges, and a low heart rate and blood pressure. Symptoms develop quickly, and affected animals typically recover or succumb to acute nightshade poisoning within a day or two.

Mechanical control is most effective when eastern black nightshade is in flower: plants should be pulled up or mowed, and then burned. Sulphonylurea- and imidazolinone-resistant (WSSA group 2) populations exist in Ontario. Regardless of control methods used, nightshade germinates throughout the year, so repeated control measures are commonly required.[1]

## Field Horsetail

### *Equisetum arvense*

Field horsetail is a perennial. It lacks flowers or seeds but instead reproduces by spores and by horizontal underground stems (rhizomes). Field horsetail is distinguished by its ashy-grey, unbranched, leafless shoots tipped with brownish, spore-producing cones in early spring, and later, from late spring or early summer onwards, by its whorls of 6–8 green, leafless branches and absence of flowers (Figure 11-5).

**Figure 11-5**. Field horsetail puts up brownish fruiting stems in spring, and green stems with leafless branches in late spring or early summer.

Field horsetail rhizomes are dark brown or blackish, spread out for long distances, often 1 m (3 ft 4 in.) below the ground surface. They send up numerous above-ground shoots but of two different types at different times of the year. In early spring, the shoots are ashy-grey to light brown, unbranched, hollow, jointed stems. Each node (joint) is surrounded by a toothed sheath and the tip of the stem ends in a brownish, spore-producing cone. After the cones have shed their spores (early May) these whitish-to-light brown stems wither and die down. At the same time, the second type of shoot emerges from the ground. These are green, slender, erect, hollow stems, leafless but with whorls of 6–8 branches at nearly every node; each branch may branch again with whorls of smaller branches; stems and branches surrounded by a small, toothed sheath at each node but never end in a spore-producing cone. Both kinds of stems are easily pulled apart at the nodes and can be fitted back together like sections of a stove pipe.

Field horsetail occurs in all parts of Ontario in depressional areas with poorly drained soils, as well as in sand or gravel-based soils with good drainage such as railroad embankments and roadsides. An intense competitor, it can severely suppress crops and other plants. Field horsetail is notoriously difficult to control.

**CAUTION!**

Field horsetail contains a substance that destroys vitamin B in animals. It is especially poisonous to young horses. Hay containing this weed may be more poisonous than fresh plants in the field. In horses it can cause weight loss (without loss of appetite), diarrhea, incoordination and may progress to staggering, nervousness, recumbency seizure and death due to exhaustion.

Several herbicides provide some level of top growth control only, because it is difficult to get the active ingredient to depths deep enough to control the rhizomes and tubers. The most effective strategies are repeated attacks over many years on the above-ground plant to deplete the rhizome and tuber reserves until the plant dies. Repetitive attacks should include herbicides, shading, mowing and hand weeding. Established stands will take a lot of persistence to manage. Cultivation should be kept to a minimum because, in most cases, it will spread the rhizomes and tubers around the field allowing plants to regenerate in new parts of the field or in new fields if the equipment is not thoroughly cleaned between fields.

## Common Milkweed

*Asclepias syriaca*

Common milkweed is a perennial, reproducing by seed and by horizontally spreading underground roots that produce new leafy stems. It has erect stems, 1–2 m (3 ft–6 ft 6 in.) high, stout, unbranched or sometimes with 1 or 2 branches near the top, usually several stems close together from the underground root system; leaves opposite (2 per node) or whorled (3 or more per node), oblong with a rounded or tapered base and a rounded to somewhat pointed tip, without teeth, underside covered with fine velvety hair, upper surface usually without hair and deeper green (Figure 11-6).

**Figure 11-6.** Common milkweed.

Common milkweed flowers in dense, nearly spherical clusters or umbels at tip of stem and from axils of upper leaves, each flower 5–10 mm (¼–⅜ in.) across, greenish to purplish or whitish, with five thin sepals and five larger petal lobes bent back along the flower stalk and an unusual arrangement of five hoods and horns forming a crown or corona around the top of each flower (Figure 11-7). The flowers are uniquely adapted for insect pollination, having waxy pollen in tiny wishbone-shaped structures that hook onto an insect's leg but come off when transferred to the flower of a different plant. Fruits at first green, fleshy, 6.25–10 cm (2 ½–4 in.) long and covered with soft, warty protuberances, later turning brown, splitting lengthwise along a single opening and releasing numerous seeds; usually only one or two (rarely up to five) seedpods develop from the many flowers of a single flower cluster; seed flat, oval, with a tuft of long silky hair at one end (Figure 11-8). The whole plant, root, stem, leaves, flowers and fruit, contains abundant, thick, white, milky juice. Milkweed flowers from mid-June to August and matures seed from August to October.

**Figure 11-7.** Common milkweed flowers.

**Figure 11-8.** Common milkweed seed pod.

Common milkweed occurs throughout Southern Ontario in pastures, meadows, waste places, roadsides and cultivated land. It is especially common in the Manitoulin Islands and the east-central portions of Southern Ontario, but it seems to be increasing in most other portions of the province as well.

It is distinguished from other milkweeds by its pairs of broad, oval, softly hairy leaves, umbels of purplish to whitish flowers with their peculiar arrangement of parts, and the large, thick, softly warty seed pods.

## CAUTION!

Other species of milkweed have been found to be highly toxic to livestock, and circumstantial evidence suggests common milkweed may, under some circumstances, also be toxic. The toxic compound in milkweeds, cardenolide, is very bitter, and grazing livestock typically avoid milkweed. Livestock poisoning is more common when hay is contaminated with milkweed. Symptoms include abdominal pain, bloat, colic, diarrhea, muscle tremors, weakness, slow and irregular heartbeat, laboured breathing, head-pressing, incoordination and seizures.

Some herbicide control options are available. Repeated mowing at 21-day intervals can be an effective control. A single cutting will stimulate the sprouting of underground root buds. Repeated cutting prior to fruit (pod) formation will reduce root reserves.

## Wild Mustard

*Sinapis arvensis, Brassica kaber*

Wild mustard is an aggressive weed indigenous throughout most of the temperate regions of Europe, Asia Minor, Southwest Asia and North Africa. It was introduced into North America and now occurs throughout all Canadian provinces, as well as in the MacKenzie District, Northwest Territories.

In Ontario, wild mustard is common in cultivated fields, gardens, pastures, riverbanks, roadsides and waste places.

Wild mustard is an annual plant that exhibits erect growth. The seedlings have broad kidney-shaped cotyledons (seed-leaves) that are indented at the tip (Figure 11-9). Older plants have alternate leaves that are somewhat hairy, especially on the lower surface of the veins. The lower leaves are usually stalked, deeply lobed with a large terminal segment and a few smaller lateral lobes. Upper leaves are stalkless, generally undivided but coarsely toothed (Figure 11-10). Plant height can range from 30–100 cm (12–40 in.) with either simple or much-branched stems. The stems usually have stiff downward pointing hairs, especially on the lower parts, and are green or somewhat purplish. Flowers are produced in small clusters at the ends of branches, these clusters elongating as the seedpods develop.


**Figure 11-9.** Wild mustard seedlings have broad kidney-shaped cotyledons indented at the tip.

**Figure 11-10.** Wild mustard leaves are stalkless, undivided, and coarsely toothed.

The flowers are bright yellow, about 1.5 cm (⅝ in.) across, with four small sepals, four petals arranged in a cross formation, four long and two short stamens (total of six), and one slender pistil (Figure 11-11). Flower stalks are thin and short (3–5 mm (⅛–¼ in.)), becoming thicker but not longer as the seedpods develop. The seed pods, called "siliques," are 2.5–5 cm (1–2 in.) long, usually hairless, often with lengthwise ribs, erect and pressed to the stem or spreading out. Each pod has a flattened terminal beak about one-third the total length of the pod having one or two seeds in its base, and a main section containing several seeds that are released when the two sides or valves of the pod split apart from the bottom end and entirely fall away. Wild mustard can be confused with other annual yellow-flowered mustards. It is distinguished by having one or two seeds in the flattened, terminal beak of the pod. Those seeds between the valves of the pod and the stalk of the pod are short and nearly as thick as the pod.

**Figure 11-11**. Wild mustard in flower.

Mature pods usually remain intact until the crop is harvested. The seeds of wild mustard are spherical, 1.5 mm in diameter, black or purplish, and appear netted under high magnification. Wild mustard reproduces only by seed and requires 10–12 weeks to produce mature plants from seed.

Wild mustard plants have from 10–18 seeds per pod and from 2,000–3,500 seeds per plant. During harvesting operations, shattering may result in large quantities of seed being left on the ground, or seeds may be transported into other fields by harvesting machinery or as impurities in crop and forage seed. Some wild mustard seed is capable of germination as soon as it is mature. However, these seeds may also remain viable in the soil for as long as 60 years, particularly those that are buried at considerable depths. Due to the longevity of wild mustard seed in the soil, it is important to control this weed and reduce the amount of seed returned to the soil. This minimizes potential economic losses in current as well as future years.

Wild mustard is regarded as palatable in young stages, but seeds may cause serious illness in livestock if ingested in large quantities.

## CAUTION!

Wild mustard seed poisoning has the symptoms of severe gastroenteritis due to toxic compounds including allyl isothiocyanate, sinapine and sinalbin. Symptoms such as severe pain, salivation, diarrhea, colic and irritation of the mouth may appear soon after ingestion of a toxic amount and could eventually result in death. Wild mustard may also contain high levels of glucosinolates, which can cause hypothyroidism and goitre.

Wild mustard is an alternative host for a number of pests including insects, nematodes, fungi, viruses and bacteria that cause damage to cultivated crops, especially members of the *Brassicaceae* (cruciferae) family. Important crop members include canola, broccoli, cauliflower, Brussels sprouts and cabbage.

Since wild mustard is an annual plant that reproduces only by seed, this weed can be controlled by mechanical cultivation of emerged seedlings. However, cultivation of infested land is often impossible since wild mustard seed germinates at about the same time as spring-planted annual crops. If cultivation is not possible select a control practice from Ontario Crop Protection Hub at ontario.ca/cropprotection.

Chemical control of wild mustard can be achieved with sulfonylurea herbicides (chlorimuron, ethametsulfuron, nicosulfuron, thifensulfuron-methyl), imidazolinone herbicides (imazethapyr, imazamox), triazolopyrimidines (flumetsulam), members of the triazine family of herbicides (atrazine, cyanazine, simazine, metribuzin), with phenoxy type compounds (2,4-D, MCPA, MCPB), substituted ureas (linuron, monolinuron, metobromuron), bentazon and benzonitriles (bromoxynil), or with tank-mixes including any of the preceding chemicals. Refer to the Ontario Crop Protection Hub for specific herbicide doses, registered tank-mixes, timing and method of application. If wild mustard is a problem in spring canola, use either ethametsulfuron-methyl or varieties of canola that are triazine tolerant. Because these tolerant varieties are not injured by recommended doses of the triazine herbicides, wild mustard can be selectively controlled within the crop.

Reports of triazine-resistant wild mustard have been recorded at isolated locations in Glengarry, Peel and Huron counties. If triazine-resistant wild mustard is suspected in a particular location, contact your nearest OMAFRA crop specialist or send a plant specimen to the Pest Diagnostic Clinic, Laboratory Services Division, University of Guelph, 95 Stone Rd. W., Guelph, Ontario N1H 8J7, so that an alternative control measure can be recommended. To help delay the development of herbicide resistance, do not use herbicides with the same mode of action year after year, or use registered tank-mixes of active ingredients with different modes of action. Consult the Ontario Crop Protection Hub for further information on managing herbicide resistance.

## Cypress Spurge

*Euphorbia cyparissias*

Cypress spurge is a perennial, reproducing by seed and from widely spreading, much-branched underground roots with numerous pink buds and forming dense stands. Cypress spurge stems are erect, 10–80 cm (4–32 in.) high, usually much-branched above; leaves alternate (one per node), very numerous, small, narrow, linear or club-shaped; tip of stem at beginning of inflorescence (flowering branches) with a whorl of 10 or more shorter leaves (Figure 11-12).

**Figure 11-12.** Cypress spurge leaves grow in a whorl pattern.
*Source:* Shutterstock.com.

Flowers are yellowish-green on a many-branched umbel (usually 10 or more main branches) at the tip of the main stem and on the upper branches; leaf-like bracts of the inflorescence short and broad, heart-shaped, tapering towards the pointed tip, at first light yellowish-green but usually turning reddish-green towards maturity; flowers very small, unisexual, without sepals or petals, and crowded together in a complex structure called a cyathium, one little cyathium between each pair of bracts throughout the inflorescence; each flower cluster producing a three-lobed seedpod containing 1–3 egg-shaped, smooth, greyish seeds 1.5–2 mm ($\frac{1}{16}$–$\frac{1}{12}$ in.) long. The whole plant contains an acrid sticky white juice. Flowering begins in late spring or early summer and may continue intermittently until late autumn (Figure 11-13).

**Figure 11-13.** Cypress spurge flowers.
*Source:* Shutterstock.com.

Two kinds of cypress spurge occur in Ontario, a sterile diploid form that does not produce viable seed, and a fertile tetraploid form that produces abundant fertile seed. The sterile form, reproducing only from underground parts, was once commonly cultivated in gardens and cemeteries. It has persisted in many localities and occasionally spreads vegetatively to surrounding roadsides and waste places. This form occurs throughout Ontario. The fertile form, which can reproduce by seed as well as by underground parts, has become a rampant and troublesome weed in Dufferin County and in the Braeside area of Eastern Renfrew County, occupying hundreds of hectares of pasture, abandoned cultivated land, woodland and roadsides.

It is distinguished from most other plants by its milky juice, its spreading perennial roots with pink buds, its numerous, small slender leaves, and its yellowish-green inflorescence. It is distinguished from the upright annual spurges (petty, sun and broad-leaved) by its perennial habit, and from these and leafy spurge by its slender stems with numerous, crowded, narrow leaves, its umbel with usually more than 10 slender branches from the tip of the main stem, its heart-shaped bracts or leaves in the inflorescence tapering towards the tip, and by the production of densely leafy branches after early summer flowering.

## CAUTION!

Although sheep can be forced to eat cypress spurge and may develop a preference for it, the literature suggests it may be toxic to cattle and horses. The milky juice can be irritating on bare skin and cause a potentially serious rash for some people.

Cypress spurge can be controlled by applying herbicide at early bud (flowers mid-summer) or in early fall. Repeated mowing at 21-day intervals can be an effective control. See the Ontario Crop Protection Hub at ontario.ca/cropprotection for details on herbicide options.

# References


1. Lingenfelter, D., and W.S. Curran. 1998. *Integrated Approach: Management of Eastern Black Nightshade.* Penn State Extension. Retrieved from: extension.psu.edu/integrated-approach-management-of-eastern-black-nightshade


## Additional Sources

This chapter contains excerpts from the following OMAFRA sources:


*Wild Mustard,* Factsheet 03-043. 2003.

*Ontario Weeds Gallery – Common Milkweed*. Last modified: 2010. www.omafra.gov.on.ca/english/crops/facts/ontweeds/common_milkweed.htm

*Ontario Weeds Gallery – Cypress Spurge*. Last modified: 2010. www.omafra.gov.on.ca/english/crops/facts/ontweeds/cypress_spurge.htm

*Nightshade Berries Contaminating Livestock Feed: Worry or Don't Worry?* Crop Talk Newsletter. Last modified: 2017. www.omafra.gov.on.ca/english/crops/field/news/croptalk/2017/ct-1117a7.htm

*Is it Possible to Control Field Horsetail?* Hort Matters Newsletter. Last modified: 2015. www.omafra.gov.on.ca/english/crops/hort/news/hortmatt/2015/03hrt15a3.htm

*Noxious Weed Profile – Cypress Spurge*. Last modified: December 29, 2006. www.omafra.gov.on.ca/english/crops/facts/info_spurge.htm

*Noxious Weed Profile – Milkweed spp.* Last modified: September 3, 2014. www.omafra.gov.on.ca/english/crops/facts/info_milkweed.htm

CHAPTER 12

# Insects and Pests

Insects and pests can reduce the yield, quality and persistence of forage crops. Common and very damaging pests of perennial forage crops are described in this chapter. Pests that primarily impact crops commonly grown for grain in Ontario (i.e., corn and cereals) are described in OMAFRA Publication 811, *Agronomy Guide for Field Crops*.

The Ontario Crop Protection Hub at ontario.ca/cropprotection is the source for information on integrated pest management (IPM) options and pest control products. Visit the OMAFRA website at ontario.ca/crops. Table 12-1 shows insects and pests that could be causing symptoms in the field.

**Table 12-1. Forage Insect and Pest Symptoms in the Field**

**Legend:** Y = symptom; – = not a symptom

| Symptom | | Insects and Pests | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Grubs | Slugs | Alfalfa Snout Beetle | Alfalfa Blotch Leafminer | Alfalfa Weevil | Pea Aphid | True or Fall Armyworm | Potato Leafhopper | European Skipper |
| Roots and seedling plants | Gaps in the stand, wilting plants | Y | Y | – | – | – | – | – | – | – |
| | Deep spiral grooves in taproot | – | – | Y | – | – | – | – | – | – |
| Foliar feeding and injury | Tunnels between layers of leaf | – | – | – | Y | – | – | – | – | – |
| | Pinholes or skeletonized leaves | – | Y | Y | – | Y | – | – | – | – |
| | Notches taken out of the leaf margin | – | – | – | – | Y | – | – | – | Y |
| | Grass leaves stripped except for midrib, panicles are fed on | – | – | – | – | – | – | Y | – | – |
| | V- shaped yellowing at leaf tip | – | – | – | – | – | – | – | Y | – |
| | Plants turning yellow and stunted. | – | – | – | – | – | Y | – | Y | – |
| | Field appears silver-grey in colour | – | – | – | – | Y | – | – | – | – |

# Below-ground Pests

## Grubs

**Crops at Risk:** corn, soybeans, grasses, winter cereals

Various types of grubs can attack field crops. European chafer and June beetle are the most common problem grubs in Ontario field crops, although Japanese beetle grubs can also cause damage. Proper identification of the species of grub present in each field is important, as their life cycles are different, which influences the management strategies implemented.

**Description:** Grubs are white and C-shaped beetle larvae, with an orange-brown head and dark posterior (Figure 12-1). When walking, they drag their posterior along the ground. Correctly identifying the species of grub requires using a hand lens focused on the anal bristles known as "rasters" that are positioned on the underside, at the last abdominal segment of the larva (posterior). Each species has a particular raster pattern. Identifying the species will determine when feeding activity is expected, how long they will remain in the soil and when control measures can be implemented.

**Figure 12–1.** Overview of a grub.
*Source:* A. Schaafsma, University of Guelph, Ridgetown Campus.

More information on the description, life cycle and damage can be found under each grub species.

**Damage:** Grubs feed on the fibrous roots 2.5–5 cm (1–2 in.) from the soil surface. In mixed forage stands, grassy roots are pruned, causing plants to become stunted and eventually wilt, leaving only the legumes to survive. Intense root feeding on susceptible crops results in poor emergence and plant death (Figure 12-2). Crop damage is dependent on the timing of planting and crop emergence in relation to larval feeding activity. If the crop is planted after the grub species has completed its larval stages (feeding stage of the insect), crop damage can be avoided. Additional damage can occur from predators such as skunks and raccoons that dig up and feed on the grubs, although the damage seldom causes economic yield loss.

**Figure 12-2.** Grub feeding on corn seedling.
*Source:* J. Smith, University of Guelph, Ridgetown Campus.

**Conditions That Increase Risk:** Fields with sandy or silty knolls and in areas close to treelines are prone to more egg laying. Fields following soybeans, alfalfa, sod, pasture cereals and potatoes are at higher risk. The establishment year is at highest risk for mixed forages. Susceptible crops grown adjacent to pasture, sod farms, parkland and golf courses are particularly prone to grub infestations. Figure 12-3 describes the life cycles and feeding periods for common grubs.

**Scouting Technique:** Fall is the best time to scout for grubs, though spring scouting before or after planting is also possible. Soil temperatures and grub life cycle determine when each grub species is feeding at the soil surface, chafer being the most cold-tolerant. See life cycle sections under each grub species to properly target scouting. Scout for grubs on the sandier knolls of fields, areas near treelines and in areas where past or current injury was/is evident.

Using a shovel, dig up approximately 30 $cm^2$ (1 $ft^2$) of soil, roughly 7.5–10 cm (3–4 in.) deep, in at least five areas of the field. Sift through the soil by hand, breaking up any clumps, and count how many grubs are found in each sample. If the crop has already emerged, find areas of the field where there are gaps in the stand or wilting seedlings. Go to the next nearest surviving plant and dig up those roots to find any actively feeding grubs.

**Threshold:** An average of two grubs (averaged over five scouting locations) indicates the need for control measures, including insecticide seed treatment or soil applied insecticides. If grub populations are high (four or more larvae per 30 $cm^2$ (1 $ft^2$)), use the higher rate of an insecticide seed treatment. For access to neonicotinoid-treated corn or soybean seeds for protection against grubs, a pest risk assessment must be completed according to specific criteria outlined in the Class E regulation requirement under the *Pesticides Act, 1990* and Regulation 63/09.

**Management Strategies:**

- Cultural options include disturbing the soil by tillage or discing (at least three passes), which brings the grubs to the surface where they are exposed to the elements and natural enemies such as birds, skunks and raccoons. For this strategy to be effective, plow in the fall before the grubs migrate below the plow depth.
- Plant the crop into ideal soil conditions so the crop will rapidly become established and able to tolerate low to moderate grub feeding.
- Use an insecticide seed treatment or soil-applied in-furrow insecticide on those crops with products available. In Ontario, the use of neonicotinoid seed treatments on corn and soybean seed is restricted. A pest assessment is required before use of these products is permitted.
- Avoid planting mixed forages or other susceptible crops that lack an insecticide seed treatment or soil-applied option in fields with a known history. If grub populations are high or June beetles are in the second year of their cycle when the majority of the feeding will take place, avoid seeding forages that year. Plant other crops that have insecticide seed treatment or soil-applied insecticide available to reduce grub populations. Re-assess the grub population following this control tactic to determine if forages can be planted in that field the following year.
- A well-managed pasture with a good mix of legume and grass species may help reduce stand loss, as grubs tend to feed more on the roots of grass species. Overseeding or reseeding may be required for a few years to compensate for what the grubs have taken out.
- Some predators, parasitoids and pathogens can help to reduce grub populations if conditions are ideal, though they are not comparable to a chemical control option.
- No rescue treatments are available.

| Insect | | Jan-Mar | April | May | June | July | Aug | Sept | Oct | Nov-Dec |
|---|---|---|---|---|---|---|---|---|---|---|
| European chafer | | 3rd instar larvae – overwintering | | 3rd instar larvae – feeding and pupation | Adults emerge, mate & lay eggs – no feeding | | 1st instar larvae – feeding | 2nd instar larvae – feeding | 3rd instar larvae – feeding | 3rd instar larvae – over-wintering |
| June beetle | Yr1 | Adults overwintering in soil | | Adults emerge, mate and lay eggs | | Eggs hatch – 1st instar larvae – feeding | | 2nd instar larvae – feeding | 2nd instar larvae – overwintering | |
| | Yr2 | 2nd instar larvae – overwintering | | 2nd instar larvae – feeding | 3rd instar larvae – feeding | | | | 3rd instar larvae – overwintering | |
| | Yr3 | 3rd instar larvae – overwintering | | 3rd instar larvae – feeding | Pupation and adults remain in soil to hibernate and overwinter | | | | | |
| Japanese beetle | | 3rd instar larvae – overwintering | | 3rd instar larvae – feeding | | Adults emerge, mate & lay eggs – no feeding | 1st instar larvae – feeding | 2nd and 3rd instar larvae – feeding | 3rd instar larvae – overwintering | |

**Figure 12-3.** Life cycles and feeding periods for common grubs (European chafer, June beetle, Japanese beetle). Shaded areas indicate damaging periods.

## European Chafer

*Rhizotrogus majalis*

**Crops at Risk:** corn; occasionally: forages and cereals

**Description:** European chafer larvae can be distinguished from other grubs by their Y-shaped raster (anal bristles) pattern (Figure 12-4). They are 4 mm (3⁄16 in.) at first instar to 25–30 mm (1–1 1⁄8 in.) at the third instar. The adult is a medium-sized scarab beetle, approximately 12.5 mm (½ in.), light brownish-beige in colour with a darker brown line at the junction of the wings. Chafer adults are smaller than June beetles but larger than Japanese beetles.

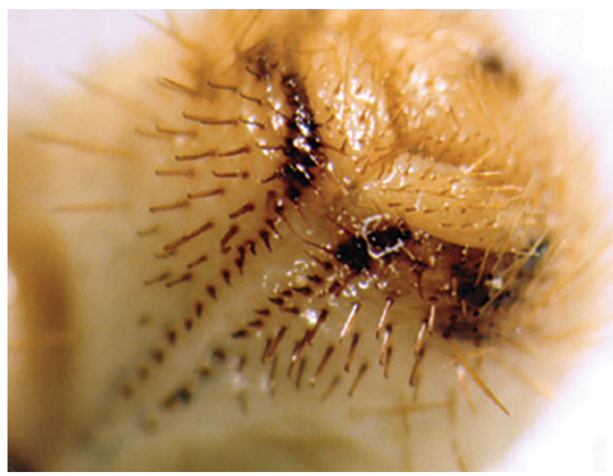

**Figure 12-4.** European chafer grub raster pattern. *Source:* A. Schaafsma, University of Guelph, Ridgetown Campus.

**Life Cycle:** The European chafer is an annual grub, having only one generation per year. Chafers overwinter as larvae or "grubs" in the soil below the frost line. In April, these larvae migrate upwards, close to the soil surface, and feed on plant roots. European chafer is more cold-tolerant than the other grub species and can feed as soon as the soil thaws, even before the snow completely melts. Adult beetles emerge from the soil in early June to early July to mate. Adult chafers congregate in conspicuous mating flights and can be seen swarming on trees and other tall structures at dusk. The adult females then locate cool, moist soil in nearby fields or lawns to lay their eggs. Newly hatched larvae begin feeding on roots in early August until the ground freezes. The grubs then migrate below the frost line to overwinter.

**Damage:** Spring feeding damage by chafer larvae starts in April and is completed by mid- to late May. Corn and forages are at the most risk during this time, while soybeans tend to miss feeding activity when planted after mid-May. Fall feeding damage by chafer larvae is most evident in the winter wheat crop. Adults do not feed on crops.

**Scouting Technique:** Scouting in the spring for this grub must take place by mid-May before they pupate, but can also be done for an extended period of time in the fall (late August until mid-November) as they stay close to the soil surface until the ground freezes.

## June Beetle

*Phyllophaga* spp.

**Crops at Risk:** corn, soybeans, forages, cereals

**Description:** June beetle larvae can be distinguished from other white grubs by their oval-shaped raster pattern, where two rows of rasters run parallel to each other (Figure 12-5). They grow in size 4–40 mm (3⁄16–1 5⁄8 in.) to become the largest of the three grub species found in field crops. The adult is the largest of the three species, roughly 20–25 mm (¾–1 in.) and is reddish-brown to black in colour. The June beetle larva is also known as the true white grub.

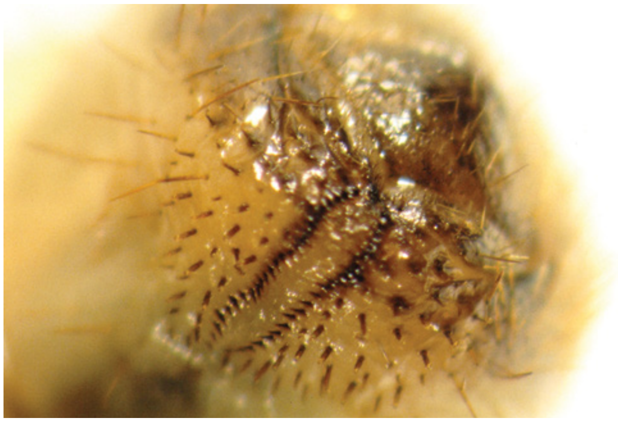

**Figure 12-5.** June beetle grub raster pattern. *Source:* A. Schaafsma, University of Guelph, Ridgetown Campus.

**Life Cycle:** June beetles have a 3-year life cycle. Adults emerge from the soil mid-May to mid-June and lay eggs. Adults tend to congregate at dusk in large masses on trees and shrubs to mate. Eggs are laid in moist soil and hatch within a few weeks. First instar larvae begin feeding on plant roots and moult into the second instar, before migrating deep into the soil to overwinter. Once the soil warms up the following spring (Year 2), the second instars begin feeding and will remain as larvae throughout the year, moulting once into the third instar. The second year of their life cycle is therefore the most destructive. Larvae again prepare to overwinter by migrating deeper in the soil once temperatures drop, until the following spring. In Year 3, the third instar larvae feed on roots for a short time before pupating and becoming adults. These adults will remain dormant in the soil for the rest of the season and only emerge the following spring.

**Damage:** Depends on which year of the life cycle the majority of the larvae are in. The second year of the life cycle is the most damaging, since they remain as grubs for the full growing season. Soybeans and forages tend to experience the most injury from this insect, especially when the crop is still young. Adults can feed on tree species and ornamental plants such as roses but do not feed on field crops.

**Scouting Technique:** The best time to scout for June beetle grubs is mid-May to early June or early fall (September to mid-October), as this grub is less tolerant to cold soil temperatures compared to European chafer. Although somewhat dependent on time of year, if the insect is in the first or third year of its life cycle, finding it in the grub (larval) stage may be difficult (Figure 12-3).

## Japanese Beetle

*Popillia japonica*

**Crops at Risk:** soybeans, forages

**Description:** Japanese beetle grubs can be distinguished from other grubs by the wide, shallow V-shaped raster pattern (Figure 12-6). The grubs are also much smaller in size than European chafer and June beetle grubs. The adult beetles are the smallest of the three grub species; approximately 12.5 mm (½ in.) in length and can be easily identified by their bright, metallic-green head and coppery wings tinged with green edges. They have 12 white tufts of hair along the margin of their abdomen.

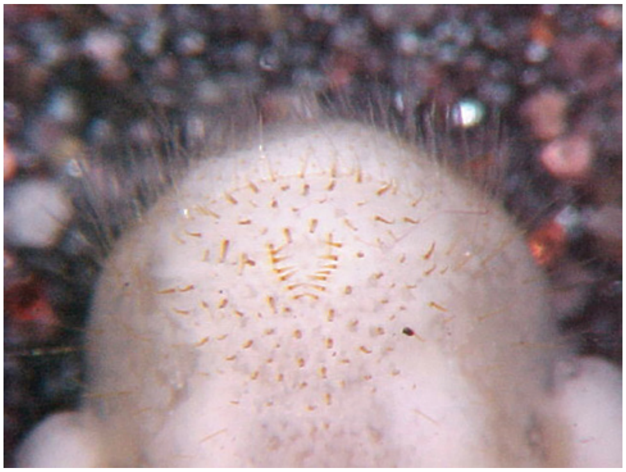

**Figure 12-6.** Japanese beetle grubs can be distinguished from other grubs by the wide, shallow V-shaped raster pattern.

**Life Cycle:** Japanese beetles have only one generation a year. They overwinter as third instar larvae below the frost line. These grubs are the least tolerant to cold soil temperatures. Once the soil has warmed up above 15°C, the larvae migrate to the surface and feed on plant roots until mid- to late June, after which time they pupate to become adults. Adults emerge in early July, live for approximately 40 days and feed on many types of plants, including soybean leaves and occasionally corn silks (Figure 12-7). Once mated, females lay their eggs in the soil, which hatch in a few weeks. Larvae begin feeding on roots, moulting through three instars before preparing for overwintering by migrating below the frost line by early October.

**Figure 12-7.** Adult Japanese beetle.

**Damage:** Both the larval and adult stages of Japanese beetle can feed on field crops. This pest is most commonly found in the Niagara/Hamilton region, though it is known to be present across Ontario. Soybean and hay fields in particular tend to experience some root-feeding damage from the larvae. Adults will also feed on soybeans, dry edible beans, fruit crops and ornamental plants, causing leaves to appear netted or skeletonized.

## Alfalfa Snout Beetle

*Otiorhynchus ligustici*

**Crops at Risk:** alfalfa; occasionally clover, grape and strawberry

**Description:** The adult is a flightless, dark-grey weevil approximately 12.5 mm (½ in.) in length (Figure 12-8). Larvae are small, white and legless with a light-reddish brown head and can be found in the soil, feeding on or in the alfalfa roots (Figure 12-9).

**Figure 12-8.** Alfalfa snout beetle adult.

**Figure 12-9.** Alfalfa snout beetle larvae and root damage.

**Life Cycle:** The alfalfa snout beetle has a 2-year cycle. In Year 1, adults emerge from their overwintering sites in April, feed on new alfalfa shoots and migrate into new fields to lay eggs. Adults may walk short distances or may be carried longer distances via the transportation of soil, gravel, hay, farm machinery and waterways. All adults are female and are capable of laying fertilized eggs. The eggs soon hatch and begin feeding on the side roots, and eventually on the main roots of the host plant. In November, the larvae burrow deep into the soil (40–60 cm (16–24 in.)) where they remain as non-feeding grubs until late summer the following year. Late in the summer of Year 2, the larvae pupate and become inactive adults until late fall. In April to May of Year 3 (Year 1 of the next generation), the adults emerge from the soil to feed and migrate to new sites to lay eggs.

**Damage:** Alfalfa snout beetles have been detected in Eastern Ontario on Wolfe Island, in the Prescott/Brockville area, in Kemptville and at the Agriculture and Agri-Food Canada Central Experimental Farm in Ottawa. The larvae start feeding on lateral roots and then move to the taproot to gouge its surface. The larvae girdle the taproot, leaving deep spiral grooves often completely severing the root. Severely injured plants may appear yellow and leafless in the fall (Figure 12-10). Adults feed on leaves and stems, causing only marginal damage. Crop damage is most evident in late summer and early fall.

**Figure 12-10.** Alfalfa snout beetle field damage.

**Conditions That Increase Risk:** Alfalfa fields on lighter soils (sandy loam, sand, gravel) in known areas of infestation (see above) are most at risk.

**Scouting Technique:** In late April to late May, scout early for signs of beetle migration in known infested counties of Eastern Ontario. Use a sweep net and also make visual assessments. Inspect field edges and sides of roads, and check hay equipment carefully before moving into uninfested fields. Later in the season (September to mid-October), use a shovel and dig up wilted alfalfa plants and surrounding soil, checking for signs of root damage and the presence of larvae. Alfalfa snout beetle have a wide range of hosts. Although it finds alfalfa to be the most attractive crop, larvae of the insect may attack all species of clover, grape and strawberry. They sometimes even feed on weeds, especially ones with fleshy roots such as wild carrot and dandelion.

**Thresholds:** None available.

**Management Strategies:**

- No chemical control is available. Insecticides have not been found to be effective at controlling this pest.
- Thoroughly clean machinery of any soil and plant debris before moving it out of an infested field. Try to complete all field work in the uninfested fields first before moving to the infested fields, to help reduce the risk of introducing the pest into new fields.
- Alfalfa snout beetle will not survive long without a host crop to feed on. Follow a tight alfalfa rotation of 2–3 years (seedling year + 1 or 2 production years) with 2 or more years of non-host crops, which include corn, soybeans or small grain cereals.
- If adults are present during harvest, they may end up in the bales and survive for some time. Store first-cut hay from infested fields for at least 2 months before it is shipped.
- If this pest is suspected, consult the OMAFRA field crop entomologist or forage specialist.
- Biocontrol nematodes have been found to be effective at collapsing populations in research trials in New York. Two native species have been isolated from soils in New York and have been shown to be persistent after application for several years, reducing stand loss from alfalfa snout beetle larval feeding by up to 88%.

# Above-ground Pests

Forages are foraged by bees. Take precautions to protect pollinators during any foliar insecticide applications. See Chapter 14 of OMAFRA Publication 811, *Agronomy Guide for Field Crops,* for more information.

## Slugs

*Deroceras reticulatum*
and other species

**Crops at Risk:** corn, soybeans, newly seeded forages, canola

**Description:** Juvenile and adult slugs are soft-bodied, legless, greyish or mottled in appearance and have a slimy or gelatinous covering that protects them from drying out. They are essentially snails without a shell. The head has two pairs of tentacles, one of which holds their eyes. Slugs usually range from 1–3 cm (⅜–1 ⅛ in.) in length but can reach up to 10 cm (4 in.) (Figure 12-11).

**Damage:** Slugs feed above or below ground, depending on the moisture level. They can feed on germinating seeds and seedlings, with no real preference for a plant part. Slugs feed on lower parts of larger plants, partly or completely eating through leaves, resulting in ragged holes that cause a skeletonized appearance on leaves of broadleaf plants (Figure 12-12). In soybeans, cotyledons may be fed on or clipped, killing the growing point of the plant. In corn, strips are scraped off the leaves, resembling hail damage, however the growing point is rarely impacted. If slug populations are high, they may feed on germinating seeds, hollowing them out before they can emerge. Slime trails may be left on the soil or leaf surface.

**Figure 12-11.** Adult slug.
*Source:* J. Smith, University of Guelph, Ridgetown Campus.

**Figure 12-12.** Slug damage in young soybean plant.
*Source:* J. Smith, University of Guelph, Ridgetown Campus.

**Life Cycle:** There is one generation per year but two populations, one maturing as adults in spring and one maturing as adults in fall. Therefore, damage can occur both in the spring and the fall on young developing plants. Both eggs and adults overwinter. Juvenile slugs are the most damaging stage of the pest life cycle. They hatch from eggs in the spring and the fall and are most active during cool and wet periods. Slugs prefer environments with high humidity and relatively cool temperatures. Debris, such as crop litter or manure, provides them with shelter from the sun.

**Conditions That Increase Risk:** Fields at risk of slug damage include no-till corn, soybeans and canola (especially fields with considerable crop residue), wheat fields underseeded with red clover, newly seeded alfalfa and fields following mixed forages (especially grasses). Open-seed furrows provide ideal living space. Mild winters with thick snow cover followed by cool, wet cloudy springs or open falls increase slug damage risk. Knowing the slug population of each field in the fall will indicate how significant the problem will be the next spring. It is the same population that overwinters and feeds in the spring.

**Scouting Technique:** Fall scouting can predict problem fields for next spring. Scout for slugs at night or in the early morning hours, when they are active (nocturnal). Look for gaps in the stand, stripping of leaf tissue and/or small holes chewed in the leaves. Check under debris and clumps of soil. A sure sign of slugs is a slimy, silver-coloured trail on the plants or soil. To determine population levels, set up shelter traps, using 30 $cm^2$ (1 $ft^2$) pieces of white roofing material (preferred) or shingles, plywood or wet cardboard. Position each trap directly on the soil surface, brushing away any crop debris or residue, and place a rock on top to keep the trap from blowing away. Use 10–15 shelter traps randomly scattered across the field to provide a good indication of population levels. Visit the boards every 5 days for approximately 1 month, counting the number of slugs present under the boards. Morning is the best time to look, since slugs will still be in their shelters before the day warms up.

**Threshold:** No thresholds are available. If slugs are commonly found under shelter traps as described above, consider the field as high risk for slug injury in the spring. Scout these fields again in the spring to confirm risk.

**Management Strategies:**

- Planting into conditions that help the crop grow quickly can avoid heavy slug damage.
- Ensure seed slots are closed.
- Use tillage against slugs to eliminate significant crop residue, exposing the slugs to dehydration and predation by birds and mammals. Zone tillage or row sweepers can help speed up the drying of the row area, thus deterring slug feeding. Moving trash away from seedlings may help reduce damage.
- Predators such as ground beetles can play a large role in reducing slug populations. Insecticides do not affect the slugs, but they can reduce ground beetle populations. If slug damage is a concern, avoid insecticide use to maintain ground beetle numbers.
- There are presently no economically feasible chemical methods available for slug control in field crops. Insecticides (seed treatment, foliar or soil-applied) do not control slugs. Slug baits, made of iron phosphate pellets, are available for field crops but are not cost effective and are only recommended for use in small problem areas of the field. Apply baits shortly after the risk of spring frost is over to achieve the highest potential for success.
- Experiments with 28% nitrogen (UAN fertilizer)/ water mixtures or foliar potash applications have proven to be inconsistent and are not encouraged.

# Alfalfa Pests

## Alfalfa Blotch Leafminer

*Agromyza frontella*

**Crops at Risk:** alfalfa

**Description:** The adult is a very small 4-mm (3⁄16-in.), black, hump-backed fly. The larvae are small, pale yellow maggots found within tunnels in the leaf tissue.

**Life Cycle:** In late May, the adult fly emerges from pupa overwintering on the soil surface. The female adult lays her eggs inside the leaves of new alfalfa plants. The larvae develop inside small tunnels in the leaves. Larvae drop to the ground when mature and pupate. A second generation of adults appears in approximately 1 week (mid-July) and a third generation appears in mid-August.

**Damage:** This pest of alfalfa is now a more serious problem in Northern Ontario. Small pinhole punctures are left in the leaves when the adult feeds and lays its eggs. The developing maggots feed inside the leaflet, creating tunnels or mines between the top and bottom layers of the leaf. These tunnels usually begin at the base of the leaflet and widen towards the leaf apex, creating a "blotchy" appearance (Figure 12-13). Feeding damage primarily decreases forage quality and seldom causes yield loss except in extreme dry conditions.

**Figure 12-13.** Alfalfa blotch leafminer damage.

**Conditions That Increase Risk:** Areas of increased foliar insecticide use can negatively impact populations of the parasitoid that helps control the pest.

**Scouting Technique:** Scout fields weekly to monitor for pinhole feeding.

**Thresholds:** Control is only necessary if more than 40% of leaflets show adult pinhole feeding.

**Management Strategies:**

- A few introduced and native species of parasite successfully control the alfalfa blotch leafminer in Southern Ontario. Insecticides are harmful to this parasite and, therefore, are not advised unless leafminer populations are extremely high.
- For insecticides to be effective, apply them no later than the pinhole stage of feeding.
- First cut may coincide with the first generation and can be an effective control measure.

## Alfalfa Snout Beetle

*Otiorhynchus ligustici*

See information in the *Below-ground Pests* section above.

## Alfalfa Weevil

*Hypera postica*

**Crops at Risk:** alfalfa; occasionally clover.

**Description:** The alfalfa weevil is a brown-snout beetle, about 5 mm (¼ in.) long, with a dark brown stripe extending from the head down the centre of the back (Figure 12-14). Larvae are bright green with a black head, six legs and a distinctive white stripe down the centre of the back. At full size, they are about 8 mm (⅜ in.) long (Figure 12-15). Silken cocoons containing the pupae may be found on rolled up leaves at the top of the plants (Figure 12-16).

**Figure 12-14.** Alfalfa weevil adult.

**Figure 12-15.** Alfalfa weevil larva.

**Figure 12-16.** Alfalfa weevil cocoon.

Clover leaf weevil are sometimes mistaken for alfalfa weevil. They grow much larger and have a light brown head. The white stripe has a pinkish edge. Clover leaf weevil rarely cause economic yield loss.

**Life Cycle:** There is one generation per year. Adults overwinter in plant debris and emerge in spring to feed on new alfalfa growth and lay their eggs in alfalfa stems in May. Larvae hatch from eggs and crawl to the tops of alfalfa where they feed on the developing leaf and flower buds. After feeding, larvae form loosely woven white cocoons in leaf masses and enter the pupa stage, usually in late June or early July. Pupae hatch in 1–2 weeks into the adult stage.

**Damage:** The larvae cause most of the damage as they feed within the leaf buds and then move to the tips of the plant. Damage starts out as pinholes and progresses to feeding between the leaf veins, resulting in a skeletonized appearance. In heavy infestations, larvae shred the leaves so badly that fields take on a greyish-white or frosted appearance. Loss of leaf tissue can quickly result in lower feed quality. Adult feeding throughout the summer does not cause significant damage.

**Conditions That Increase Risk:** Frequent use of foliar insecticides can negatively impact natural enemies. Fields located in areas of frequent insecticide use are at higher risk of weevil problems. Dry springs may hinder the development of the beneficial pathogens that also help to control alfalfa weevil. Mild winters may increase adult survival over winter and a warm May could result in the early emergence of the adults, ahead of the crop, making early harvest an impractical control measure.

**Scouting Technique:** Examine each field twice a week from mid-May to June. Check several areas throughout the field. Look for damage to show up first on shallow soils or on southerly slopes, particularly during warm, dry springs. Experience in Ontario has shown that the peak of larval attack usually coincides with the bud stage of the first crop. To count larvae, collect 30 stems in an M-shaped pattern. Place them inside a white pail and beat them against the side to knock off the third-to-fourth-stage instar larvae. First and second instars are smaller — 3 mm or less — pale yellow-to-light green, with the white stripe not yet distinguishable. They may be in the upper leaves, but do not include these younger larvae in the count. Check to see whether the weevil larvae look active and healthy. Larvae infected by the fungus pathogen are slow-moving, yellow or tan.

**Threshold:**

- Leaf-tip damage and weevil counts are used in assessing threshold levels and appropriate action of either harvesting or insecticide application. If there is 40% leaf-tip feeding, with two or three active weevils per stem, and there is more than 7–10 days to the preferred harvest date, consider applying an insecticide. ("Leaf-tip feeding" refers to the percent of plant tips showing obvious signs of damage, which is not to be confused with the percent defoliation.)
- Less than one active larva per stem does not require action, but continue to monitor.
- Two larvae per stem requires action if the alfalfa is less than 40 cm (16 in.) high.
- If there are more than three active larvae per stem, immediate action is required. Occasionally, if weevil populations are high on an early first cut, surviving larvae will feed on the regrowth. Such feeding can eliminate alfalfa regrowth, which may lead to a loss of the stand. With a severe infestation, be sure to monitor stubble regrowth. The characteristic symptom is the alfalfa plant not greening up, due to weevils

feeding on the developing crown buds. The presence of two or more active larvae per crown, or 4–8 larvae per 30 $cm^2$ (1 $ft^2$) indicates a need to spray the stubble with insecticide.

**Management Strategies:**

- Insecticides are recommended only when cutting is impractical, such as when the alfalfa is in the pre-bud stage. Cutting before the bud stage may result in reduced alfalfa vigour and excessive forage quality for most livestock. It can result in reduced yields due to extensive weevil damage to second cut regrowth.
- The key to weevil control is proper timing of harvest or insecticide application based on field inspection. When threatening infestations occur, cut fields immediately to eliminate feeding damage. Most of the larvae will be removed from the field, while any remaining larvae usually dry out, starve and are exposed to natural enemies.
- Use of foliar insecticides will also kill beneficial insects, the natural enemies of alfalfa weevil. This increases the potential for future outbreaks of this pest.
- Occasionally, warm May weather will result in an early hatch of weevil. Feeding damage will show before the bud stage when it would be practical to harvest the alfalfa. In those situations, an insecticide may be warranted.

## Pea Aphid

*Acyrthosiphon pisum*

**Crops at Risk:** forage peas, alfalfa, clover; occasionally other legumes.

**Description:** Pea aphids are pear-shaped with soft bodies, about 3 mm (⅛ in.) long. Their legs are typically visible from above, which, along with their slow movement, helps differentiate them from potato leafhoppers. Pea aphids vary in colour from light to dark green and may occasionally be pink. They can be differentiated from other aphid species by their red eyes, their long cornicles (tailpipes) with dark tips, and long antennae that have dark bands along each segment (Figure 12-17).

**Figure 12-17.** Pea aphids have red eyes, long cornicles (tailpipes) with dark tips, and long antennae with dark bands along each segment.
Source: Shutterstock.com

**Life Cycle:** There are several generations per year. Eggs are laid in the fall and overwinter at the base of legume plants. These hatch the following spring. All spring and summer generations of pea aphids are entirely female, and they reproduce asexually, giving birth to female nymphs. Some of the nymphs will have wings, while others are wingless. It takes about 10 days for a pea aphid to reach maturity, and an adult aphid lives about 30 days. Throughout the summer, female aphids will give birth to more female aphids. In the fall, shorter day length will cause the aphids to give birth to both male and female offspring. This generation will mate, and the females will lay eggs.

**Damage:** Pea aphids suck juices out of stems and new leaves, which can reduce forage yield and quality. High levels of aphid feeding will cause alfalfa to turn yellow and wilt. Stems may become spindly, and new leaves will be small. Forage palatability to livestock is reduced where sooty mould grows on the honeydew secreted by aphids. Pea aphids spread alfalfa mosaic virus, among other plant diseases.

**Conditions that Increase Risk:** Hot, dry conditions are ideal for aphid infestations when temperatures are 23°C–28°C. Mild winters can improve their overwinter success. Areas of high forage and legume production are at higher risk. Insecticide applications, often done to control other pests, such as alfalfa weevil or potato leafhopper, will suppress natural enemies of aphids. Aphid populations can very rapidly exceed the threshold when their natural enemies have been removed from a field.

**Scouting Technique:** Scout weekly throughout the growing season. Clip 30 stems at the base (not whole plants). Turn the stems upside down in a white bucket to count the total number of aphids. Calculate an average per stem by dividing the total by 30. Populations are generally not evenly distributed across the field, so scouting in several areas is recommended.

**Threshold:** The threshold changes with the height of alfalfa.

- Where alfalfa is less than 25 cm (10 in.) tall, threshold is 30–50 aphids per stem.
- From 25–50 cm (10–20 in.), the threshold is 50–75 aphids per stem.
- If alfalfa is taller than 50 cm (20 in.), the threshold is 100 aphids per stem.

If potato leafhoppers are also present in the field, make spray decisions based on leafhopper populations rather than aphids.

**Management Strategies:**

- A good fertility program will help alfalfa grow quickly to stay ahead of aphid populations and maintain plant vigour against diseases aphids transmit.
- Harvesting alfalfa removes the aphids' food source and is an excellent way to reduce the population.
- Natural enemies (such as ladybugs, lacewing larvae, damsel bugs, minute pirate bugs and parasitoids) will usually prevent aphid populations from reaching threshold on alfalfa regrowth.
- Insecticides may be used if the population is above threshold, natural enemies are scarce and the crop is more than 2 weeks away from harvest. However, insecticide use may cause the aphid population to rebound, since natural enemies will also be killed.[1]

## Potato Leafhopper

*Empoasca fabae*

**Crops at Risk:** alfalfa, soybean, clover, potato, apples, beans, and others

**Description:** The potato leafhopper adult is a pale green, wedge-shaped, winged insect about 3 mm (⅛ in.) long, with piercing and sucking mouthparts (Figure 12-18). It is most broad towards the head, tapering evenly to the wing tips. It has a row of six rounded, white spots behind the head. Nymphs are smaller than adults and are wingless (Figure 12-19).

**Figure 12-18.** Potato leafhopper adult.

**Figure 12-19.** Potato leafhopper nymph.

**Life Cycle:** Potato leafhoppers do not overwinter in Ontario but migrate north every spring, carried by weather fronts that start in the Gulf of Mexico. Adults may arrive in late spring and begin sucking on plant juices. Females lay their eggs in the tissue of main veins and petioles of leaves. Development from egg to adult takes approximately 4 weeks.

**Damage:** Most severe in new seedlings and young regrowth. As potato leafhopper nymphs and adults suck juices from plant foliage, they inject a protein that blocks veins. This causes the leaf edges to become yellow and puckered, with a characteristic yellow "V" shape beginning at the tip of the leaves. When severe, the leaves appear burned, which is called "hopperburn" (Figure 12-20). Potato leafhopper feeding causes reduced stem elongation, reduced root development, leaf cupping and stunting. Yields can be lowered by as much as 50% with a severe infestation, accompanied by a reduction in protein levels of 2%–3%. Decreased stand vigour results in slow regrowth following cutting and increased winterkill. Border areas are usually affected first. Most of the damage occurs from June to mid-August. High-risk factors include hot, drier-than-normal seasons. Symptoms of potato leafhopper are commonly confused with nutrient deficiency or herbicide injury, and are often dismissed as drought damage.

**Figure 12-20.** Potato leafhopper burn on alfalfa.

**Conditions That Increase Risk:** Hot dry conditions can promote outbreak years. Fields in counties along Lake Erie tend to experience more frequent infestations.

**Scouting Technique:** Economic losses occur before plant symptoms develop, so it is important to identify the presence of large leafhopper populations before the damage occurs, especially in new seedings. Scout frequently as potato leafhoppers can arrive on storm fronts and land in fields at threshold levels overnight. Scouting with a sweep net will help determine whether early harvest or spraying is needed. Scout at intervals of 5–7 days, beginning after first cut.

Standard 37-cm (15-in.) diameter sweep nets are available commercially. While walking through the canopy, swing the net from side to side in a pendulum-like motion, across the top of the canopy so the top of the net is sweeping the top 37 cm (15 in.) of the canopy. Avoid collecting soil in the net during the sweeping procedure. For potato leafhopper, one sweep is defined as one 180° arc, bringing the sweep net from one side of the body to the other only once; the definition of one sweep may be different for other pests.

Take 20 sweeps from five areas of the field beginning in late June. Avoid field edges. Quickly close the top of the net by grasping it just below the ring. Slowly open the net, remove any plant debris collected, identify and count the insects captured. Determine the average number of potato leafhoppers per sweep. Take 20 alfalfa stems at random and record the average plant height.

**Thresholds:** Thresholds change with alfalfa height. Table 12-2 will help determine when potato leafhopper thresholds have been reached.

**Table 12-2. Thresholds for Potato Leafhopper on Alfalfa**

| Stem Height | # of PLH per sweep[1] | |
|---|---|---|
| | Conventional varieties | PLH highly resistant varieties |
| 9 cm (3-½ in.) | 0.2 adults | 0.8 adults |
| 15 cm (6 in.) | 0.5 adults | 2.0 adults |
| 25 cm (10 in.) | 1.0 adults or nymphs | 4.0 adults or nymphs |
| 36 cm (14 in.) | 2.0 adults or nymphs | 8.0 adults or nymphs |

[1] 1 sweep = 180˚ arc.
*Notes:* The taller the alfalfa, the more leafhoppers can be tolerated before control is necessary.

**Management Strategies:**

- Resistant varieties that use glandular hairs as the resistance factor are available. These glandular hairs, both on the leaves and stems, act as mechanical barriers to potato leafhopper feeding. Use the conventional alfalfa variety thresholds in Table 12-2 for new seedings of potato leafhopper-resistant varieties since the glandular hairs are not fully expressed in the first year.
- When deciding whether to use a potato leafhopper-resistant variety, consider the level of potato leafhopper infestation expected in a typical year (higher in Lake Erie counties), cost of scouting, insecticide and spray application, any additional cost of potato leafhopper-resistant varieties and other variety performance traits (e.g., yield and disease resistance).
- Cutting alfalfa early will potentially reduce egg, nymph and adult populations. A naturally occurring fungal pathogen helps reduce the populations of the potato leafhopper under cool, moist conditions.
- Before applying an insecticide, ensure that thresholds have been reached and cutting is not possible. Spraying insecticides on alfalfa will also kill the natural enemies of alfalfa weevil and other forage pests.

# Grass Pests

## True Armyworm

*Mythimna unipuncta*

**Crops at Risk:** grasses, cereals, corn

**Description:** Full grown, true armyworm are 3.75 cm (1 ½ in.) long. The dull-green to brown larvae can easily be confused with other caterpillars, including variegated cutworm and fall armyworm. Variegated cutworm have distinctive yellow dots along the top of the first few abdominal segments of the larvae. Both true and fall armyworm have white-bordered stripes running laterally along the body, but only true armyworm have dark diagonal bands at the top of each abdominal proleg (Figure 12-21). The head is yellow-brown with a network of dark-brown lines creating a mottled pattern. The adult sand-coloured moth has distinctive white spots on the centre of each forewing.

**Figure 12-21.** True armyworm larva.

**Life Cycle:** There are two generations per year, but the first generation tends to do the most damage to cereals and corn in Ontario. True armyworms overwinter as far north as Pennsylvania. Moths emerge in early spring and migrate into Ontario via weather fronts. Adults prefer to lay their eggs in grassy vegetation, including grassy weeds, cereals, grassy forages and rye cover crops. Larvae hatch from the eggs and feed at night or on overcast days, for approximately a month. Ontario has experienced injury in corn from second-generation larvae in late June in rare, extreme outbreak years. Outbreak years tend to coincide with cool wet springs that are detrimental to the parasites that typically control armyworm.

**Damage:** There is more of a concern for mixed forages in outbreak years when armyworm has also been a problem in cereals and corn. Armyworm larvae feed at night and do not feed on pure stands of alfalfa but will feed on alfalfa/grass mixtures. Larvae strip the grass leaf margins, moving up the plant to feed on the panicles leaving only the midrib. Infestations tend to be caused by second generation true armyworm once cereals and other preferred hosts are more advanced, although first generation true armyworm can be a concern if neighbouring fields of cereal and corn crops are infested in June. Fall armyworm is a concern in late summer.

**Conditions That Increase Risk:** Mixed or grass forage crops that are adjacent to cereals and corn fields in outbreak years.

**Scouting Technique:** The best time to scout for armyworms is at or shortly after dusk. Examine 10 areas of the field, assessing the number of larvae per 30 $cm^2$ (1 $ft^2$). Scout along the field boundaries bordering cereal and corn crops as larvae will "march" in from neighbouring fields and may be controlled prior to larvae entering the forage crop. During the day, the larvae may be found among the crop debris on the soil surface or under soil clods. Brown frass, often mistaken for eggs, may also be detected on the soil near the plant. When scouting, check the backs of armyworms for eggs. These small, oval, yellowish eggs are usually located just behind the head of the larva. These are eggs of a parasitic fly (Figure 12-22). The eggs will hatch, and the maggots will kill the armyworm larvae.

**Figure 12-22.** Fall armyworm parasitized by tachinid fly. *Source:* J. Smith, University of Guelph, Ridgetown Campus.

**Threshold:** Control is warranted when five or more larvae (smaller than 2.5 cm (1 in.) in size) are found per 30 $cm^2$ (1 $ft^2$). In seedling crops, 2–3 larvae (smaller than 2.5 cm (1 in.) in size) per 30 $cm^2$ (1 $ft^2$) may warrant control. Avoid treating with insecticides when large numbers of parasitized larvae are present.

**Management Strategies:**

- If the larvae are over 2.5 cm (1 in.) long, there is no benefit in applying insecticide, since most of the feeding damage has already occurred.
- Treatment may be confined to infested areas. If armyworm are migrating from adjacent cereal or corn fields, spraying an insecticide along the field border may be sufficient.
- Parasites and other beneficial organisms usually keep armyworms from reaching damaging levels, although cool, wet springs are not favourable for these parasites.

### European Skipper

*Thymelicus lineola*

**Crops at Risk:** timothy, some other grasses

**Description:** European skipper is a sporadic pest of timothy, both in hay and seed production. Larvae can usually be found within rolled leaves where they feed. Younger larvae have black heads that eventually turn brown. Mature larvae are light green, approximately 20 mm (¾ in.) in length and have brown heads with two light bands. The adult is a pumpkin-orange butterfly with a 2.5 cm (1 in.) wing-spread that skips about hay fields in midsummer (Figure 12-23).

**Figure 12-23.** European skipper adult.

**Life Cycle:** There is one generation per year. Eggs overwinter on the stems of crop debris and weeds and hatch in the spring. Young larvae roll themselves up in the leaves and seal the leaves closed with silk webbing. Larvae feed on timothy and other grasses until late June. The larvae then attach themselves to grass stems or the underside of weed leaves and develop into chrysalids (the pupa stage of the butterfly). In approximately 2 weeks, the adult skipper emerges.

**Damage:** Larval feeding causes leaf margins to become irregularly notched and when abundant can cause defoliation that is often confused with armyworm injury. When the population is very high, the larvae will also feed on the heads of plants, leaving only the stems remaining in a field. Adult skippers feed on the nectar of flowers and weeds and do not cause any damage to plants.

**Scouting Technique:** Begin scouting for larvae by late April. Remove five random, 30 $cm^2$ (1 $ft^2$) samples of forage down to ground level and place them along with the old crop residue into a bag. Tie the bag and leave overnight at room temperature. The caterpillars will crawl out of the residue and can be easily counted.

**Threshold:** Control may be warranted when 6–8 larvae in a 30 $cm^2$ (1 $ft^2$) area are found in the early, brown-headed stage.

**Management Strategies:**

- See the Ontario Crop Protection Hub at ontario.ca/cropprotection for insecticide recommendations
- Products containing *Bacillus thuringiensis* (Bt) are available for organic production.

# Pests at Feed-out

It is very unusual for insect pests to cause issues in hay during storage and feeding. However, when issues do occur, they can be serious.

## Blister Beetles

*Epicauta* spp.

**Description:** Blister beetles are very rare in Ontario but have been occasionally found in alfalfa fields north of Lake Erie. They are more common in arid climates, such as the U.S. Midwest, and are often associated with grasshopper infestations. The three most common species are the black blister beetle (*E. pensylvanica)*, the ash grey blister beetle (*E. fabricii*) and the striped blister beetle (*E. vittata)*. Blister beetles have soft bodies 1–2.5 cm (⅜ –1 in.) long. The thorax between their head and abdomen is long and narrow, making it look like a neck. Their wings tend to be shorter than their abdomen.

The black and ash-grey blister beetles are solidly coloured as their names describe (Figures 12-24 and 12-25). The striped blister beetle is black and yellow. Its head has two black spots, and its thorax has two black stripes running lengthwise. The wing covers typically have two black stripes; striped blister beetles from the Southern U.S. may have three black stripes.

**Figure 12-24.** Black blister beetle.
*Source:* David Cappaert, bugwood.org.

**Figure 12-25.** Ash grey blister beetle.
*Source:* Ward Upham, Kansas State University, bugwood.org.

**Life Cycle:** There is one generation per year. Eggs are laid in the soil in July or August. Larvae hatch 2–3 weeks later and are beneficial, feeding on grasshopper eggs. Larvae go through three instar phases, then pupate to overwinter in the soil. Adults emerge in June or July and feed on pollen, nectar and flowers of host plants such as alfalfa and flowering weeds. They mate, and after 2 or 3 weeks, the female lays eggs.

**Damage:** Blister beetles do not negatively impact crop growth.

## CAUTION!

Blister beetles contain cantharidin, which causes blisters to the skin on contact and inside the digestive tract if eaten. Horses are particularly sensitive to cantharidin, though ruminants are also affected. Symptoms of blister beetle poisoning include blistering on the skin (especially around an animal's lips), mouth ulcers, colic, diarrhea, bloody feces and bloody urine. If enough cantharidin is ingested, death may occur within 72 hours.

**Scouting Technique:** Scout for blister beetles 2–3 days before cutting, focusing on the field edges and any areas with flowering weeds. The beetles tend to congregate in clusters. If blister beetles are found, delay hay harvest until the beetles have left the field.

**Threshold:** There are no established economic thresholds for blister beetles. Presence of these insects will affect marketability of the crop.

**Management Strategies:** To avoid contaminated hay, producers should cut alfalfa before it reaches 5% bloom, which reduces the crop's appeal to the beetles. First cut hay is typically safe from beetles as the insect will still be below ground in its larval stages. Scout all other cuttings for beetles prior to harvest. Dead blister beetles contain the same amount of toxins as live ones, so insecticides are not recommended for blister beetle control.[2]

## Itch Mites
*Pyemotes tritici*

**Description:** Hay or straw itch mites are about 0.2 mm long and usually require a microscope to see. Females may reach 2 mm in length just prior to egg-laying. Itch mites are parasitic predators of soft-bodied insects. They live and breed in stored grains, grass hay or straw but can also be present in hay fields and pastures.

**Life Cycle:** The full development from egg to egg-laying adult takes 2–4 weeks. Itch mites feed on insect larvae. They multiply quickly under warm, humid conditions. Open hay storages exposed to rain-bearing winds with warm temperatures provide a suitable environment for their development. Populations usually peak during late summer when insect populations also peak.

**Damage:** Itch mites do not negatively impact crop growth.

### CAUTION!

Itch mite bites cause red, itchy lumps on human skin. The mites can bite humans and livestock while searching for insects to feed on, but fortunately cannot live or breed on them. Unlike scabies, itch mites do not burrow into the skin. Sensitivity to itch mite bites varies from person to person; in severe cases, people have reported headache, mild fever, nausea, vomiting, diarrhea and aching joints in addition to the itchy bites. Less frequently, horses or other livestock eating infected hay or bedded with infected straw can also be affected.

**Scouting Technique:** Bites from itch mites are typically found on any areas of the skin that come in contact with hay, such as forearms, legs and neck. However, if they get under clothing, mite bites are often found around the waist, underarms and on the inside of the legs.

**Threshold:** There are no established economic thresholds for itch mites.

**Management Strategies:** After an itch mite attack, remove and wash clothing and take a shower. Try not to scratch the bites. Seek medical attention to reduce bite symptoms. Insect repellent containing DEET can help prevent bites. Eliminate the infested hay or straw and thoroughly clean the storage facility. If the forage cannot be eliminated, avoid feeding it until the spring after harvest to allow time for the itch mite population to decline over winter.

# Promoting and Protecting Natural Enemies

Natural enemies play a key role in managing many of the major pests found in forages. Perennial crops like mixed forages tend to support a diverse community of natural enemies compared to annual crop species. Perennial crops help provide predators and parasitoids with shelter, pollen and nectar sources and some protection from the pesticide applications taking place in adjacent fields. Protecting these natural enemies involves following integrated pest management practices, including scouting for pests and natural enemies, timing cuttings and harvest to reduce pest populations and selecting reduced-risk insecticides when thresholds are reached and cutting is not practical.

Simply recognizing some of the key natural enemies of the pests of forages can increase awareness of their importance and help determine if and when chemical control is necessary. Some of the most common natural enemies that can be found in forage crops are described in Chapter 14, *Integrated Pest Management and Protecting Natural Enemies and Pollinators,* of OMAFRA Publication 811, *Agronomy Guide for Field Crops.*

Honey bees, native bee species (e.g., bumble bees, squash bees) and other pollinating insects are important pollinators for many Ontario crops (see Chapter 9, *Managing for Healthy Soils and Ecosystems*). Insecticides, some of which may negatively affect bees, require careful management to achieve both pollination and insect control.

Growers and licensed commercial applicators can protect bees by following these suggestions:

- Time insecticide applications to minimize bee exposure (e.g., apply post bloom). Daytime treatments, when bees are foraging, are most hazardous. Insecticide applications in the evening are the safest, unless there is evidence of a strong temperature inversion or high humidity. Under normal circumstances, spraying after 8 p.m. allows the spray to dry before the bees are exposed to it the next day. Spraying during early morning is the next best time, when fewer bees are foraging, but pesticide residues may still be present. Spraying should be completed well before 7 a.m. While honeybees and most other pollinating insects do not usually forage at temperatures below 13°C, bumblebees do. If you plan to spray in the morning, contact beekeepers who have bees within 5 km of your crop and spray site. The beekeepers may then have the option of taking any possible protective action.
- Do not spray any flowering crop on which bees are foraging.
- To prevent drift toward nearby hives, do not apply insecticides on windy days or when there is evidence of a strong temperature inversion.
- Bees and other pollinators may be poisoned by visiting flowering weeds, trees and cover crops that have come into contact with an insecticide via spray drift or drift of insecticide-contaminated dust during planting. Avoid spray drift to flowering weeds that are adjacent to or within the target field. Where possible, mow down flowering cover crops or flowering weeds in and bordering target fields prior to spraying to help safeguard the bees. Control dandelions and other flowering weeds within fields before spraying or planting seeds treated with an insecticide.
- In crop settings where pesticide use is highly likely, beekeepers should remove honeybee colonies as soon as pollination and bloom are complete in the crop and before any insecticides are applied post bloom. In emergency situations, if the colonies cannot be removed in time, beekeepers can place burlap or cloth soaked in water at the entrance of the hive to disrupt the flight of the bees for up to 12 hr and provide more time for spray to dry. To help prevent overheating of the hive during this time, keep an opening of 2.5 cm on each side of the hive entrance so bees can still get out and ventilate the hive. Also, the water on the burlap or cloth will help cool the colony.
- Not all pesticides are equally toxic to bees. If there is a risk of honey bee poisoning, try to choose an insecticide that is not highly toxic to bees. When there is a choice, choose a product formulation that is less hazardous to bees.
- Always read the most current pesticide label for guidance. Some pesticides cannot be used when bees are active in the crop.

# References

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2. Boxler, D. 2020. *Dealing with Blister Beetles*. University of Nebraska – Lincoln. Retrieved from: beef.unl.edu/beefwatch/2020/dealing-blister-beetles

## Additional Sources

This chapter contains excerpts from the following OMAFRA source:

Publication 811, *Agronomy Guide for Field Crops.* 2017.

CHAPTER 13

# Diseases

Diseases reduce the yield, quality and persistence of forage crops. A few pathogens can produce mycotoxins, which are anti-nutritional compounds that can negatively impact animal health and production.

For perennial forage crops, prevention is usually more economical than treatment. Growing resistant varieties, using appropriate seed treatments, meeting the crop's fertility requirements, planning harvest schedules and cleaning equipment are all part of managing forage crop diseases. Understanding which diseases are present in a field is necessary to mitigate the impact on the farm's forage supply. Weekly scouting can help farmers stay ahead of crop diseases.

Refer to OMAFRA Publication 811, *Agronomy Guide for Field Crops,* for descriptions of economically significant crop diseases in corn and cereals.

## Alfalfa Diseases

### Seedling Diseases

#### Pythium Seed Rot, Damping-Off or Seedling Blight

*Pythium* spp.

**Incidence:** Pythium seed rot, damping-off or seedling blight is predominantly an early-season fungal disease of alfalfa. Infection of alfalfa plants most often occurs from the time of planting to several weeks after emergence.

**Appearance:** Infected seeds may rot, and severely infected seedlings may wilt, collapse and die. Look for wet or watery lesions on the roots and hypocotyl of infected plants. A girdling, pinching or damping off of the stem, at the soil line, causing the seedling to fall over and die, may be seen. Fields are most often affected by the disease in circular or irregular patches.

**Disease Cycle:** Pythium seed rot, damping-off or seedling blight is closely related to phytophthora root rot. Both produce mobile spores that move through the water film between soil particles to locate and subsequently infect alfalfa roots.

**Management Strategies:** Refer to the Ontario Crop Protection Hub at [ontario.ca/cropprotection](ontario.ca/cropprotection) for fungicide seed treatment guidelines. Drain excess soil moisture and avoid compaction. Plant when soil and weather conditions favour rapid emergence and early growth of seedlings. Increase plant populations to compensate for any plant losses.

# Crown and Root Rots

## Anthracnose (in Alfalfa) and Northern Anthracnose (in Red Clover)

*Colletotrichum trifolii* and *Kabatiella caulivora*

**Incidence:** In alfalfa, anthracnose occurs mostly in the extreme southwest portion of the province, whereas northern anthracnose is more widely distributed in red clover fields. Losses in both alfalfa and red clover due to anthracnose can be as high as 25%.

**Appearance:** Although symptoms can occur on the stem and leaves, it is the damage to the crown area that is most important. Stem symptoms on resistant varieties are small, black, irregular-shaped lesions, whereas lesions on susceptible varieties are large, sunken and oval-to-diamond-shaped. These lesions have a tan- to straw-coloured centre with a dark brown border. When the fungus reproduces, the centre of those stem lesions produced on susceptible varieties will contain small, black, fruiting bodies. These can be easily seen with your eye or a simple hand lens. In severe cases, the lesions will join together and eventually girdle the entire stem, causing wilting or killing the stem. Dead stems and leaves (shoots) become white and have a characteristic shepherd's hook appearance. These are scattered through the field and are often confused with two other diseases (rhizoctonia crown rot or fusarium wilt) or from frost injury. Damage to the crown appears as a blue-black discolouration of the crown tissue. Infected plants are easily broken at the base. If the diseased tissue is light brown, the cause is most likely not anthracnose but either rhizoctonia crown rot or fusarium wilt. Crown infection results in fewer stems per plant and eventually plant death.

In red clover, northern anthracnose can be very destructive. In addition to most of the symptoms described above, infection can result in cracking of the stem surface.

**Disease Cycle:** The fungus thrives during moderate temperatures and humid weather conditions and survives in diseased stems, leaves or debris. Spores produced in the spring are spread by rain. The rain causes splashing, which moves spores from infected plants to neighbouring plants. The fungus can be spread from field to field, for example, through equipment and soil erosion.

**Management Strategies:** Varieties with moderate-to-high resistance to anthracnose are available. Harvest equipment should be cleaned between fields. Crop rotation has been found to have limited success in managing anthracnose in alfalfa but has had better success in red clover, which does not have the same degree of resistance.

## Aphanomyces Root Rot

*Aphanomyces euteiches*

**Incidence:** Aphanomyces root rot is an economically significant alfalfa disease that is considered a major disease in alfalfa seedlings, especially in heavy, wet soils. Aphanomyces root rot also affects surviving adult alfalfa plants and can dramatically reduce yield and vigour of established plants.

**Appearance:** Aphanomyces root rot causes symptoms on both seedlings and older plants. Infected seedlings are stunted and have yellow leaflets and cotyledons. Roots and stems are grey and water-soaked in appearance. Severely infected seedlings turn light to dark brown. Older or established plants that are infected are stunted and yellow and have a reduced root system. These symptoms are often confused with nitrogen deficiency. Regrowth of infected plants is slow following harvest and winter.

**Disease Cycle:** The fungus survives in the soil on infected plants or debris. For infection to occur, the soil must be saturated. Disease development is favoured when moderate-to-high temperatures occur (16°C–30°C) during humid or wet conditions. Fields that are compacted or drain poorly are especially prone to the disease. Infection occurs as the plant emerges, so new seedings are most at risk. Risk declines somewhat with the age of the stand.

**Management Strategies:** Aphanomyces root rot is best managed through resistant varieties. Since saturated soils are needed for disease establishment, improving soil drainage and reducing compaction will reduce the disease. For additional information visit ontario.ca/crops.

## Brown Root Rot

*Phoma sclerotioides*

**Incidence:** Brown root rot was confirmed in Ontario in 2007. It is most likely widespread in the province and most often occurs in areas with severe winter conditions, since the disease is often associated with winter-killed areas. Plants with brown root rot are slow to emerge from winter dormancy and have delayed spring growth, resulting in lower yields.

**Appearance:** The tap roots, lateral roots and/or crown have characteristic sunken brown lesions (almost black), and in severe cases the tap root is rotted completely. The fungus does not infect the above-ground parts of the alfalfa plant.

**Disease Cycle:** The brown root rot pathogen thrives when soil temperatures are 15°C or less, hence the fungus is most active in the fall and spring when environmental conditions are favourable for infection and the plants are dormant. Infection of the roots and/or crowns can have a detrimental impact on overwintering health and promote other diseases, winterkill, stand decline and yield loss. Since the fungus grows very slowly, damage is not often noticed until the second or third year when plants become stunted or die.

**Management:** Since the availability of resistant varieties for Ontario is limited, other management strategies that reduce plant stress going into winter, such as avoiding late or excessive fall harvest, maintaining proper soil fertility and rotating out of alfalfa for at least 3 years, can help reduce losses and increase stand longevity.

## Phytophthora Root Rot

*Phytophthora medicaginis*

**Incidence:** Phytophthora root rot is an important and common disease of alfalfa. The disease shows up mainly on poorly drained or clay loam soils during extended periods of wet weather.

**Appearance:** Infection occurs as plants emerge; therefore new seedlings are most at risk. As the stand gets older, the risk declines somewhat. Infected seedlings are stunted, grow slowly due to a reduced root system and eventually begin to wilt. A girdling, pinching or damping-off of the stem at the soil line may be seen, causing the seedling to fall over and die. The field is often affected by the disease in circular or irregular patches. In older seedlings or on established plants, a reddish-brown, water-soaked lesion may develop on the roots (Figure 13-1). In severe cases, root lesions become black, and the taproot may rot entirely. Since the roots are unable to supply water and nutrients, the plant wilts and dies. Lower leaves are yellow at first, and, as the disease progresses, may turn reddish-brown.

**Figure 13-1.** Phytophthora root rot infection begins as the plants emerge. Infected seedlings are stunted and begin to wilt.

**Disease Cycle:** Phytophthora root rot is a soil-borne disease that can cause root injury or plant death. The fungus survives as thick-walled spores (oospores) that produce mobile spores in the spring that migrate and infect the plants' roots. Water is important since these mobile spores (zoospores) move in the water film between soil particles. Disease development is favoured when moderate to high temperatures occur (21°C–32°C) during humid or wet conditions. Fields that are compacted or poorly drained are especially prone to the disease. Risk declines somewhat with the age of the stand. The fungus is able to survive for many years in infected plant tissue as oospores.

**Management Strategies:** For fields with a history of phytophthora root rot, use highly resistant varieties and seed treatments. Consult technical variety data from forage seed companies for tolerance and/or resistance to various diseases, including phytophthora root rot. Refer to the Ontario Crop Protection Hub at ontario.ca/cropprotection for fungicide seed treatment guidelines. Crop rotation has little effect on this disease. Other management practices that help in managing this disease include:

- maintaining good soil fertility, which will promote lateral root growth
- removing excess moisture through improved tile drainage
- ensuring reduced compaction
- avoiding other stresses such as leaf-feeding insects, weed escapes and untimely cuttings that make plants more susceptible to *Phytophthora*

### Other Crown and Root Rots in Alfalfa and Red Clover

Stresses such as leaf diseases, insects, frequent or untimely harvests, harsh winter conditions and low soil pH all increase the severity of crown and root rots. Stresses during the growing season render the plants more susceptible to winter stress. To help reduce disease severity, employ good crop management practices, including:

- a suitable harvesting schedule
- maintenance of adequate soil fertility and proper pH
- control of leafhoppers in alfalfa
- avoiding mechanical injury of the crowns since crowns are easily injured by machinery and by livestock tramping, especially when the soil is wet

## Leaf and Stem Diseases

### Alfalfa Mosaic Virus

*Alfamovirus*

**Incidence:** Alfalfa mosaic virus reduces plant vigour and can cause stand losses over time. High levels of infection may reduce yield in first cut up to 30% the year after a plant contracts the virus; later cuts are less affected. Other susceptible crops include clovers, peas, potatoes and soybeans.

**Appearance:** Yellow mottling on the leaves (Figure 13-2). Symptoms tend to be most visible in spring and fall when the weather is cooler.

**Figure 13-2.** Alfalfa mosaic virus.

**Disease Cycle:** Alfalfa mosaic virus is commonly spread by pea aphids. When symptoms show up in spring growth, the infection likely occurred in the fall and the virus overwintered in the crown of the plant. Infected seed may also introduce the disease to a field.

**Management Strategies:**

- Insecticides against aphids are not effective in controlling the spread of alfalfa mosaic virus. After spraying, the field is quickly repopulated by aphids from neighbouring fields that continue disease transmission.
- Alfalfa mosaic virus can be spread through infected seed. Use certified seed to reduce the risk of bringing in an alfalfa mosaic virus in alfalfa seed.
- Manage broadleaf weeds in the field and field boundaries that may host alfalfa mosaic virus to help reduce spread.
- Where infection is severe enough to significantly impact yield, terminate the stand and rotate out of alfalfa.

## Bacterial Wilt

*Clavibacter michiganensis*

**Incidence:** Bacterial wilt has historically been one of the most important alfalfa diseases not only in Ontario but anywhere it is grown. The development of resistant varieties has made the disease less common.

**Appearance:** Symptoms become apparent as the stand gets older (3 or more years). Infected plants are stunted and have a yellow-green colour. In severe cases, the plant has spindly stems with small, distorted leaves. Infected plants that are stressed by water, heat or both will wilt or die and are scattered throughout the stand. Infection stresses the plant and increases its susceptibility to winterkill. Cutting the taproot in half (cross-section) will show a light brown-to-yellow discolouration of the vascular tissue near the outer edge.

**Disease Cycle:** This disease is caused by a soil bacteria that survives in diseased alfalfa roots and in plant debris for at least 10 years. Infection occurs through wounds to the roots and crown or through cut stems. The bacteria causes the plant to wilt since it grows in the water-conducting tissue (vascular system) of the plant, thereby blocking water and nutrient movement in the plant.

**Management Strategies:** All recommended varieties are resistant to the disease. Since the bacteria can be spread through wounds, it is a good idea to cut young, less-susceptible stands first and then move to older stands. Cut stands when the plants are dry. This will limit or reduce potential spread from infected to uninfected plants. The bacteria can be spread in seed and in hay.

## Common Leaf Spot and Leptosphaerulina (Lepto) Leaf Spot

*Pseudopeziza medicaginis* and *Leptosphaerulina trifolii* or *L. briosiani*

**Incidence:** Although both these leaf spot diseases occur in Ontario, common leaf spot is the more destructive. Leaf spot infection can cause premature leaf loss and thereby reduce the quality and yield of hay, as well as the health and vigour of the crop. Lepto leaf spot can be confused with common leaf spot since leaf symptoms begin as small, black spots (1–2 mm (about 1⁄16 in.)) that have a light tan or brown centre. A yellow halo usually surrounds the leaf spots. Unlike common leaf spot, these lesions will join together to form larger lesions (Figure 13-3).

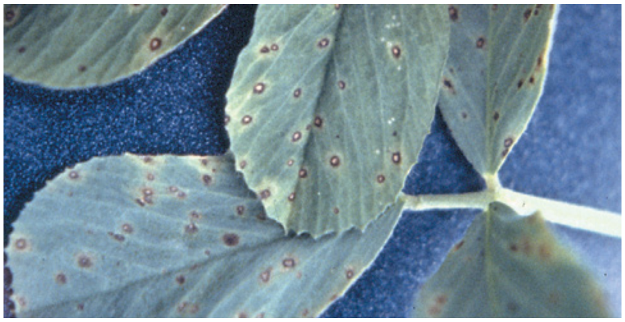

**Figure 13-3.** Leptosphaerulina (lepto) leaf spot starts as small dark spots that enlarge until spots join together. Spots will have a tan centre and a yellow halo.

**Appearance:** Leaf spot diseases are first seen on the lower leaves and then develop or move up the plant. Common leaf spot produces small, circular (1–2 mm (about 1⁄16 in.)) leaf spots that are brown to black. These lesions rarely join together to form larger lesions. Lesions on the upper leaf surface often have a raised centre. Within these raised centres, the black fruiting bodies (bumps) are easily seen with a hand lens. If unsure, put some infected leaves into a plastic bag with some wet paper towels. This will help speed the production of these fruiting bodies. Infected leaves become yellow (chlorotic) and drop prematurely.

**Disease Cycle:** Cool, wet weather favours leaf spot development, so it is found primarily in the early cuttings (spring and early summer) and regrowth (fall). These fungi survive in infected leaves and on dead leaves found on the soil surface. Spores produced on living and dead leaves are spread through the air where they infect new growth. Young leaves are the most susceptible to leaf spot diseases.

**Management Strategies:** Timely harvesting of forages is important to reduce leaf loss and minimize disease in the regrowth. Varieties with tolerance of common leaf spot are available, but no resistance or tolerance to lepto leaf spot has been found. There are few practical control strategies available for leaf spot diseases in forages. Leaf spots can reduce the protein level in legume leaves, so it is important to balance the timing of harvest between the optimum stage for highest protein (bud stage in alfalfa) and the level of leaf spot disease. Refer to Ontario Crop Protection Hub suggested products.

## Fusarium Wilt

*Fusarium oxysporum*

**Incidence:** High soil temperatures favour fusarium wilt. The disease is typically found in stands that are at least 2 years old.

**Appearance:** Early symptoms are wilting stems followed by bleached leaves and stems. Sometimes these take on a reddish colour. Fusarium root rot appears as rusty, dark brown streaks in the centre of the taproot (Figure 13-4). It is often confused with bacterial wilt, which is generally a more yellow-brown colour. In young plants it may appear as damping-off.

**Figure 13-4.** Fusarium root rot appears as rusty, dark brown strands in the xylem of the root.

**Disease Cycle:** Fungal spores can survive indefinitely in the soil.

**Management Strategies:**

- Use varieties that are resistant or highly resistant to fusarium wilt.
- Long crop rotations — at least 3–4 years out of alfalfa — may help lower spore counts somewhat.
- Lime to ensure soil pH is between 6.5 and 7.0, which can reduce disease.

## Verticillium Wilt

*Verticillium albo-atrum*

**Incidence:** Verticillium wilt of alfalfa is a disease that increases with stand age; therefore, it mainly occurs after the second year of production. The fungus responsible for this disease can be found in most areas of Southern Ontario. Fields with a history of the disease may find dead plants in younger stands (second-year). Verticillium wilt can reduce yields up to 50% and shorten the life of the stand.

**Appearance:** Initially, a few stems are affected and eventually, the leaves on infected plants wilt, curl inward and become orange-brown or a bleached tan-brown (Figure 13-5). In the early stages of disease development, leaves will exhibit a V-shaped yellowing of the leaflet tips. Growth is often considerably stunted, and plants eventually die. Although all the plant leaves may die, the stems remain green. The fungus enters through the root or cut stems and is spread from older infected stands to younger stands by harvest equipment, insects and manure. The disease causes a brown discolouration of the interior root and stem (vascular) tissue. Cutting the stem in half will usually reveal this browning.

**Figure 13-5.** Verticillium wilt initially affects each stem causing stems to wilt; curl inward and become bleached. Growth is stunted.

**Disease Cycle:** The *Verticillium* fungus enters the plant primarily through the roots. The fungus blocks or inhibits the plant's ability to move water, resulting in wilting. The fungus survives (overwinters) in infected plant debris. During cool, moist conditions, numerous spores are produced on diseased tissue.

**Management Strategies:** The disease is best managed using varieties rated as resistant and highly resistant. Consult technical variety data from forage seed companies for tolerance and/or resistance to various diseases including verticillium wilt. Treating seed with a fungicide will help reduce early infection. For fungicide guidelines, refer to the Ontario Crop Protection Hub at ontario.ca/cropprotection. The fungus is spread primarily on the cutting bar of forage harvesting equipment. Before harvesting, clean the cutting bar with a 1% solution of bleach followed by a clean water rinse and oil spray. Cut the youngest non-infested fields first, working towards the oldest fields. Early harvest can limit yield and quality losses and slow fungus spread from field to field. Wait 2–3 years between alfalfa crops. Maintain a good weed control program, since some weeds can be alternate hosts.

# Grass Diseases

## Powdery Mildew

*Blumeria graminis*

**Incidence:** Powdery mildew affects most grass and cereal species. It has not historically been considered an economically significant disease in forages, but it can affect the marketability of timothy hay in premium export markets. Powdery mildew can negatively impact both yield and quality.

**Appearance:** The characteristic symptom of the disease is the production of a fluffy white-to-grey fungal growth that often begins on the lower leaves (Figure 13-6). Infection can move rapidly up the plant on leaves, sheaths, stems and heads under favourable conditions. Leaves develop elongated yellow streaks or areas that may turn brown and die prematurely. Severely diseased plants may lodge. Older, light-grey areas of fungal growth often have small black spots. The white-to-light-grey fungal growth is most noticeable in the early morning while the plants are still wet. The infection is superficial, and the fungal growth can be easily removed by scraping the surface.

**Figure 13-6.** Powdery mildew symptoms.

**Disease Cycle:** The fungus survives on crop residues, such as straw or stubble, and living host plants like perennial grasses and fall-planted winter cereals and timothy. Spores that are released are primarily spread by the wind. The spores require near 100% relative humidity and temperatures between 15°C and 21°C. Weather conditions that promote drying of the crop environment such as hot, dry, sunny weather will slow the progression of the disease. Powdery mildew growth stops when temperatures are above 25°C. A dense stand and vigorously growing crop can lead to poor leaf-drying conditions, which are favourable for powdery mildew. Powdery mildew also thrives in fields where high rates of nitrogen have been used. Nitrogen not only increases tiller formation, causing dense stands, but also increases the susceptibility of the crop. Watch for mildew in fields that have had more than 78 kg N/ha (70 lb N/acre).

**Management Strategies:**

- A crop rotation that limits timothy, wheat or other susceptible species from being planted in the field for a minimum of 2 years may lower disease risk.
- Use resistant varieties where available.[1]

# Rusts

Rusts are the most common diseases in forage grasses. The fungi do not produce mycotoxins, but high rust levels may result in feed refusals or coughing in livestock. Rust affects the marketability of hay crops.

## Crown Rust

*Puccinia coronata*

**Incidence:** Crown rust is a major disease of fescues and ryegrasses, but also impacts bromegrasses, orchardgrass, timothy, bluegrasses and reed canarygrass. It is a major disease challenge in forage oats, though it is frequently called "leaf rust" in oats. Crown rust in oats is often serious, and substantial losses can occur, especially in Central and Eastern Ontario.

**Appearance:** The most distinctive symptom of the disease is the production of orange pustules (volcanoes) on the oat leaves and sheathes. These pustules can produce thousands of orange-yellow coloured spores that can spread to other fields or infect adjacent plants. The disease can develop quickly under ideal conditions, and the new pustules can be formed every 7–10 days.

**Disease Cycle:** The pathogen is not seed- or soil-borne. European buckthorn is the primary local source of spores, while another source of spores is blown in from the Southern U.S. There are different races of the fungus and they change over time, which can affect a variety's performance over time. Crown rust is most problematic when the disease develops early and the conditions are mild to warm (20°C–25°C) during the day and mild at nights (15°C–20°C) with adequate moisture (rains, frequent dews).

**Management Strategies:**

- Remove the alternate host, European buckthorn, to reduce crown rust.
- Choose varieties with resistance to crown rust, where available.
- Cut early to reduce losses.[2]

## Leaf Rust and Yellow Leaf Rust

*Puccinia poarum/Uromyces dactylidis, Puccinia poae-nemoralis*

**Incidence:** Host species of *P. poarum* include timothy, fescues and bluegrasses. Leaf rust in orchardgrass is typically caused by *U. dactylidis,* though the fungus can also infect fescues and bluegrasses. Yellow leaf rust affects bluegrasses and fescues. Heavy infection can reduce forage yield and quality.

**Appearance:** Leaf rust affects the leaf blades and sheath. Pustules are found on the upper leaf surface and may be orange-yellow or yellow-brown in colour.

**Disease Cycle:** *P. poarum* overwinters on coltsfoot, which is a source of infection the following spring. It has a similar life cycle to the fungus that causes stem rust. *U. dactylidis* overwinters on *Ranunculus* spp., such as crowfoot and buttercup.

**Management Strategies:**

- Choose varieties with resistance to leaf rust, where available.
- Cut early to reduce losses.[3]

## Stem Rust

*Puccinia graminis*

**Incidence:** Stem rust reduces forage yield and quality, as well as seed production. Timothy, orchardgrass, fescues, ryegrasses and bluegrasses are all host species. *P. graminis* is the same fungus that affects cereals.

**Appearance:** Stem rust begins as dark, reddish-brown spots on both sides of the leaves, stems and heads. When developed, spots will rupture through the surface, releasing spores into the air. The surface of the tissue appears ragged and torn (Figure 13-7). If the plant is allowed to mature, the fungus may also have a black rust stage, which appears as brown-black oblong spots.

**Figure 13-7.** Stem rust can be found on the leaf, sheath, stem, and head.

**Disease Cycle:** Common barberry is necessary for the stem rust fungus to complete its life cycle. The spores resulting from black rust infect barberry, where the fungus completes another growth stage and releases spores that cause red stem rust on forage grasses.

**Management Strategies:**

- Remove the alternate host, common barberry, to reduce stem rust.
- Use resistant varieties where available.
- Cut early to reduce losses.[4]

## Stripe Rust

*Puccinia striiformis*

**Incidence:** Stripe rust can make grasses unpalatable and reduce seed production. Host species include timothy, orchardgrass, fescues, ryegrasses and bluegrasses. *P. striiformis* is the same fungus that affects cereals.

**Appearance:** Stripe rust (Figure 13-8) commonly affects leaf blades and is occasionally observed on heads when the disease is very severe. Infection of the leaf sheaths or stems is rare. The yellow-orange coloured lesions of stripe rust are small, round, blister-like lesions that merge to form stripes.

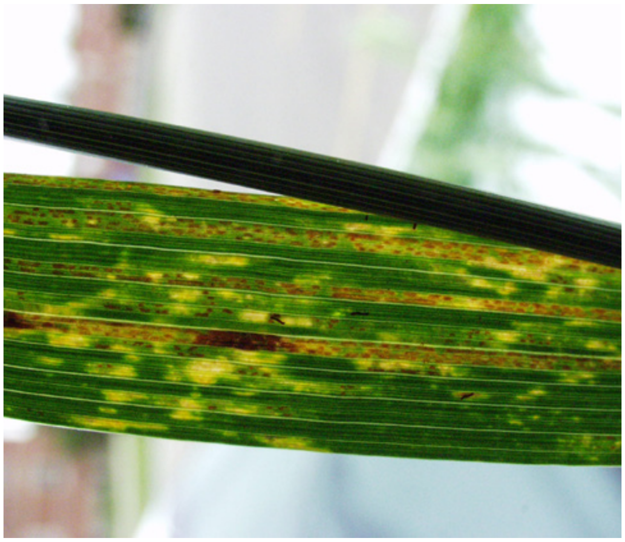

**Figure 13-8.** Yellow-orange coloured lesions of stripe rust and small, round, blister-like lesions that merge to form stripes.

**Disease Cycle:** Stripe rust does not require an alternate host to complete its life cycle. Stripe rust does not overwinter in Ontario and of the rust diseases, stripe rust prefers cooler temperatures. Early spring conditions or a prolonged cool period (10°C and 15°C) with increased leaf wetness are ideal for stripe rust development.

**Management Strategies:**

- Choose varieties with resistance to stripe rust, where available.
- Cut early to reduce losses.[5]

## Septoria Leafspot and Leaf Blotch

### *Septoria* spp.

**Incidence:** Many *Septoria* species cause leaf diseases in grasses and cereals. These have not historically been considered an economically significant disease in forages, but they can affect the marketability of timothy hay in premium export markets. Other host species include bromegrasses, ryegrasses and reed canarygrass.

**Appearance:** Initial infections from septoria leaf spot appear as small, light-green-to-yellow spots between the veins of the lower leaves (Figure 13-9). These spots elongate to form irregular reddish-brown lesions. Embedded in these lesions are small, dark-brown-to-black fungal bodies (pycnidia) that can be seen easily with the use of a hand lens.

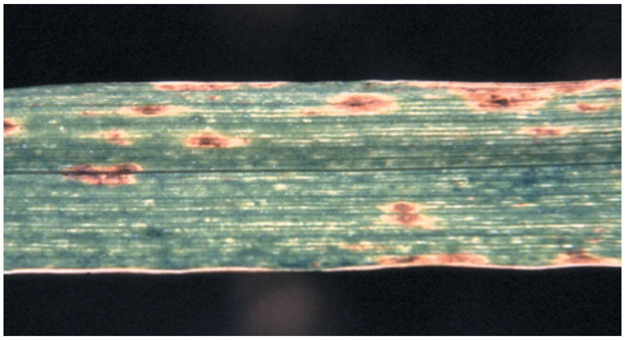

**Figure 13-9.** Septoria leaf spot appears as small light green-to-yellow spots that elongate to form reddish-brown lesions.

**Disease Cycle:** *Septoria* fungi survive on seed, straw, stubble or dead leaves and are favoured by wet or humid conditions, and moderate temperatures. Along with powdery mildew, leaf diseases caused by *Septoria* are often the first that occur in the spring since they thrive under cool, humid, wet conditions. Prolonged wet periods in May and early June result in increased disease incidence. The leaf phases characteristically move from infected lower leaves upward (secondary disease cycles). Septoria leaf spot may develop under snow.

**Management Strategies:**

- Rotate with non-host crops (i.e., legumes and forbs).
- Removing or plowing down plant residue may reduce the amount of spores.
- Dense stands going into winter can increase disease incidence the following spring. A balanced fertilizer program can prevent excessive fall growth that could contribute to disease.[6]

## Endophytes

Endophytes are fungi that grow inside plants. Infected plants do not appear different from uninfected plants. While endophytes are not typically considered a disease of forage crops, their relationship to both animal and plant production is important. Once a stand is infected (often by establishing seed containing the fungus), the endophyte cannot be removed.

Tall fescue toxicosis in livestock is caused by an endophyte that produces the alkaloid ergovaline when stressed. If cattle, sheep and other livestock graze on large amounts of infected tall fescue, their health may be compromised. Cattle may also be more sensitive to heat stress. In horses, tall fescue toxicosis affects broodmares, causing prolonged gestation, abortions, difficulties foaling and a lack of milk production.

Similar endophyte-related animal health issues can occur in perennial ryegrass.

The endophyte also causes palatability issues in grasses. Use endophyte-free seed to reduce palatability problems. Palatability is also better in the fall with the onset of cooler weather and frosts. Tall fescue hay is palatable to cattle and sheep. The seed supply of forage varieties of tall fescue is basically endophyte-free, and animal health problems should not be a concern. Avoid using turfgrass varieties of fescues and ryegrasses, as these frequently contain endophytes.

Researchers in New Zealand realized that endophyte-free varieties of tall fescue and perennial ryegrass were less persistent and more susceptible to insect pests. They developed a novel endophyte that does not produce the alkaloids that impact livestock performance, but still protects the host grass. Currently, novel endophyte-infected varieties of tall fescue and perennial ryegrass are not available in Canada.

# Disease Management

## Crop Rotation

Crop rotation is an important foundation in any pest management program. Rotating to a non-host crop can help break pathogen life cycles and reduce disease pressure. Feed requirements play a large role in determining which crops are included in a forage crop rotation. Work with a nutritionist to determine where crop swaps might be feasible in the ration to diversify the crop plan.

Correctly identifying disease challenges can inform crop rotation decisions. It is easy for forage rotations to become grass-heavy, and a good understanding of which diseases cross species can help prevent issues. Where possible, alternate a grass-type plant with a legume or non-legume forb.

Consider the length of persistence of pathogens. Recommendations for brassicas are that they should not be grown in the same field more than once every 4 years to reduce the impacts of soil-borne diseases.[7]

## Foliar Fungicides

Fungicide labels include a pre-harvest interval (PHI) that provides information on how much time is required between application and cutting or grazing. Not all fungicides are appropriate for use on forages, despite being labelled for use on forage crop species — especially species that are commonly grown for grain. Some products will clearly state that the formula is not safe for use on feed, fodder, forage or silage. There will be products that do not mention silage or feed on the label. These have not been tested for their effects on livestock, and crops treated with them should not be fed.

Refer to the Ontario Crop Protection Hub at ontario.ca/cropprotection, for more information. Always read and follow the label.

Research on the return on investment of applying a fungicide to forage crops is limited to only a few species and diseases.

### Alfalfa

Work out of Wisconsin suggests that, even when hay prices are high, the odds of a fungicide application paying for itself in added value are less than 50%. However, the results of several studies indicate that fungicides on alfalfa are most likely to pay for themselves when the following criteria are met:

- weather conditions favour fungal disease development
- a cultivar resistant to fungal diseases is not available
- the crop has a high yield potential
- the cutting interval is long (35+ days)[8,9,10]

### Corn

There is a lack of consensus in the scientific literature on whether the risk of mycotoxins in silage corn is higher or lower than in grain corn. Some studies show that leaves and stalks tend to have higher deoxynivalenol (DON) concentrations than ears and kernels.[11,12] Other studies maintain that while stalks and secondary ears may be most susceptible to fungal disease, since the whole crop is harvested, any mycotoxins present are diluted in silage corn, resulting in a lower risk than when feeding grain.[13]

Most research on fungicide use in corn focuses on grain production. A research project in Eastern Ontario looked at mycotoxin reduction and silage corn yield from 2013–2015. Weather conditions had the biggest impact on whether mycotoxin levels were high enough to negatively impact animal health or production. DON was the mycotoxin found in the greatest quantities in all 3 years. Fungicide applications reduced the amount of DON in the silage by an average of 66%. While there was a slight yield improvement (on average 4%), the yield improvement alone was not enough to pay for the fungicide application.[14]

### Oats

Oats can be very susceptible to crown rust. Select resistant varieties for forage. The Ontario Cereal Crops Committee trial results on gocereals.ca provide resistance ratings. Monitor the stand for signs of the disease. If crown rust is found and the weather is conducive for continued development, consider a fungicide application. Refer to Ontario Crop Protection Hub at ontario.ca/cropprotection for fungicide options.

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# Additional Sources

This chapter contains excerpts from the following OMAFRA source:

Publication 811, *Agronomy Guide for Field Crops.* 2017.

CHAPTER 14

# Harvest

## Timing

Stage of maturity at harvest is the most important factor in determining the nutritional quality of a forage crop.

Forage yield is the amount of dry matter produced. Just like grain crops have industry-accepted moisture contents for standardizing yield (e.g., grain corn is 15.5% moisture, soybeans are 13%), forage yield is always on a dry matter basis, or 0% moisture. Since forages differ from grains in that they can be successfully stored at a wide range of moisture contents, using dry matter for yield enables comparisons between forages stored in different ways. In addition, livestock rations are formulated on a dry matter basis. Typically, forages reach peak yield at full bloom, however, some multi-cut crops yield better over the entire growing season if cut earlier, as cutting before they enter reproductive growth stages encourages more regrowth.

As plants mature, nutritional quality declines. The exception is silage corn, due to the high starch content of the kernels (see Chapter 4, *Silage Corn,* for more details). While the forage is in the vegetative growth stages, the decline in crude protein and digestible fibre, and the correlating increase in lignin, is relatively small. However, once the plant enters its reproductive growth stages, the rate of lignification increases, and crude protein and digestible fibre contents drop much quicker. Correctly timing forage harvest involves balancing increasing yield with decreasing nutritional quality to match livestock needs as closely as possible.

Grasses lose nutritional quality faster than legumes. Mixed stands should be harvested when the grass (including cereals) is ready. If the legume is maturing later than the grass, waiting on the legume component to reach the ideal growth stage will result in higher yields of a lower-quality forage.

In addition, dry weather is required to make dry hay. A compromise may have to be made between rained-on hay at the ideal time of cutting, or hay that is a little more mature that has not been rained on. Silage and baleage do not require as much wilting, so the window of dry weather required to dry down the crop is generally shorter. This usually reduces how often producers must choose between optimum maturity or a cut crop that has not been rained on.

## Growing Degree Days

Growing degree days (GDD), an estimate of accumulated heat, are used to predict the growth and development of plants, insects and diseases during the growing season. Insect, disease and plant development are very dependent on temperature and the daily accumulation of heat. The amount of heat required to advance a plant or pest to the next development stage remains constant from year to year, however, the actual amount of time (days) can vary considerably because of weather conditions.

Each crop, insect and disease species has a minimum base temperature or threshold below which development does not occur. These base temperatures have been determined experimentally and are different for each organism. GDD information can be very useful for predicting plant, insect and disease development. To calculate GDD, first determine the mean temperature for the day. This is usually done by taking the maximum and minimum temperatures for the day, adding them together and dividing by 2. The base temperature is then subtracted from the mean temperature to give a daily GDD. If the daily GDD calculates to a negative number, it is recorded as 0. Each daily GDD is then added up (accumulated) over the growing season.

**The GDD equation used by OMAFRA is calculated as follows:**

**Daily GDD = ((T max + T min) ÷ 2) – T base**

**T max** = the daily maximum air temperature

**T min** = the daily minimum air temperature

**T base** = the GDD base temperature for the organism being monitored

**Example:**

Maximum temperature: 28°C

Minimum temperature: 15°C

Crop: alfalfa

Base temperature for alfalfa: 5°C

**Calculation:**

Daily GDD = ((28 + 15) ÷ 2) – 5 = 16.5

Therefore: 16.5 GDDs were accumulated for that day for the alfalfa GDD model.

Tracking GDDs can help producers consistently harvest at their ideal forage stage. For example, it takes about 390 GDDs (Base 5˚C, March 1 start) for alfalfa to reach the early flower stage.

# Equipment

## Mowers and Mower-Conditioners

Cut height affects forage yield and quality, as well as crop regrowth and persistence. A low cutting height creates a risk of scalping the field and throwing soil into the forage, which increases ash content and can contaminate the feed. Cutting is a stressor, and cutting crops too low can remove growth points and any above-ground energy stores that are needed for regrowth. As a general guide, do not cut forages lower than 5–7.5 cm (2–3 in.). Different crop species have different tolerances for cutting heights, so check the crop chapters to determine if the cut height should be higher. In general, legumes can be cut closer than grasses, and cool-season crops can be cut closer than warm-season crops.

Conditioning speeds drying time and synchronizes the drying of stems and leaves. Conditioners crimp or crack the stems of forage plants to allow stem moisture to escape more readily. The goal of conditioner maintenance and adjustment is to have adequate conditioning and optimize drying, while minimizing shattering and leaf loss. Under-conditioning increases the risk of rain damage, while over-conditioning increases cutting, raking and baling losses. Ontario's humid climate can result in heavy dews and prolonged drying time, so conditioning is especially important when making dry hay.

Adjust mower-conditioners according to the owner's manual. The adjustments on roll conditioners include roll clearance and roll pressure. Adjustments on impeller conditioners, designed for grasses rather than alfalfa, include impeller speed and clearance between the impeller and the hood.

Roll clearance should be slightly smaller than the alfalfa stems, which usually means setting the clearance at 1.5–2.5 mm ($\frac{1}{16}$–$\frac{3}{32}$ in.). Too big a gap results in under-conditioning. Rolls that touch wear prematurely and cause excessive leaf loss. Heavier crops, such as first-cut, require more roll pressure (spring tension). Too much pressure can cause excessive leaf loss. Alfalfa stems should be crimped or broken every 7.5–10 cm (3–4 in.) to allow moisture to escape. At least 90% of the stems should be cracked or crimped, with less than 5% of legume leaves bruised or blackened.

Increasing the swath width is often limited by the width of the conditioner on the mower. Wide swaths wilt faster than narrow ones, but if a producer must forgo conditioning to widen the swath, does that negate any advantage of having a wide swath? According to research from Cornell University, conditioning reduces wilting speed in wide swaths at haylage moisture levels by disrupting the capillary flow and evapotranspiration of moisture through the stems to the stomata (pores) in the leaves.

In a narrow dense windrow, the stomata close, so conditioning is an important drying mechanism. On the other hand, where there is a wide swath with sunlight to keep the stomata open, the Cornell research indicates producers could forgo conditioning in a haylage system.

This is in contrast to a field study by Dr. Kevin Shinners (Agricultural Engineering, University of Wisconsin) that showed a benefit to conditioning in all haylage swath width situations. He concluded that it may only be advantageous to give up conditioning in situations where swath width could be nearly doubled (i.e., 35% to 65%) by eliminating the conditioner. More research is being done to sort out these conflicting conclusions.

Conditioning is unquestionably essential when moistures fall below 60%–65% during dry hay making (see Moisture Content and the Hay Drying Curve later in this chapter). Conditioning stems is extremely important at lower moistures in making dry hay. Strategies for wilting silage are quite different from dry hay making, but wide swaths are advantageous for both.

## Tedders

If a partially dried hay field does receive a heavy rain, tedders or rotary rakes can break up a windrow that has clumped and matted into the stubble. Moving a windrow onto a drier surface or fluffing onto stubble can speed drying. Tedders are better suited to grasses than alfalfa. Avoid using a tedder on alfalfa at moistures less than 50%. Avoid driving with tractor tires on the swath and causing leaf loss.

Tedders can also be used to shake a heavy dew off a cut crop very early in the morning. This will speed up drying throughout the day. Tedding should be finished before the top of the swath is dry.

## Rakes and Mergers

Raking is done to narrow the swath for the baler, and to move the wetter material at the bottom of the windrow to the outside. Every time hay is raked there is some leaf loss, so rake strategically. The drier the hay is at raking, the greater the leaf loss. If possible, raking alfalfa at moistures between 30% and 40% is often a good compromise between low leaf loss and good drying. Leaf loss can be extremely high if raking at 20% moisture. Hay that is almost dry is less likely to shatter when raked in the early morning when the dew is still on.

Some rake designs are more aggressive and do a better job of fluffing but are also more prone to leaf loss, particularly at lower moistures. Uniform, consistent raking without bunching is required to avoid wet bales.

Ground-driven wheel rakes should not be used for baleage production. They are not designed to move a heavy, wet crop and because of this they incorporate more soil into the windrow than other types of rakes. The soil is more likely to stick to the wet forage and cause clostridium contamination. Wheel rakes were designed for dry hay production, where they are moving a dryer, and therefore lighter crop, and the lower moisture content reduces soil retention.

## Effect of Wheel Traffic on Forage Crops

Hay fields must be driven on to harvest a crop. Unlike haylage systems, where the forage is completely removed a day or two after cutting, dry hay harvest results in a great deal of wheel traffic that often occurs 5 days or more after cutting. Additional traffic activities include raking, baling and bale removal with a front-end loader tractor and wagons. Research began in 2000 in numerous U.S. states by Dr. Dan Undersander (University of Wisconsin) and others, to investigate the effects of wheel traffic on alfalfa yield.

This research showed that there can be significant yield losses as a result of wheel traffic damage, and that some alfalfa varieties are more susceptible than others. Driving over the plots reduced subsequent yields (second and third cuts) by an average of about 25%–30% in the wheel tracks. Typical operations of cutting, raking, baling and hauling results in about 25%–30% of the field being in at least one wheel-track, but this could be as high as 60%.

Traffic damage yield reductions are largely a result of the breakage and damage to new shoot regrowth. Soil compaction may play a much smaller role. Regrowth typically begins 5 days after cutting. The longer the delay after cutting, the more regrowth and the more damage results. Weakened plants may also result in a carryover effect to the following year.

Dr. Steve Bowley, University of Guelph, investigated wheel traffic using some of the Ontario Forage Crops Committee variety plots at the Elora Research Station in 2003. This research showed a negative yield response to wheel traffic in grass species, as well as legumes.

There is still much to learn about the significance of wheel traffic damage in dry hay harvest and management practices that can help to minimize it. Here are a few recommendations:

- Harvest as soon as practical after cutting.
- Use smaller tractors where possible. For example, do not use the big loader tractor to rake.
- Avoid unnecessary trips across the field.
- Collect bales and remove them from the field as soon as possible after baling.
- If manure is going to be applied, traffic damage is another reason it should be done as soon as possible after cutting.
- Use traffic tolerant varieties when they become identified by research.

# Moisture Content and the Hay Drying Curve

Correctly timing how long to let the crop wilt when harvesting a forage crop will help ensure that it stores well. It either needs to have enough moisture to ferment correctly, or low enough moisture content to preserve as dry hay.

There are three types of moisture to consider when wilting a forage crop: stem moisture, dew moisture and air humidity. Stem moisture is the amount of water within the plant. Dew moisture is water outside the plant, whether it is from rain or condensation (dew). Air humidity affects how quickly the crop can dry. If the air is already holding a lot of water, it takes longer for the forage to dry down, even if the air temperature is hot.

A standing forage crop is typically between 70% and 85% moisture. During the first phase of drying, the plants are losing moisture through open stomata in their leaves (Figure 14-1). Forage crops do not stop photosynthesis and cellular respiration when they are cut. These processes continue until the plant's moisture level drops below 60%. Stomata will stay open and enable crop drying so long as the leaves are exposed to light. Most of the wilting for a silage/haylage crop occurs in this way. Part of why hay at the bottom of a windrow dries more slowly is because the stomata are closed in the dark bottom of the pile. This is one reason wide swaths reduce drying time.

In the second phase of drying, the stomata are closed (moisture content is less than 60%), and the crop is losing moisture from the stem rather than from inside the leaves. This wilting is slower than the first phase. Conditioning the crop can speed up this second phase by cracking the stem to allow more moisture out. Most of the dew moisture on the outside of the plant is lost during this second phase. Crops wilted for baleage will have some of their drying time in this phase.

The third drying phase is the slowest, as the remaining water (<30%) is held very tightly in the stems. However, it is critical for dry hay to get the moisture content below 18% for small square bales, and below 14% for large bales. Air humidity has a large effect on this drying phase, which makes it challenging in Ontario's climate. Hay dryers can be used to speed up this phase, reducing the risk of the crop being rained on.

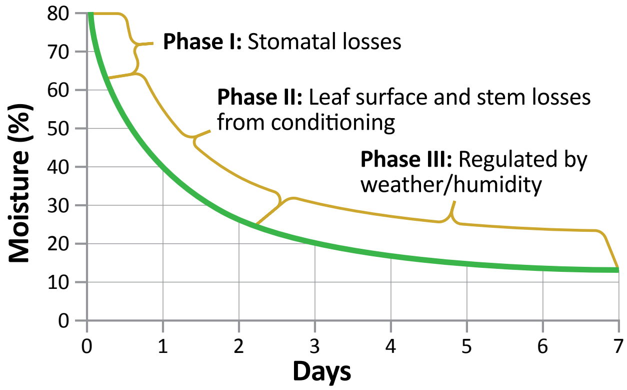


**Figure 14-1.** Hay drying curve.

# Moisture Testing

The only way to know whether a crop is appropriately dry is to measure the moisture content. Using the results to guide the rest of the harvest process will protect yield and quality in storage. There are several methods available to measure the moisture content of a forage.

Be aware that samples have residual moisture that is not removed when dried with a Koster Tester or microwave but will be removed in laboratory ovens. The most accurate option is to send a sample by overnight delivery to a forage laboratory for oven drying. Results can be e-mailed immediately.

The Miner Institute has estimated that Koster Testers and microwaves underestimate moisture by about 3%. A 68% moisture sample reading is actually about 71% moisture. When using a Koster Tester or microwave, taking the time to carefully dry the sample is important. The finer the sample is chopped, the easier it will be to dry and the more accurate the result.

## Microwave Oven Method

A microwave oven can be used to dry forage samples quickly. The main advantages to this method are the speed of drying and the availability of the equipment. Care must be taken not to burn the sample. The disadvantages of using a microwave to determine moisture content are that it can only dry one sample at a time, it takes time and the smell tends to linger.

**Technique:**

1. Weigh the container and record the empty weight; OR tare the scales with the empty container on them.
2. Add 100 g (3.5 oz) (W1) of forage to the container.
3. Spread the weighed forage sample on a paper plate or place it in a paper bag and put it in the microwave oven.
4. Place a 250 mL (1 cup) glass three-quarters full of water in the microwave to prevent igniting the sample or damaging the microwave oven.
5. Heat at 80%–90% of maximum power for 4 minutes.
6. Remove the sample, mix it and weigh it.
7. Continue to reheat for 2-minute intervals, re-weighing each time. To prevent burning, use lower heat and 30-second time intervals as it approaches being dry. If the weight of the sample does not change after two or three drying intervals, it is 100% dry. This is the final dry weight (W2). A slightly charred sample should not affect accuracy of the moisture determination but if the sample burns the test should be repeated.
8. Calculate moisture content as follows:
   Moisture Content = (W1–W2) ÷ (W1) × 100

**Example:**

W1 = 100 g
W2 = 36 g

Moisture Content = (100–36) ÷ (100) × 100 = 64%

## Koster Tester Method

The Koster Tester was specifically developed for drying grains and forages for moisture testing. Its main advantage is the ease of use; however, the drying time involved can result in a mismatch between the sample result and a cut crop wilting in the field.

**Technique:**

1. Weigh the drying basket of the tester and record the empty weight; OR tare the scales with the empty basket on them.
2. Add 100 g (3.5 oz) (W1) of forage to the drying basket.
3. Place the basket with forage sample on top of the heating unit and let it dry for 30 minutes.
4. Weight the sample and record the weight.
5. Dry the sample for an additional 10 minutes. Weigh the sample again and record the weight.
6. Repeat step 5 until the weight change is less than 2 g (0.07oz) repeatedly (W2).
7. Calculate moisture content as follows:
   Moisture Content = (W1–W2) ÷ (W1) × 100

**Example:**

W1 = 100 g
W2 = 36 g

Moisture Content = (100–36) ÷ (100) × 100 = 64%

## Electronic Testers

Electronic moisture testers estimate percent moisture by measuring the resistance of electricity to move through a hay sample. The wetter the hay, the more electricity flows through. There are two basic types: in-baler sensors and hand-held probes.

In-baler moisture sensors enable the operator to monitor moisture on-the-go from the tractor seat. Sensors can be located in-chamber on square balers, and on the sidewalls of large round balers. In-baler sensors have the advantage of giving numerous, continuous readings. They are usually installed as a component of a hay preservative application system. Preservative application rates can then be adjusted either manually or automatically according to the moisture. In-baler moisture sensors with automatic applicators are commonly included on large square balers and are also available for large round and small square balers.

Hand-held probes are designed for measuring the moisture content of a bale. Accuracy is affected by bale density, whether it is grass or alfalfa, whether the water is stem moisture or dew moisture, and whether acid has been applied. Electronic moisture testers need to be calibrated to the conditions and well maintained. Beware that digital readings do not give you a false sense of accuracy. Moisture testers should be used to supplement personal experience.

Hand-held probes cannot accurately measure the moisture content of forage in a windrow. Ron Thaemert from the University of Idaho developed a windrow sampling tool that enables producers to compact a sample of cut hay so that a probe can measure the moisture content (Figure 14-2). Materials required to build a windrow sampling tool are as follows:

- 61 cm (2 ft) of 2 in. diameter ABS pipe
- 91 cm (3 ft) of 1 ¼ in. diameter PVC pipe
- two 1 ¼ in. PVC pipe caps
- 2 in. ABS female coupling
- 2 in. ABS cleanout adapter
- 2 in. ABS cleanout plug
- solvent cement

With solvent cement, attach the pipe caps on the 1 ¼ in. PVC pipe. This will be the plunger. Glue the cleanout adapter on one end of the 2 in. ABS pipe. Screw the ABS cleanout plug into the adapter. This is the collection tube and it will simulate a bale chamber.

To use the windrow sampling tool, turn a portion of a windrow over. By feel, select the dampest hay in the sample area and fill the collection tube. Place the capped end of the collection tube on the ground. Insert the plunger into the collection tube to compress the hay. Insert the moisture testing probe into the collection tube and record moisture readings at depths of 10 cm (4 in.), 20 cm (8 in.), 30 cm (12 in.) and 40 cm (16 in.). Use the highest of these readings as the sample moisture.

Moisture content varies within and along windrows, and across the field. A minimum of 20 windrow samples are recommended for every 180 tonnes (200 tons) of forage to give producers a clear indication of how dry the crop is.[1]


**Figure 14-2.** An electronic bale moisture probe cannot measure the moisture content of loose hay. Using a windrow moisture sampler to compact the hay sample makes rapid moisture testing before baling possible.

### Near Infrared Reflectance Spectroscopy (NIRS) Testers

NIR spectrometers shine infrared light, which is invisible to human eyes, at the forage sample and measure how much of the light bounces back. The bounce pattern is compared to a calibration for the type of forage in question, which provides an estimate of the amount of water in the sample. Handheld NIR spectrometers are capable of measuring moisture content very quickly and easily.

# Harvesting Hay

Fast drying is key to successful haymaking. In this part of the world, good haymaking periods without rain are frequently narrow. It is often a struggle between getting the hay dry enough to bale before the next rain or baling before the hay is quite dry enough and getting mouldy, dusty hay.

Conditioning and raking must be balanced against excessive leaf loss. While the weather is beyond a grower's control, there are management decisions that can be made to increase the chance of making good-quality dry hay.

Swath width is an easy adjustment that has a big impact on drying time. Spread the crop as wide as practical. Do not cut hay into a tight windrow. A wider swath will dry faster, because more area of the hay is exposed to sun and wind. Solar radiation cannot penetrate very deep into the swath. University of Wisconsin research indicates that a 3.6-m (12-ft) haybine laying a 2.7-m (9-ft) swath will reduce drying time by 35% versus a 1.8-m (6-ft) swath. Wind speed and humidity are the most influential weather factors affecting drying time.

A higher cutting height (7.5–10 cm (3–4 in.)) comes at the compromise of some yield loss but allows air to move underneath the swath and speeds drying. If the ground is wet and in contact with the windrow, the hay will absorb moisture.

Cutting hay in the morning, after the dew is off, maximizes daylight hours for drying and minimizes respiration losses. Research that suggests delaying cutting until late in the day to maximize sugar content is based on the dry environment of the western U.S. and does not typically apply to the high humidity conditions of the Great Lakes area.

The reasons for using either round or square bale systems vary from farm to farm (Table 14-1). Existing baling and handling equipment, storage facilities, amount of hay made and the availability of local custom operators are all factors to take into consideration.

**Advantages of round bales:**

- more widely available, less expensive baling and wrapping equipment
- variable diameter bales (hard core balers) can be made smaller to reduce weight

**Advantages of large square bales:**

- safer to handle than round bales
- higher stacking density (reduced storage space and cost)

**Table 14-1. Approximate Bale Weights**

| Bale Type | Bale Size | Approximate Bale Weight (as fed)[1] |
|---|---|---|
| Small square bales | 0.9 m × 0.38 m × 0.45 m (3 ft x 1.25 ft × 1.5 ft) | 22–35 kg (50–75 lb) |
| Large round bales – soft core | 1.2 m × 1.5 m (4 ft × 5 ft) | 180–275 kg (400–600 lb) |
| Large round bales – hard core | 1.2 m × 1.5 m (4 ft × 5 ft) | 385–408 kg (850–900 lb) |
| Large round bales – hard core | 1.5 m × 1.8 m (5 ft × 6 ft) | 690–910 kg (1,500–2,000 lb) |
| Large square bales | 0.9 m × 0.9 m × 2.1 m (3 ft × 3 ft × 7 ft) | 164 kg/linear metre) (110 lb/linear foot) |

[1] Bale weights will vary with moisture content, density and species composition
*Source:* Clarke and Stone, 2016.

## Preservatives

Hay preservatives are additives that contain acid, which enables dry hay to be baled at slightly wetter moisture content than ideal. The goal of using a preservative is to prevent mould growth and spoilage in "almost dry" hay.

> **CAUTION!**
>
> Hay preservatives should not be confused with silage inoculants, as these products work in opposite ways. Preservatives lower the pH of the hay to a point where mould and other microbe growth is limited, which prevents spoilage. Inoculants contain living bacteria that will ferment a forage crop in an airless environment like a silo; they will not prevent damp hay from spoiling.

Moulds greatly reduce the value of dry hay, particularly when targeting the high quality horse hay or dairy hay markets. Moulds consume hay nutrients and cause dry matter losses, as well as producing toxins that are detrimental to animal health. Mouldy, dusty hay contains spores that can cause respiratory problems, particularly with horses. Mould growth can even result in hay fires from spontaneous combustion.

The most common acid in hay preservatives is propionic acid. Propionic acid is an organic acid that acts as a fungicide, inhibiting the growth of aerobic microorganisms that can cause heating and moulding. Other organic acids, such as acetic and citric acids are sometimes also included, but propionic acid is the most effective as a mould inhibitor. The propionic acid inhibits mould growth while the bales "sweat" and cure down to safe moisture levels by dissipation and evaporation.

There are three situations when propionic acid application to dry hay is most economical:

- used strategically to avoid rain damage on "almost dry" hay when the weather does not cooperate
- large dense bales that are difficult to dry to low enough moistures to avoid mould
- custom operators and producers baling large volumes that can pass the costs onto customers that demand mould- and dust-free hay

Propionic acid is sprayed onto hay as it enters the baler. Equipment includes a baler-mounted applicator with a pump, nozzles and tank.

Read and follow label directions. Enough acid must be applied using the correct rate of active ingredient for various moisture levels for it to work properly. Different products have different concentrations of active ingredients. Using very dilute products provides greater coverage but requires more water to be applied on the hay you are trying to dry.

Application at the correct and uniform rate is key. Uneven windrows or fields with wet spots will not have uniform moisture. Use a moisture tester to determine application rate, using the highest reading. If you use the average reading, you won't get enough acid on much of the hay to prevent spoilage. Spraying should be as uniform as possible to ensure good coverage.

Hay can still heat and become mouldy and discoloured if inadequate acid is applied. Tightly stacked bales in a confined area do not allow the bales to "sweat" and cure. The acid can dissipate in 4–6 months, which may be before hay moisture is low enough if conditions are unfavourable. Extended periods of high humidity will extend the curing time. Do not store treated and untreated dry hay in direct contact with each other, as the moisture will migrate to the untreated hay.

The original propionic acid products were unbuffered, which meant they were highly corrosive, very volatile and difficult to work with. Products now marketed are buffered to a pH of 5.8 to 6.0 with ammonium hydroxide. Buffered products are much less volatile and corrosive, making them much easier to use. Other ingredients sometimes included are surfactants and green colouring. Products differ in concentration of propionic acid, so purchase decisions should be based on the price per kg of active ingredient.

Hay treated with buffered propionic and other organic acid products is safe to feed to livestock. Propionic and acetic acids are organic acids that are produced by microbes in the rumen (and the cecum and colon of horses) and then used by the animal as part of the digestion process. Some horse owners are not comfortable feeding acid-treated hay and prefer not to purchase it. There may initially be some propionic odour in the hay until it has dissipated. Be sure to inform hay buyers that propionic acid has been applied.

## Dryers

A properly managed hay drying system reduces field curing time, lessens the risk of losses due to rain, minimizes leaf loss and eliminates the danger of fire due to spontaneous combustion. In Ontario's humid climate, a hay dryer is a valuable tool for consistently making high-quality hay.

The hay dryer is designed to dry tough or damp hay but not wet hay. Field dry the hay to an average moisture content of 25% before baling. Hay with a high grass content may be baled with a slightly higher moisture level. Bale the hay at normal baler tension and make slight adjustments, if necessary, for high moisture content. Remember that the bales will shrink slightly during the drying process.

The capital cost of the hay drying system varies, depending on the type and size of the system. Operating costs depend on hay moisture content and weather conditions during the drying period.

# Harvesting Baleage

The key to good baleage is the exclusion of oxygen quickly and completely. Start with a very compact bale to reduce air pockets in the bale. Tight bales are made by reducing the tractor speed and picking up hay directly from the windrow that has not been raked. If raking is required to allow faster drying, try to maintain a wide windrow. Hard-core balers are preferred over soft-core balers. Both roller and belt type balers can be used. Bale density should be around 192 $kg/m^3$ (12 $lb/ft^3$). This equates to a weight of 544 kg (1,200 lb) in a typical 1.2 m × 1.2 m (4 ft × 4 ft) round bale at 50% moisture. Plastic twine is recommended for tying bales, as the oil-based preservative in sisal twine will degrade plastic wrap.

Bales should be moved to the storage area immediately. If left too long, they will begin to heat and lose feed value. The sun may evaporate moisture on the outside of the bale, making stems brittle. Bales, especially higher-moisture bales, lose shape, making them more difficult to wrap. Storage should be complete 6 hours after baling and not later than 12 hours.

**Advantages of baleage:**

- uses existing haymaking equipment
- lower harvest losses than dry hay
- less weather dependent than dry hay systems
- higher-quality feed (due to earlier harvest window)

**Disadvantages of baleage:**

- heavier bales may require larger handling equipment
- increase in annual costs
- potentially higher storage losses

Dry matter losses in the field, largely the result of shattering and loss of protein-rich leaves, are cut substantially by harvesting a wetter material. For example, harvesting baleage at 55% moisture as opposed to dry hay at 18% can cut field and storage losses approximately in half (Figure 14-3).

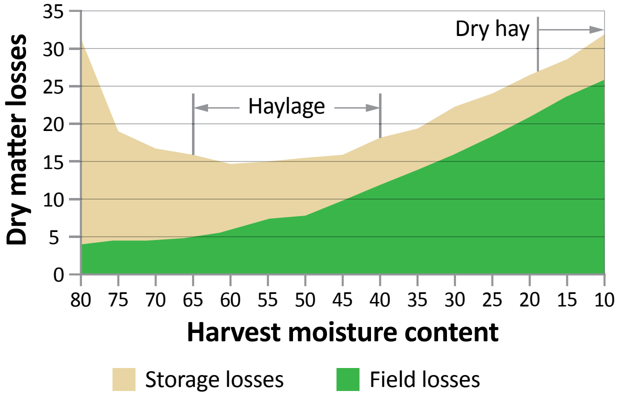


**Figure 14-3.** Field and storage losses.

Use only top-quality forage for baleage. Poor quality, rain-damaged material, or a forage crop that is mature and lacks the sugars necessary for good fermentation will not produce quality feed and will have a reduced storage life.

Wilt the crop to 50%–60% moisture. At this moisture level, fermentation is more favourable in terms of sugar content than in wetter material, and seepage losses are minimized. The amount of forage mowed must be coordinated closely with drying conditions, baling and covering. If the crop gets much drier than 40% moisture, let it dry for hay. Ensiling material with too little moisture increases the risk of heating due to increased oxygen penetration, which will lead to mould growth and a marked depression in the protein digestibility.

Proper machinery for making and transporting heavier, high-moisture bales is necessary. Do not attempt to work with very large bales. A 1.2 m × 1.2 m (4 ft × 4 ft) (diameter × length) bale at 55% moisture will weigh 544 kg (1,200 lb) whereas a 1.2 m × 1.5 m (4 ft × 5 ft) bale at 55% moisture content will weigh 680 kg (1,500 lb).

It is important to move the bales to storage and enclose them in plastic as soon as possible after baling. Regardless of whether the baleage is stored individually, in tubes or in stacks, sealing all air out is critical. During the respiration stage of the ensiling process, the oxygen that is trapped in storage is rapidly consumed by aerobic bacteria. Anaerobic bacteria, which survive in the absence of oxygen, begin to grow and multiply in the fermentation stage and convert the plant sugars into organic acids – mainly lactic and acetic.

With production of acids, the pH of the silage is reduced from an original level of 7.0 to a final pH of 4.0-5.0, while baleage has a pH of 4.5–5.5. Fermentation ceases when bacteria growth is stopped by the accumulation of acids. The forage will then remain at a stable pH with no bacterial growth and can be preserved for a long time, providing there is no exposure to air.

Using silage additives to aid fermentation is generally unnecessary, however they may be beneficial in situations where forage material is drier than recommended, or the wilting conditions are cool and dry.

# Harvesting Silage

## Wilting

Wide swath haylage to achieve “haylage-in-a-day” and improve forage quality is becoming a popular management practice. This is contrary to the more typical practice of using the mower-conditioner to place the swath in a narrow windrow for a day or two of wilting, and then chop directly. Wide swath haylage requires some innovation and significant changes in both equipment and management, but research indicates that improvements in forage quality can be quite impressive.

Rapid wilting after cutting is critical to minimize respiration losses of sugars in high-quality haylage. This is especially true for higher yielding first-cuts. Plant respiration continues after cutting until about 60%–65% dry matter, when the cells die. Respiration converts stored carbohydrates (starch and sugar) to carbon dioxide, heat and moisture, and causes dry matter losses and increased fibre percent. Forage that is higher in the soluble carbohydrates will have greater digestible energy, but also can provide a more readily fermentable substrate to lactic acid bacteria, resulting in better haylage fermentation. The longer the wilting period in the field, the greater the respiration losses (less sugars), and the lower the forage quality.

Wider swaths dry faster, so adjusting the mower to leave as wide a swath as possible makes sense. Research by Tom Kilcer, Cornell University Extension, indicates that wide swath width (85% of cutter-bar width) and sunlight (cutting in the morning) are the keys to fast wilting for haylage high in digestible energy and improved fermentation. Freshly cut forage does not know it is dead yet. Carbohydrates gained from photosynthesis in a wide swath exposed to sunlight typically exceeded the respiration losses. The Cornell research indicates that wide swaths can significantly improve forage quality, consistency and milk-per-ton of haylage. Milk per ton was improved by 136 kg (300 lb). As a bonus, haylage-in-a-day also reduces the risk of rain damage.

Most mower-conditioners have an easy swath width adjustment. Dr Ron Schuler (Extension Engineer, University of Wisconsin) reports that the average maximum swath width on the North American market is 61.4% of the cut width, with a range of 28%–87%. Self-propelled widths are usually narrower. Swath width percentage should be a consideration when purchasing a new mower; the wider the better.

Of course, wide swaths will likely require that the swaths be moved and narrowed for chopping. This is an obstacle preventing many from making wide swath haylage. Some are adopting the use of windrow mergers that use a pickup and belt (similar to an inverter, but wider) rather than rakes, in order to reduce the risk of rocks, clostridia and ash. A rock in the chopper is a problem to be avoided. Combining two or more windrows into one with a merger requires an extra field operation, but it increases chopper capacity and speed. Moving an “almost ready” swath with a merger also speeds wilting. A merger is cheaper and faster to run than a harvester.

There is some concern about driving on a wide swath. The Cornell research indicates that in a wide swath situation, driving on the cut swath with the tractor is not an issue that significantly affects drying. However, there may be some potential for soil contamination that adversely affects fermentation, particularly in wet field conditions. Tractor tires can be set as wide as possible.

Before purchasing wide swath haylage equipment, it is important to consider the compatibility of the:

- mower (or mower-conditioner) swath width
- merger pick-up width
- forage harvester pick-up width

Leaf stomata are generally open during the day and closed at night (or on the bottom of a tight swath). A wide swath maximizes exposure to sunlight, which keeps the stomata open and maximizes exposure to solar radiation (heat and lower humidity). Contrary to some Western U.S. research, in conditions similar to Ontario with high humidity and warm nights, respiration losses during the night exceed the extra sugars expected by cutting late in the day.

## Chopping

The size of chopped forage particles affects how well the crop packs in the silo, which influences fermentation efficiency. Large particles resist packing more than small ones, and this resistance increases the amount of air left in the silo. The extra air slows fermentation, which can increase shrink.

Particle size also affects how the silage feeds out. If the chop length is too short, the forage will pass through the ruminants’ digestive tracts too quickly and can cause health issues such as rumen acidosis. If the forage is not chopped fine enough, the coarse material will fill animals quickly, and dry matter intakes will decline. Particles chopped to an ideal size will stimulate chewing and saliva production, buffer against rumen acidosis and optimize dry matter intake.

Theoretical length of cut should be set at 10 mm (⅜ in.) for alfalfa haylage to provide 15%–20% of forage particles at greater than 37.5 mm (1 ½ in.) long. This short length aids packing, and in the case of tower silos makes for easier unloading.

## Penn State Particle Separator

A Penn State Particle Separator (PSPS) can be used to measure the physical effectiveness factor, or particle length, of total mixed rations and forages (Figure 14-4). Unlike other established laboratory methods for assessing physically effective fibre, the PSPS is a fast and practical tool that can be used to estimate physically effective fibre in the ration on-farm.

**Figure 14-4.** Penn State Shaker Box used to measure particle size distribution in ruminant rations

The 2013 version of the PSPS has three sieves (19-mm, 8-mm and 4-mm openings with a bottom pan). The physically effective component of a ration is calculated as the amount of material retained on the three sieves, expressed as a percentage of the whole sample.

**Technique:**

1. Stack the four separator boxes. The sieve with the largest holes (19 mm) should be on top, followed by the sieve with medium-sized holes (8 mm), then the sieve with small holes (4 mm). The solid box is on the bottom of the stack.
2. Place about 1.5 L (6 cups) of forage or total mixed ration (TMR) in the top sieve.
3. Shaking must be done on a smooth surface. To shake, slide the stack of boxes away from, then towards the operator in a quick motion. The stack should slide about 17.5 cm (7 in.) away from the operator. There should be no vertical movement of the separator boxes. For best results, operators should aim for a rate of 1 shake/second.
4. Shake the stack five times. Turn the stack one-quarter turn (90˚).
5. Repeat step 4 seven times. This is a total of 40 shakes, or eight sets of five shakes.
6. Weigh the material in each box and record the weights.
7. Sum the weights of the materials in each box together.
8. To calculate the percent of material in each box, divide the weight of material in one box (step 6) by the total weight of material in the sample (step 7). Multiply by 100.

To estimate physically effective NDF (peNDF), the proportion of feed on the top three sieves is multiplied by the NDF content of the feedstuff or ration. Caution must be taken when accounting for the 4 mm (bottom) screen, since this screen is meant to capture particles that are high in fibre, but other feed ingredients and by-products can also be trapped on this sieve. When a large amount of grain and supplement is trapped on this bottom sieve, which is often the case with finishing rations, the bottom screen should be discounted when calculating peNDF.

**Table 14-2. Particle Size Recommendations for Lactating Dairy Cows**

| Box | Pore Size (mm) | Particle Size (mm) | Corn Silage (%) | Haylage (%) | TMR (%) |
|---|---|---|---|---|---|
| Upper sieve | 19 | >19 | 3–8 | 10–20 | 2–8 |
| Middle sieve | 8 | 8–19 | 45–65 | 45–75 | 30–50 |
| Lower sieve | 4 | 4–8 | 20–30 | 30–40 | 10–20 |
| Bottom box | | <4 | <10 | <10 | 30–40 |

Adapted from Heinrichs and Jones, 2013.

The role of effective fibre in maintaining rumen health and influencing milk composition has been well-established in the dairy industry, and the results of a PSPS can be interpreted to adjust the chop length of dairy rations (Table 14-2). Research is underway to expand the use of the PSPS to beef finishing rations.

More information about using a PSPS is available at extension.psu.edu/penn-state-particle-separator.[2]

## Silage Inoculants

Silage inoculants are additives that contain bacteria that manipulate fermentation. The goal of using an inoculant may be to improve fermentation efficiency in storage, improve aerobic stability once the silo is opened or both.

### CAUTION!

Silage inoculants should not be confused with hay preservatives, as these products work in opposite ways. Inoculants contain desirable living bacteria, while preservatives inhibit microbes (including bacteria) and prevent the fermentation that is necessary to ensile forage correctly.

There is an interaction between the crop and commercial inoculants, so only inoculants selected and labeled for a particular crop should be used on that crop. For example, do not use an inoculant labeled only for corn silage on alfalfa or grass haylage, or vice versa.

Read and follow product label directions, including application rates, storage, re-hydration, handling and application. Product labels will detail colony forming units (CFU) per gram of forage to apply at recommended rates. Inoculants should be stored in a cool, dry place to maintain bacteria viability. Dead bacteria (also called non-viable) don't work.

Be sure to properly calibrate the applicator. Inoculant application at the chopper usually works the best, especially with drier forage. Liquid products have an advantage over granular products because of more uniform application. Research suggests that liquid inoculants are more effective than dry inoculants when applied to haylage that has been wilted to lower moistures.

Remember, the application of a silage inoculant will not overcome the effects of poor silage management or poor weather conditions. The keys to good silage fermentation are harvesting at the correct moisture and chop length, quick and adequate packing, and sealing immediately after filling. However, under good management, commercial inoculants can be a valuable tool in silage systems.

Whether or not the benefits of using an inoculant are greater than the cost of the product can sometimes be a challenging question at the farm level. It is difficult for a farmer to see reduced dry matter losses and subtle improvements in animal performance, even when they exist. Are the increased gains or milk production due to the inoculant, or are they due to some of the many other management factors in silage and livestock management? University research, conducted by some of the silage experts, has shown that indeed some of the inoculant products work very well in certain situations. Many dairy, beef and sheep producers are now using haylage inoculants as a standard management practice.

## Lactic Acid Bacteria

Lactic acid bacteria (LAB) are also known as homofermenters because they produce only one fermentation product: lactic acid. LAB inoculants are used to improve fermentation efficiency. Lactic acid is a strong acid that causes the pH of the forage to drop quickly, which minimizes dry matter losses (shrink). Dry matter losses in a well-managed bunker silo can typically be reduced from 15% to 12%–13%, a reduction of 2–3 percentage points. Since lactic acid contains almost as much energy as the original sugars in the forage, animal performance may be improved by using a LAB inoculant compared to not inoculating.

The most common LAB in commercial inoculants are *Lactiplantibacillus plantarum*, *Enterococcus faecium*, various Pediococcus species and other *Lentilactobacillus* species. Species and specific strains of LAB in commercial inoculants have been selected because they grow rapidly and efficiently and produce primarily lactic acid. There are significant genetic differences between LAB species and strains. Not all products are equally effective, but it is difficult to compare products. Ask company representatives to provide research that substantiates their claims for the product. Determine whether these claims are of value to the farm operation. Check whether the company can provide product quality control assurances.

If there is a high natural population of lactic acid bacteria, an inoculant is less likely to dominate the fermentation and provide a benefit. A long wilting time (>2 or 3 days), low silage moistures (<60%), rainfall during wilting and higher wilting temperatures, decrease the chances of an inoculant being successful, because these situations increase naturally occurring LAB. Therefore, the conditions for the greatest chance of an economic benefit from a haylage inoculant would be:

- first-cut and fall-cut (lower wilting temperatures)
- fast drying summer cuts (<1 day wilting), and
- higher moistures (65%–70%)

When forage in the windrow is rained-on, undesirable soil-borne bacteria are splashed onto the crop. It is sometimes difficult to dominate these undesirable bacteria with a commercial inoculant, and an inefficient fermentation may be the result. Also, because sugar is the principal food for LAB, low sugar levels in alfalfa can limit the success of inoculation. Rainfall will leach out some of the soluble sugars, which could be more limiting to a successful fermentation than inoculation.

## *Lentilactobacillus buchneri*, formerly known as *Lactobacillus buchneri*

Some species of *Lentilactobacillus* bacteria produce both lactic and acetic acid. These are called heterofermenters because they produce more than one fermentation product. *Lentilactobacillus buchneri* are by far the most common heterofermenters used as silage inoculants. Acetic acid is much better than lactic acid at suppressing yeast and mould growth and slowing heat production once the silo is open. This means that the silage stays fresher for longer, which is also known as aerobic stability.

The increased acetic acid and aerobic (exposed to air) stability comes at the expense of increased fermentation dry matter losses. However, dry matter losses due to aerobic spoilage of corn silage are typically much larger than fermentation losses. In situations where spoilage at feed out is an issue, the use of *L. buchneri* inoculant on corn silage may result in less mould and mycotoxins, improved palatability and intake, and reduced total dry matter losses.

*L. buchneri* inoculants should be considered in situations where aerobic stability is a greater risk. Although *L. buchneri* inoculants could work similarly with alfalfa and grass haylages, aerobic stability is more of a problem with silages that contain large amounts of starch, such as cereal silage and corn silage. High dry-matter corn silages, and bunk, pile or pit silos with large exposed surfaces usually have greater problems with aerobic stability and may benefit more from *L. buchneri* inoculants. The same may be true for the top loads in either vertical or horizontal silos. In tower silos, it is usually the bottom of the silo that is fed during the warmer summer temperatures, when there is increased risk of aerobic spoilage.

Another application where *L. buchneri* inoculants may be a benefit is in situations where corn silage is expected to be transferred from one silo to another. *L. buchneri* inoculants have also been shown to increase aerobic stability in high-moisture corn. Remember that aerobic stability is also improved by proper silage management practices, including recommended moisture and chop length, rapid filling and packing, sealing, face management, removal rate and feed bunk management.

### Enzymes

Enzyme additives are sometimes included in inoculant products. Enzymes include cellulases, hemicellulases and amylases to help break down cellulose, hemicellulose and starch. In theory, these enzymes break down some of the fibre and starch sooner than normal, and therefore provide additional initial substrate for the bacteria to ferment. Research results are mixed. In situations where plant sugars are low and limiting to the fermentation, this may result in improvements. Product cost and effectiveness should be considered.

Silo filling and packing are described in Chapter 15, *Storage*.

# References

1. Thaemert, R. 2002. *Sampling the Moisture Content of Alfalfa in the Windrow.* California Alfalfa Symposium. Retrieved from: alfalfa.ucdavis.edu/+symposium/proceedings/2002/02-169.pdf

2. Heinrichs, J., and C.M. Jones. 2013. *Penn State Particle Separator.* Penn State Extension. Retrieved from: extension.psu.edu/penn-state-particle-separator

## Additional Sources

This chapter contains excerpts from the following OMAFRA sources:

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*Preventing Mouldy Hay Using Propionic Acid.* Virtual Beef Newsletter. Last modified: February 9, 2010. www.omafra.gov.on.ca/english/crops/facts/preventing.htm

*Silage Inoculants.* Last modified: June 6, 2006. www.omafra.gov.on.ca/english/crops/facts/info_silageinoc.htm

*Harvesting Corn Silage at the Correct Moisture Content,* Factsheet 13-051. 2013.

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CHAPTER 15

# Storage

Unlike for grains and oilseeds, there is more than one way to store forage crops for use later. Drying hay to less than 18% moisture restricts the amount of water available to microorganisms that would spoil the forage, which preserves the crop. Silage is made by fermenting the forage; many of the microbes that would spoil the crop do not function without oxygen, and those that can function do not like acidic environments (pH of 4.5 to 5.5). Baleage is too dry to ferment completely, and the pH drop is generally not as extreme as in silage, so preventing oxygen from entering the bales is the main preservative. Good storage practices maintain these conditions until the forage is fed out.

## Dry Hay

Storing hay outside and exposed can cause large losses due to spoilage, often up to 61%. While precipitation usually takes the blame for spoiled hay, the bales also wick moisture up from the ground.

Storing hay under a roof will minimize spoilage. Typical storage losses under a roof are 2%–10%. While an initial capital expense, building long-term inside hay storage can be one of the best on-farm investments. When storing hay inside, make sure the hay is dry. Concrete floors will “sweat” when warm air and cool concrete cause condensation, and this moisture can be drawn up into hay bales. A gravel floor can reduce sweating to hay on the bottom versus hay stored on a cement floor.

Pallets have been used successfully to raise bales off a cement floor to prevent the hay from wicking up moisture. Hay should be at least 60 cm (24 in.) away from the roof to promote air flow. If the hay shed has walls, it is recommended to leave at least a 50-cm (20-in.) gap between the wall and the hay. This space prevents the bales from wicking condensation from the walls and allows air flow around the stack. This space also keeps the hay from leaning against the shed walls, which are generally not designed to support the extra weight of hay bales. A larger space can be left to enable checking the hay for heat.

**Figure 15-1**. Hay that has been wrapped shows little spoilage.

If a shed is not available, the next best option to reduce spoilage is to wrap the dry hay (Figure 15-1). Wrapping or using a bale sleeve typically results in 4%–8% dry matter losses during storage. Some producers use one to two wraps, while others use up to six layers, similar to haylage.

If the wrapped hay is damp, there may still be spoilage on the outside of the bales. Even wrapping with more plastic will not stop spoilage of damp hay.

Covering bales with tarps can reduce spoilage. Losses in tarped hay stored on the ground range from 4%–46%. A well-drained base reduces the odds of the bottom row sitting in pooled water — losses are generally 2%–17% when the storage site drains well. Keeping the tarps on through the winds of winter is a challenge. Make sure the tarps are secured well, so the wind does not shred them. Some producers tie down the tarps to the bales themselves. Others use tires or sandbags to secure the tarps. Feeding bales from a tarped stack can be more time-consuming as the tarp will need to be rolled back as you feed the bales out.

Square bales must be covered to prevent significant amounts of spoilage, however, because of their shape, round bales have some ability to shed precipitation. Round bales should not be stored on their flat ends, as they lose the ability to shed water and have a greater surface area touching the ground to wick up moisture.

If bales must be stored outside, remember that net-wrapped bales tend to be wound tighter and held together more firmly than twine-wrapped bales (Figure 15-2). Net-wrapped bales shed rain more effectively with less spoilage. University of Wisconsin researchers measured moisture levels in the outside hay rind of net-wrapped alfalfa bales and twine-wrapped bales. They found that net-wrapped alfalfa bales shed rainfall better than twine-wrapped bales. Nutrient composition was significantly higher in the outside hay rind and losses were lower for bales wrapped with net wrap compared to bales wrapped with twine. The core of the bale was generally unaffected by wrap type. Average overall total dry matter losses were 11.3% and 7.3% for plastic twine-wrapped bales and net-wrapped bales, respectively. It is important to consider that, in either situation, bales that are not stored on a well-drained surface can absorb moisture at the bottom of the bales.

**Figure 15-2.** Net wrapped bales shed water better than twine wrapped bales and are better suited to outdoor storage.

Another method to reduce spoilage is to leave space between bales as they are stored (Figure 15-3). This means the rain water does not collect between the bales and the bales, reducing spoilage.

**Figure 15-3.** Leaving a gap between bales stored outside prevents moisture being trapped between bales.

When hay is stored outside, it is important to have a dry base for the bales (Table 15-1). Having a gravel base lets rain water drain away, rather than collect into the bottom of the bales.

**Table 15-1. Hay Loss Associated with Various Storage Methods**

| Storage Type | Dry Matter Loss (%) |
|---|---|
| Under roof cover | 2–10 |
| Plastic wrap —on the ground | 4–7 |
| Bale sleeve — on the ground | 4–8 |
| Covered — elevated or gravel pad | 2–17 |
| Covered — on the ground | 4–46 |
| Uncovered — elevated or gravel pad | 3–46 |
| Uncovered — on the ground with net wrap | 6–25 |
| Uncovered — on the ground with twine | 5–61 |

Adapted from Holmes, 2004.

# Baleage

Baleage does not reach as low a pH as chopped haylage (and other types of silage). This means that greater emphasis must be put on good silage-making processes, especially the exclusion of oxygen (see *Fermentation* below). The length of storage time and how long the bales are exposed to oxygen before feed-out must be adjusted to weather conditions. In general, successful use of baleage will involve:

- baling a good-quality forage within 40%–60% moisture content in a very compact, even bale
- avoiding contamination by manure use or from soil-borne bacteria splashed up with rains or by raking
- wrapping the bales quickly, excluding the oxygen as soon as possible
- monitoring bales to maintain a continuous seal
- sizing the storage structure to allow efficient, quick feed out
- using good-quality plastic to produce a sealed environment

Weather conditions are the prime reason that most people try a baleage system. The quality of the material produced, the use of existing equipment and the ability to schedule harvesting operations to reduce the weather risk have increased the popularity of the system. It offers flexibility and the ability to store forage quickly if required.

## Moisture Content

The moisture content of baleage at storage is one of the more important factors affecting quality. Baleage can be stored at moisture levels ranging from 40%–60%. At either end of the range, the risk of storage problems increases. Therefore, harvest should be geared to wilt material to an average of 50% moisture.

Many farmers prefer to harvest baleage on the dry side, which may be as low as 30% moisture. This exact moisture is difficult to establish at times because moisture determination on the farm is sometimes more qualitative than absolute. Drier forage makes handling bales easier, especially when loader equipment is small. The main problem is to be able to exclude the oxygen. Dry baleage contains more oxygen that must be used up in fermentation. It is extremely important to have tight bales made with a variable chamber baler when moisture levels approach 40%. It is difficult to make tight bales with mature forage because the coarse material won’t pack but it is safer to wilt more vegetative alfalfa and grass to drier moisture levels. If the material is not well packed, more heat is produced from prolonged respiration. Heat damage may increase dry matter losses and bind protein, lowering the feed quality.

Extended wilting of the forage increases the risk of harvest losses. If the weather forecast is predicting rain, consider making baleage on the wet side to reduce weather losses. Baleage should be stored without rain damage. Moisture levels from 45%–55% offer the best storage for crops harvested for baleage. The moisture in the baleage should come mostly from the plant. Surface moisture from dew or rain does not provide sufficient moisture for fermentation. Baleage from forage originally intended for hay that had been rained upon or that was just too tough to dry bale often will not store well. Baleage will salvage this type of forage, but the product may lack the high quality expected.

Bales with higher moisture content are more likely to freeze or have more effluent that collects at the bottom of the silage bags. Problems with frozen large bales have been reported. These problems are more apt to occur as moisture levels increase above 50% and during extremely cold winters.

## Storage Type

Baleage may be stored in bags, tubes or stacks. The oxygen present within any of these “containers” is not sufficient to cause excess respiration. If the oxygen can be kept out successfully throughout the storage time, good quality baleage can be made by any of these methods.

The trend in storage systems is toward using stretch wrap on individual bales or continuous line wrappers. Polyethylene tubes are still used but many farmers are using tubes of stretch plastic. Systems that minimize oxygen re-entry at feeding will reduce baleage deterioration.

The major suppliers of plastic wrap will guarantee plastic for up to 1 year. Properties of plastic include ultraviolet light inhibitors, stretch, puncture resistance and stickiness. Cheaper plastic often is of reduced quality. Most manufacturers recommend at least 4 layers of plastic with up to 6 layers for storage up to a year.

### Individual Bales

Wrapping big bales with “stretch” plastic has proven to be an effective method of storage. This plastic film is basically a low-density polyethylene with a tacky additive to help it create a tight seal.

Individual wrapping is generally performed by machinery that rotates the bale on a turntable. The farmer starts the wrapping procedure by tucking the end of the plastic film under the twine, and when wrapping is complete, cuts the wrapped bale free. Wrapping machines are available to handle round or square bales of various sizes. Some equipment will handle both types of bales, however they are more costly.

Best results are expected when firm and intact bales are wrapped as tightly as possible (Figure 15-4). It is recommended that bales be wrapped with at least 4 layers of film for short storage and at least 6 layers of film for storage until the following spring to early summer.

**Figure 15-4.** Individually wrapped round bales.

When handling individually wrapped bales, a grapple loader attachment is ideal (Figure 15-5). The use of a spear will break the seal and spoil the bale if not immediately fed or patched with a good-quality silage tape. If stacking individually wrapped round bales, it is best to place bales two high on the flat end where there is more plastic.


**Figure 15-5.** A grapple minimizes punctures in the plastic wrap.

The biggest advantage offered by individually stored baleage systems is the potential to minimize spoilage. Losses for well-wrapped quality baleage stored at the proper moisture content (60%) have been estimated at 5% of dry matter. For tight, well-wrapped bales, a hole in the plastic will mean only localized mould and spoilage rather than the widespread spoilage that develops when loose-fitting plastic covers are punctured. Another advantage to individually wrapped bales over multi-bale systems is the ability to market off-farm as it is very difficult to move a multi-bale unit (in-line or stack).

The latest major innovation in individually wrapped bales is the combination baler-wrapper, which wraps each bale as it comes out of the baler. This minimizes the amount of time the baleage is exposed to air before wrapping to maximize forage quality.

An alternative to using stretch film is the manual placement of bales into individual bags. If dealing with a large number of bales, the bagging will work best with three people. Check all bags for holes immediately after bagging and then periodically afterwards. Patching can be effective if done with minimal delay. Haylage bags come in various sizes and thicknesses. The lighter bags are 4-mil polyethylene (1 mil = 1/1,000 in., or 0.0254 mm) and have a 1-year life expectancy, while 5- and 5.5-mil bags will often provide 2 seasons of use if the farmer is willing to patch any holes before reusing.

## In-Line Systems

Multi-bale in-line systems were developed to decrease the cost, labour and time required wrapping or bagging individual bales. It is estimated that in-line systems use up to 40% less plastic over individual wrapping and will therefore be lower cost. There are in-line systems that can be used to store both round and square bales as baleage.

In Ontario, wrappers are the most common in-line system. These use the same stretch film as individually wrapped bales (Figure 15-6).

In-line systems that use stretch film involve the placement of a bale onto the drum of the machine, which is then wrapped with the film. The greatest advantage to this system over a flex tube is that the length of each line of bales is variable and can be adjusted to fit individual operation feed out times and yard space.

**Figure 15-6.** An in-line wrapper.

Flex tubes are another in-line storage option. These tubes are tied off at the end to keep air from getting into the line of bales. Some models are loaded one bale at a time (like the in-line wrappers), while others require the line of bales to be set up first so the filling machine can pull the tube over the bales. There are different machines of this style, which work with either loose-fitting bags or tight flex (stretch) tubes. With a tighter fitting flex tube, both plastic cost and potential for mass spoilage are reduced.

## Stacks

Covering and sealing stacks of baleage bales with a double layer of 6-mil polyethylene can preserve them. This method works well for both round and big square bales. As shown in Figure 15-7, the outer layer provides the seal, while the inner layer protects it from stem punctures, especially where twine or rope tie-downs are placed. Sand is used to seal the edges of the outer layer, and substantial tie-downs are required to minimize wind buffeting.

Do not use construction-grade polyethylene since a big percentage of it is made from a variety of reclaimed plastics, resulting in an inferior product with variable thickness. Although silage films cost more, they are made from pure resins and exhibit vastly superior physical properties (stretch, puncture and fatigue). In quality silage films, a uniform thickness is maintained.

The amount of air initially trapped under the plastic is not critical, since the respiration process quickly uses up oxygen. However, any subsequent hole in the plastic will allow oxygen to enter freely and cause extensive spoilage. As with the other options, take steps to minimize rodent problems and check the cover periodically.

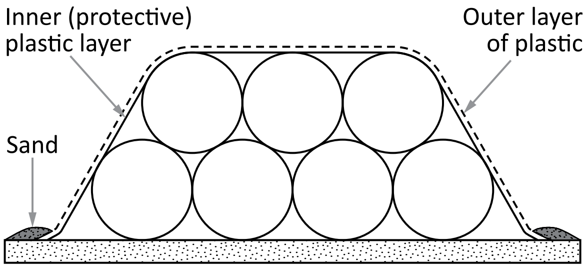


**Figure 15-7.** Round bale stack face (stacks should be 3–5 bales long).

Some farmers have chosen to place loose haylage in the voids between bales and between the bales and the plastic cover. The benefit gained here is that the free movement of air through the stack may be lessened if the stack's seal is broken.

Once a stack is opened deterioration of the balelage commences and continues at a rate that varies with air temperature. Eventually, mould becomes visible on the face of the bales and gradually will penetrate the bales. Plan your stack size so that once opened, it will be entirely fed out: within 1 week in summer, within 2 weeks in spring and fall and within 4 weeks in winter.

If stacks are kept small (21–35 round bales or 20–40 square bales), placing the plastic will be easier, minimizing problems with ice and snow during winter feed out.

When stacking round bales (Figure 15-7), do not build stacks more than 2 bales high due to the tendency of these heavy bales to squat and become somewhat unstable. In a high stack there is potential for the top bales to shift in any direction, possibly breaking the polyethylene seal.

The stacking method shown in Figure 15-8 works best with square bales as more hay can be fit under the same sheet of plastic. Due to their flat edges, square bales have fewer tendencies to shift and settle and are therefore less likely to break the seal of the stack.

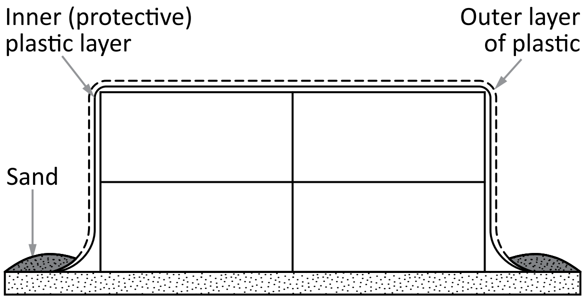


**Figure 15-8.** Big square bale stack face (stacks should be 5–10 bales long).

For any baleage system, air holes will cause extensive spoilage and, if undetected, may render the bale(s) a complete waste. Avoid rodent damage by eliminating long grass around the storage site. Keep in mind that even a pinhole allows enough air exchange for spoilage to occur.

## Storage Time and Location

The longer the time in storage, the higher the risk of silage deterioration. Baleage that is fed out in the fall or winter has generally not been a problem. Cool temperatures work in favour of preservation, keeping microbial activity limited. When temperatures start to increase in late March, moulds that were in the baleage at low levels may develop into a problem. If fermentation is not complete, spoilage will be more severe.

Farmers have observed that fall silage put up in late summer or early fall does not change colour or have any acid smell. This indicates fermentation either did not take place or was very limited. Cooler temperatures and lower numbers of bacteria may be responsible. It is possible fermentation will start again as temperatures warm up in the spring, but this assumes oxygen has not penetrated over winter. This silage is best fed out during the fall and winter to avoid spoilage.

Plastic will attract rodents and just about any other animal capable of putting holes in plastic. The storage area should be clean of vegetation as much as possible to prevent cover for rodent movement and be protected from other animals.

## Moulds

A farmer considering baleage must accept that moulds are a fact of life. Even under ideal circumstances, a small percentage of bales will exhibit some white mould. A bale that has been exposed to oxygen for an extended period will exhibit severe black mould throughout much of the bale.

Secondary mould growth may take place as baleage is removed from the tubes. If the baleage has not properly fermented or contains high populations of yeast and/or mould, oxygen entering the tubes will quickly deteriorate the baleage. The implications of oxygen breakdown are important with round bale baleage systems using tubes because oxygen may enter the tube as soon as it is opened. Slow feed out through the spring and summer may cause problems. Bales should be fed within 1 week in the summer, 2 weeks in the fall and early spring, and 4 weeks during the winter after opening the tube or storage structure.

Livestock will usually still consume mouldy material unless there are too many spores, which cause lung irritations. People can also be affected by these spores, which can lodge within the lungs. The acids produced by fermentation are volatile and thus may migrate from the bale if air enters or may also be leached with moisture migration resulting in areas where moulds may establish.

A white mould or yeast is very common. It produces a large spore that will not irritate lung tissue or cause feed refusal. Other moulds that may occur are aspergillus, a grey/blue mould, which may aggravate allergies or cause abortions in cattle, and fusarium, a red or pink mould that can produce deoxynivalenol (DON), T2 and other toxins that cause feed refusal and vomiting, and have estrogen-like effects in livestock. The spores produced by the moulds usually cause the most damage. White mould is not a problem, but the other coloured moulds should be regarded with care.

Temperature affects how quickly moulds develop. Fusarium grows at 4.5˚C–15.5˚C, but aspergillus and penicillin grow at 18˚C–35˚C. This silage would be just warm to the touch. As outside temperatures rise, the temperature of the material will rise into these ranges. The acids produced by fermentation inhibit mould growth, which is why good fermentation practices are so important when making silage and baleage.

Manure should not be applied to the forage stand before harvest as this introduces undesirable bacteria to the forage that may stimulate mould growth. Raking seems to make the problem worse. Rain during wilting may splash soil-borne bacteria and mould onto the forage. Manure contamination will spoil a pocket of the bale but not necessarily the entire bale unless other problems exist.

# Silage

## Silo Gas

### CAUTION!

Silo gases can be deadly. Farmers exposed to silo gas (nitrogen dioxide, $NO_2$) are at risk of severe respiratory distress, permanent damage to lungs and even sudden death. It is difficult to predict when silo gas will be produced, so always take precautions following harvest.

Weather conditions and agronomic practices affect the amount of nitrates in plant material, which set the stage for the production of nitrogen dioxide ($NO_2$) in the silo. For example, a dry period during the growing season followed by abundant rainfall will encourage a corn crop to take up high levels of dissolved nitrates. If the corn is harvested before the nitrates can be converted to proteins, nitrogen dioxide is produced.

Silo gas is produced almost immediately after filling a silo. The greatest risk is the first 12–60 hours after filling the silo, and then risk declines for approximately 4–6 weeks when silage fermentation is complete. Silo gas has a bleach-like odour and may be visible as a reddish-brown haze. However, it is not always visible.

Nitrogen dioxide is heavier than air, therefore it tends to be located just above the silage surface and on the ground around the silo. It may flow down silo chutes and into feed rooms. Tower silos are a greater risk because the silo gas is contained at the silage surface level, and operators often enter the silo after filling to level silage and set up the unloader.

When inhaled, nitrogen dioxide mixes with body moisture to form nitric acid, which causes severe burning of the lungs and the rest of the respiratory system. Pulmonary edema results. Victims often collapse. Other people attempting a rescue can also be overcome. People exposed to silo gas should get immediate medical attention.

To reduce the risk of injury or death from silo gases:

- Post a “Danger, Deadly Gases” warning sign in a visible location near the silo.
- Do not allow children or visitors near the silo for 3 weeks after filling.
- Provide sufficient feed room ventilation to exhaust any silo gas that might have spilled down from the silo.
- Check with your local fire department to see if pressure-demand remote breathing apparatus is part of their emergency equipment. Self-contained breathing apparatus (i.e., scuba) equipment is not suitable because of the air tank. It is sometimes too big for climbing the silo chute or the outside ladder-cage or too small to contain enough reserve air to rescue someone.
- During filling, adjust the distributor as needed to level the silage. Do not level the material by hand.
- If it is necessary to enter the silo when filling is complete, do so immediately following the last load, on the same day. Remember to leave the blower running while inside.

Oxygen-limiting silos are a special case and should never be entered. If it becomes absolutely necessary to enter such a silo, it is essential that an external air supply be worn, and back-up emergency safety measures are in place. Consult Publication I33 *Alert: Atmospheric Hazards Associated with Oxygen-Limited Structures (Silos) on Farms*, by the Ontario Ministry of Labour, Training and Skills Development for suggested precautions.

A top unloader can ventilate a silo effectively. However, if it becomes necessary to service a defective unloader, assume that gases are present. To expel gases before entering, run the forage blower with the chute doors closed and the roof vent open. If the head space is greater than 5 m (15 ft), attach a tube adapter to the blower pipe (Figure 15-9 and Figure 15-10). For a 7.2-m (24-ft) diameter silo with 5–10 m (15–30 ft) of head space, let the blower run for 30 minutes. For larger diameter silos or silos with a deeper head space, increase the ventilation time. Leave the forage blower running while in the silo.

If someone collapses inside a silo, begin ventilating with the forage blower immediately, as explained above, and contact your local fire department. A fresh air supply is critical for both the victim and rescuers. Never attempt to rescue someone yourself. This has been attempted many times and, without the proper equipment and training, has resulted in many incidents of multiple fatalities.

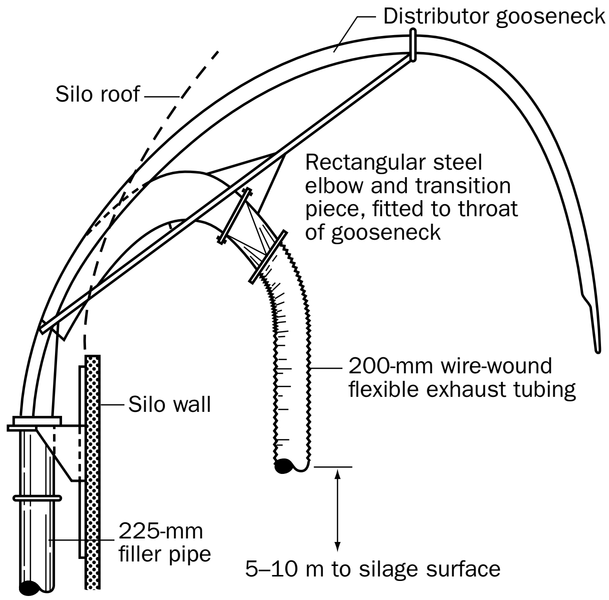


**Figure 15-9.** Suggested ventilation adapter for rotary distributors.

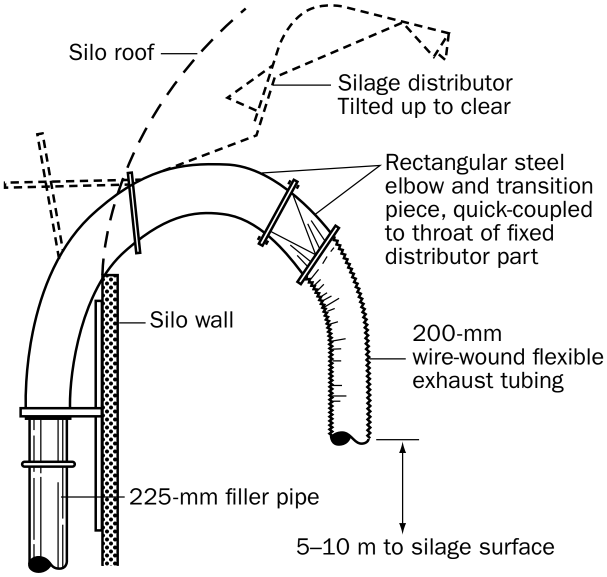


**Figure 15-10.** Suggested ventilation adapter for fin-type distributors.

For more information on preventing injury or death from silo gas, refer to *Silo Safety – Workplace Safety and Prevention Services*, published by the Workplace Safety and Prevention Services at [https://www.wsps.ca/resource-hub/material-handling/silo-safety](https://www.wsps.ca/resource-hub/material-handling/silo-safety).

Farmers with concerns about silo gas should contact the Workplace Safety and Prevention Services (formerly the Ontario Farm Safety Association) at 1-877-494-9777.[1]

# Fermentation

When forage is first put into a silo, conditions are aerobic (oxygen is present in the silage). Plant respiration and aerobic bacteria convert carbohydrates into carbon dioxide, water and heat, and use up the oxygen present. This phase should be as short as possible.

The silage then becomes anaerobic (without oxygen). The growth of anaerobic bacteria ferments sugars to organic acids (primarily lactic and acetic acid) and other products, including carbon dioxide, heat and water. This biological conversion from fresh plant material to fermented silage also results in the shrink or fermentation losses of dry matter and energy. A fast, efficient fermentation that is dominated by lactic acid bacteria (LAB) producing primarily lactic acid, reduces these losses to a minimum. In 2–4 weeks, the silage reaches a stable pH of 3.8 to 4.5, and all bacterial and enzymatic activity stops. Once this stable pH has been reached, further breakdown of nutrients and spoilage is prevented, and the silage will keep for extended periods of time, provided air (specifically oxygen) is excluded (Figure 15-11).

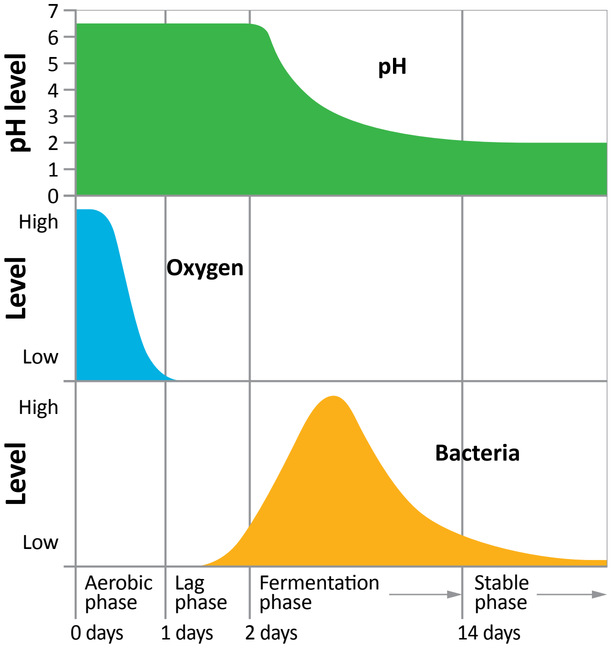


**Figure 15-11.** The fermentation process.

Good silage management is aimed at minimizing fermentation losses in dry matter and energy, commonly known as shrink. Shrink reduces both yield and nutrient quality. A poor or extended fermentation results from the following factors and will increase losses:

- slow filling
- poor packing
- poor covering
- improper harvest moisture, or
- lack of a suitable inoculant

When excessively wet material is put into a silo, moisture can squeeze from the silage. The seepage carries sugars and other nutrients out of the silo. In addition, seepage can lead to excessive corrosion of the silo walls and result in the possible collapse of the silo. Silo seepage can also lead to fish kills if it enters a watercourse.

Species and maturity of the forage affect silage fermentation. Early-flowering legumes and vegetative grasses contain adequate sugars for fermentation by bacteria. Protein and energy values for livestock are optimal at this stage.

Grasses are easier to ferment than alfalfa and red clover as they contain a higher sugar content than the legumes; in fact, close to twice the amount. Mature legumes may lack sufficient sugar content for good fermentation. Wilting concentrates the sugars in the plant so that a minimum content is present to complete fermentation.

Fresh and fermented forages feed out differently. It is a good practice to have enough ensiled forage to allow a newly harvested crop to ferment for at least 2 weeks, although 6–12 weeks is better. This enables the forage to reach the stable phase of fermentation before it is fed.

## Storage Type

The storage and handling of livestock feeds in the ensiled form has several advantages. These, however, can only be fully realized if producers select the type of storage structure (silo) most suited to their farm situation. It is important to think of each part of the feed handling picture, from field to feed bunk, as a total feed handling system. This means that each segment (each piece of equipment, storage structure, etc.) must be chosen with the whole operation in mind, so that it fits well with every other segment to make the total the most effective, efficient combination possible. No one part should be allowed to create a bottle-neck in the system.

A silo is more than just a structure to hold a harvested crop in one place until it is needed for livestock feed. Its most important function is to provide the right environment for a proper ensiling process to take place, thereby minimizing feed loss and making a high percentage of nutrients grown in the fields available to livestock. Essentially this means the exclusion of air from the ensiling mass. In addition, the structure should be so designed and located that it provides labour-saving storage that fits into a totally efficient handling system.

The type of silo that is most economical depends on the amount of forage required by the farm. Each type of silo has advantages and disadvantages, and good management of each type is different (Table 15-2).

**Table 15-2. Estimate of Silage Losses During Filling, Storage and Feed Out**

| | | Filling | Seepage | Gaseous | Top Surface | Feed-out | Total |
|---|---|---|---|---|---|---|---|
| **Silo Type** | **Moisture (%)** | **DM Loss (%)** | | | | | |
| Conventional tower | 80[1] | 1–2 | 7* | 9* | 3* | 1–5 | 21–26 |
| | 70[1] | 1–2 | 1* | 8* | 4* | 1–5 | 15–20 |
| | 65 | 1–3 | 0* | 8* | 3* | 1–5 | 13–19 |
| | 60 | 1–3 | 0* | 6* | 3* | 1–5 | 11–17 |
| | 50 | 2–4 | 0* | 5* | 3* | 1–5 | 11–17 |
| Oxygen-limiting tower | 70[1] | 0–1 | 1* | 7* | 0* | 0–3 | 8–12 |
| | 60 | 1–2 | 0* | 5* | 0* | 0–3 | 6–11 |
| | 50 | 2–3 | 0* | 4* | 0* | 0–3 | 6–12 |
| | 40 | 2–4 | 0* | 4* | 0* | 0–3 | 6–13 |
| Bunker, no cover[2] | 80[1] | 2–5 | 6* | 10* | 6* | 3-10[2] | 27–37 |
| | 70[1] | 2–5 | 1* | 9* | 9* | 3-10[2] | 24–34 |
| | 60 | 3–6 | 0* | 10* | 12 | 5-15[2] | 30–43 |
| Bunker, covered[2] | 80[1] | 2–5 | 4* | 9* | 2* | 3-10[2] | 20–30 |
| | 70[1] | 2–5 | 1* | 7* | 3* | 3-10[2] | 16–23 |
| | 60 | 3–6 | 0* | 6 | 4 | 5-15[2] | 18–31 |
| Bags | 80[1] | 1–2 | 2 | 6 | 2 | 1–5 | 12–17 |
| | 60–70[1] | 1–2 | 0 | 5 | 2 | 1–5 | 9–14 |
| Baleage | 60–70[1] | 1–2 | 0 | 8 | 5 | 1–5 | 15–20 |
| | 50–60[1] | 2–3 | 0 | 6 | 6 | 1–5 | 15–20 |

[1] Avoid ensiling hay crops above 70% moisture in structures and above 60% moisture in wrapped bales to prevent clostridial fermentation.

[2] Feed out loss is 3%–5% with good management on a concrete floor. Use 4%–8% for asphalt and 8%–20% with earth floor, assuming good face management. With less-than-good face management, add up to 7% additional loss.

*Based on *Forages: The Science of Grassland Agriculture*, 4th ed. See Bickert, et al. (1997).
Adapted from Holmes, 2000.[2]

A comparison of the suitability of different types of silos should include not only the initial capital cost, but also the yearly operating costs for the entire feeding system.

Any comparison of capital costs of silos must be based on equivalent storage capacity. Unfortunately, there is no uniformly accepted standard by which capacities are stated. One common measure is volume of usable storage space. However, a major disadvantage with this type of measure is that it does not take into consideration the compaction effect on silage due to height. This puts higher, larger diameter tower silos at a disadvantage. Another measure is the tonnes of silage the silo will hold. This, of course, is subject to wide variations in moisture content, fineness of chop, species of plant, method of distribution and packing, number of times the silo is refilled, etc.

One method of stating silo capacity for whole-plant silages, which eliminated some of the variation (particularly due to moisture content) is in terms of dry matter capacity. Within certain limits, it has been observed that a particular size of silo will hold a fairly constant amount of dry matter, regardless of the moisture content. Since the basis of ration formulation is dry matter, this method of stating silo capacities seems to be both practical and appropriate.

The fixed cost of owning a storage structure should include a value for such items as depreciation, interest, repairs, taxes and insurance. Variable or operating costs should include a value for the cost of labour and equipment operation.

The most suitable type of storage structure for a particular farm situation will vary with the type of livestock, the feeding program, the size of the operation and the types of feed.

The amount of snow and ice expected during a winter season should also be taken into consideration in selecting the type of silo. The more open a storage structure, the more adverse weather conditions affect the smooth, efficient operation of the silage handling system. In other words, farmers must recognize the normal winter-time climatic conditions where they live and select a silo and feeding system accordingly.

## Tower Silos

In the past, vertical or tower silos have been constructed of many different materials. Today, nearly all are built of either concrete or steel. Tower silos may be further divided into two types: (a) open to the atmosphere on top, (i.e., open-top), or (b) sealed to control the internal atmosphere (i.e., oxygen-limiting).

### *Open-Top Silos*

Nearly all open-top silos today are made of concrete, either cast-in-place (poured) or pre-cast stave. Basically, all open-top silos use some type of top unloader.

### *Oxygen-Limiting Silos*

Most oxygen-limiting silos are constructed of steel or concrete. Of the steel units, the most popular is made of bolted panels of glass-fused-to-steel. As well, there are units available that consist of galvanized steel with some type of interior lining or coating to protect the steel from the corroding effects of silage acids. Oxygen-limiting silos are also constructed of concrete. Until the early 1980s, these were all cast-in-place units; since then several companies have started to market oxygen-limiting silos made with precast concrete staves together with some type of interior lining.

Nearly all oxygen-limiting silos are equipped with some type of bottom unloader; one silo construction company uses a top unloader with bottom delivery in its forage units.

Dry matter losses in well-managed tower silos are low, ranging from 5%–10%. Tower silos require no packing or covering, and therefore involve less labour at filling. Applying additives is simple. Tower silos unload in any weather and require less space. When all factors are considered, tower silos appear well-suited for farms using up to 150 tonnes (165 tons) of dry matter of a type of forage annually. Once this size is exceeded, the disadvantages of tower silos quickly outweigh the advantages.

The disadvantages of tower silos include potential safety issues with silo gas and the height of the structure, bottlenecks in the production process created by slow filling and the need to refill, and the incompatibility of slow unloading with total mixed ration (TMR) feeding.

Tower silos taller than 21.3 m (70 ft) restrict the moisture content of the forage stored. Excessive leaching forces owners of 24.4–30.5-m (80–100-ft) silos to harvest corn silage at more than the desired 35% dry matter, thereby compromising feed quality. Low-moisture corn silage has lower starch and fibre digestibility. Fibre digestibility has been found to decrease by over 10% as moisture decreases from 70%–58%. Kernels that are too dry will become hard and can pass through the cow undigested. The use of a processor or finer chopping can help compensate to some extent.

Use of a distributor will ensure adequate packing along tower silo walls and will help limit air movement into the silage from walls and doors. The filling rate should be very rapid for good packing. This will reduce air trapped in silage and minimize air traveling through silage. Temporary covers can be used if there are long periods of time between fillings, but beware of silo gases.

## Bunker silos

**CAUTION!**

Faces of bunker silos can be dangerous should an avalanche of forage material break loose. Take precautions and avoid working near the face of the bunker closer than twice the height of the face material. Avoid removing forage material in a way that develops overhangs of forage at the top of the face.

Bunker silos enable farms to handle large quantities of forage more efficiently. Silo height and width should be carefully planned to allow removal of a minimum of 15 cm (6 in.) of silage each day. A thicker slice will make the bunker easier to manage during the summer.

Dry matter losses in a well-managed bunker silo typically range from 10%–15%. Compaction studies have shown that the minimum height of a bunker silo should be 1.8–2.4 m (6–8 ft) to achieve the proper level of compaction. Width should be equal to or less than five times the height in order to maximize volume and minimize exposure to air at the bunker face.

The appropriate size for a bunker silo will depend on the amount of forage to be stored and the anticipated feed out rate. Dimensions become a function of size and management objectives. The recommended length for convenient packing is 45.7 m (150 ft) or less, and since two bunkers, emptied in alternate years, works best, two side-by-side bunkers of 27.4 m (90 ft) each could be sized width-wise to allow for 15 cm (6 in.) removal for year-round storage. Some producers ask about opening both ends of a bunker, but since the floor must slope away from the face, working from alternate ends is not practical.

The minimum recommended width is twice the width of the packing tractor or about 5.5–6.1 m (18–20 ft). Wider bunkers are appropriate if more capacity is needed, but since a 1-to-4 sloped crown is desirable to drain off rainwater, wide bunkers become very high in the centre. Wide bunkers also require additional walking to apply plastic and tires.

Sidewalls should be 2.4–3.1 m (8–10 ft) high. Most loaders can reach about 4.3 m (14 ft). This will be the height of silage in the centre of a 9-m (30-ft) wide bunker with a 1:4 sloped crown, and a 3.1-m (10-ft) sidewall. For bigger bunks, higher walls cost more per tonne of feed stored than additional floor area.

Bunker walls provide greater safety than unwalled piles for packing. Sidewalls also reduce the size of the face and the labour needed to pack and cover the silo. Instead of a single wall between bunkers, the more common design is for two interior walls, 1.2–1.5 m (4–5 ft) apart. Since cross-bracing increases the strength of this design, less concrete and steel is used in each of the walls and total cost is only slightly higher than a properly engineered single wall. The space between the walls is tile drained to the back of the silo and filled to 0.6–0.9 m (2–3 ft) of the top with gravel. When the silo is filled and crowned to the top of the wall, the space provides a safe working area for applying plastic and facilitates drainage of rainwater outside the silo. When the plastic is removed, the wall space has room for storing tires. Steps formed into the front panel of the double wall improve access to this area.

Bunker floors should slope 1% toward the opening for proper drainage. Asphalt has been gaining acceptance as a flooring material for bunker silos. Asphalt handles acids and freezing better than concrete. Place asphalt over a well-packed base. Use fabric under the base for stability. Construct a concrete curb around the edge of the apron to prevent damage from traffic entering and exiting the pad. On very hot days, tractor operators must take care not to spin tires, as the asphalt becomes softer in extreme heat.

**To estimate how much silage is in a bunker silo:**

Length (m) × width (m) × height of silage (m) × density (kg/m$^3$ wet basis) = kg of silage in silo

Length (ft) × width (ft) × height of silage (ft) × density (lb/ft$^3$ wet basis) = lb of silage in silo

Alberta Agriculture and Forestry has an online calculator to estimate how much silage is in a bunker silo: www.agric.gov.ab.ca/app19/calc/volume/silageweight.jsp.

### *Filling and Packing*

The target density in a bunker silo is 224–240 kg dry matter/m$^3$ (14–15 lb DM/ft$^3$). Moisture content of the ensiled material should be no less than 60% and no more than 72% to allow adequate compaction and provide good fermentation. Filling should be done as fast as possible to maintain quality and stability of the silage during feed out.

Data collected in Ontario on the density of corn silage in bunker silos had an average of 211 kg DM/m$^3$ (13.16 lb DM/ft$^3$), which is below the target of 224-240 kg DM/m$^3$ (14–15 lb DM/ft$^3$).

The time required for proper packing is determined by the weight of the packing tractor. Multiply the weight of the packing tractor (in kilograms) by the time spent packing the silage (in hours). Then divide the result by the tonnes of silage dry matter stored. A total of 800 hour-kilograms per tonne (1,600 hour-pounds per ton) is required to achieve proper packing. If the packing tractor isn't heavy enough, consider adding weights to the tractor or tires, bringing in a second tractor or slowing down the harvest speed.

**Example:** A forage wagon containing 3.5 tonnes of dry matter takes 12 min (0.2 hr) to pack with a 14,000-kg payloader and 28 min (0.47 hr) with a 6,000-kg tractor. Many custom operators harvest this amount in 8–10 min. To keep up to silage delivery at this speed, use a heavier packing tractor or an additional packing tractor.

Bunker silos should be filled from back to front, in a wedge shape with a slope of 1:4, and by packing layers no more than 15 cm (6 in.) thick at a time. This method is known as a "progressive wedge." Research has shown that the progressive wedge method improves preservation of digestible carbohydrates and increased stability at feed-out, apparently because of reduced exposed surface area when compared with the full-length method. It also permitted easier packing than the full-height method.

## CAUTION!

Packing silage can be a dangerous operation; never fill bunkers higher than the walls to reduce the risk of a tractor dropping off. Backing tractors up steep slopes can lower the risk of a roll-over. Be sure to use roll-over protection systems (ROPS) on all packing tractors and develop a drive plan to avoid collisions if multiple tractors are used.

### *Covering*

Research data from K.K. Bolsen and his Kansas State University team have shown that silage will lose an average of 30% or more of its dry matter when stored in an uncovered bunker silo.

The best option is to use an oxygen barrier plastic film specifically designed for covering silages. The use of 6- or 8-mil (1 mil = 1/1,000 in. or 0.0254 mm) plastic film is an alternative. In concrete bunkers, plastic should be used on the side walls and folded over the pile when the bunk is full to help prevent precipitation from running down the inside walls of the bunker. Drainage conduit is one option to use along the concrete edge to protect the side plastic from tearing while it is hanging over the side wall during filling. Weigh down the entire silage surface with tires, pea-gravel filled bags or other suitable materials. Research results show that a greater tire density increases silage preservation. For optimal results, place tires close enough to touch each other. It’s critical to seal the bunker properly as soon as possible after filling is finished. Do not follow any advice that suggests that the silage be left to settle after tractor packing is complete or wait to cover the pile until the next day. Greater losses occur the longer the pile is exposed to the oxygen in air.

Sausage-bags are an alternative to tires. Instead of tires, sausage-bags filled with sand or gravel anchor the cover in place. The advantages of this system are the added protection, improved sealing, flexibility and ease of installation and storage of the sandbags. A polyethylene sleeve holds together several of the sausage-bags across the width of a silo. This product reduces the chance of air infiltration between the sausage bags. Figure 15-12 shows sausage bag placement. Use the sausage bags directly on the silo plastic, to reduce the cost and replace the use of tires. This is a good solution if birds or animals tear the plastic seal.

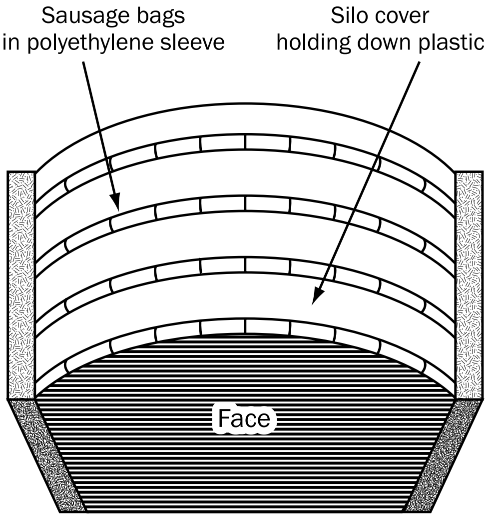


**Figure 15-12.** Sausage-bag placement.

### *Feed Out*

Feed out management is as important as filling. Losses can be large when the bunker is opened, and the face is exposed to oxygen. Take precautions to minimize oxygen penetration. Shaving or chipping the face will help achieve this goal. Keep the face as clean as possible. Removing the required amount of feed will reduce heating and keep dry matter losses to a minimum.[3]

## Bag Silos

Bag silos are frequently used as temporary silage storage when farms are expanding, or when they have higher forage yields than anticipated (Figure 15-13). If the integrity of the bag is maintained, dry matter losses are low and feed quality is excellent. For longer-term use as a permanent system, bags have a number of disadvantages. Unless they are placed on a well-drained, weed-free base, rodent damage is a constant threat. Hail and birds can also be a problem, and fighting the mud adds to labour costs. Bags require a large storage area. When the cost of preparing a large well-drained pad for the bags is included, the system becomes costly for long-term use.[4]

**Figure 15-13.** Bag silo.

# Seepage

Silage seepage presents two concerns for the agricultural industry — water pollution, and corrosion and deterioration caused by the silage juices.

When silage is harvested and stored at low moisture contents, less than 70% for horizontal silos and 60% for tower silos, there is minimal corrosion and pollution threat. Above this moisture level, significant flow of silage juices (or seepage) from silos may occur (Table 15-3 and Figure 15-14). Corrosion happens where the seepage is trapped for a period of time.

The production of seepage can be reduced or eliminated through cropping techniques and harvest timing (see Chapter 14, *Harvest*).

However, there are conditions where seepage cannot be avoided. For example, weather conditions may force a farmer to harvest wet silage or ensile byproducts such as sweet corn materials. Both will result in seepage production.

**Table 15-3. Tower Silo — Maximum Moisture Content to Minimize Seepage, Whole-Plant Silages**

| Silo Size | Maximum Moisture Content |
|---|---|
| 3 m × 11 m (12 ft × 40 ft) | 72% |
| 4 m × 15 m (14 ft × 50 ft) | 70% |
| 5 m × 18 m (16 ft × 60 ft) | 68% |
| 6 m × 21 m (20 ft × 70 ft) | 66% |
| 7 m × 26 m (24 ft × 85 ft) | 63% |
| 9 m × 26 m (30 ft × 110 ft) | 60% |

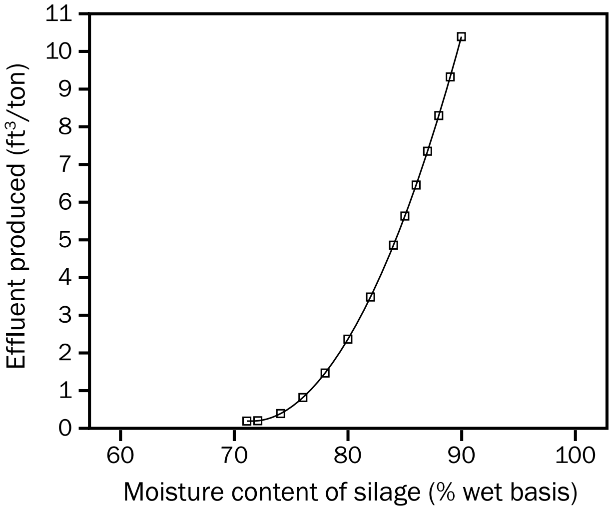


**Figure 15-14.** Horizontal silo — seepage production based on silage moisture content.

The greatest percentage of silage seepage is produced within 5–10 days of storage loading. For normal silage and haylage production, the remaining seepage is usually produced within the following 30 days. The volumes produced are dependent on the vertical pressure in the silo and the initial moisture content of the crop.

The addition of acid additives to silage facilitates higher crop moisture, which can result in a higher initial rate of silo seepage.

Seepage flow out of vertical silos is the greatest during the first month of storage. In silos with good internal drainage (i.e., a network of floor drains to carry out leachate), it tapers off after that. Where internal drainage of the silo is poor (or the ensiled material is higher moisture), flow will occur throughout the total storage period as the silo is being emptied. Rainwater on uncovered silage can produce additional effluent.

For horizontal silos, the rain runoff or snowmelt from the floor area inside the storage and feed preparation area adds more effluent to the collection system. The highly concentrated effluent base flow will be increased on occasion by rainstorms and snowmelt.

## Environmental Concerns

Most of the environmental problems associated with silage/haylage seepage on farms (mostly the risk of seepage entering surface or ground water) come from improper or inadequate collection and retention of the seepage draining from the silos. An adequate collection and storage/treatment system is essential if seepage is anticipated.

Silage seepage in an undiluted form has extremely high BOD (biochemical oxygen demand) values, ranging from 12,000–90,000 mg/L (1.6-12 oz/gal) (Table 15-4), which is approximately 60–450 times stronger than domestic sanitary sewage. Even a small discharge of seepage into a watercourse can remove enough oxygen for a fish kill to occur. Charges have been laid in Ontario where silage seepage was linked to fish kills. In addition, cases of silage seepage contaminating wells in Ontario and the U.S. have been reported.

Table 15-4 shows that seepage contains significant nutrient concentrations (similar to liquid dairy manure). Seepage is an excellent nutrient source for growing crops if properly applied to land. However, similar to other nutrients, seepage can become a pollutant if it enters surface water or groundwater. See Chapter 2, *Soil Fertility and Nutrient Use,* for more information on applying nutrients to forage crops.

It is important that all the base flow from the silo along with the first flush of precipitation runoff is collected and stored, since this material has higher concentrations of organic matter and nutrients.

**Table 15-4. Constituents of Silage Seepage**

| Constituents | Silage Seepage (typical) | Liquid Dairy Manure (typical) |
|---|---|---|
| Dry matter (%) | 5 (range 2–10) | 5 |
| Total nitrogen (mg/L) | 1,500–4,400 | 2,600 |
| Phosphorus (mg/L) | 300–600 | 1,100 |
| Potassium (mg/L) | 3,400–5,200 | 2,500 |
| pH | 4.0 (range 3.6–5.5) | 7.4 |
| Biochemical oxygen demand (mg/L) | 12,000–90,000 | 5,000–10,000 |

## Acid Corrosion and Deterioration of Silos

Most deterioration of concrete silos is caused by the attack of silage acids. When moist plant material is put into a silo, it goes through the ensiling process, which produces silage acids, principally lactic and acetic acids. When these acids touch the concrete silo walls, they react with the Portland cement matrix that binds the aggregates together. As the structure ages, there is a gradual decline in strength.

The same acids also corrode tower silo hoops, reinforcing steel or hardware associated with the silo. Without proper maintenance and repair, this can ultimately lead to silo failure. Table 15-5 provides information on the acids in silage seepage that cause silo corrosion.

**Table 15-5. Aggressive Constituents of Silage Seepage**

| Constituents | Quantity |
|---|---|
| Lactic acid | 4%–6% |
| Acetic acid | 1%–2% |
| Butyric acid | Normally less than 1% |
| pH | 3.5 to 5.5 |

The rate and severity of this deterioration depends on such factors as:

- the size of the silo
- the moisture content of the ensiled material
- the amount of continuous protection given to the concrete

Silage pressure plays a large part in determining the rate and extent of acid deterioration. In any silo, the highest pressure is at the bottom. Taller silos produce higher pressures. This creates increased squeezing on the ensiled mass, which creates even more free liquid and seepage. These acid-laced silage juices are then forced into the tiny pores in the concrete. As a result, larger silos often suffer more acid deterioration than smaller silos. Ensiling higher-moisture material leads to more fermentation and a higher level of acid production. This, in turn, results in accelerated concrete deterioration.

**CAUTION!**

The collapse of a tower silo can have serious consequences. In Ontario, farm owners and workers have died as a result of a silo collapse. The silos have fallen onto adjacent barns, injuring or killing animals, destroying property and ruining any silage or grain stored there.

To prevent, or at least reduce the severity of, silage acid action, you can:

- Build or buy a quality silo, where the walls are made of high-quality concrete. Strong, dense concrete provides good acid resistance.
- Protect the silo walls by preventing silage acids from coming into contact with the concrete.
- Apply a suitable acid-resistant coating to the bottom quarter to third of the inside wall surface of the new silo prior to use.
- Renew this coating as required to maintain a barrier.
- Reduce deterioration caused by silage acid by harvesting crops at a moisture content low enough that seepage will not occur.
- Ensure that whole-plant silages contain enough moisture for good fermentation, yet are dry enough to avoid free liquid being squeezed out.
- Use a moisture tester to determine when the crop is at the proper moisture level for storage.

- If possible, remove all silage from the silo once a year. This reduces the time the bottom of the silo wall will be in contact with wet silage.
- Allow the inner silo wall surface to dry out between fillings.

The only warning sign of impending failure of a silo is cracking in the concrete. At least annually, scan the entire outside of the silo to determine if new cracks have developed. Use binoculars to do a cursory inspection.

If a silo shows signs of distress, contact a professional engineer before emptying the silo.

**CAUTION!**

The consequences of a structural failure are severe and can be life threatening. Emptying a silo can cause a significant increase in the loads applied to the structure. If a failure is about to happen, unloading the silo can cause an instantaneous structural failure. If you suspect that your silo has structural problems, do not fill or empty it before having a professional engineer on-site to evaluate the situation.

It might seem logical to take older, concrete silos and use them for dry grain storage. Do not undertake this without professional advice. Silos designed for whole plant silage or haylage must have additional reinforcement to convert to dry grain. This is usually in the form of steel hoops at vertical intervals on the outside of the silo. Contact an engineer to design this increased reinforcing.

Do not convert a silo to dry storage without contacting a professional engineer.

## Storage and Treatment of Silage Seepage

**CAUTION!**

Never mix silage effluent in enclosed tanks, especially tanks within barns, because silage effluent mixed with manure slurry will accelerate the release of hydrogen sulphide gas. Add seepage only to uncovered outdoor storages.

Recommended practices for managing silo seepage include:

- Cover the silo to prevent precipitation from entering and leaching through the silage/haylage.
- Divert all surface water away from the silo site, as this is considered clean water and does not require collection and storage.
- For new silos where any seepage is expected, install a seepage collection and storage system.
- Inspect the interior silo surface each time the silo is empty for signs of corrosion. Wherever corrosion is severe, recoat the inside of the silo.
- For horizontal silos, there are several options to manage seepage:
  - **Existing horizontal silos:** Place a 100-mm (4-in.) tile drain on the floor where the wall meets the silo floor.
  - **New silos:** Form holes in the wall to drain silo seepage to an outside drain. Protect steel from silage acids with adequate (75 mm (3 in.)) concrete cover.

- **Existing or new horizontal silos with good floor drainage to the front of the silo:** Install a catch basin that collects seepage and drains to a long-term storage tank. A horizontal interceptor drain to the front of the silo is very effective in collecting leachate and leachate-impacted runoff from the silo area. (Figure 15-15)
- Flow may occur throughout the total storage period as the silo is emptied. Diluted flow or flow in periods where seepage is not collected must not directly enter a watercourse or catch basin or run across land with shallow bedrock.
- Contact a professional engineer to design storage and treatment facilities for silage seepage.

**Figure 15-15.** Intercepting drain to collect seepage from bunker silos.

Concentrated seepage may have to be mixed with the same amount of water (1:1) for application directly onto crops. Seepage is considered a nutrient, and the amount being applied must be accounted for in the Nutrient Management Plan.

Seepage is also used as a supplementary feed. Due to its high potassium and nitrate levels, only feed seepage after getting expert advice.

Seepage can also be used as an input for a digester system. To avoid operational issues, make sure it is introduced slowly.

Producers should contact their local environmental officer prior to using a vegetated area as a silage seepage treatment option. Release any dilute material or runoff to a vegetated area. Do not do this if the vegetated area is on shallow bedrock. Make sure adequate distance to surface water or tile drain inlets exists.

As a good management practice, the Environmental Farm Plan recommends:

- locating seepage collection tanks at a distance of 60 m (200 ft) or greater from surface water (i.e., streams, ditches, ponds or tile inlets)
- setting separation distances between seepage tanks and wells at 23 m (76 ft) or greater for a drilled well and 46 m (151 ft) or greater for a bored/dug well

Locate storage sites for bagged, wrapped or tubed haylage (baleage) at least 9 m (30 ft) from surface water sources and field drainage tiles to reduce the risk of contamination.

# Spontaneous Combustion (Fire)

The process of forage heating up and then burning is typically called spontaneous combustion. Spontaneous combustion for hay usually occurs within the first two months of storage. In silos, forage can dry down if air enters the silo through leaks in walls or doors; this results in the potential for fires throughout the whole year.

Spontaneous heating and combustion occur when sufficient moisture (above 25% and below 45% moisture content for forages), oxygen (air) and organic matter are present together to support the growth of bacteria and moulds. This growth results in an initial temperature peak of 54°C–65°C. When the forage reaches this temperature range, a chemical process called the Maillard Reaction may occur, causing additional heat generation. This reaction can be self-sustaining and does not require oxygen (air) to continue. The gases produced will ignite if they have reached a high enough temperature and are exposed to oxygen (air).

**What Is the Cause of Fires?**

- Hay that is too wet will heat (above 25% moisture content) and then enter the spontaneous combustion cycle (see Figure 15-16 and Table 15-6).
- Silage and haylage that is too dry will heat (below 40% moisture content) and then enter the spontaneous combustion cycle (See Table 15-6).
- A large mass of forage that allows the heat to build up.
- A slow trickle of air moving into the material.
- Old silage (2 years) in silo, drying down to critical level.

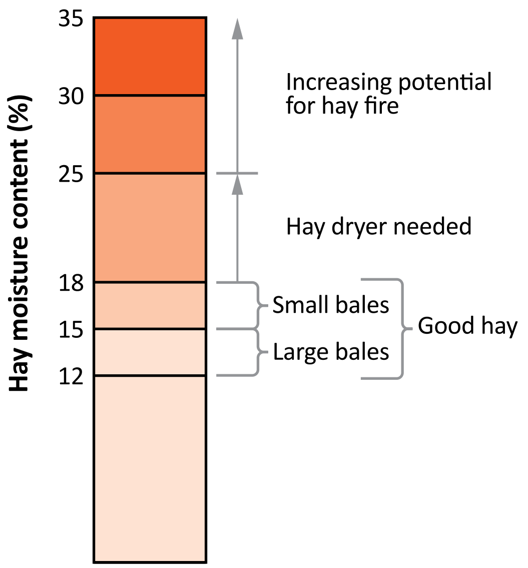


**Figure 15-16.** Moisture levels for dry hay.

# Fire Prevention

The moisture of the hay or silage/haylage is the main factor in forage fires (Figure 15-16). To reduce this burning issue, know the crop moisture content. Buy a moisture tester or use your microwave oven to determine the moisture content. See Chapter 14, *Harvest,* for information on moisture testing forages.

For hay above recommended moisture levels, a hay dryer should be used. Stack hay on edge to keep bale shape and allow some air flow. Large bales, due to their higher density and greater volume, inhibit dispersal of heat and moisture. Therefore, large bales will burst into flames easier than small square bales if baled too wet. See Table 15-6 for recommended moisture levels.

**Table 15-6. Recommended Storage Moisture Contents**

| Storage Type | Recommended Storage Moisture (%) | Recommended Dry Matter Content (%) |
|---|---|---|
| **Hay** | | |
| Small square bales | 15–18 | 82–85 |
| Large round bales: soft core | 13–16 | 84–87 |
| Large round bales: hard core | 12–15 | 85–88 |
| Large square bales | 12–14 | 86–88 |
| **Silage or Haylage** | | |
| Horizontal silo | 60–70 | 30–40 |
| Tower silo | 60–65 | 35–40 |
| Oxygen-limiting tower silo | 45–55 | 45–55 |
| Bagged (chopped) | 60–70 | 30–40 |
| Baleage | 50–60 | 40–50 |

*Notes:* Calculated on as-fed basis.
*Source:* H. Bellman, S. Clarke, B. Stone.

Many farmers sprinkle salt on hay as it is stored, in an effort to prevent hay fires. However, tests have shown that salt has no effect on controlling spontaneous combustion. Dry ice, liquid nitrogen or carbon dioxide gas pumped into the hay will prevent combustion by eliminating the oxygen from the hay mass.

Check hay regularly. A slight caramel odour or a musty smell are signs that the hay may be heating.

The key to fireproofing silos lies in eliminating the combination of dry silage and fresh air. The following components of a silage storage are necessary to make silage and to prevent fires:

- Check doors on tower silos regularly and if loose fitting or damaged, repair so air does not enter the silage.
- Air can also enter through damaged silo walls. Empty silo completely every 2 years. Check walls for damage and repair if necessary.

Most silo fires occur because the silage is too dry. Silage should be between 45% and 65% moisture content. Silage below 40% moisture content, coupled with extra air from poor packing or leakage of air into the silo creates a risk of heat damage or fire.

**Fire Danger Zone?**

- If the shed or silo warms up.
- If you see wisps of water vapour (steam).
- If you smell a slight caramel odour.
- If you smell a pungent, scorched stench like burning baler twine. **Call the fire department.**
- If you see smoke or flames. **Call the fire department.**

# Assessment by Probing

## Hay

When it is evident that hay is heating, the primary goal is to measure the temperature by probing the hay with a homemade device similar to that shown in Figure 15-17. Probing will determine if there is a fire and its location, or it will help assess the likelihood of a fire. Use the temperature information in Table 15-7 to help in the decision-making. The simplest test is to stick an iron or copper rod deep into the centre of the forage and leave it for about an hour. If it's almost too hot to hold when removed, there is a problem.

A probe can be made from a 3-m (10-ft) piece of electrical tubing. Rivet a hardwood pointed dowel to one end and drill eight 5 mm (¼ in.) diameter holes in the tube just above the dowel. Drive the probe into the hay mass and lower a candy thermometer on a long string into the probe. The thermometer should be left for 10 minutes to ensure an accurate reading.

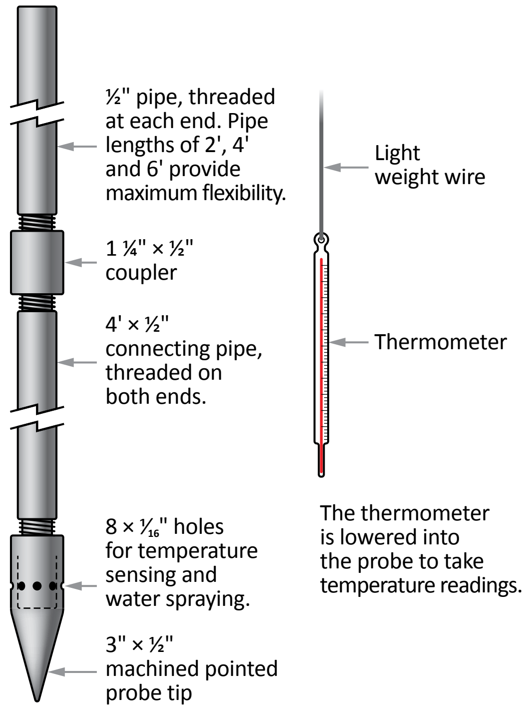


**Figure 15-17.** Hay probe and thermometer.

**Table 15-7. Critical Temperatures for Spontaneous Combustion**

| Temperature | Action |
|---|---|
| 65˚C | Check temperatures daily. Below this point, temperatures are not considered abnormal, although anything above 52˚C is unusual. |
| 70˚C | Danger! Measure the temperature every 4 hours and inspect the hay storage. |
| 80˚C | **Call the fire department!** Keep all doors and other openings closed to prevent drafts, which add oxygen to the fire.<br>Remove animals and tools from the structure before touching the hay. With help from the fire department, wet the hay down and remove it from the barn. Forage above 82˚C may burst into flame when exposed to air. Hay should be placed a good distance away from buildings as it is removed from storage in case it starts to burn. |

### Silage

For silage, temperature readings above 82°C indicate that the material will eventually char, smoulder or burn. Probing silage is mainly used to find the location of the fire, since in most cases a fire is burning before anyone notices the signs of heating. Typically, the fire will be in the top 3 m (10 ft) or around poorly sealed silo doors. Infrared scanning can also be used to indicate the hot spot location. Access to this equipment may be obtained through your farm safety officer, the Ontario Fire Marshal's Office in Toronto or local insulation companies.

## Extinguishment Procedures

### Hay

For hay storage, heating is often confined to a pocket within the storage. Attempting to remove this pocket should only be done when the fire department is there with a water truck, since the material may flame when exposed to air. Removal of hay may be accomplished by using a High-Hoe or a logging clam. Hay should be placed a good distance away from the barn in case it starts to burn.

If the fire is so active that it must be extinguished in the barn, wet the hay and remove it immediately. Workers must be aware of the potential for collapse of bridged hay over fire cavities in the barn.

Extreme caution should be taken when fighting a hay fire if hay has been treated with chemical preservatives. Hay treated with preservatives containing ethoxyquin and butylated hydroxytoluene (BHT) will produce hydrogen cyanide gas at around 115°C (240°F). This gas is very deadly. Additives containing primarily propionic acid do not produce hydrogen cyanide during a fire.

### Silage

Call the fire department and let them put the fire out. Firefighters will require full turn-out gear including self-contained breathing apparatus due to dangerous silo gases. In conventional open-top silos, they will locate the hot spots with a probe and put it out by injecting small streams of water through the probe right to the seat of the fire. Gases may be produced when injecting water into a hot silage fire. However, there is no containment of gases since the silo is open and not sealed, which practically precludes the occurrence of an explosion.

In conventional open-top silos, unloading of fire-damaged silage is recommended:

- since there is very little nutritional value left
- water has leached the acids allowing moulds to grow and spoil the silage
- re-ignition of silage material may occur

**Table 15-8. Estimate Amounts of Carbon Dioxide, or Liquid Nitrogen for Control of Silo Fires**

| Silo Size Diameter × Height | Carbon Dioxide ($CO_2$) | Liquid Nitrogen ($N_2$) |
|---|---|---|
| 6 m × 18 m (20 ft × 60 ft) | 20 cylinders | 40 cylinders |
| 6 m × 21 m (20 ft × 70 ft) | 22 cylinders | 44 cylinders |
| 6 m × 24 m (20 ft × 80 ft) | 30 cylinders | 60 cylinders |
| 7 m × 18 m (24 ft × 60 ft) | 30 cylinders | 60 cylinders |
| 7 m × 21 m (24 ft × 70 ft) | 35 cylinders | 70 cylinders |
| 7 m × 24 m (24 ft × 80 ft) | 40 cylinders | 80 cylinders |
| 9 m × 18 m (30 ft × 60 ft) | 45 cylinders | 90 cylinders |
| 9 m × 21 m (30 ft × 70 ft) | 50 cylinders | 100 cylinders |
| 9 m × 24 m (30 ft × 80 ft) | 60 cylinders | 120 cylinders |

*Note:* Gas cylinders are large size.
*Source:* Murphy, Dennis J. and William C. Arble. *Extinguishing Silo Fires and (NRAES-18)*. Pennsylvania State University.

Thorough dousing of the top layers of forage before unloading and running the unloader intermittently will minimize unloading problems due to fire and motor overheating.

In oxygen-limiting silos, a fire is potentially very dangerous, since there is containment of explosive gases. The method of control will be to inject liquid nitrogen or carbon dioxide into the silo to cool the fire. See Table 15-8 for the amounts needed.

Every oxygen-limiting silo should have valves specifically designed to inject gases for fire control. Check the owners' manual for specific information about extinguishing a silo fire.

# Recycling of Plastic Films

Recycling means moving plastic from the agricultural waste stream back into the manufacturing process. To make recycling a reality, there must be a system or infrastructure in place. Collecting, sorting, reprocessing and marketing are the basic components of any such system.

The major problems associated with recycling agricultural film are:

- Inability to keep the material clean
- Ultraviolet degradation
- High cost of collection and sorting
- Lack of reliable end use market

Efforts are under way to collect and recycle agricultural plastic films throughout the world. These problems will be solved in the near future. Currently, the best recommendation for Ontario farmers is to store the plastic film for future off-farm recycling.

## Collecting

Recyclers must collect a lot of material from many farms. However, used plastic film is bulky and cannot be transported very effectively. To reduce transport costs for this bulky material, farmers can compact and bale clean plastic film on the farm. Specially-designed compactors have been developed for this purpose.

Steps to prepare for off-farm recycling:

- Once the plastic film is removed, shake it to get contaminants off (dirt, haylage, water, ice, etc.). Separate strings from the plastic.
- Store plastic films immediately indoors. This will keep it from further contamination and sunlight. Some farmers are storing plastic in hay wagons inside machinery sheds.
- Keep plastic clean and dry.
- Compact into bales for easier handling, storing and transporting. Note: Bale only with plastic string not jute.
- Send bales to a pilot recycling project in your area or store for a future full scale recycling program.

# Sorting

Agricultural plastic film is mainly low density polyethylene. Sorting of this material is needed because there are different plastic products and additives. For example, plastic wrap is 0.5 to 1 mil thick and has tacifiers (glue) compared to tube plastic which is 4 to 15 mil thick with no tacifiers.

# Reprocessing

Agricultural plastic films must be cleaned before being converted into pellets for film or formed into moulded products like plastic lumber and fence posts. Incoming plastics must be inspected for contamination and are accepted or rejected depending on the level of contamination. Contamination includes dirt, sand, stones, grease, vegetation, water, other types of plastic, glue, tape and ultraviolet (UV) light degradation. If the film has lost its flexibility and is crinkly, it has serious ultraviolet light damage. UV damage can severely limit the recyclability of agricultural plastic film.

Plastic films are then chopped in a grinder, washed to remove contaminants, then fed into an extruder where heat and pressure melt the plastics. The molten plastic is extruded into fine strands, then cooled and chopped into pellets. These pellets are used by manufacturers to make new plastic film products.

Some plastic film is chopped then melted and formed directly into moulded products.

# Marketing

## Recycled Film

For agriculture, plastic films could be recycled back into plastic film. This is the best option since there is no need to develop a market for the recycled plastic.

## Plastic Moulded Products

Here are several options for molded products such as landscape timbers, fencing, planking for farm pens, roadside posts, benches, picnic tables and pallets. All these options require a marketing plan for selling the new products.

With fine tuning, 97% recovery of plastic films into pellets for remanufacturing is possible. These pellets could then be used for making recycled film in a 50/50 blend with virgin pellets, garbage bags, ground cover sheets, luggage, weather stripping, etc. Preliminary results indicated that during processing, stretch wrap curls up on itself, is hard to wash, water and dirt is trapped, and extruding filter screens tend to plug up. These results indicate that process adaptations will be needed to make agriculture plastic film into pellets or flakes for remanufacturing.

The results of using agriculture plastic film to manufacture plastic lumber is very promising. Some problems are the material being too wet and dirty to handle, and brown stripes caused by the heating of silage and haylage residues in the plastic. Modification of the process to handle wet material by adding a drier or collecting only dry plastic and using darker colouring may solve these problems.

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3. Ruppel, K.A., R.E. Pitt, L.E. Chase and D.M Galton. 1995. *Bunker Silo Management and Its Relationship to Forage Preservation on Dairy Farms.* Journal of Dairy Science. 78:141-153.

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# Additional Sources

This chapter contains excerpts from the following OMAFRA sources:


Publication 811, *Agronomy Guide for Field Crops.* 2017.

*Silo and Hay Mow Fires on Your Farm,* Factsheet 93-025. 1993.

*Harvesting and Storing Large Bale Haylage*, Factsheet 01-073. 2001.

*How to Handle Seepage From Farm Silos,* Factsheet 15-003. 2015.

*Spontaneous Combustion and Hay Fires.* 1998.

*Planning Dairy Operation Feeding Systems for Expansion.* 2011.

*Deterioration of Concrete Tower Silos,* Factsheet 08-057. 2008.

*Farm Silo Selection.* 1981.

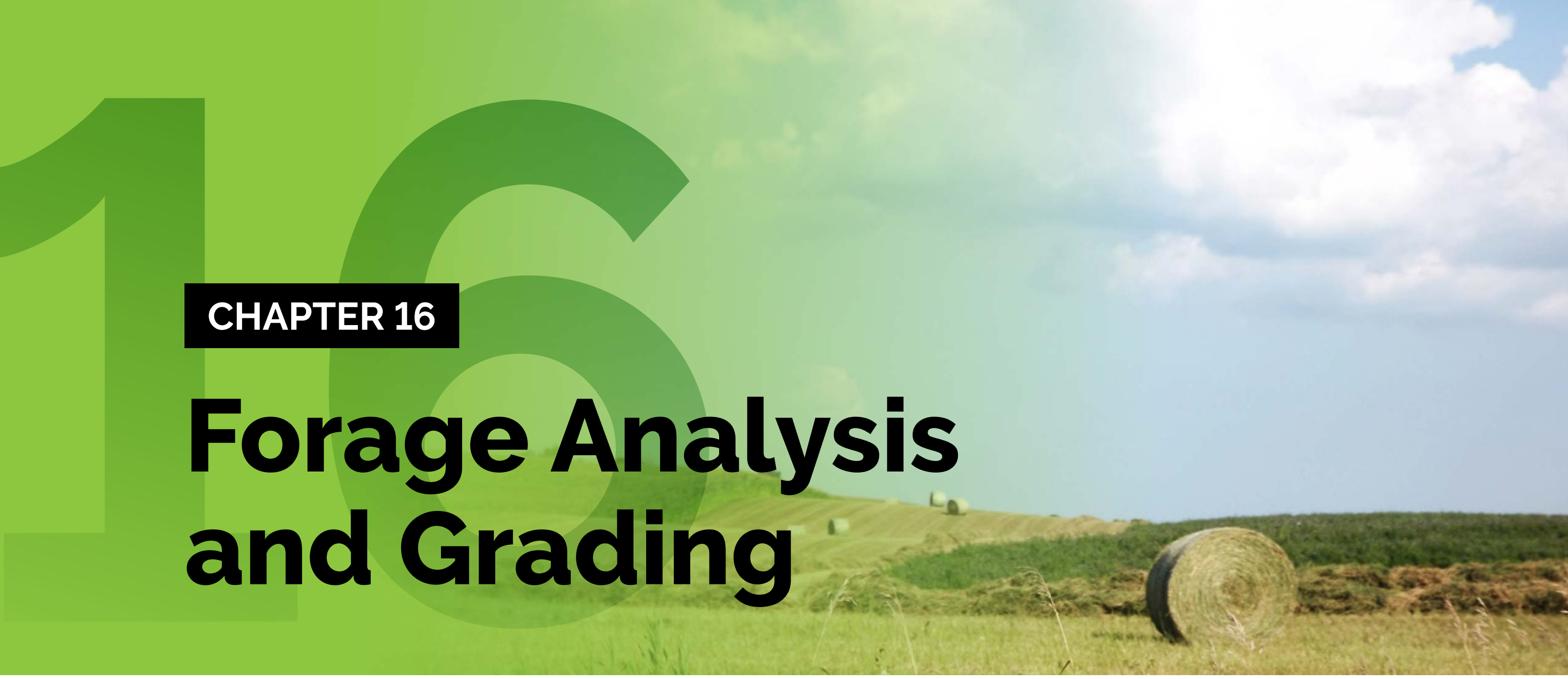
*Reducing Hay Storage Waste.* OMAFRA Virtual Beef Newsletter. Last modified: February 15, 2019. www.omafra.gov.on.ca/english/livestock/beef/news/vbn0219.htm

*Hazardous Gases on Agricultural Operations,* Factsheet 14-017. 2017.

*Maintaining Quality in Large Bale Silage,* Factsheet 98-069. 1998.

*Bunker Silo Management*. 2000. www.omafra.gov.on.ca/english/livestock/dairy/facts/info_bunker.htm

*Recycling Farm Plastic Films*, Factsheet 95-019. 1995.



CHAPTER 16

# Forage Analysis and Grading

## Taking a Forage Sample for Analysis

Forage sampling is very straightforward and is the critical part of determining forage quality. Taking a forage sample is necessary to correctly balance rations, which will deliver a desired animal performance and help determine the market value of a forage.

There is considerable variation in a forage lot. A lot is one cut from one field, harvested at a similar maturity and under the same weather conditions. To take a representative sample, follow the techniques outlined below.

### Sampling Hay

It is impossible to get an accurate sample by grabbing handfuls of hay, so a sample probe is essential. There are many different types of commercially available sample probes. Push types operate manually, while drill types that use either a hand brace or electric drill are more common. Many newer probes have a canister collection chamber that holds the core samples. The inside diameter should be 1–2 cm (⅜–¾ in.). A smaller diameter may not cut properly. A large diameter probe may result in a sample that is too large for the lab. Avoid open augers that lose leaf particles when withdrawn from the bale. Sample probes should allow penetration 30–55 cm (12–22 in.) into the bales. Research has shown that an extra long probe is probably not required for large bales.

Probe tips may be serrated, scalloped or straight (Figure 16-1). Make sure that the probe tip is sharp. Sharp tips cut cleanly through the forage, while dull tips push stems aside and bias the sample. Scalloped or straight-tipped probes can be manually sharpened with a file. The cutting edge should be at right angles to the probe. Serrated tips require special equipment to sharpen, so it is often easier to replace them when they are dull.

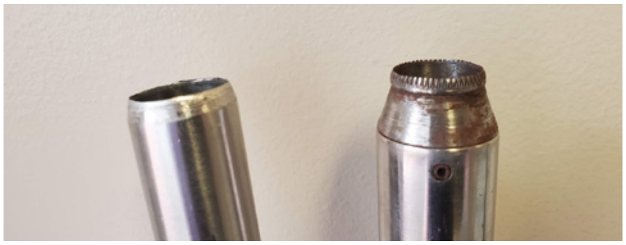


**Figure 16-1.** Forage probe tips may be straight, scalloped (not shown), or serrated.

**CAUTION!**

The tips of sample probes are very sharp and must be handled with care to avoid serious injury.

**Technique:**

1. Insert the probe at a 90˚ angle and remove the core.
   - Round bales: Sample from the round edge of the bale.
   - Large square bales: Sample from the butt end of the bale.
   - Small square bales: Sample from the centre of the butt end of the bale.
2. Repeat step 1 until a minimum of 20 bales (1 core per bale) are sampled.
3. Combine core samples into a single sample. Put the sample in a plastic freezer bag, remove air from the bag and seal well.

## Sampling Baleage

Baleage sampling is very similar to sampling large bales of hay. A sharp probe is necessary to collect a representative sample. Bales should be sampled at random and at various heights. This is particularly important for baleage because the bales will be wetter at the bottom, and fermentation may be uneven throughout the bale.

Fermentation takes up to 8 weeks to complete. Once fermentation is finished, the forage analysis will be consistent for a long time. For the most accurate results, wait 8 weeks after harvest to take the sample. However, if the baleage will be fed less than 8 weeks after harvest, take a sample before feeding and another after 8 weeks to rebalance the ration.

**Technique:**

1. Use a utility knife to make a slit in the bale wrap large enough to insert the probe. Insert the probe at a 90˚ angle and remove the core.
   - Round bales: Sample from the round edge of the bale.
   - Large square bales: Sample from the butt end of the bale.
2. Seal the hole with a high-quality silage tape. Use several layers of tape to prevent spoilage.
3. Repeat steps 2 and 3 until a minimum of 20 bales (1 core per bale) are sampled.
4. Combine the core samples into a single sample. Put the sample in a plastic freezer bag, remove air from the bag and seal well.

## Sampling from a Tower Silo

Tower silos use gravity to pack and remove air from the silage. This means that the silage at the top of the tower is less dense and may spoil. An accurate sample does not include this top material.

Just like with baleage, fermentation takes up to 8 weeks to complete. Waiting until fermentation is finished will result in a more stable forage for sampling. However, if the silage will be fed less than 8 weeks after harvest, take a sample before feeding and another after 8 weeks to rebalance the ration. Resample during feed-out as per your nutritionist's direction.

If the change between cuts is marked in some way, resample when the next cut is reached.

**Technique:**

1. Remove the first metre of silage.
   - Option 1: Collect handfuls of silage from the conveyor as it comes out of the silo.
   - Option 2: Collect handfuls of silage from the feed cart at the silo exit.
   - Option 3: Unload silage into a container (wheelbarrow, etc.), mix it and take a sample.
2. Put the sample into a plastic freezer bag, remove air from the bag and seal well.

## Sampling from a Horizontal Silo (Bags and Bunkers)

### CAUTION!

Very tall faces of bunker silos can be dangerous should an avalanche of forage material break loose from the face. Take precautions and avoid working near the face of the bunker closer than a distance of twice the height of the face material. Avoid removing forage material in ways that develop overhangs of forage at the top of the face.

Waiting 8 weeks after harvest before sampling allows for fermentation to finish. However, if the silage will be fed before then, a sample should be taken prior to feeding and again at 8 weeks. Repeat samples may have to be taken at regular intervals as the silage is fed out, to rebalance the ration. Resample during feed-out as per your nutritionist's direction. If the change between cuts is marked in some way, resample when the next cut is reached.

**Technique:**

1. Use the front loader of a tractor or a silage defacer to bring down a pile of silage. Move the silage pile to a safe distance away from the silo face.
2. Collect 5–8 handfuls from the pile of silage that was brought down. Mix well in a clean bucket.
3. Put the sample into a plastic freezer bag, remove air from the bag and seal well.

## Submitting a Forage Sample

Samples tend to separate into leaf and stem particles, so do not subsample or divide this composite sample. The sample should be about 200 g (0.4 lb). Avoid samples that are too large and difficult for the lab to grind without subsampling. Subsampling defeats the purpose of careful sampling. Avoid samples that are too small to be representative of the hay.

Label samples clearly. As a minimum, the label should include the grower's name, the sampling date and what type of forage it is. Other useful information for the label includes the field the forage came from and which cut. Laboratories that offer forage analysis each have their own submission form that must accompany the sample(s). Contact the laboratory for a copy, or check their website for an online submission form.

How the sample is handled between the farm and the laboratory can affect the accuracy of the results. To minimize the amount of time between sampling and analysis, mail samples on a Monday, Tuesday or Wednesday to ensure they arrive before the weekend. Samples that cannot be mailed right away should be frozen.

There is no accreditation program for forage analysis in Ontario, so be sure to use a reputable laboratory.

# Understanding the Forage Analysis

There are two ways a laboratory may analyze a forage sample, either using wet chemistry or near infrared reflectance spectroscopy (NIR). Wet chemistry measures the nutritional value using heat and chemicals to break down the forage. NIR estimates the nutritional value of the feed using light reflection rather than chemistry to identify and measure amounts of compounds in a sample. The reflectance values are entered into calibration equations that estimate nutrient values. The equations are based on studies that use wet chemistry to validate NIR results. NIR provides fast and cost-effective results with minimal sample preparation by the laboratory. Wet chemistry is the more accurate test; NIR is an estimate and is only as good as the calibration equations.

Common analyses found on forage laboratory reports are described below.

## Dry Matter

Each report specifies the dry matter of the feed analyzed. This is the moisture-free material left after drying the sample in a laboratory oven. The reason for obtaining the dry matter is because moisture dilutes the concentrations of the nutrients present, and it is standard practice to evaluate the feed and balance rations using a dry matter basis.

### As Fed

As fed is an expression of feed nutrient content with moisture included. Nutrient content on an as fed basis is always lower than on a dry matter basis.

## Protein

Proteins are made up of complex combinations of amino acids and are essential for animal growth, production and reproduction.

### Crude Protein (CP)

Crude protein is an estimate of the total protein content of a feed determined by analyzing the nitrogen content of the feed and multiplying the result by 6.25. Crude protein includes true protein and other nitrogen-containing substances such as ammonia, amino acids and nitrates. Crude protein does not give an indication of the quality of protein in the forage. For this reason, reports generally split this parameter down further into soluble protein, acid detergent fibre-CP (ADF-CP), neutral detergent fibre-CP (NDF-CP) and rumen undegradable protein (RUP) also known as by-pass protein.

### Soluble Protein

Soluble protein is most readily available to animals. This consists of small amino acid chains, or non-protein-nitrogen that will solubilize in rumen fluid and be absorbed across the rumen wall. Soluble protein is the same whether you look at the As Fed or Dry Matter columns on the feed sheet because it is expressed as a percentage of the total crude protein. Preferably, this number should be 43%–63% of the CP in corn silage and 49%–67% of CP in haylage. Remember that the soluble protein content increases for corn silage as it ferments, so it is important to regularly test corn silage.

### Acid Detergent Fibre-Crude Protein (ADF-CP)

The ADF-CP is associated with the portion of the CP that is unavailable to the animal as a result of heat damage. In forages, this can be due to the natural heating of fermentation, whereas for some feed ingredients, such as distillers' grain, it is the actual heating process that occurs during grain processing. The preferred range is 0.8%–1%. Within this range, minimal damage has happened to affect the feed quality. Once elevated to 1.5%–2%, overheating has occurred and could mean potential damage to the feed quality, making some crude protein in the feedstuff unusable to the rumen microbes or to the animal.

## Rumen Undegradable Protein (RUP)

Rumen undegradable protein is the fraction of protein that is resistant to degradation by rumen microbes and can be absorbed in the small intestine. This fraction also can be called other names like undegradable intake protein (UIP) or by-pass protein.

# Carbohydrates

Carbohydrates are energy-providing substrates, including starches, sugars, cellulose and hemicellulose (Figure 16-2). All carbohydrates contain carbon, hydrogen and oxygen, and are usually divided into two fractions: structural (fibre from plant cell wall) and non-structural (sugars and starches from plant cell contents).

## Fibre (Structural Carbohydrates)

### *Neutral Detergent Fibre (NDF)*

Neutral detergent fibre measures the plant cell wall (lignin, cellulose and hemicellulose) content of the forage by boiling the sample in a detergent solution with a neutral pH. NDF is of low digestibility but can be broken down somewhat by the digestive tract microorganisms. NDF value is used to predict ruminant feed intake. The NDF value is related to the amount of forage the animal can consume and as NDF increases, the dry matter intake generally decreases.

NDF for corn silage commonly ranges between 38%–50%. For haylage, 39%–50% is typical. NDF increases with forage maturity.

### *Acid Detergent Fibre (ADF)*

Acid detergent fibre measures the lignin and cellulose content of the forage by boiling the sample in an acid detergent solution. The ADF value is used to predict the energy content (total digestible nutrients, net energy) of forages. The value is important as it relates to the ability of an animal to digest the forage; a higher ADF suggests a decrease in digestibility.

ADF for corn silage commonly ranges between 22%–30%. For haylage, 30%–39% is typical. ADF increases with forage maturity.

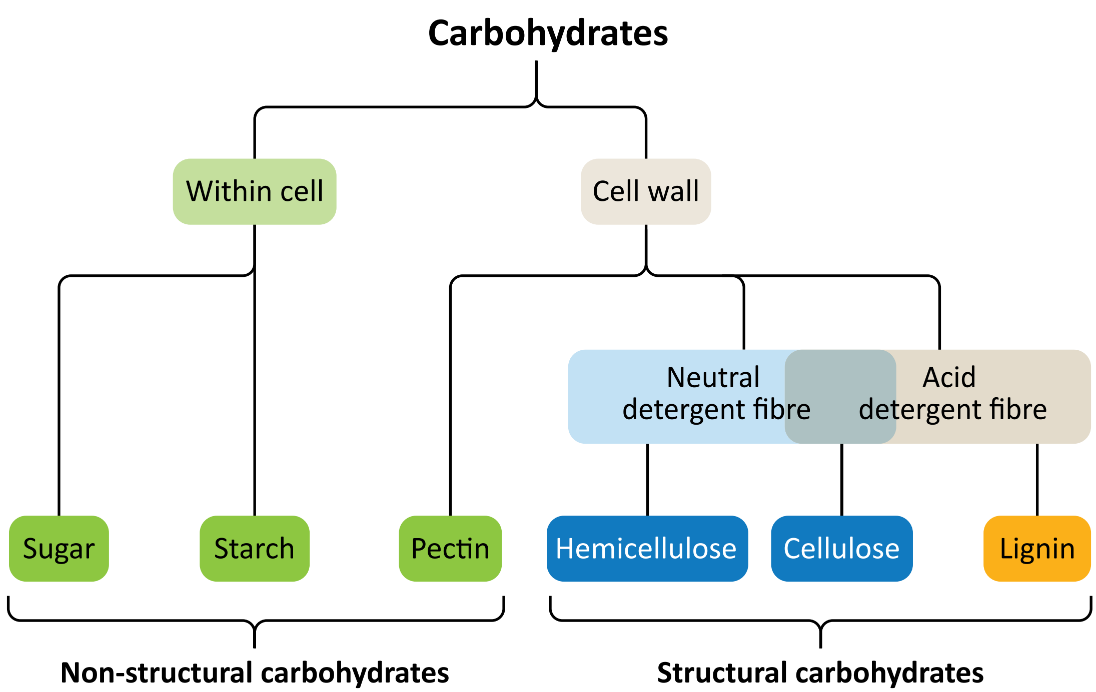



**Figure 16-2.** Types of carbohydrates in forages.

### *Lignin*

Lignin is the indigestible portion of the plant cell, also known as the glue that holds everything together. This number will increase with the maturity of the forage and usually ranges from 2%–4% for corn silage and 4%–12% for haylage. It is a good indicator of any digestibility issues as lignin negatively affects the digestion of the cell wall by acting as a physical barrier to the microbial enzymes.

### *Digestible NDF (NDFd)*

Digestible NDF is a measure of how digestible the neutral detergent fibre fraction of forages is for ruminants. NDFd provides a better estimate of feed value than reliance only on measures of lignin and acid detergent fibre. The NDFd24 and NDFd48 indicate the number of hours the in-vitro digestibility test was run to determine how digestible the feed source is. In other words, how much of the feed material has been digested by the microbes in the rumen fluid after a set amount of time. For the NDFd24, a number in the 40s is preferred, however, the higher, the better. This means that within the time frame of 24 hours, more was digested, and indicates that the feed is being used properly by the rumen microbes. For NDFd48, a higher number is ideal as the test has now run twice as long. A number in the mid- to high 60s is preferred; some may even see values in the 70s. The NDF disappearance rate is the rate per hour and is based on an equation from Cornell University.

## Sugars and Starches (Non-Structural Carbohydrates)

Non-structural carbohydrates is a measure of carbohydrates not included in NDF, namely water-soluble carbohydrates and starch. Non-structural carbohydrates are rapidly and easily digested by the animal.

### *Starch*

Starch is an energy store for plants that is easily digested by animals. Starch contents will be higher in warm-season grasses and grains than in cool-season grasses and legumes.

### *Water-soluble Carbohydrates (WSC)*

Water-soluble carbohydrates are a measure of sugars and fructans. Hay buyers from overseas frequently ask for this test prior to purchase.

### *Ethanol-soluble Carbohydrates (ESC)*

Ethanol-soluble carbohydrates are a measure of sugars. The difference between WSC and ESC is most important for equine nutrition, as high-fructan diets have been linked to laminitis.

## Other Measures of Energy

See Figure 16-3 for a visual representation of how different measures of energy are related to one another. The ones most commonly seen on forage analyses and used in ruminant and equine nutrition are described in more detail below.

### *Total Digestible Nutrients (TDN)*

An equation is used to calculate energy or total digestible nutrients (TDN), since energy is not a single nutrient. This equation includes NDF, lignin, fat, starch, mineral and bound protein and is used to estimate energy values. TDN is comparable to digestible energy in accuracy. TDN over-estimates the energy value of roughages in comparison to grains.

### *Digestible Energy (DE)*

Digestible energy is the apparent energy that is available to the animal by digestion, measured as the difference between gross energy content of a feed and the energy contained in the animal's feces (gross energy minus fecal energy). Digestible energy is used to balance equine rations.

***Net Energy (NE)***

Net energy is the amount of feed energy actually available for animal maintenance and production, representing the energy fraction in a feed left after fecal, urinary, gas and heat losses are deducted from the gross energy value of a feed. Net energy can be further partitioned into the net energy necessary for maintenance, growth and lactation. Net energy lactation ($NE_l$), net energy gain ($NE_g$) and net energy maintenance ($NE_m$) are listed on the report also, but in recent years have generally been derived from all the other components put into a ration balancing program. Generally, the $NE_g$ is always the lowest number of the three and should be a number greater than 1. It is looked at mostly by beef producers as they observe weight gain in their cattle as a benchmark. The $NE_m$ is generally the highest of the three, although similar in range to $NE_l$.

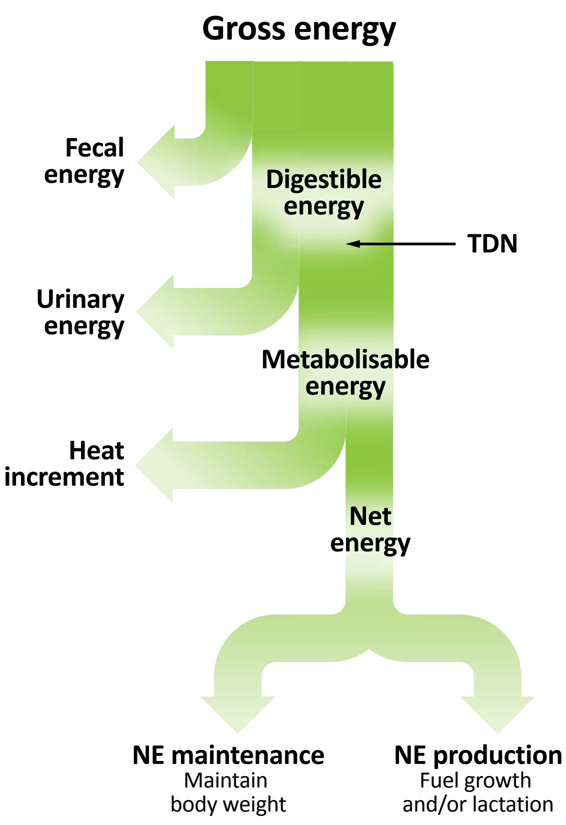



**Figure 16-3.** Relationships between different types of feed energy.

# Fat (Lipids)

Lipids are substances found in plant and animal tissues that are insoluble in water, but soluble in benzene or ether, including glycolipids, phosphoglycerides, fats, oils, waxes and steroids.

Fat reported is a general term but is not only fat and should be written as an ether extract (EE). On some reports it is called ether extract, since it consists of waxes, cutins, etc. The range for EE on a corn silage sample analysis usually falls between 3% and 4%, and 3.1%–4.6% is typical for haylage.

# Minerals

## Ash

Ash is the inorganic mineral elements of plants, determined in a laboratory by burning off the organic matter at a high temperature and weighing the residue (ash). Ash includes both the minerals inside the plant that contribute to animal nutrition, and any soil contamination introduced to the forage during harvest. Ash in haylage ranging between 7%–8% indicates little contamination, 9%–11% indicates contamination, whereas above 11% is considerably problematic. Corn silage ash content varies, but generally the corn is cut high enough that it contains limited amounts of ash due to soil contamination, with numbers ranging from 2.5%–3.5%.

## Macrominerals

Macrominerals are minerals required in relatively large amounts by livestock. Includes calcium (Ca), phosphorus (P), magnesium (Mg), potassium (K), chlorine (Cl), sulphur (S) and sodium (Na).

Calcium and phosphorus are generally the main focus for ruminant producers and a ratio of 2:1 (Ca:P) is desired. Monitoring and balancing for potassium level is critical in dry cow rations. The mineral results of a forage test can be used to create a custom mineral supplement to meet livestock needs.

## Microminerals

Microminerals are minor mineral elements required in very small amounts in rations for animals, including manganese (Mn), copper (Cu), zinc (Zn), selenium (Se), iron (Fe), cobalt (Co), iodine (I) and fluorine (Fl).

# Other Tests

In addition to the above analyses that are used to balance rations, there are other tests that can be done on forage samples. Often these are not included in a standard analysis package, but rather are available on request. Tests for anti-quality components (i.e., contaminants or toxins) may be requested if a problem is suspected with the forage.

## Relative Feed Value (RFV)

The relative feed value is a standardized measure of forage quality calculated from acid detergent and neutral detergent fibre contents. Forage with NDF values of 53% and ADF values of 41% represent a value of 100. Forages with values greater than 100 are of higher quality, and forages with a value lower than 100 are of lower quality. Dry matter intake (DMI) and digestible dry matter (DDM) values of forages can be used to calculate RFV or use the formula with ADF and NDF values.

$$RFV = (\%DDM \times \%DMI) \div 1.29 \text{ or}$$

$$RFV = [(88.9 - 0.78 \times ADF\%)) \times (120/NDF\%)] \div 1.29$$

RFV is not used much anymore, but often still recorded on the certificate of analysis. RFV was developed by hay producers years ago as an estimate of intake and digestibility to market alfalfa-based hay. RFV can be used when comparing alfalfa varieties to each other, but without NDFd, it consistently underestimates the digestibility of grasses compared to alfalfa.

## Relative Forage Quality (RFQ)

The relative forage quality analysis was developed to more accurately predict animal performance than RFV. RFQ combines crude protein, digestible fibre and estimated dry matter intakes (DMI) into one number.

$$RFQ = (DMI, \text{ \% of BW}) \times (TDN, \text{ \% of DM}) \div 1.23$$

Different equations to calculate DMI and total digestible nutrients (TDN) have been developed for legumes and grasses. Forages with the same RFV can have very different RFQs, and animals eating those forages would perform differently. RFQ is good for matching a lot of forage to a group of animals, setting a fair price for hay based on nutritional value, and assessing legumes and cool-season grasses. RFQ is not designed for corn silage (due to high starch content), comparisons between warm-season and cool-season grasses, balancing livestock rations or use on non-legume forbs (broadleaf species) or other alternative forages.

## Fermentation

Fermentation analysis is used to check the quality of the ensiling process, especially if feed intakes are low or nutritional quality is poor. A fermentation analysis typically measures pH, lactic acid, acetic acid, propionic acid, butyric acid, ammonia and ethanol (Table 16-1). Atypical results can help producers identify problem areas in their silage-making process.

**Table 16-1. Typical Levels of Fermentation Products in Common Silage Crops**

| | Corn Silage | Legume Haylage >65% moisture | Legume Haylage <55% moisture | Grass Haylage |
|---|---|---|---|---|
| pH | 3.7–4.2 | 4.3–4.5 | 4.7– 5.0 | 4.3–4.7 |
| Lactic acid % | 4–7 | 7–8 | 2–4 | 6–10 |
| Acetic acid % | 1–3 | 2–3 | 0.5–2.0 | 1–3 |
| Propionic acid % | <0.1 | <0.5 | <0.1 | <0.1 |
| Butyric acid % | 0 | <0.5 | 0 | 0.5–1.0 |
| Ethanol % | 1–3 | 0.5–1.0 | 0.5 | 0.5–1.0 |
| Ammonia-N (% of CP) | 5–7 | 10–15 | <12 | 8–12 |

*Source:* Dr Limin Kung, University of Delaware.

pH above 5 (or 5.5 in baleage) indicates a poor or restricted fermentation that will be less stable and result in poor bunk life and more spoilage at feeding. Legume haylage has a higher buffering capacity than grass haylage and corn silage, and quite often has a higher pH.

Lactic acid should make up over 65%–70% of the total silage acids, with a lactic/acetic acid ratio of at least 3:1. Lactic acid is the most desirable product of fermentation because it is produced most efficiently, with the least dry matter loss. Lactic acid is the most effective in lowering pH and is what we are trying to improve by using a commercial lactic acid bacteria (LAB) inoculant (see Chapter 14, *Harvest*). Lactic acid has little odour.

Acetic acid levels greater than 3%–4% can result from poor fermentation, especially if lactic acid levels are low. *Buchneri* inoculants are sometimes added to corn silage and high moisture corn to produce acetic acid late in the fermentation to improve bunk life. Do not mistake this for a poor fermentation. Acetic acid smells like vinegar. Too much acetic acid relative to lactic acid means the fermentation was less than optimally efficient, and possibly could have benefited from a commercial LAB inoculant.

High ethanol indicates yeast that reduces dry matter recovery and makes the silage more prone to mould and feed-out spoilage. Off-flavours in milk can also sometimes result. A sweet smell, like hard cider, is likely high concentrations of ethanol produced by spoilage yeasts. Fermentation losses were likely high, and this silage will be prone to heating and spoiling in the bunk.

High ammonia-N indicates excessive protein breakdown and possibly excess rumen-degraded protein. Levels greater than 12%–15% can be a problem for the dairy nutritionist. A bleach-like smell indicates excessive protein breakdown to ammonia and amines, which could be due to a clostridia fermentation or high pH.

High butyric acid levels result in high losses of dry matter and digestible energy and indicate that there are management issues that may have to be corrected. In the ruminant, it results in poor intakes and metabolic problems. If possible, silage high in butyric acid should be discarded. Dr. Gary Oetzel, University of Wisconsin, recommends the following butyric acid daily limits to prevent off-feed and ketosis in dairy cows:

- fresh cows: <50 g (1.8 oz)
- early lactation: <150 g (5.3 oz)
- all other lactating cows: <250 g (8.8 oz)

A rancid, fishy odour is also indicative of butyric acid resulting from clostridia contamination from soil. Clostridia silage can result from cutting or raking too close to the ground, soil from packing tractor tires, splash from rain, or manure applied too late after the previous cutting. Butyric acid also commonly results from silage that is too wet (>70% moisture). As well as its foul odour, this silage sometimes has a slimy, sticky texture. Haylage can clump into characteristic butyric balls. Fermentation losses of non-structural carbohydrates are high, so ADF levels are high. Protein is degraded. Palatability, intake and digestible energy are low, and livestock performance is poor.

## Nitrate-Nitrogen/Nitrates

Nitrates ($NO_3$-N) in forage are converted to nitrites ($NO_2$-N) in the rumen. Normally, the nitrites are quickly converted to ammonia ($NH_3$-N) by rumen bacteria and absorbed into the bloodstream to be excreted with urine. When there are high levels of nitrates in the feed, the rumen microbes cannot keep up with nitrite production. The nitrites form methemoglobin in the blood, which reduces oxygen-carrying capacity. Signs of acute nitrate poisoning in animals include staggering, vomiting, laboured breathing, blue-grey mucous membranes and death (typically within 3 hours). Chronic nitrate poisoning often appears as reduced weight gain, early-stage abortions and premature births. Refer to Chapter 10, *Weather Stress,* for more information on conditions that increase the risk of high nitrate levels in forage crops.

Testing the forage is the only way to know whether the level of nitrates may pose a problem. Most laboratories that conduct feed and forage analysis offer a nitrates test. Be sure the sample is representative of the feed, and it should be frozen to keep the nitrate levels from changing between the farm and the lab. The test results may report nitrates in a few different ways: as nitrate ($NO_3$) or as nitrate-nitrogen ($NO_3$-N). These measurements may be expressed as a percentage or in parts per million (ppm) (Table 16-2).

To reduce the risk of acute nitrate poisoning, feed animals several meals a day, rather than one large meal. Livestock fed once a day tend to eat a very large meal when the feed arrives; if the ration is high in nitrates, there is a large spike in their methemoglobin levels about 8 hours later. Feeding twice a day results in ruminants eating smaller meals, and a smaller methemoglobin spike 4 hours after each meal.

Another option to manage nitrates is dilution. Blending high-nitrate forages with other low-nitrate feedstuff may bring the amount of nitrate in the ration down to safe levels. Talk to a nutritionist about diluting nitrate concentrations in forages.

**Table 16-2. Guidelines for Forage Nitrate Levels on a Dry Matter Basis in Livestock Rations**

| | Nitrates ($NO_3$) | | Nitrate-Nitrogen ($NO_3$-N) | | Potassium Nitrate ($KNO_3$) | |
|---|---|---|---|---|---|---|
| | % | ppm | % | ppm | % | ppm |
| Generally safe | 0.15 | <1,500 | <0.04 | <350 | <0.81 | <8,100 |
| Generally safe for non-pregnant livestock. Limit to 50% of total ration for bred animals. | 0.15–0.5 | 1,500–5,000 | 0.04–0.11 | 350–1,130 | | |
| Limit to 25%–50% of ration for non-pregnant livestock. Do not feed to pregnant animals. | 0.5–1.0 | 5,000–10,000 | 0.11–0.23 | 1,130–2,260 | 0.81–1.63 | 8,100–16,300 |
| Do not feed | >1.0 | >10,000 | >0.23 | >2,260 | >1.63 | >16,300 |

*Sources:* Glunk et al., 2015.[1] Saskatchewan Ministry of Agriculture, Natural Resources and Industry.[2]

## CAUTION!

Nitrogen oxide gases (NO, $NO_2$, $N_2O_4$) can form from the breakdown of nitrates during ensiling. High-nitrate forages can lead to greater releases which can quickly reach lethal levels. See Chapter 15, *Storage*, for safety information.

## Mycotoxins

Mycotoxins are substances produced on plants by fungi, particularly during weather stress in the growing or harvest seasons, that are toxic to animals (e.g., vomitoxin (DON), zearalenone, aflatoxin and T-2). Mycotoxins in feed can reduce intakes, which affects production in dairy and meat animals (Table 16-3). Research suggests that consuming mycotoxins can also negatively impact the immune system, which puts livestock already at higher risk for health problems — such as young stock and high-producing animals — at even greater risk.

**Table 16-3. Mycotoxin Guidelines in Total Rations on a Dry Matter Basis**

| | | Potentially Harmful Level[2] (ppm) | | |
|---|---|---|---|---|
| **Mycotoxin** | **Concern Level[1] (ppm)** | **Cattle** | **Sheep and Meat Goats** | |
| DON/vomitoxin | 0.56 | 2.5–6.0 | pre-breeding | 5 |
| | | | pregnant females | 5 |
| | | | replacement females | 10–15 |
| | | | growing lambs/kids | 15 |
| Zearalenone | 0.56 | 3.9–7.0 | pre-breeding | 0.5 |
| | | | pregnant females | 5.0 |
| | | | replacement females | Unknown |
| | | | growing lambs/kids | 10 |
| T-2 | 0.25 | 0.7–1.5 | – | – |
| HT-2 | 0.25 | 1.5–3.0 | – | – |

[1] Concern level: Indicates favourable conditions for mycotoxin production. May require further testing, especially if moderate symptoms are present. Limit the amount of suspect feed fed if performance and/or health symptoms persist. Discontinue use if severe production decreases occur and/or acute clinical symptoms appear.

[2] Potentially harmful level: Mycotoxins at these levels suggest toxin involvement in depressed performance and/or acute clinical symptoms. Discontinue feeding, at least temporarily, sample and test.

*Source* (Potentially harmful level for cattle): Wright 2016.

*Source* (Potentially harmful level for sheep and meat goats): Neary 2009.[3]

In years where fungal growth on crops is a concern, producers should talk with their feed advisor or veterinarian about mycotoxin testing silage after fermentation is complete and before feeding it. This will help determine if additional management is needed when the silage is fed. Note that not every lab that offers forage analysis is equipped to screen for mycotoxins.

The Canadian Food Inspection Agency (CFIA) has legislated the maximum total dietary inclusion levels of:

- DON (vomitoxin) at 5 ppm for cattle over 4 months of age, and 1 ppm for calves under 4 months of age
- HT-2 at 1 ppm for cattle, except for dairy animals where the maximum inclusion level is 0.025 ppm

In addition to these legislated maximums, the CFIA recommends limiting mycotoxins in rations as follows:

- zearalenone in cow diets to 10 ppm (1.5 ppm if other toxins are present); in sheep diets to 5 ppm
- ergot alkaloids to 2–3 ppm in cattle, sheep and horse rations

# Hay Grades

The U.S. Department of Agriculture (USDA) Agricultural Marketing Service developed a hay grading system to make price reporting at auctions consistent across the country. The physical descriptions can be used for pure legume, pure grass or mixed legume/grass hays intended for ruminant forage (see Table 16-4).

**Table 16-4. USDA Hay Quality Designations Physical Descriptions**

| Grade | Description |
|---|---|
| Supreme | Very early maturity, pre-bloom, soft fine-stemmed, extra leafy — factors indicative of very high nutritive content. Hay is an excellent colour and free of damage. |
| Premium | Early maturity (i.e., pre-bloom in legumes and pre-head in grass hays), extra leafy and fine-stemmed — factors indicative of a high nutritive content. Hay is green and free of damage. |
| Good | Early to average maturity (i.e., early- to mid-bloom in legumes and early head in grass hays), leafy, fine- to medium-stemmed, free of damage other than slight discolouration. |
| Fair | Late maturity (i.e., mid- to late-bloom in legumes, head in grass hays), moderate or below leaf content, and generally coarse-stemmed. Hay may show light damage. |
| Low | Hay in very late maturity, such as mature seed pods in legumes or mature head in grass hays, coarse-stemmed. This category could include hay discounted due to excessive damage and heavy weed content or mould. |

In addition to the physical description, the USDA developed guidelines for the forage analysis in pure alfalfa hay (see Table 16-5).

**Table 16-5. USDA Alfalfa Quality Designations (Domestic Livestock Use and Not More Than 10% Grass)**

**Legend:** ADF = acid detergent fibre; TDN = total digestible nutrients; NDF = neutral detergent fibre; CP = crude protein; RFV = relative feed value index

| Grade | % ADF | % NDF | RFV[1] | % TDN[2] | % CP |
|---|---|---|---|---|---|
| Supreme | <27 | <34 | >185 | >62 | >22 |
| Premium | 27–29 | 34–36 | 170–185 | 60.5–62 | 20–22 |
| Good | 29–32 | 36-40 | 150–170 | 58–60 | 18–20 |
| Fair | 32–35 | 40-44 | 130–150 | 56–58 | 16–18 |
| Low | >35 | >44 | <130 | <56 | <16 |

[1] RFV is calculated from ADF and NDF: RFV = [88.9 – (0.779 × %ADF)] × [(120 ÷ %NDF) ÷ 1.29

[2] TDN = [82.38 – (0.7515 × ADF)] according to Bath and Marble, 1989.

*Notes:* Guidelines are used along with visual appearance to determine grade. All figures are expressed on a dry matter basis.

## Horse Hay

Livestock producers harvest hay in the early flower stage to obtain high protein/high energy hay. This approach is not appropriate for producing horse hay. Horse owners determine quality of hay by physical characteristics: dust-, weed- and mould-free, green in colour, and containing recognizable timothy heads. Because the horse market defines quality differently from ruminant livestock producers, surplus hay sold to the horse market may not command the premium price that can be realized by a purpose-grown hay crop.

Horse owners prioritize dust- and mould-free hay. Mouldy hay is the result of rain damage, baling at moistures that are too high, slow drying in the windrow during high humidity or improper storage. Horses are very susceptible to mould spores and suffer irritation of the respiratory tract. This can result in temporary coughing, or the more permanent chronic obstructive pulmonary disease, also known as heaves. Horses develop a chronic cough and wheezing that is very serious and damaging. Mouldy hay can also cause colic, a digestive disorder that can be fatal to horses.

Colour does not provide any direct information on the nutritional content of hay, but a poor colour can be an indicator of problems during harvest and storage. A rich green colour indicates that the hay was not rained-on, dried quickly (indicating higher sugar content) and did not heat or mould during storage. Hay with a sweet smell is more palatable to horses. Like colour, poor odours can often indicate harvest and storage problems, particularly mould. Weeds and trash, such as old stubble, will reduce the value of horse hay. Weeds may be present in pasture and hay that are highly poisonous to horses.

Soft hay is more palatable to horses. Unlike cattle, horses use their lips to manipulate hay and pasture plants when eating. They easily sort their feed and eat leaves while leaving the coarse stems. The mouth, lips and tongue are soft and sensitive, so they will avoid and waste coarse materials.

The USDA hay quality designations are not appropriate for the horse hay market. While good colour grades well on the USDA scale, the horse market prefers timothy in head, which reduces it to a USDA Fair grade. This grading does not reflect the premium price available to growers who can produce desirable horse hay. Talking to horse owner clients about what characteristics they are looking for in their horse hay is the best way to meet the needs of this market.

## Overseas Markets

There is demand for pure alfalfa and pure timothy hay.

Alfalfa is used as a protein source in livestock rations. The USDA grades are recognized internationally for alfalfa hay. Genetically modified varieties are not accepted in overseas markets.

Timothy is used as a fibre source in livestock rations. Like the horse market, the USDA grades are not suitable for assessing timothy hay for export. Buyers expect long heads — 10 cm (4 in.) — which would reduce the hay to a USDA Fair grade and not adequately reflect the other parameters that command a premium price. For example, some markets value a bright green colour, while others do not mind some discolouration, provided the water-soluble carbohydrate levels meet their specifications. Talking to clients about what characteristics they are looking for in their hay is the best way to meet the needs of overseas markets.

# References


1. Glunk, E., K. Oslen-Rutz, M. King, D. Wichman, C. Jones. 2015. *Nitrate Toxicity of Montana Forages.* Montana State University Extension. Retrieved from animalrange.montana.edu/documents/extension/nittoxmt.pdf

2. Saskatchewan Ministry of Agriculture, Natural Resources and Industry. Date Unknown. *Nitrate Toxicity*. Retrieved from: www.saskatchewan.ca/business/agriculture-natural-resources-and-industry/agribusiness-farmers-and-ranchers/livestock/animal-health-and-welfare/nitrate-toxicity

3. Neary, M.K. 2009. *Mycotoxin Concerns in Sheep and Meat Goat Feeding* [Factsheet AS-597-W]. Perdue University Cooperative Extension Service, West Lafayette, IN, U.S. 47907.


## Additional Sources

This chapter contains excerpts from the following OMAFRA sources:


*Take An Accurate Hay Sample.* 2003. www.omafra.gov.on.ca/english/crops/facts/info_haysamp.htm

*Silage Fermentation Problems.* 2010. www.omafra.gov.on.ca/english/crops/field/forages/silage-ferm-prob.htm

*Feed Analysis Reports Explained*, Factsheet 16-049. 2016.

*DON in Corn Silage.* Field Crop News Blog. 2019. fieldcropnews.com/2018/12/don-in-corn-silage/

*Hay for Horses*. 1999. www.omafra.gov.on.ca/english/livestock/horses/facts/info_hay.htm

*Bunker Silo Management*. Milk Producer Magazine. Dairy Farmers of Ontario. 2000.

*Moulds and Mycotoxins: Mycotoxin Levels and Interpretation*. Last modified: 2016. www.omafra.gov.on.ca/english/livestock/dairy/herd/food/mico4.htm

*Definitions of Feed Manufacturing and Livestock Nutrition Terms,* Factsheet 08-039. 2008.

# Appendices

## Appendix A.
## Contact for Additional Forage and Grazing Information

**Agricultural Information Contact Centre**

Provides province-wide, toll-free technical and business information to commercial farms, agri-businesses and rural businesses.

1 Stone Rd. W.

Guelph, ON N1G 4Y2

**Tel:** 519-826-4047

**Toll-free:** 1-877-424-1300

**TTY:** 1-855-696-2811

**E-mail:** ag.info.omafra@ontario.ca

## Appendix B.
## Additional Resources

- OMAFRA Publication 19: Pasture Production ontario.ca/crops
- Ontario Crop Protection Hub ontario.ca/cropprotection
- OMAFRA Publication 611: Soil Fertility Handbook ontario.ca/crops
- OMAFRA Publication 811: Agronomy Guide for Field Crops ontario.ca/crops
- AgriSuite software ontario.ca/agrisuite
- FieldCropNews.com Blog https://fieldcropnews.com/
- Dairy and Beef Cattle Production Blog https://dairyandbeef.wordpress.com/
- Sheep & Goat Production Blog sheepandgoatproduction.ca
- GoForages.ca www.goforages.ca

ontario.ca/omafra