Perennia

Nova Scotia's Food Development Agency

# Pasture Manual

# Introduction and Acknowledgements

Pastureland is an integral part of Atlantic Canadian agriculture, using the land for both animal grazing and harvesting forages. Well-managed pastures can improve soil health and biodiversity on-farm. However, many pastures in Atlantic Canada do not realize their full production potential. This manual aims to guide Atlantic Canadian producers on beneficial management practices for pasture management to improve production and environmental sustainability.

Most pastures in Atlantic Canada are not intensively managed. Stocking rates of one cow-calf pair per 3 to 4 acres is common. The potential for increased animal productivity through improved pasture management in Atlantic Canada is huge. On-farm studies have shown that when native pastures are well managed and intensively grazed, stocking rates of 1.0 acre per cow-calf pair or 4-5 ewes per acre are achievable. Farms practicing such intensive management grazing have reported producing over 600 lb of beef per acre and over 200 lb of lamb per acre: three times the productivity expected under a more traditional continuous grazing system.

This project aimed to produce a comprehensive but practical pasture management manual for the Atlantic provinces. The information and recommendations in the manual have been shown to be effective tools in this region for improving animal and pasture productivity. The manual is written from the perspective that animal productivity will improve as a result of improved pasture productivity and health. The manual covers a range of information, including grazing management systems, pasture fertility, fencing, drought management, riparian management and methods for extending the grazing season.

This Pasture Manual is an updated version of the Maritime Pasture Manual, and we would like to acknowledge all contributors from the previous version. The updated version of the pasture manual was Funded by Agriculture and Agri-Food Canada through the Agricultural Climate Solutions – On-Farm Climate Action Fund. The goal of the current version was to update any information and provide relevant and useful information for livestock producers throughout the Atlantic provinces.

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# How to use this manual

The updated Maritime Pasture Manual is organized similarly to previous editions: there are ten chapters covering the topics of pasture management and grazing how-to.

Chapters may be used as standalone resources for practical reasons; it is the intent of the authors for readers to be able to open the manual to the section relevant to their needs without needing to read from start- to-finish. There are references to other chapters or resources where some concepts are expanded upon.

One notable difference from previous iterations of the manual is that the chapter focused on **organic farming** is gone, and information concerning organic farmers has been integrated into the rest of the manual. "Organic content" is noted with a green leaf for any producers specifically seeking it. There are some technical terms and abbreviations used throughout the pasture manual. There is a **glossary**, list of **abbreviations** and **appendix** at the end of the manual.

# CHAPTER 1
## Plant Growth

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# Plant Growth

It is important to consider the requirements of both plants and animals when developing a grazing system. While livestock products are the end result, "ruminant livestock producers" are, in fact, "forage farmers", marketing the grass through livestock. If the livestock are simply a means of marketing the grass, the forage must be managed for optimum productivity.

To optimize pasture yields and reduce the potential for losses from animal impacts, a grazing plan must be developed that meets the specific requirements of the plants in the sward (i.e., an expanse of ground covered with grass). This does not mean that any one type of grazing system is the correct one; instead, it means that depending on the type of plant species in the sward, as well as the class and type of livestock grazing the pasture, certain grazing systems are more effective than others at maximizing yields and reducing wastage (Emmick & Fox, 1993).

It is important to understand basic forage growth dynamics when deciding which grazing system to implement on your farm (Chapter 2- *Grazing Systems*). How a plant grows, and the effect of grazing on plant growth will determine overall pasture productivity and quality. This chapter provides an overview of grass and legume growth characteristics, benefits, and consequences of poor and good grazing management.

## GRASS GROWTH CHARACTERISTICS

### Basic Grass Physiology

The growth of forage grasses and legumes depends on photosynthesis—photosynthesis converts the energy of sunlight into carbohydrates. For photosynthesis to occur, plants must have light, water and carbon dioxide. The water is absorbed through the plant roots and root hairs and carried to the leaves. The leaves trap light and absorb carbon dioxide from the air and move it to the cells containing chlorophyll (a green pigment found in plant cells). Photosynthesis occurs in two stages. In the first stage, the chlorophyll pigment captures light's energy and uses it to make high-energy molecules. The second phase uses the energy captured in Phase I to combine hydrogen with carbon dioxide to make simple carbohydrates (sugars). The plant uses the sugars for energy to grow. The plant also stores carbohydrates as starch to help it live through stress (e.g., drought, suboptimal growing temperatures, pest attacks, etc.) and/or initiate growth after defoliation or winter dormancy.

When a plant is frequently defoliated by grazing or regrowth is subjected to long periods of stress such as drought, sugar reserves become limited as the plant does not have the leaf area required to photosynthesize at full potential. To further complicate the situation, when the top growth is subjected to frequent grazing or environmental stress, plant roots begin to die off and recede, reducing the amount of water and soil nutrients taken up to support plant growth. Poor grazing management compounds the effects of environmental stresses. While environmental stresses cannot be controlled, a good grazing regime can help maintain healthy, vigorous pastures.

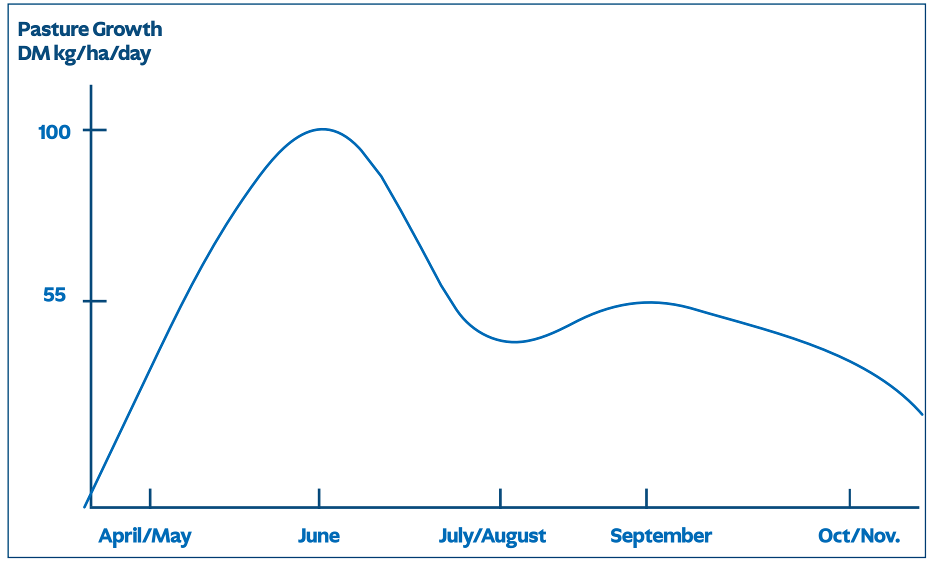


**Figure 1.1 Seasonal pattern of dry matter (DM) accumulation over the growing season.**

The initial spring growth of pasture plants is supported by carbohydrate (sugar) reserves from the previous growing season. The buds produce new shoots and leaves, which photosynthesize sunlight to promote more vigorous growth. The plant growth rate in the spring is generally twice the summer growth rate, with a moderate increase in the fall. Kunelius & Goit (1982) recorded pasture growth at 100 kilograms of dry matter per hectare per day (kg DM/ha/day) when growth peaks in May-June but drops to 40 kg DM/ha/day in July-August. This was followed by an increase to 55 kg DM/ha/day in September-October (Figure 1.1). The flush of growth in the spring is related to the development of flower and seed production. Knowledge of this natural cycle is key to implementing a good grazing management system.

While total seasonal dry matter (DM) accumulation varies by month and year due to precipitation and temperature, the growth pattern is predictable from year to year. Knowing this pattern is valuable when determining the total number of paddocks required for the season (this is discussed in more detail in Chapter 2 – *Grazing Systems*). The high amount of growth in the spring can sustain livestock on fewer paddocks than in late summer; therefore, planning to deal with surpluses in spring and shortages later in the summer is crucial. Cool-season grasses can develop so rapidly in the spring that grazing alone may not keep up with DM accumulation. Therefore, it may be desirable to determine which pastures are easily harvested mechanically and manage the excess forage growth through harvesting for hay or silage. Clipping pastures at various times over the season may also become necessary, depending on climate conditions and animal requirements.

## Grass versus Legume Growth Pattern

Grasses and legumes differ in their growth pattern over the grazing season (Figure 1.2). Cool-season grasses, such as tall fescue and timothy, tend to have high productivity in spring to early summer and then drop in productivity as the season progresses. These grasses usually become more productive again by early fall once moisture returns. In contrast, legumes tend to have a more evenly distributed seasonal yield because they maintain their productivity better through the drier summer period. Some grasses and legumes can withstand drought better than others, and the growth pattern of certain species varieties may differ, affecting the pasture yield distribution. Therefore, choosing the correct species for a pasture mixture can significantly affect seasonal yield.

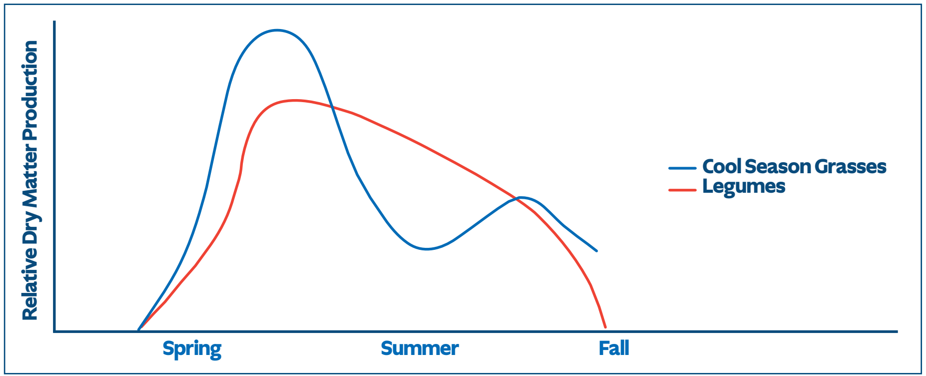


**Figure 1.2 Typical growth pattern of different pasture species over the growing season.**

## Balancing Yield and Quality

When plants begin to grow in the spring, the initial growth (vegetative stage) is leafy and has a higher percent protein and digestibility. As the plant continues to develop and grow taller, the upper leaves will start to shade the lower leaves, resulting in an accumulation of dead or dying leaves at the lower part of the plant. As the plant matures, producing flowers and seed heads (reproductive stage), its growth rate slows down, and the leaves and stem decrease in quality. In general terms, the amount of indigestible fibre increases with maturity. This increase in indigestible fibre is accompanied by a decrease in digestible energy (DE). Therefore, the DE available to the animal is high when the plant is young and immature but declines as the plant ages and accumulates DM. A similar decline in crude protein occurs with plant maturity.

To optimize the grazing potential of a pasture, it is important to factor in the yield and the rate of recovery and determine the point where both yield and quality are balanced. This will provide the highest yield of quality forage (Bartholomew, 2004). See Figure 1.3.

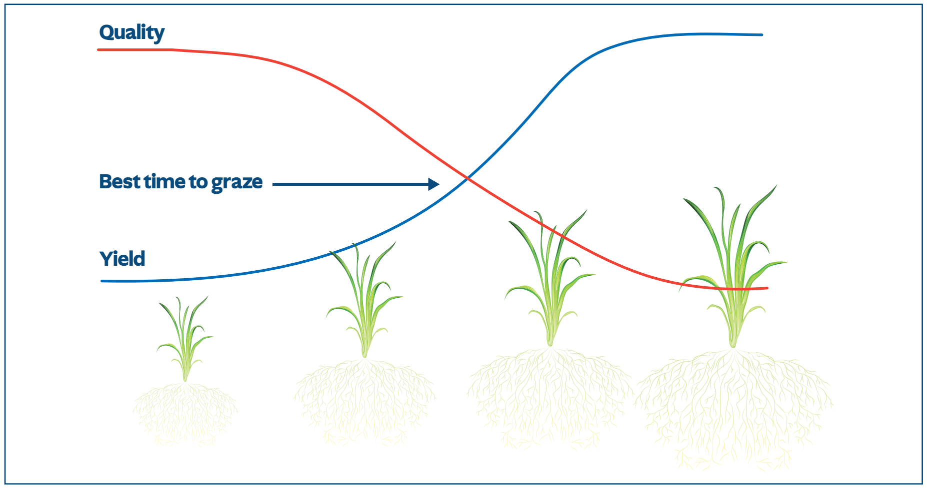


**Figure 1.3 Typical Maritime forage growth curve showing the best time to graze.**

Overall, it is important to monitor the growth of pastures. Once plant growth and its relation to plant recovery and forage quality is understood, it becomes a very effective tool for planning and managing the use of pastures. For more details about individual species of pasture grasses and legumes and their growth patterns, see Chapter 6 - *Pasture Species Identification and Recommended Pasture Mixes.*

## GRAZING MANAGEMENT

Good grazing management is essential for successful pasture-based livestock production. Proper stocking rates and the timing and length of each grazing period are key. When pastures are managed effectively, an overall increase in production can be expected over time. Also, the pasture's fertility, quality, and longevity can be increased. Good grazing management controls the frequency, intensity, timing, and duration of grazing so that the plants stay healthy and productive. Under a continual grazing system, pasture growth can only be managed through grazing intensity. It is not easy to maintain pasture productivity under a continuous grazing system. A rotational grazing system is a more effective method of managing pasture productivity.
***A rotational grazing system uses specific grazing intervals and rest periods to manage forage growth for quality and pasture performance.***

### The Importance of a Proper Rest Period

The rest period is the period of time given to the pasture to recuperate between successive grazing and is the main tool to control the frequency of grazing over a season. The number of days required to rest a pasture will increase as the plant growth rate decreases over the season, and it will vary depending on the growing conditions, the productivity of the pasture, and the amount of stored carbohydrates in the plants. For example, rest periods in the spring will be about half as long as in the middle of summer because forages grow twice as fast in the spring. The rest period should always be long enough to ensure adequate pasture regrowth (i.e., 10-15 cm sward height). It should not be so long that the pasture becomes overgrown, reducing forage quality and causing losses in yield by trampling and rejection. It is important to remember that book values are only a guide: be sure to observe your pasture.

### When to Graze

The growth of a plant goes through three phases during initial spring growth and following defoliation (Figure 1.4). In Phase I, the plant's growth rate is slow because it does not have the required leaf area to harvest the sun's energy effectively and must use its root reserves. Phase II is characterized by a high growth rate, as the number of tillers increases, producing more and more leaves to photosynthesize, thereby increasing the total amount of energy available to the plant for growth. After this, the plant goes into the third or reproductive phase, in which the rate of growth has essentially stopped, and the yield decreases somewhat. By this time, the top leaves have shaded out the lower leaves for a long enough period of time that the lower leaves die. Also, once a grass has gone into the reproductive phase, new tillers will not be produced until after harvesting or flowering.

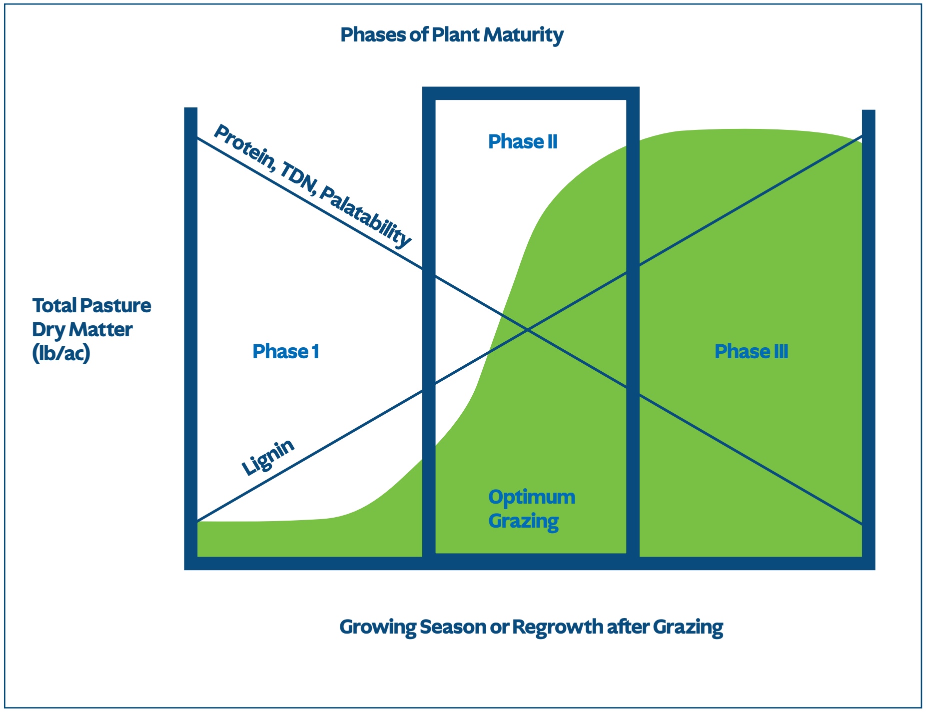


**Figure 1.4 Phases of plant maturity showing the optimum time for grazing.**

Figure 1.4 shows that the optimal time to begin grazing is near the end of Phase II when the yield is greater. It is important to keep the sward from being grazed so short that the plant must depend on carbohydrate reserves to regrow (Phase I) instead of depending on regrowth from its leaf biomass (Phase II). In this way, the plant's ability to regrow is preserved, and the rest period is shorter, but more importantly, it is less stressful on the plant, and it can rebound quicker.

### Grazing Intensity

Grazing intensity is an expression of the number of animals grazing a defined area for a certain period of time (#cows/acre/day). Forage utilization and grazing efficiency increase as the grazing intensity increases because livestock have less chance to be selective. The ideal grazing intensity will vary depending on the type of forage species, the time of year and the class of livestock being grazed. The optimum grazing intensity is a balance between livestock performance and pasture yield. Moving from an extensive (i.e., covering a large area of land) grazing system to a moderately intensive (i.e., focusing on a concentrated area of land) grazing system will increase the amount of forage available but will still allow livestock to graze selectively on the highest quality forage; at this point, both the gain per head and the gain per acre will increase. Increasing the grazing intensity further will improve the forage utilization by forcing the livestock to consume all the available forage, including the coarser stems and leaves; the gain per acre will continue to increase, but the competition between animals for the available feed will mean that gain per head will plateau or decline. As management intensity increases, you must choose between maximizing return to land or livestock.

### Exit and Entrance Heights

The height to which a grass grows affects when the livestock must be removed from the pasture. The growing points of tall species such as timothy or smooth bromegrass are elevated and are several centimetres off the ground, so the plant material should not be grazed too short. These species are termed jointed grasses. On the other hand, non-jointed species like Kentucky bluegrass possess growing points closer to the ground and can, therefore, withstand closer grazing. It should also be noted that all forage species handle grazing differently, no matter what their classification. Tall fescue, while being a tall grass, can handle intensive grazing better than smooth bromegrass, as it has more basal leaves.

In chapter 2, Table 2.5 Average recommended management heights, there are recommendations for entrance and exit heights as well as recommended rest periods depending on tall or short growing cool season grasses and legumes. The general recommendation is to not graze below 10 cm (4 in) for stands with predominately tall growing grasses and legumes or below 5 cm (2 in) for stands with predominately short growing grasses and legumes. When plants of each category are grazed below these heights it may take longer for them to recover and could impact the rotation plan.

Book values are only guidelines, and in the end, a good rest period is most important in the recovery and subsequent high productivity of the pasture. Plan for a “sacrifice paddock” if grazing gets ahead of forage growth rather than moving livestock into paddocks without adequate regrowth.

The time of year influences how tall the sward should be when it is grazed. In the spring, the various pastures are usually uniform in growth; therefore, waiting for a specific or “ideal” height to begin grazing the first pastures would result in the other paddocks becoming over-mature. This would reduce quality and risk yield losses from trampling and rejection. In the spring, it is recommended to start grazing, particularly the first paddock, at a lower initial height. This will help prevent the remaining paddocks from becoming too mature.

Using a sacrifice paddock during wet periods will help protect the other paddocks. Similarly, during periods of drought, the soil will be better protected if the livestock are removed sooner from each grazed paddock. Leaving a little more forage after grazing will help keep more moisture in the top layers of the soil and allow the plants to regrow quicker once adequate levels of moisture return. When little pasture is available, paddocks are often overgrazed. Still, it is better to supply the animals with stored feed and allow the pastures sufficient stubble height for faster regrowth when the moisture returns.

### Grazing Period Length

The total length of time livestock are in a particular section of pasture or paddock should be balanced with the stocking rate. Too long a period and the animals begin to graze regrowth. Short-duration stays require smaller paddocks or more animals and may require more labour. The length of stay on a pasture should be, at most, five to seven days in spring or 10 to 12 days in mid-summer. As the time spent on a pasture increases, trampling and fouling increase, which can decrease animal performance (Emmick & Fox, 1993). Livestock will graze the leaves first, meaning that feed quality declines the longer they are in a paddock, and at a certain point, the remaining forage will be so fibrous that it will limit feed intake. Shorter stays on pasture will promote increased forage intake that is also higher in quality.

**Table 1.1 Recommended pasture residency periods for livestock (Adapted from Emmick & Fox, 1993).**

| LIVESTOCK CLASS | NUMBER OF DAYS IN A PADDOCK | |
|---|---|---|
| | Spring | Summer |
| Lactating dairy cattle | 0.5-2 | 0.5-2 |
| Milking sheep or goats | 1-2 | 3-4 |
| Growing stock (steers, heifers, lambs) | 2-4 | 6-8 |
| Beef cow/calf, ewe/lamb | 3-4 | 7-10 |
| Most adult non-lactating stock | 5-7 | 10-12 |

Over or under-grazing are two symptoms of incorrect grazing frequency and duration, often appearing within the same pasture. When a pasture is repeatedly overgrazed, the grass and legume species are not given an opportunity to recover sufficiently after grazing. If the plant is given little or no rest period, it cannot rebuild its carbohydrate reserve and will be weakened and may die. Shorter plant species, which tend to be more shallow rooted, will dominate. In the long term, the pasture sward's root mass will be minimal, and productivity will be low. A similar species disappearance can happen when the pasture is undergrazed due to shading and competition from tall, over-mature and unpalatable plants, as most grazing livestock are selective grazers. The long-term result, in this case, is a patchy pasture, with some areas being overgrazed and others eventually being taken over by weeds and then woody plants.

Pastures will begin to decrease productivity with poor grazing management, such as chronic over or undergrazing. Uncontrolled, this decrease in productivity can begin an undesirable cycle that will result in poor livestock and pasture production and a substantial decrease in monetary return (Figure 1.5) (Thomas & Goit, 1986). This cycle is referred to as "The Cycle of Poverty."

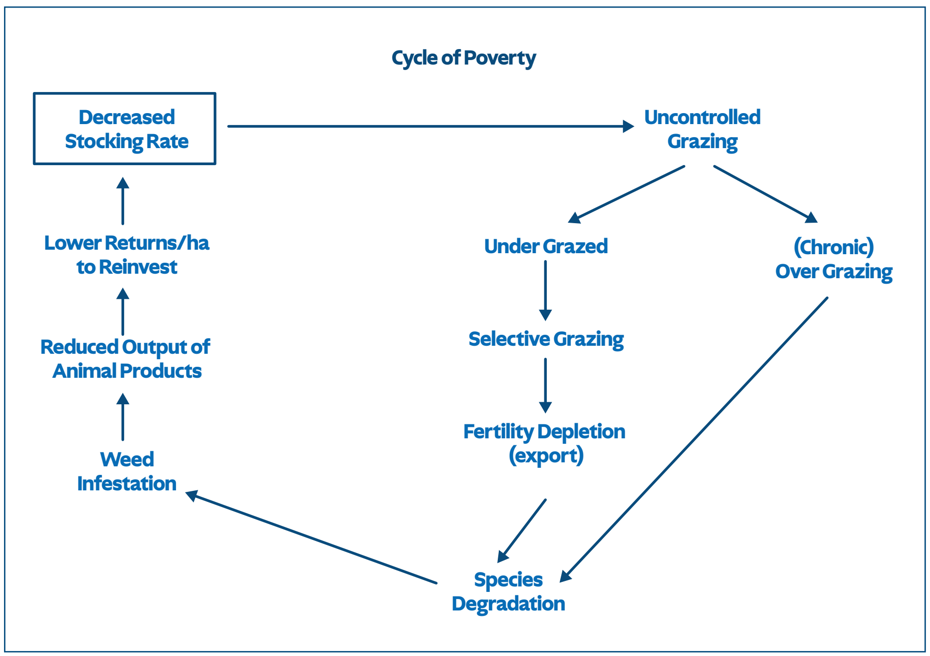


**Figure 1.5 How uncontrolled grazing contributes to the "Cycle of Poverty" (Adapted from Thomas & Goit, 1986).**

Given the opportunity, livestock will only eat what is most palatable and use preferred areas of the pasture. As desirable forage species decline and disappear, weeds will grow in their place, either because of actual patches of bare ground or by being able to outcompete the weakened plants. There is good reason to control the frequency and length of time that the livestock stay on a given pasture.

The entire system becomes healthier when grazing is controlled, known as the "Cycle of Plenty" (Figure 1.6). Pastures under a controlled grazing system tend to have a higher carrying capacity because they yield more and can physically support more animals with good soil and sward structure. They tend to have fewer weeds because there is less grazing selectivity, and the forages can easily compete for nutrients and light. Fertility levels tend to be more evenly distributed over the entire pasture, further increasing pasture productivity, and forage is given rest to recover and allow the roots and leaves to regrow adequately.

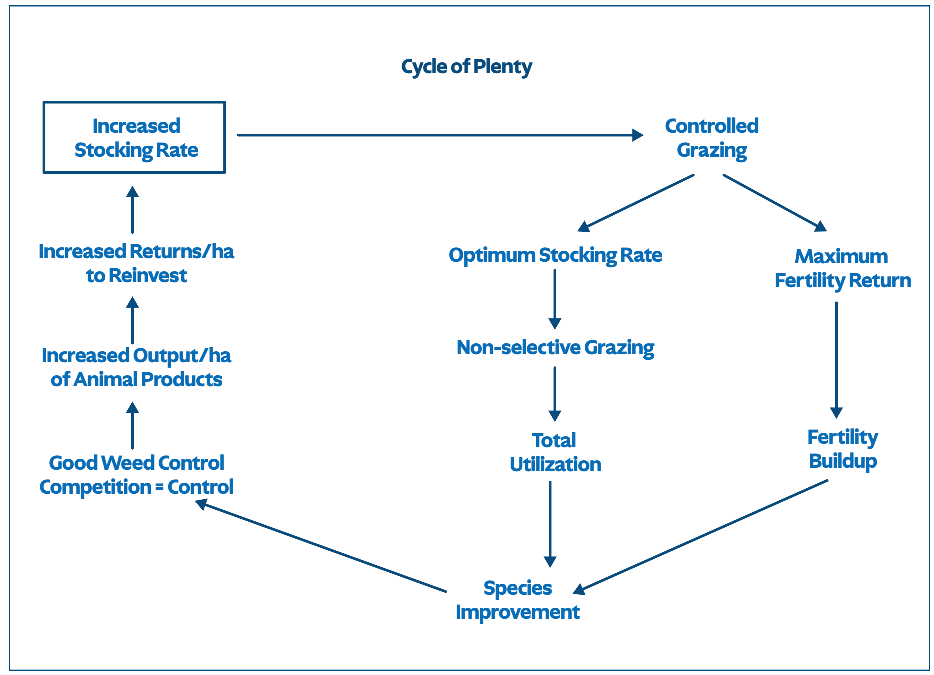


**Figure 1.6 How controlled grazing contributes to the "Cycle of Plenty" (Adapted from Thomas & Goit, 1986).**

# CHAPTER 2
## Grazing Systems

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# Grazing Systems

An effective grazing system is the cornerstone of successful pasture management. The number and species of animals, the size and characteristics of the farm, the production goals, and management styles are all considered when planning the use of the pasture and designing a grazing system.

It is natural to focus on pasture productivity in terms of pounds of gain or litres of milk produced, but successful graziers recognize that their crop is forage and that livestock are the harvesting units. The goal of a successful grazing system is to ensure that adequate quantity and quality of forage is available for the livestock throughout the season. Achieving this system is a balance of pasture growth, the quality of that growth, the nutritional needs of the livestock grazing, and the number of livestock available to eat the forage. If any of these get out of balance, the performance of both the livestock and the pasture will suffer in both the short and long term.

Regardless of the type of grazing system implemented, it is essential to have a sound understanding of the animal's general requirements as well as the forage species currently in the pasture(s). Without this knowledge, it is not possible to design an efficient, productive grazing system. Assessing the amount of available forage or biomass can be done using several techniques, ranging from visual assessment to using specifically designed equipment. Several techniques used together can be the most effective method for assessing the biomass of a pasture and will especially assist while first developing "an eye" for grazing system development.

Planning and record keeping are important to the success of developing a grazing system and reaching goals. Once the available pasture species and mass (i.e., the measure of how much biomass) has been determined and the forage requirements of the animals have been estimated, it is important to document the information. Record keeping is a critical part in design, planning, and budgeting for the available pasture. A grazing system plan should be somewhat flexible as it is impossible to predict exact pasture masses throughout the season.

This chapter outlines the methods of determining pasture mass and animal requirements, along with an example of a pasture mass budgeting and a planning system worksheet. Paddock design and function are outlined and explained. Finally, results and examples from research conducted in this region are presented. In this chapter, the concept of grazing organically is also introduced.

## GRAZING SYSTEMS

It is important to review the options for grazing in order to decide which grazing system is best for the situation. Once both the strengths and limitations of available resources have been assessed, the producer can choose which of the grazing systems listed below fits their farm. Most grazing systems fall under two broad classifications: continuous and rotational grazing (with rotational systems ranging in intensity). Options and features of different systems are discussed below with the assumption that some type of controlled grazing is used with every system.

### Continuous Grazing

Continuous grazing is a system that has animals grazing on one set pasture for at least six weeks and can be as long as the entire grazing season (White & Wolf, 2000). This system is often used by producers with a relatively large pasture base and low numbers of livestock. Continuous grazing usually results in slightly lower productivity per animal and lower output per unit of land. Due to the inefficient forage utilization that results from this type of system, it is best suited for animals that do not require high maintenance, such as dry cows, growing heifers and low-milking ability beef cows.

As with any system, there are advantages and disadvantages to continuous grazing (Table 2.4). Using only one pasture all season long decreases the required amount of labour, fencing, and water sources. The pasture does not need to be monitored as closely, and animals selectively graze the most palatable and highest quality forage, which can increase gains per animal. However, selective grazing reduces total pasture productivity as some areas are overgrazed while others become over-mature and are hardly grazed at all. Also, because of selective grazing, continuously grazed pastures often become patchy and vulnerable to drought and weed growth. This can be a particular challenge if the pastures are invaded by unpalatable weed species (e.g., knapweed, thistles) or woody plants (e.g., hawthorn). Forage use can be improved by varying the stocking rate (a "put-take" system) or temporarily fencing off part of the pasture for mechanical harvest ("buffer" system).

### Buffer/Put and Take

Buffer and put and take are terms used for systems for controlled continuous grazing that incorporate ideas from rotational grazing into a continuous system.

## Buffer System

The buffer system uses a large pasture with a mobile fence that adjusts the size of the paddock to manage the amount of grass the livestock has access to (Figure 2.1). If the pasture has a large quantity of high-quality forage, the mobile fence can be adjusted to keep the animals in a smaller area in order to reduce the amount of forage being wasted. Likewise, if there is a low volume of forage, the fence can be adjusted to allow the animals to graze a larger area.

The buffer system requires less management than a rotational system but provides greater utilization of the available forage than with continuous grazing. The disadvantage is that it does not give you as much control as with a rotational grazing system.

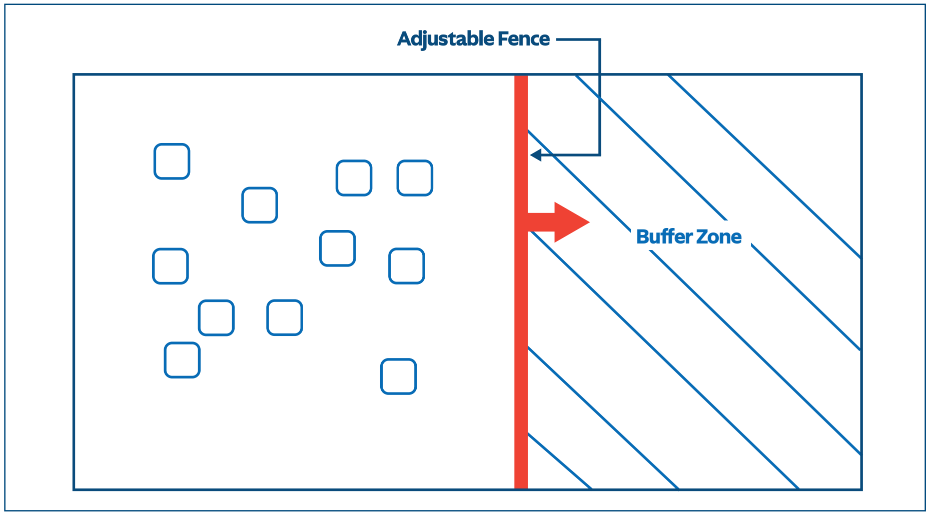



**Figure 2.1 Buffer system; the fence can be moved back or forth as more or less forage is required.**

## Put and Take System

A put-and-take system adjusts the stocking rate in any given pasture to ensure optimum grass utilization (Figure 2.2). For example, in the spring, a pasture may have an abundance of high-quality forage. In the put-and-take system, the stocking rate would be increased in the spring when high-quality forage is abundant. Likewise, when the pasture decreases in productivity, some of the animals will be removed so the pasture is not overgrazed.

The advantages to this system are that no extra fence is required, and less planning is required than with a rotational system. The major disadvantage to this system is the transportation of animals from pasture to pasture or alternate locations when they are removed from the pasture. It also requires closer management of animals than in a continuous system.

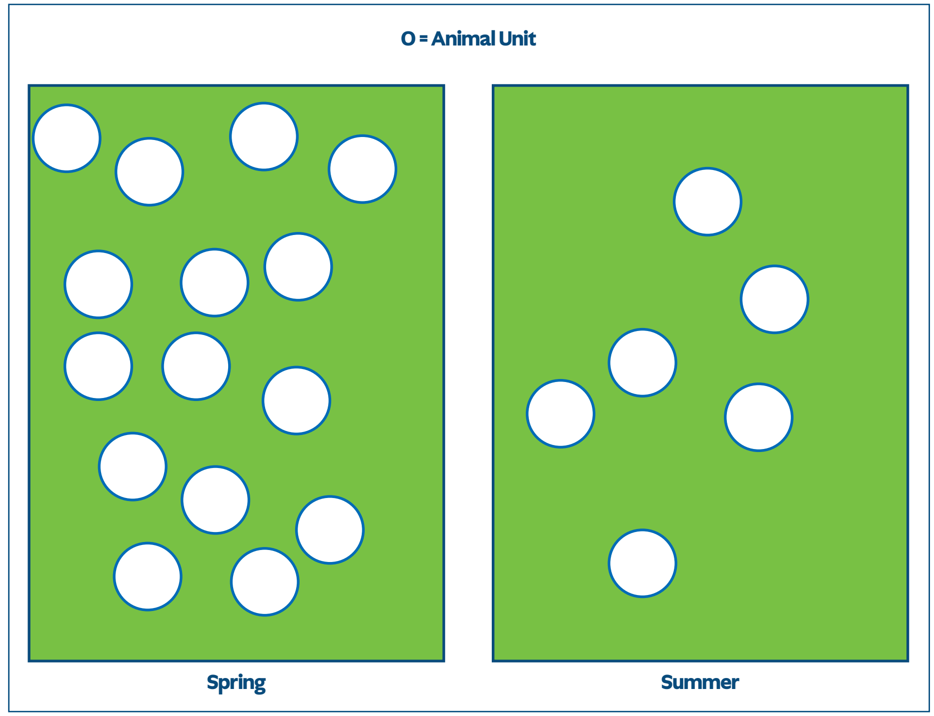



**Figure 2.2 Put and take system; adding or removing livestock as required.**

## Rotational Grazing

The most basic definition of rotational grazing is the grazing of two or more paddocks of pasture in sequence, with the main purpose of giving pastures an adequate rest period for plant recovery. Adequate rest periods are an essential tool for managing a pasture for productivity. The time of year directly influences the duration of the rest period. Using only two paddocks would not provide an adequate rest period and would stress the plants in use by grazing the regrowth too quickly. Increasing the number of paddocks to at least six will provide rest periods to maximize production.

Many expert graziers talk about “managing the second bite” (Gerrish, 2004). This means managing the pasture rotation so that livestock never bite the same plant twice in one grazing period. It prevents overgrazing and allows the plants to keep their carbohydrate reserves based on paddock size, how long the animals stay in a paddock and when they come back to it.

In a rotational grazing system, as covered in Chapter 1 - *Plant Growth*, animals are moved from each paddock after a length of time determined by the rate of pasture growth and sward height. There are varying degrees of intensity that can be used to establish an excellent grazing system (Table 2.1).

**Table 2.1 Types of Rotational Grazing.***

| TYPE OF GRAZING | COMMENTS |
|---|---|
| **Rotational Grazing** | Only part of the pasture is grazed at any given time while the remainder of the pasture rests. Pastures are subdivided into two or more (usually >6) paddocks and livestock are moved from one paddock to another throughout the season. |
| **Management Intensive Grazing (MIG)** | "The thoughtful use of grazing manipulation to produce a desired agronomic and/or animal result." (Gerrish, 2004). An intensive rotational grazing system in which the grazing period can be shorter than 12 hours, allowing much higher forage utilization and providing high-quality forage. |
| **Leader-Follower Grazing** | The leader group grazes an area first, usually for a short period, grazing the tops of the forage. The follower group grazes directly after the leader group and finishes grazing the paddock to the desired height. The leader group is comprised of livestock with high nutrient/DM requirements, while the follower group requires much less. Examples: lactating dairy cows as leaders with heifers/dry cows as followers; growing steers first followed by ewes with lambs. |
| **Forward Creep Grazing** | A type of leader-follower system used with females with their young. The forward fence is kept high enough for the young to easily travel under it so that they have access to fresh forage, but the mothers cannot access the area. |
| **Mob Grazing** | Using a high stocking density (number of animals per unit of land for a given time) to graze and/or trample down a paddock evenly. Mob grazing works well when a pasture is overly mature and can replace clipping. |
| **Strip Grazing** | Livestock are given a narrow strip of pasture with a front and back fence. The forage is of high quality, there is little waste, and the utilization rate is enhanced.<br><br>This system minimizes the time animals spend in one paddock and maximizes the rest period length. Strip grazing also works well for grazing annual crops such as corn and brassicas as it will minimize wastage. |
| **Mixed Grazing** | Different species of livestock grazing either together or in a leader-follower grazing system relies on different livestock species selectively choosing different plants or portions of plants to graze. Example: sheep and cattle. |

***Adapted from Gerrish & Roberts (1999) and Undersander et al. (2002).**

Rotational grazing enables the livestock producer to provide the animals with economical, high-quality feed. Like continuous grazing, the management of rotational grazing carries advantages and disadvantages.

The major advantage of a rotational grazing system is the more uniform seasonal forage productivity and resulting increased carrying capacity. Also, the manager has more control over weeds, forage species, animal health and the fertility of the paddock. The biggest disadvantage is the increase in labour required to maintain the system since the pastures will need to be checked and the livestock moved more often. However, once the system has been in place for several weeks, both the producer and the livestock become accustomed to it, and the livestock are easily moved to the next paddock. A side benefit of this system is that the livestock will become easier to handle in general (i.e., for weighing, vaccinating, etc.). Drawbacks include the initial capital cost of fencing and watering systems. Table 2.2. summarizes the advantages and disadvantages of both continuous and rotational grazing.

Table 2.2 Advantages and Disadvantages of Continuous and Rotational Grazing.

| | TYPE OF GRAZING | |
|---|---|---|
| | **Continuous Grazing** | **Rotational Grazing** |
| **ADVANTAGES** | • Low fencing costs<br>• Low daily management<br>• Good animal gain if stocking number is correct<br>• Low labour requirements | • More uniform seasonal forage production and quality<br>• More control over animal intake<br>• Higher forage yield and quality result in healthier, more productive livestock<br>• Closer watch on animal health<br>• Effective, efficient manure and fertility management<br>• Good ground cover helps control soil erosion and weeds |
| **DISADVANTAGES** | • Little control of the grazing intensity and timing<br>• Decreased gains when overstocked<br>• Often results in poor forage utilization<br>• Lower forage production when overgrazed<br>• Less uniform forage quality<br>• Weed proliferation<br>• Selective grazing can result in patchy pastures<br>• May require more frequent clipping | • Higher management requirements to coordinate forage production with animal production<br>• Higher fencing and watering costs than for continuous grazing<br>• Higher labour requirements: moving fencing, water sources |

Rotational grazing also requires additional planning in order to determine the paddock size, position and gate sites, stocking rate, and timing of movement through the sequence. Timing is dependent on a number of things, such as the stocking rate and the quality and quantity of forage. However, the key component in determining the movement of animals from one paddock to the next is accounting for the rest period required for grass regrowth. The rest period varies primarily by the time of year but can also vary depending on the type of forage. Typically, the amount of time for a paddock to recover in the Maritime region is approximately 15 to 20 days in the spring and about 35 to 45 days in the summer. Pasture masses range anywhere from a maximum yield of 3600 kg/ha in the spring to as low as 2400 kg/ha by the end of fall. Table 2.7 gives estimates of Maritime native pasture masses.

Determining the number of animals to be grazed beforehand is also essential information for designing a rotational grazing system. Information on designing a balance sheet to plan pasture design and animal movement can be found in the appendix.

As a general rule, 55 lactating dairy cows or 60 cow-calf pairs will consume 1 acre/day. These are estimates; it is best to determine the actual length of stay, as shown in the appendix.

## Designing a Rotational Pasture System

In designing paddocks, there are some important factors to consider (Table 2.3). They include topography, soils, forages, water and shade, the shape of the paddock, paddock orientation, gates and laneways and pasture maintenance (Undersander et al., 2002). The most important asset in designing paddocks is lessons learned from experience and knowledge of the land. Other farmers' experience and advice can provide considerable assistance in fine-tuning plans for a grazing system.

Guidelines for paddock layout and design (Bartholomew, 2004; Emmick & Fox, 1993) to keep in mind are:

- Keep the system as flexible as possible. Design on paper first.
- The greater the number of paddocks in a system, the greater the efficiency of forage utilization.
- The best utilization occurs when pastures are no greater than four times longer than wide. The closer the paddock shape is to square, the better. A square shape increases the animals' use of forage.
- All paddocks in the system should be able to produce approximately the same amount of forage so that fewer adjustments need to be made.
- Fencing should be inexpensive and easy to manipulate (electric is both).
- Always give hilly land special consideration. South-facing slopes will likely give earlier growth and should be rotated first.
- When slopes are greater than 15%, fence so that livestock will graze on the contour. Paddocks oriented up and down steep slopes with the water source at the bottom will have overgrazing at the bottom of the slope and under-grazing at the top.
- Establish laneways on higher, drier land.

- Group plants with similar maturity in the same paddock where possible. Consider varying maturity of some paddocks to better handle growth rates.
- Clip if required to maintain forage quality, but needing to clip is a symptom that stocking rates are not matched to forage growth.
- Allow for extra grazing land close to the paddock system to ensure that there will be extra feed if needed (e.g., hayland).
- Place gates in the direction of the natural movement of the herd as they travel to and from the water source, barn or other paddocks. Generally, gates should be in the paddock corner closest to where they need to travel.
- The more accessible the water source - the better: with guidelines of a water source every 500 ft for dairy cattle and 1000 ft for all other livestock. In some rotational grazing systems, water is accessible in every paddock, allowing individual animals to go for a drink on their own without the whole herd and vastly improving the distribution of manure and urine on the pasture.
- Limit livestock access to streams and low banks.

Properly located and constructed laneways and gateways are critical to good rotational pasture management systems. The laneways must be designed to allow for livestock movement from one paddock to any other paddock or the barn/handling system without moving back through a paddock. This is because it is nearly impossible to keep animals moving through a new paddock, and they will be very reluctant to go back into recently grazed ones. Laneways should be built on higher and drier soils and should follow the contour of the land to help prevent erosion (Ohio State University, 2008). Better to have livestock follow the contour rather than walk up and down a hill. The Manitoba Forage Council (2008) recommends that laneway length be minimized, and the laneways be five to seven meters (16-24 ft) in width. These dimensions will help reduce the amount of damage to the laneway and discourage loafing by the livestock. Blanchet et al. (2003) recommend the use of fine granular materials on top of the laneway to help prevent the development of mud holes. Caution: some coarse textured materials may cause injuries to the feet of livestock.

**Will Virtual Rotational Grazing Replace Fences?**

With the cost of GPS systems coming down, and advances in remote sensing, it is not hard to imagine the day when livestock are directed to graze particular areas in response to cues from a collar connected to GPS rather than by opening and closing gates in electric fences. This would give almost infinite flexibility with minimal labour. These systems are not commercially available yet although there are some limited research trials. People may feel they might give up the cross fences, but it is believed perimeter fences will be here to stay.

The livestock and frequency of movement are also important to remember when designing laneways. The laneway must be built in accordance with the livestock use and intensity. The greater the frequency and intensity of use, the more durable the laneway will need to be. For example, milking cows may need to move from one area to the barn twice per day, while beef cattle will not.

In some systems, laneways are also used by the livestock to access a water source and are therefore frequently travelled.

Gates should be located in the paddock corners closest to the barn or the next paddock in sequence. They should be situated so as to lead the animal in the direction you want them to move. The size of the gate is also important to consider, as moving large groups of animals through small gates can be difficult (Ohio State University, 2008). Gates should be wide enough to allow the passage of farm machinery (e.g., 24-30 ft wide).

As with all grazing systems, the rotational system has its advantages and disadvantages. However, rotational grazing can be incorporated and managed effectively on all types of grazing livestock farms. Table 2.3 discusses potential factors that may be faced when designing a rotational grazing system. It compares suggestions offered by three different resources.

Table 2.3 Paddock Design Factors.

| FACTOR | UNDERSANDER ET AL. (2002) RECOMMENDATIONS | BLANCHET ET AL. (2003) RECOMMENDATIONS | EMMICK & FOX (1993) RECOMMENDATIONS |
|---|---|---|---|
| **Topography** | • Separate different slopes into different paddocks<br>• Fence hillcrest and valley separate from slopes | • Each paddock should have similar topography | • Do not combine steep hills and flatlands in the same paddock |
| **Soils** | • Different soils will have different productivity | • Paddocks should group similar soils | • Combine similar groups of soils as much as possible |
| **Forages** | • Coordinate different forage growth rates with time of year and soils | • Including similar forage types helps management | • Combine similar groups of forages as much as possible |
| **Water** | • Water must be accessible from all paddocks | • Put a water source no more than 800 ft from where the livestock graze to encourage water consumption | • Dairy should have a water source every 500 ft.<br>• Other animals should have a water source at least every 1000 ft |
| **Shade** | • Fence shady and sunny areas separately | | • Unless there is extreme temperature, not needed |
| **Shape** | • Square or rectangular paddocks are not the best choice for hilly and non-uniform land | • Paddocks should be as square as possible | • Should be as square as possible |
| **Orientation** | • Run paddocks across the contour | | • Do not run paddocks up and down hills |
| **Gates and Laneways** | • Gates should be located closest to the barn<br>• Laneways should be placed on higher ground | • Lanes connect all paddocks to allow for flexibility in forage management | • Gates located in the corner closest to the barn<br>• Laneway is wide enough to get machinery through as well as livestock |
| **Maintenance** | • Set aside larger open areas for hay-making when pasture is plentiful (spring) | • Clipping should be done if necessary | • Dragging the manure may be required |

## ORGANIC SYSTEMS

Another layer of grazing systems is the option to manage pasture and livestock organically. Choosing to be certified organic means careful record keeping and minimal exposure to synthetic inputs (e.g., antibiotics, synthetic fertilizer, genetically modified organisms (GMOs), or pesticides). In exchange, an organic producer will obtain evidence (organic certification) they abide the Canadian Organic Standards and can therefore access niche markets and premium prices (if they so choose).

Why would a grazier choose to be organic? Sometimes, it is for the organic premium if there is market demand, but it is also a personal value-based decision. The Canadian Organic Standards define organic production as "a holistic system designed to optimize the productivity and fitness of diverse communities within the agro-ecosystem, including soil organisms, plants, livestock and people." Organic livestock production emphasizes the circular use of nutrients, requires grazing for herbivores, and prohibits most synthetic inputs like inorganic N fertilizer (e.g., urea or UAN) and herbicides. It puts strict limits on the use of treatments like antibiotics, dewormers and bloat treatments while requiring animals to be given sufficient space and get most of their nutritional needs from pasture or nature-based feeding systems.

The idea is that the production system promotes healthy soil and healthy animals with good welfare that shouldn't require routine synthetic, energy-intensive and expensive inputs. It can sometimes require more labour and more land, especially at first.

Certified organic farms are required to follow the organic regulations. Any situations where organic regulations are different from non-organic practices are highlighted throughout this pasture manual. Certified organic production rules are listed in the Canadian Organic Standards, and the inputs you're allowed to use on an organic farm are listed in the Permitted Substances List. These documents are available on the Canadian Food Inspection Agency's website (https://inspection.canada.ca/en/food-labels/organic-products/standards). There is also the Organic Standards Interpretation website where the Standards Interpretation Committee posts official, clarifying answers to questions about the Organic Standards (https://organicfederation.ca/resource/final-questions-answers-canadian-organic-standards/) To be organic, a farm needs to be inspected annually by a certification body (e.g., Ecocert or Procert). Prior to implementing a new practice, input, or if there is any doubt about a substance or practice, organic producers should always check with their certifying body.

Generally, good pasture management and good organic pasture management are nearly the same. Healthy soil and good pasture management leads to plentiful, high-quality, nutrient-dense forage, leading to healthy, productive animals. The alternative strategies that organic farmers must use can be useful tools for any farmer. Pasture and organic farming go hand in hand: a careful grazier can absolutely be successful within the limits of organic.

### RESEARCH CASE STUDY: Evaluation of Continuous and Rotational Grazing on Native and Improved Pasture for Beef Production

A study demonstrating pasture management techniques to enhance forage yield and to compare animal productivity on native grass and seeded legume-grass pasture mixes was conducted on a community pasture in Cape Breton in 1990 and 1991. The study compared a continuous grazing system on a native pasture, a rotational grazing system on a native pasture, and a rotational grazing system on an improved pasture using an orchard grass/meadow fescue/white clover mix. Animal production data was collected, and general forage quality trends were assessed (Cummings, 1991).

Each of the three pasture sites supported approximately the same number of beef cattle at the start of the season. However, as the season progressed, the number of cattle had to be decreased on the continuous and native rotational grazed pastures but was increased on the improved pasture rotationally grazed.

The two rotational grazing systems resulted in higher animal and forage productivity than the continuous grazing system. The rotational grazing system on the native pasture had higher average daily gains (ADG) and total beef production than the continuous grazing on the native pasture, even though the carrying capacity was lower with the rotational grazing. Rotational grazing on the improved pasture gave higher ADG, forage yield, forage quality, total beef production and carrying capacity than either the rotationally grazed native pasture or the continuously grazed native pasture.

In this comparison of continuous and rotational grazing systems, the rotational system yielded the best animal and forage production.

## SIMPLE METHODS OF MEASURING PASTURE BIOMASS

### Visual Estimate

Graziers are accustomed to estimating a pasture's carrying capacity by visual estimates or by "eyeballing", a skill that is developed over many grazing seasons. By visually inspecting the pasture with a walk-through, the producer estimates how much forage is available in the paddock and how many days the animals can stay. It is important to walk through the pasture rather than rely on a broad visual scan because open spots are not always apparent. This method of pasture biomass determination is very subjective and will only give the producer a rough estimate.

### Using a Rising or Falling Plate Meter

A rising plate meter or a falling plate meter is a simple but effective tool in pasture management. It estimates forage cover by measuring pasture height and density. This method can give the producer a more accurate estimate of how much available feed is in the paddock.

The rising plate meter comes in a variety of styles, from a basic design of a disk (which can be metal or plastic) that fits over a meter stick with strings attached (See appendix for more detail), to more sophisticated designs with computerized measuring devices. More information on constructing and using plate meters can be found in the appendix.

### Dry Matter Yield by Quadrat Harvest

The accuracy of the visual or "eyeballing" method and the rising plate meter estimations of biomass can be checked by using DM estimates on 0.25 $m^2$ quadrats (squares 0.5 m on each side or circles with a diameter of 56.4 cm) (see Figure. Collect fifteen to twenty 0.25 $m^2$ quadrats randomly in the pasture. To do this, walk a pre-determined pattern in the pasture (like a diagonal line, a zigzag, W or X), collecting a sample each time you walk a set number of paces. Cut all of the forage near the soil surface and put samples from each quadrat into a separate paper bag. Then dry the samples for one day at 70°C (160°F) (Murphy, 1994). Multiply the weight (in kg) of each dry sample by 40,000 to convert the dry weight to kg of DM yield/ha.

Figure 2.3 Dry matter yield quadrant.

### Remote Sensing to Estimate Forage Biomass

The drawbacks to manual methods of estimating or measuring forage biomass are the labour requirements to take the measurements at many points within each paddock and the relatively sparse spatial density of these measurements. Remote sensing technology is being developed that can overcome these drawbacks, although it is not yet commercially available in easy-to-use packages. The most promising approach seems to be some form of optical or hyperspectral sensor (e.g., normalized difference vegetation index, aka NDVI) combined with a measurement of the sward height by LiDAR or ultrasonic sensor mounted on an unmanned aerial vehicle (UAV) or ATV (Ghajar & Tracy, 2021). The combination of these two measures has given good accuracy in research trials and overcomes the issue of NDVI readings becoming "saturated" when there is high biomass accumulation.

## DETERMINING THE BIOMASS AVAILABLE FOR GRAZING

### Pasture Entrance and Exit Heights

As discussed in Chapter 1, *Plant Growth*, to maintain a high-performing pasture, it is important to manage the grazing duration and rest period. Grazing duration is set by the number of animals, animal intake, size of pasture and amount of available feed. A good way to determine the amount of available feed is to compare the average height of the pasture when the cattle enter the paddock (pasture entrance height) and the average height when the animals leave (pasture exit height).

It has been found that short, intense periods of grazing are better for forage growth and quality (The Land Conservancy, 2008). The livestock will consume the forage evenly under this grazing pattern with less selectivity, so the diet consumed by the livestock is more consistent, and regrowth will be even. The feces and urine from the animals are also more evenly distributed, so pasture fertility is maintained more effectively.

The grazing period is so important that if one has to choose between the appropriate exit height and an adequate grazing period, always try to follow the grazing period in order to allow for quick and healthy regrowth. A general "rule of thumb" is to pasture the animals in a specific area for a maximum of 5 days or shorter in the spring and 8 – 10 days in mid-summer for more uniform plant growth. If you do not reach the adequate exit height within 5 days, you either do not have enough animals, or the paddock is too large. Remember to "manage the second bite" - there are times of year when the grass may be growing so fast that the animals would ideally be moved in less than 5 days.

The following Table 2.4 shows the approximate yields of Maritime pastures at different heights at various times during the growing season. The amount of available forage for grazing is calculated by subtracting the amount of forage at the pasture exit height from the amount of forage at the pasture entrance height, using one of the methods of measuring pasture biomass that was already discussed. An entrance height of about 20 cm and an exit height of 10 cm is a good rule of thumb to follow for a 1 cow/calf pair per acre stocking rate.

Table 2.4 Approximate yields of Maritime pastures per season.

| MONTH | MARITIME NATIVE PASTURE MASS ESTIMATIONS (KG DM/HA) | | | |
|---|---|---|---|---|
| | Plant Height 5 cm | Plant Height 10 cm | Plant Height 15 cm | Plant Height 20 cm |
| May/June | 1440 | 2920 | 3990 | 4760 |
| July/Aug | 1350 | 2490 | 3740 | 4450 |
| Sept/Oct | 1370 | 2780 | 3800 | * |

Using Table 2.4 and a pair of boots, a producer can effectively estimate the amount of forage in a paddock. On the leg of a pair of rubber boots, a mark can be made to indicate entrance and exit heights for an average pasture (Figure 2.4). The producer can compare the average growth to the boot marks to easily estimate the biomass of the pasture. The entrance and exit heights will vary with the needs of the species present in the pasture.


Figure 2.4 Boot method of forage assessment.

In order to use this method most effectively, the forage estimates should be documented by the paddock and compared with more analytical methods, such as using a rising plate meter. There are two additional factors to take into consideration when determining specific paddock entrance and exit heights: plant species and time of year. Different forage species need slightly different height management (Table 2.5).

**Many pastures in Atlantic Canada are long-term permanent pastures, or “naturalized pastures”, meaning that they are a diverse mix of forage species that have not been recently seeded. These pastures have the potential to be productive under good management (Papadopoulos et al., 1993). The challenge is clear: how should grazing exit and entrance heights be decided in a diverse, mixed sward?**

The residual left behind after grazing determines how the plants will recover (Gerrish, 2004). Grazing regularly to the same low exit height will select for low-growing plants such as Kentucky bluegrass and white clover. While these can provide high-quality forage, they are lower-yielding and shallow-rooted. They do not perform well in drought conditions: like a lawn, they simply stop growing when it is dry, eventually going brown and dormant. To encourage deeper-rooted plants in the sward that can withstand dry conditions by pulling water from deeper in the soil profile, a grazier can vary the exit heights over time. Leaving more leaves behind on the taller plants will select for those species.

Varying the exit heights in different grazing periods can be a useful tool for different stages of livestock production as well. For example, heavily lactating cows can be given higher-quality feed by moving them at a higher exit height, whereas dry cows could be pushed to graze lower. It is important to understand, however, that although better quality forage can be obtained during the grazing period by leaving more residual behind, the regrowth will not be as high quality as if it was grazed low. This is why Gerrish (2004) recommends using different exit heights over the course of a year.

Adequate rest periods are an essential tool for managing a pasture. The time of year directly influences the duration of the rest period. Less recovery time is required in the spring than in the hot, dry summer.

Table 2.5 Average recommended management heights.

| SPECIES | ENTRANCE HEIGHT CM (IN) | EXIT HEIGHT CM. (IN) | REST PERIOD REQUIRED (WEEKS) |
|---|---|---|---|
| **Tall growing cool season grasses:** orchardgrass, smooth bromegrass, tall fescue, timothy, reed canarygrass | 20-25 (8-10) | 10 (4) | spring 2 summer 4-6 |
| **Legumes:** alfalfa, alsike clover, ladino clover, red clover, birdsfoot trefoil | 20-25 (8-10) | 10 (4) | 3-4 |
| **Short growing cool season grasses and legumes:** bluegrass, naturalized white clover | 10-15 (4-6) | 5 (2) | spring 2 summer 4-6 |

*Adapted from Undersander et al. (2002).

## DETERMINING FORAGE REQUIREMENTS

The forage requirement of an animal is dependent on many factors, including the size of the animal, its stage of production, the quality of the pasture, and environmental conditions. All these factors are important to consider when budgeting pasture. It is important to know the forage requirements of the animals when designing a grazing system.

The body weight of the ruminant animal is the best predictor of its required forage intake (Blanchet et al. 2003). The following formula can be used to estimate the daily forage requirement of a herd of animals:

(# animals) x (average weight of animals) x (daily utilization rate*) = daily forage requirement

*Blanchet et al. (2003) suggest using a 4% daily utilization rate (based on a 2.5 % forage intake, 0.5% trampling loss, and a 1% buffer).

**Example:** 20 cow/calf pairs x 545 kg average weight (1200 lbs) x .04 = 436 kg (960 lbs) forage/day required

More information on determining forage usage can be found in the appendix.

This calculation produces a rough estimate: it is important to be flexible and to monitor your pastures and animal health to ensure that your system is providing what is required for your animals.

Organic producers are required to document the source of all their feed, whether it is from on-farm or purchased. For ruminants, it is required that they get at least 30% of their daily forage intake from grazing in the pasture season and more than that during times of good pasture growth. Ruminant diets in organic systems must be made up of at least 60% forage. An organic grazier could be asked to show these calculations during their annual inspection to demonstrate compliance.

The organic standards also provide a minimum amount of pasture per animal unit. For example, one cow requires at least 1/3 acre of pasture to be available for grazing. What this means in practice is that enough pasture must be provided to make up a substantial part of the animals' feed requirements, not a small, overgrazed field with a hay feeder.

### Dealing with Variations in Forage Supply

Pasture growth varies throughout the grazing season, both due to the cyclical nature of pasture growth from spring through fall and to the irregular variations in growth in response to weather. This can result in surpluses of growth at some points during the season and shortages in others, which must be managed to maintain the productivity of the pasture and the livestock.

### Surplus Forage

More grass than the livestock can eat may seem like a good problem to have, but it can lead to feed wastage through trampling, selective grazing where the most palatable forage is heavily grazed while other patches in the paddock are left to become over-mature, and a decline in forage quality as plants are not harvested at the optimum time. The short-term gains from excess forage growth early in the season can be lost in poorer productivity of both forage and livestock later in the season if not properly managed.

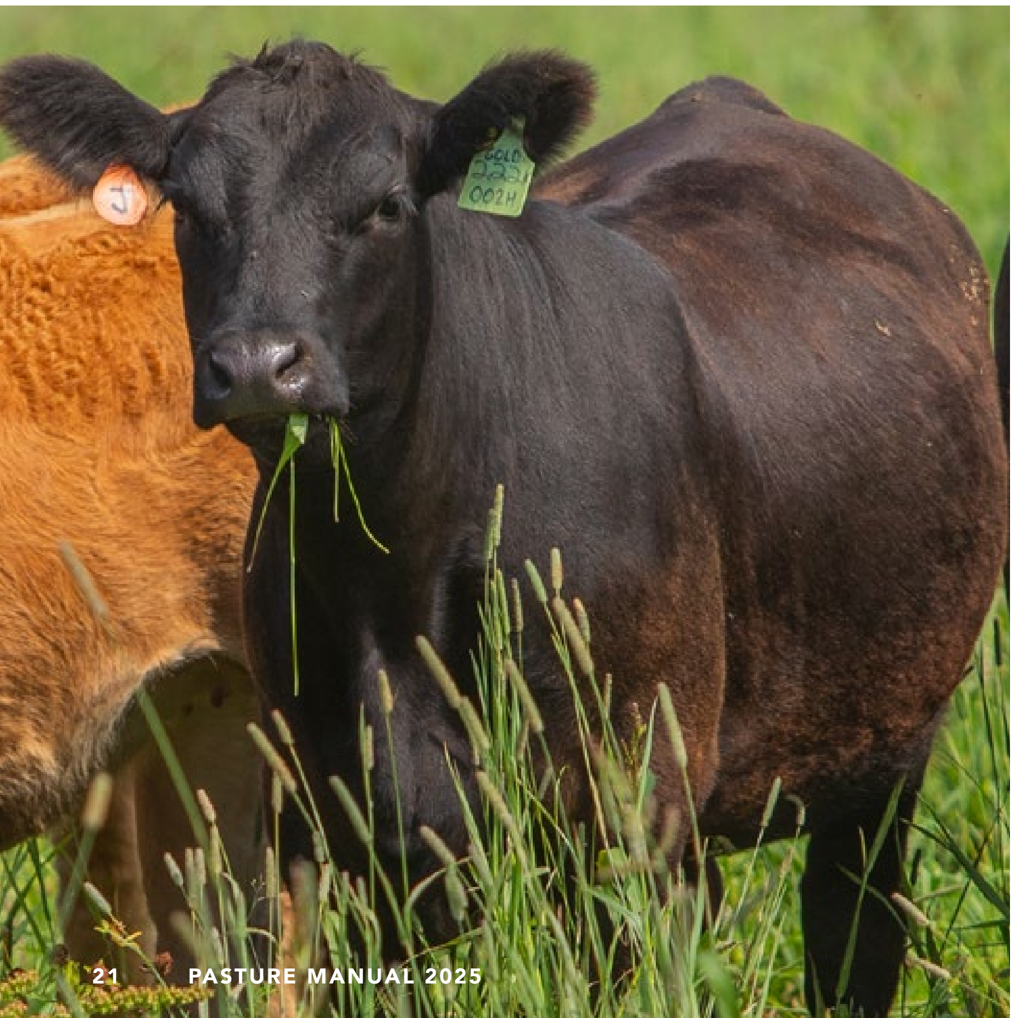
While it may seem wasteful to trample some of the forage, it is a practice that can lead to long-term pasture health – and it can help deal with the conundrum of "too much grass". With the advent of more intensive grazing, as described with management-intensive grazing and mob grazing in Table 2.1, trampling is used intentionally to store soil carbon and improve soil nutrient cycling. It allows livestock to be somewhat selective and get good forage quality from what they eat while promoting good regrowth because any overly mature or unpalatable forage is trampled – the best of both worlds.

Local experts are now aiming to graze half and trample half of the forage in a given paddock in some situations (Roger, 2023). Most importantly, trampled forage is left on the ground, where the carbon and nutrients from the trampled plants will be incorporated into the soil. What is left behind nourishes the soil and the soil biology better than clipping, without having to run the mower, and better than forcing animals to eat poor-quality feed (Duynisveld, 2023).

There are several options for dealing with a temporary surplus of forage (some of which have already been discussed):

- Increase the stocking rate early in the season ("Put and Take" system).
- "Blaze grazing" early in the season, where livestock are moved to new paddocks before the forage has been grazed down to its normal exit height, can help to keep the later paddocks from becoming over-mature.

- Harvest some paddocks for stored feed and bring them back into the grazing rotation later in the season.
- If the livestock have not been grazing the forage evenly, and some patches are getting over-mature, mechanical clipping after removing the livestock will keep the growth stage of the stand relatively even and encourage fresh vegetative growth. As mentioned above, in high stocking density situations (lots of animals on a smaller paddock), trampling excess forage can be used as an efficient alternative to clipping.
- Surplus growth in the fall can be left in the field for stockpile grazing, either as standing forages or in the swath (Note: this will not provide high-quality forage for rapidly growing or lactating animals but is an excellent option for maintenance rations. Not appropriate for areas that receive heavy snow in the fall, especially if a hard crust tends to develop.)



### Shortage of Forage

Lack of forage for livestock is an immediate and pressing concern, and an observant grazier knows that the signs are evident well before the livestock are hungry. Planning ahead for periods when pasture growth may not keep up with livestock demand will not only maintain the productivity of the livestock but also allow the pastures to recover more quickly. Over-grazed paddocks during the "summer slump" will be slow to regrow in the cooler days of fall, extending the period of reduced forage supply.

As with surplus forage, there are several options that address a shortage, many of which are complementary to the options for surplus:

- DO NOT rotate livestock into a fresh paddock until there is adequate regrowth. Not allowing adequate regrowth will reduce the rooting depth as well as the top growth, compromising the plant's ability to access soil moisture.
- Plan a "sacrifice paddock" that can be used during periods of slow pasture growth; it is better to reduce the productivity of one paddock rather than the entire pasture.
- Provide supplementary feed to slow-growing pastures, rather than waiting until the pastures are depleted. This could be the hay that was harvested from the surplus paddocks.
- Bring additional paddocks into the grazing rotation.
- Reduce the stocking density on each paddock.
- Plant additional paddocks with annual forages that can be used as emergency feed.

## FINAL REMARKS

The best choice of grazing system depends on the land resources, the livestock and the availability of time and money. Records of animal and pasture measurements and observations will provide valuable information when evaluating your current grazing system or when planning changes. Designing an optimal system can make a farm more productive and profitable.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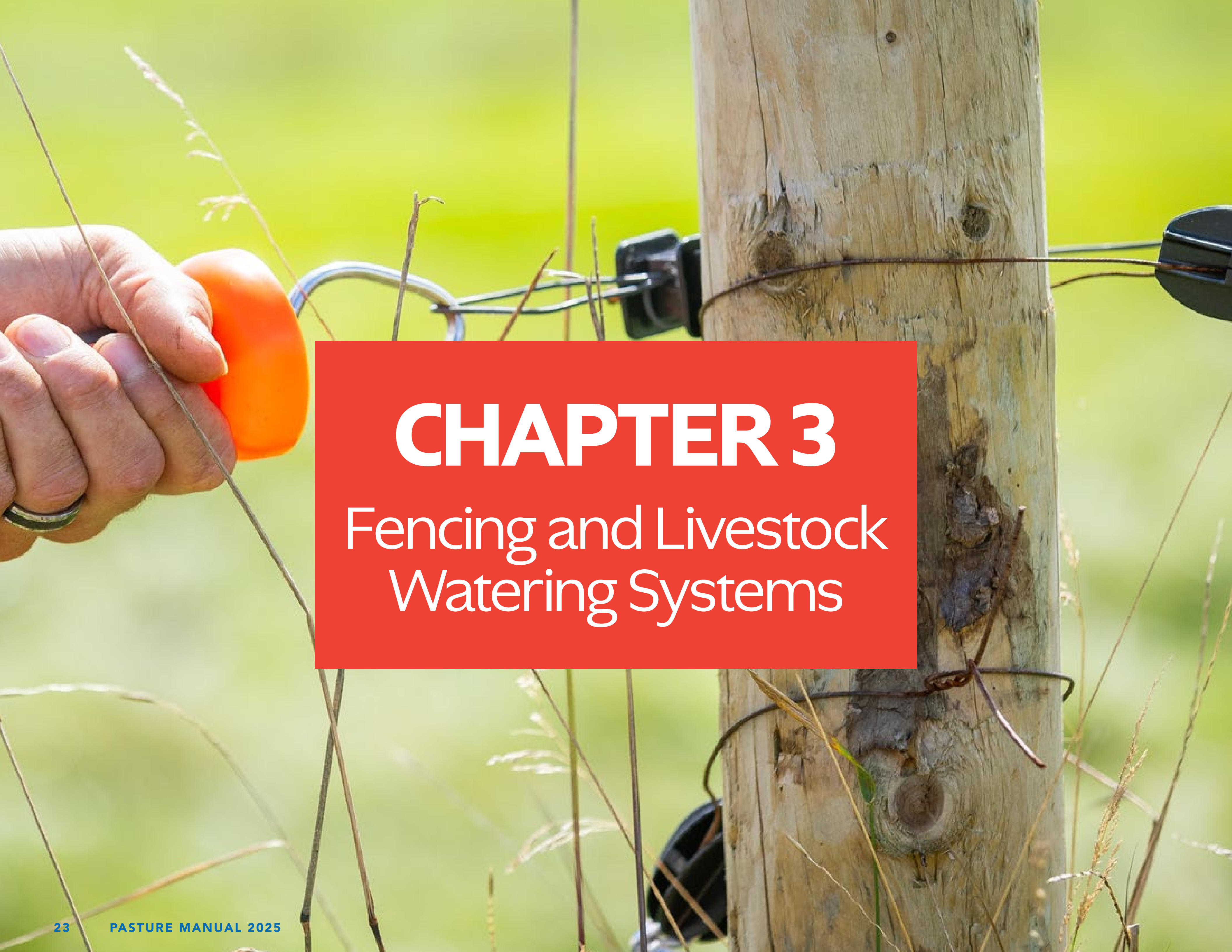


# CHAPTER 3

## Fencing and Livestock Watering Systems

# CHAPTER 3
# Fencing and Livestock Watering Systems

Good fencing is the foundation of good grazing management. It allows the producer to rotate pastures when required and protect the animals against predators. Fences such as stone, rail, page wire and barbed wire provide a physical barrier strong enough to discourage or prevent animals from crossing the fence (over, under or through). An electric fence uses a psychological barrier based on electric shock that discourages animals from challenging a physically weaker fence (Gay et al., 2003).

Animal species, age, breed and production system are factors that influence the fencing requirements of livestock. Intensively managed grazing systems are different than extensively managed grazing systems (see Chapter 2 for information on grazing management systems). Another factor to consider is whether the fence is to be a permanent fixture or part of a temporary paddock. Ultimately, the fencing system's projected affordability, maintenance, durability and effectiveness at containing livestock must all be considered when determining the type of fence required (Gay et al., 2003).

In a controlled grazing system, careful planning and proper layout of a fence system are necessary to optimize the system's productivity and provide control of the grazing animals. Dr. E. Ann Clark, a former University of Guelph researcher, states, "fences need only be as good as the pasture is bad." This is not strictly true, but it illustrates that animals will be easy to contain if they are well fed and hard to contain when there is insufficient quality or quantity of feed. Fencing can be a major capital investment and requires planning to make it efficient and economical.

## COMMON TYPES OF FENCING: PERMANENT VERSUS TEMPORARY FENCING

Permanent boundary fences hold grazing animals in the pasture area, while temporary fencing can be used to subdivide pastures into paddocks among which livestock are rotated (Gay et al., 2003). The energizer generates one to two second high-voltage pulses (the current), which are sent through the fence line. When the animal touches the fence, the current flows through the animal, into the earth and back to the ground system, completing the circuit and giving the animal a shock.

### Electric Fence

- Acts as a psychological barrier – livestock must be trained to avoid the fence.
- A power source is needed to provide shocks – typically, a wire carries current along a fence, and when grounded (touched) by the animal, the circuit is completed, and the animal receives a shock.
- An energizer regulates the flow of energy in the fence wire by supplying pulses of high voltage (and low amperage) electricity for a short duration.
- It can be a temporary and/or permanent system.
- Used in combination with offsets, it can extend the life of a page wire or rail fence. A good ground and its maintenance are critical to the effectiveness of the fence. A fence line free of vegetation requires less power to maintain adequate voltage levels.
- Solar or battery-operated energizers are useful in remote locations but can be more expensive and require more maintenance.

There are two ways to set up an electric fence system: 1) an all-live wire system and 2) a ground wire return system (Figure 3.1). An all-live wire system is the preferred method in regions with fairly even rainfall and green vegetation for most of the year. In an all-live wire system, the circuit depends on electrons travelling through the animal, into the ground and up into the grounding rods back to the energizer. The ground is a better conductor when it is moist. A ground wire return system depends on the current to go back to the energizer by way of a ground wire. In this situation, an animal touches both a live and a ground wire, which completes the circuit. The ground wire return system is used where there is low rainfall or if soil conditions are stony, dry or frozen. A ground wire return system is also needed for some types of predator control fencing.

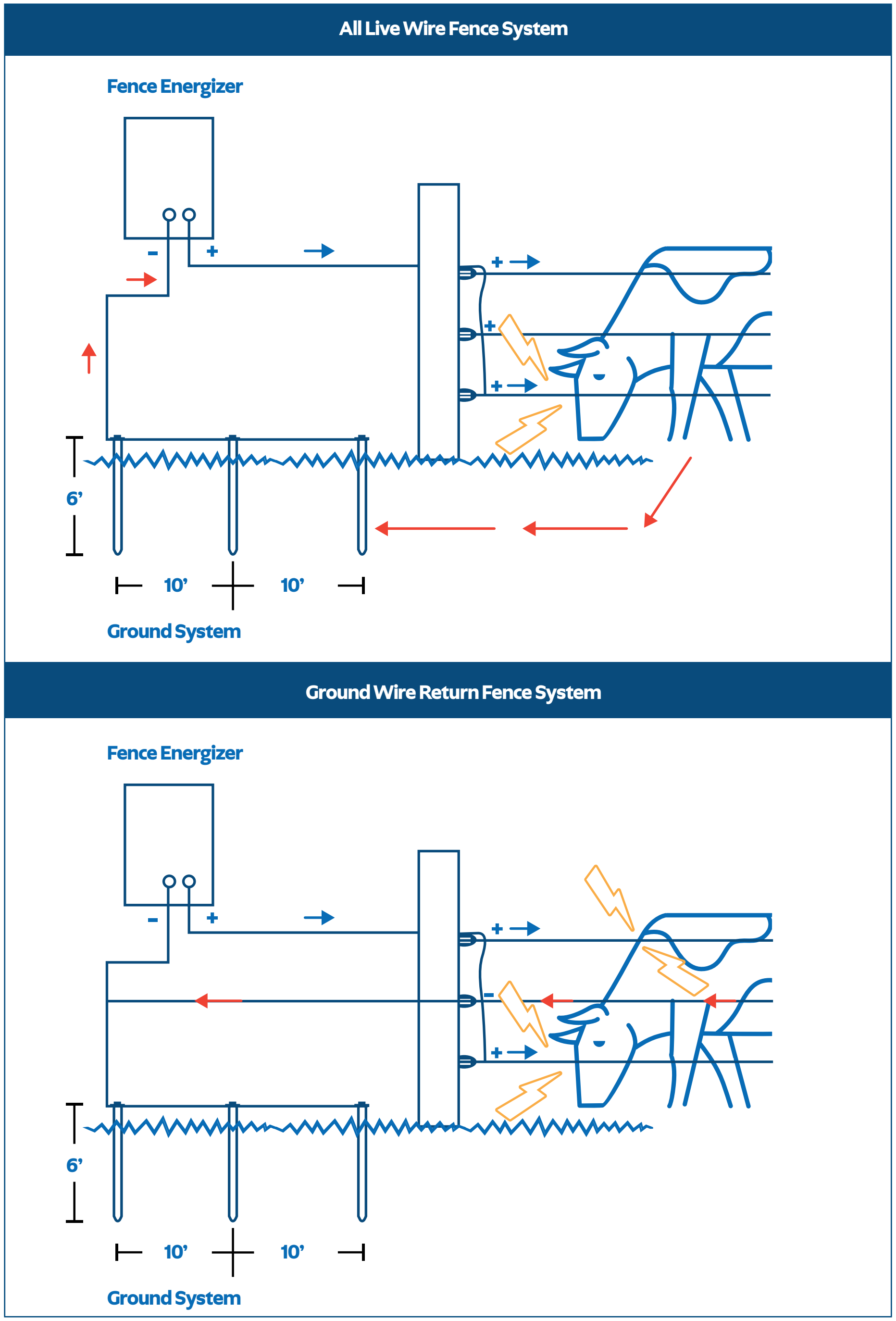



Figure 3.1 Comparison of an all-live wire fence system and a ground wire return fence system.

## Amperage, Voltage, Wattage and Joules

It is often easiest to understand the terms used in electric fencing systems by comparing an electrical system to a water system. Amperage is a measure of current, like the flow of water through a pipe. Voltage is the difference in electrical potential between two points in an electrical circuit, or similar to water pressure in the pipe. Wattage is a measure of the rate at which electrical energy is transferred by an electric circuit (amperage x voltage). Wattage is comparable to the rate of water flow times its pressure, which equals the pump horsepower. Fence controllers can be energy rated by their wattage per second or the joule output. In electric fence systems, voltage typically ranges from two to 10 kilovolts (kv), but it is not the voltage itself that deters animals from touching the fence. Instead, it is the joules, or quantity of energy, that passes through the animal. However, voltage is important because a certain amount is required to overcome resistance (such as wool) and allow the energy to flow. The minimum voltage should be above 3.5 kv to be effective for most large livestock, but sheep and other livestock with heavy coats require a higher voltage (above 6 kv). Most problems with low voltage are due to insufficient ground or faults like cracked insulators, excess vegetation, etc., which are grounding out the system.

Finally, pulse rate and intensity are important for safety. Some energizers range from 0.003 to 0.03 second pulses, and these should be avoided. The longer pulse time allows heat to build up and can potentially create arcs (i.e., when an electrical current jumps a gap in a circuit). The pulse should be very intense and last for only 0.0003 seconds, so fire risk is greatly reduced. Energizers with short pulses are called low-impedance energizers and are more expensive but worth the money. For a more detailed description of electric fence ratings and terminology, visit: http://www.pakton.com.au/terminology%20and%20units1.html

## Proper Grounding

The key to an effective electric fence system is the grounding component. It is said that 90% of all problems with electric fence systems are due to an improper ground, and this is understandable, considering the ground is half of the entire system. Ground rods catch the returning electrons like a radio antenna catches radiowaves. As such, care must be taken in determining their location and layout. The ground rods should be placed about 2 m (6 ft) in the ground and spaced about 3 m (10 ft) apart, preferably in a moist area. The minimum number of rods for any system is three, but this number will increase as the total system energy rating increases. A good rule is to add another rod for every 5 joules (so a 12-joule energizer would require three ground rods, while a 25-joule energizer requires five rods). More rods increase the chance to complete the circuit, especially in dry soils. Also, be sure to use one continuous ground wire to connect every ground rod.

Gallagher Electric Fencing™ has a good rule to remember:

- 4 meters between ground rods
- 3 ground rods minimum
- 2 meters minimum in length
- 1 wire to join all the ground rods

It is important to routinely test the charge on both the fence and the ground system using a voltage meter. There is a range in the quality of voltage meters that can be purchased, but it is wise to invest in a good meter, preferably one that shows the direction of a fault. This will greatly shorten the time and effort required to search for the fault in the fence. Along the fence, the voltage should be between 3 and 8 kv, depending on the size of the system required. To test the ground system, measure the voltage in the ground wire running between the energizer and the first ground rod. The optimum reading is zero volts, but if it reads more than 500 volts, then the system is insufficiently grounded.

## Reducing Resistance

Here are some suggestions to help reduce resistance in an electric fence system:

- The heavier the wire or thicker the diameter (lower gauge), the lower the resistance.
- The leadout (the section of fence from the energizer to the main fence) can be electrified and should have the same number of wires as the main fence. One strand can be used, but then must be sized for low resistance.
- Do not connect different metals; this will cause rapid corrosion and cause high resistance. Specifically, do not join steel and copper.
- Correctly connect charged wires together (Figure 3.2). Do not twist wires together; instead, use clamps, and limit the total number of connections and clamps. Increasing the total number of joints will increase resistance.

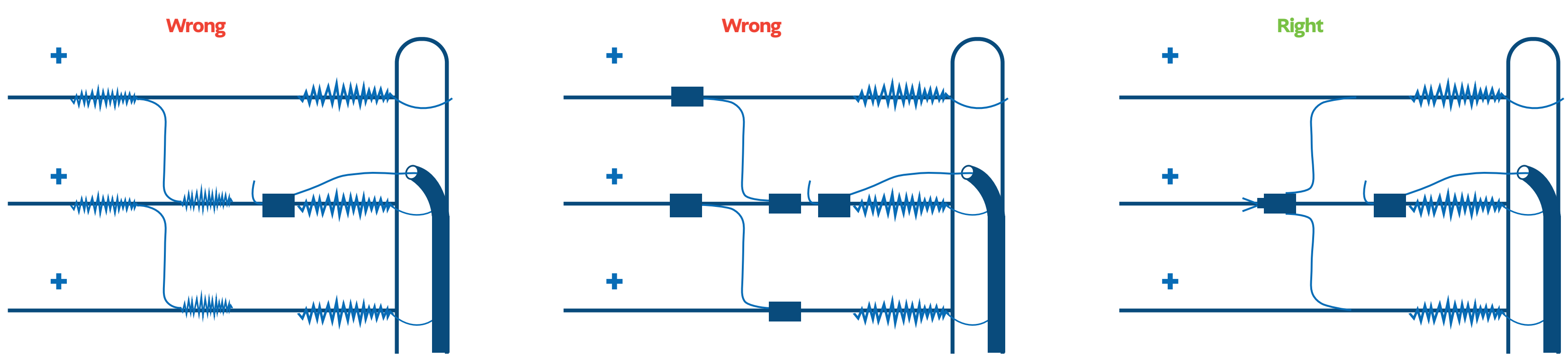



**Figure 3.2 Limiting joints in the fence limits resistance problems. Adapted from www.agf.gov.bc.ca/resmgmt/publist/300series/307300-1.pdf.**

## Maintenance

To ensure that the fence works well, make sure that livestock are trained to respect the charged wire before putting livestock in an electrified pasture. To accustom the livestock to the charged wire, install it inside a large loafing area, such as a turnout pen, and leave the livestock to become familiar with the electric fence.

The greater the fence load or the amount of vegetation touching the fence along its length, the more power is required to maintain the correct voltage levels. Vegetation touching the fence reduces its effectiveness. In order to eliminate this problem, begin with high voltage to burn off the vegetation, which means never shutting off the power or trim under the fence as necessary to eliminate or at least reduce the amount of vegetation that contacts the fencing wire. Herbicides can also be used to eliminate the herbage under the fence line.

Organic does not permit herbicides like glyphosate because it aims to minimize the impact on the surrounding ecosystem. It permits some non-synthetic herbicides like horticultural vinegar, but it would be expensive and impractical to spray horticultural vinegar on fence lines. For organic producers, if vegetation control is needed, trimming – or coming up with an innovative under-fence mowing setup (there are some examples online) – is the only practical option.

## Uses of Electric Fences

The biggest advantage of electric fencing is that it can be used as a permanent or temporary structure and can be used both on the boundaries of pastures and as a divider within pastures. In most situations, electric fences can be easily modified to adapt to pasture needs.

**Permanent** electric fence structures require heavier (lower) gauge high tensile wire (12.5 gauge is commonly used). Usually, permanent electric fences are used as boundary fences, but they can also be used to divide a pasture into long-term paddocks. On flat land, posts should be placed at 15 to 30 m (50-100 ft) intervals with the hillier the terrain, the closer the fence posts should be installed. If desired, fence droppers can be placed every 7.5 metres (25 ft) to prevent wires from being easily spread apart. A fence dropper, or stay, is a lightweight post that is attached to all the wires of a multi-wire fence but not driven into the ground. They keep the wires in the correct position over a spread between posts. Droppers allow posts to be farther apart and, therefore, require fewer posts to be driven into the ground.

Insultimbers™, which are high-density wood posts that do not conduct the electrical charge, can be used along long stretches of fence line instead of wood posts and insulators.

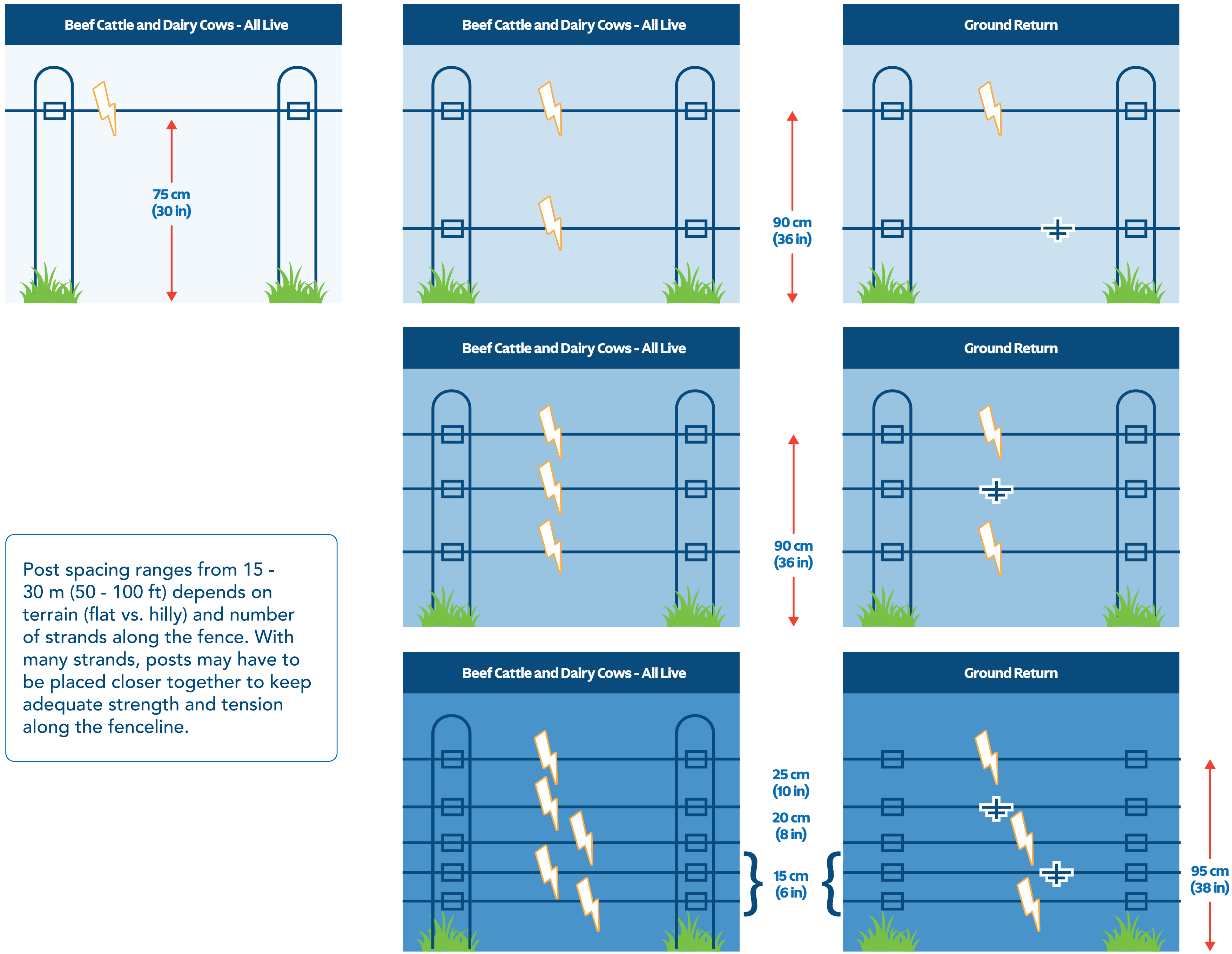
The number of wire strands required in a fence system depends on the class of livestock being confined as well as the location of the fence (Figure 3.4). For example, cattle next to the barn may only require a fence of only two or three wires. In contrast, a boundary fence that is being designed for sheep

close to a forest may require a predator control fence of five or six wires. A boundary fence is really the last line for the livestock to cross before leaving the property, so it should be very strongly constructed.

A permanent electric fence used to divide a pasture into paddocks requires fewer wires than a boundary fence. In this case, the purpose of the fence is to keep the animals within a section to use the forage efficiently, not for the protection of the livestock. Cattle trained to respect electric fencing are easily contained with one strand of high tensile wire; sheep will stay in place with three strands once they are trained.

**Temporary** electric fencing is generally used to subdivide larger paddocks or pastures into smaller ones or to create grazing strips. These fences can be constructed with any type of electric fence wire, including poly wire, 12.5, 14 or 16 gauge smooth wire or polytape since animal security is not the primary concern. The most important consideration is to choose a material that is easy to move but will not easily break. Poly wire is very light and easy to move but does not have a long lifespan. The wire is held up with movable posts and connected to permanent fences with either gate handles or reels. Sometimes, producers try to overcome the problem of frequent breakage by tying the ends back together, but the more connections made in the line, the higher the resistance becomes. After several breaks, it is best to replace the wire.

**Figure 3.3 3-wire temporary fence for sheep. Photo provided by Margaret Graves.**




Post spacing ranges from 15 - 30 m (50 - 100 ft) depends on terrain (flat vs. hilly) and number of strands along the fence. With many strands, posts may have to be placed closer together to keep adequate strength and tension along the fenceline.

Figure 3.4 Depending on what species of livestock you are grazing, your fencing set up may change.

## Moving Electric Fences

There are several devices designed for both poly wire and high tensile electric fences to assist moving front and back temporary fences, which can make the rotational system more convenient.

For poly wire fencing use one or more reels suspended by step-in posts to easily wind, unwind and move the fence (Figure 3.4). When purchasing reels, it is recommended to invest in a geared reel. It makes winding up a fence faster because every turn of the reel collects more of the poly wire (3x more for Gallagher™ geared reels). A non-geared reel requires fast winding and slow walking, sometimes resulting in tangles from a loosely wound reel. The most common step-in posts are made of steel (with integrated insulators) or fiberglass.

High tensile wires can be easily moved to the next section in a rotational grazing system using a tumble wheel. Tumble wheels roll easily over the ground, and the fence they support then attaches to the side fences with gate handles.

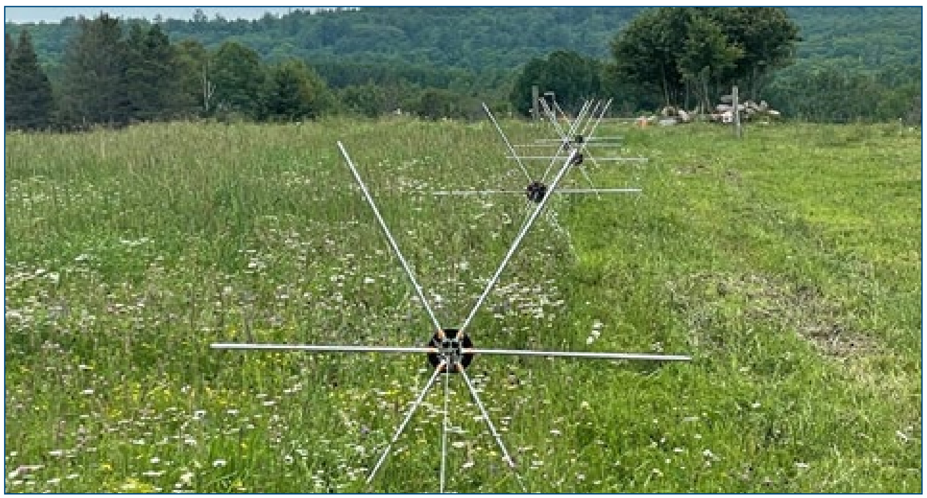


**Figure 3.5 A reel and tumble wheels make easy-to move temporary fencing. Photo credit to Dave Hamlin.**

## Electric Net Fencing

Electric net fencing (Fig 3.6) is a portable type of fencing that is made of a nylon-coated wire mesh, so it is highly visible. It is very light with the stakes built-in, making the netting easier to set up and move. This type of fencing is useful to subdivide pastures, especially for mature sheep, since it is both a physical and psychological barrier. It is also useful for keeping predators out, especially if set up and electrified a few weeks in advance of livestock turnout. There are two downsides to this practice: one is the drain on the fencer because of the greater number of poly wires, and the other is the potential of deer breaking the fences. Electric nets are more expensive than the alternatives, and when there are breaks in the wire, it is difficult to obtain a good charge through the whole fence, so it pays to be careful with them.

Electric net fences may need a higher-powered fencer because they have many wires with low ground clearance. Especially for sheep, it is important to have sufficient power in the net. If power is too low (because of contact with grass, a dead short somewhere in the system, an insufficiently sized fencer, or there is a break in the wire), or sheep motivation is too high (if they haven't been moved fast enough) they will put their heads through to graze on the other side and get stuck. This can be a particular issue with lambs that are small and new to electric fencing. Sheep stuck in electric net fences can die of strangulation or shock, or they will break the fence, causing more resistance in the fence in the future and a shortened life of the net.

The net fencing comes in a variety of mesh diameters. Mesh fence heights range from 85 – 120 cm (33 to 48 in). It is generally sold in rolls of 25 – 50 m (80 – 165 ft). Electric net fencing should be electrified at installation. Electric net fencing has to be kept clear of brush and other debris that has blown into it, and it helps to clip the grass underneath the fence to prevent grounding out. It should be set up so that it does not droop between posts.

**Figure 3.6 Electric net fencing is one type of portable fencing. Photo credit to Margaret Graves.**

## Electric Fence Hints and Troubleshooting

- 90% of all electric fence problems have to do with incorrectly grounding the system.
- Having a mix of electrified and other types of fencing on a farm is less effective since livestock may test the electrified fence more often; using an offset electrified fence around the inside perimeter of the page and barbed wire fences can be useful in mixed fencing systems.
- When looking for electrical faults in an extensive fence system, use switches installed at junctions and gateways to turn sections of pasture fencing on or off.
- Build gates so that they are charged only when connected; this prevents fence drainage if it lies on the ground.
- Use a voltage meter with a fault direction indicator to more easily find electrical faults.
- Never charge page or barbed wire - it can be very dangerous if livestock or people get caught or tangled in it.
- Reduce the number of wire connections as each connection will reduce the total voltage on the fence line.
- Run insulated wire underneath the gate to prevent it from being damaged. Electrified fences should be kept charged throughout the pasture growing season to prevent grounding out through vegetative growth. If grass growth is abundant enough, trimming under the fence will be necessary.

## Page Wire Fencing

Page wire is used for permanent perimeter fencing to control livestock, protect crops and enclose pastures. Page wire is sold by rolls [1 roll = 20 rods, 1 rod = 5 m (16.5 ft)] and comes in both one m (39 in) and 1.2 m (48 in) heights. The 1.2 m type is used more often, but the 1 m fence can be used for small livestock. They come in 9-strand panels and range from 9 to 12.5 gauge. Corners must be constructed correctly for maximum strength (see Figure 6.7). Anchors, corners and stretch posts must be made of wood.

Post spacing varies between four to five m (13 – 16 ft). Post lengths vary with page wire fencing height. Generally, for cattle, a 2.4 m (8 ft) post is used with 1.5 m (5 ft) above ground.

The benefits of page wire include its security and visibility to livestock. However, this form of fencing is costly to purchase (three times the cost of electric fencing) and results in higher installation costs due to increased labour requirements, equipment, and materials necessary for on-site construction (Stone & Leahy, 1999). Also, it cannot be used to temporarily subdivide pastures, and incorporating electric fencing can be difficult. This results in a fencing system with little adaptability. Furthermore, it can be easily damaged by snow loading and animals reaching over the top. Some fences incorporate a single strand of barbed wire above page wire to reduce animal pressure.

## Barbed Wire Fencing

As permanent fencing, barbed wire is less expensive than page wire, but more maintenance is required. Several strands of barbed wire can be used on interior and perimeter fencing, with posts spaced 5 m (15 ft) apart. Barbed wire is stretched tight during installation and stapled securely to each post. The number of wires used depends on the class of livestock being fenced in or out and can range from two wires spaced 60 cm (24 in) from the ground and 45 cm (18 in) apart to four wires, with the bottom strand 30 cm (12 in) above the ground and each subsequent wire above spaced at 25-30 cm (10-12 in) intervals.

Double strand 12.5-gauge barbed wire is the standard type and comes in 400 m (1,300 ft) rolls. Barbed wire is used where a lot of repelling action against livestock is required. However, the barbs make it hard to handle, and the fence is susceptible to permanent damage and sagging. Barbed wire fencing should not be tightly stapled to each post to allow for occasional tightening of the wire. The spacing of a 4-wire fence will not be able to hold small animals. Barbed wire fencing also contributes to an increased risk of wildlife injury (Stone & Leahy, 1999).

While barbed wire fencing is an effective method of keeping livestock in, it does have limits on predator control. It is easily damaged by snow load, although animal pressure (i.e. when livestock reaches over it) is not an issue as it can be with page wire.

## Offset Fencing

Offset fencing is used to increase the longevity and effectiveness of existing non-electric fences by protecting the non-electric fence from livestock. Offset fencing is also used to carry a charge from non-electric fences to electrified ones. For example, a large non-electrically fenced pasture can be subdivided into smaller temporary paddocks with electric fencing by running an offset electric line along the exterior fence and connecting it to the interior electric fence. This way, the permanent fence does not have to be replaced with an electric fence, and it is also protected from animal pressure. Offset fencing should only be used where the non-electrified fence is sound since contact between the offset and loose non-electrified wires will cause a dead short in the system.

Offset fencing consists of brackets attached to either the posts or the existing fence wire, and these brackets hold an electrified wire at two-thirds the height of the animal being contained (Figure 3.7). It also reduces damage to animal hides as it prevents the animals from rubbing against the non-electrified fence.

**Figure 3.7 Offset fencing can be used on existing permanent fencing to reduce animal pressure.**

## Fence Posts

The usual choice for fence posts is pressure-treated wooden posts that are pounded in with a post driver, usually mounted on a tractor. Some local producers are using plastic posts that can be easily pounded in by one person by hand. Examples are the Timeless Fence System™, with PVC t-posts, and the Gallagher™ Insulated Line Post. These plastic posts are more expensive but longer lasting than wood. Both wooden posts and plastic posts can be pulled out and re-used if they are structurally sound.

Whenever wooden posts are used on organic farms, they cannot be treated with prohibited substances. This means that the usual pressure-treated posts are not allowed unless they are already on the farm at the time of certification. In that case, they can be re-used.

Posts made of heartwood of cedar, redwood, black locust or other rot-resistant tree species are logical alternatives to treated wood (Taylor et al., 2013).

There may be wood preserving treatments that are acceptable for organic, but the certification body would have to confirm before a producer used them. Some examples of acceptable treatments, according to the organic standards interpretation committee (Organic Federation of Canada, 2023), are dipping the post in paraffin wax or using a polyethylene sleeve. These could be used on the part of the post that will be in contact with the ground to reduce the rate of decay.

## Bracing Corners and Ends

Regardless of the type of fence being used, the recommendations for corner and end section assembly and installation are the same. Corners and end sections must be correctly constructed for maximum support of the fence, as properly tensioned fence wires exert a great amount of force on the assemblies. Though both are similar in construction, a corner assembly is used when tension comes from two or more sides, while an end assembly is used when tension only comes from one side.

The most common type of corner brace assembly is the H brace because of its strength and relative ease of construction (see Figure 3.8). 8-foot posts should be the minimum length for corner and brace posts; a corner post will need a brace assembly for each direction that the fence joins to it. Notice that the brace wire is placed in the direction of the pull. End and gate braces are similar in design if the length of the fence from the corner post is greater than 60 m (200 ft), a double bracing system should be installed.

Anchors, corners and stretch posts must be made of wood.

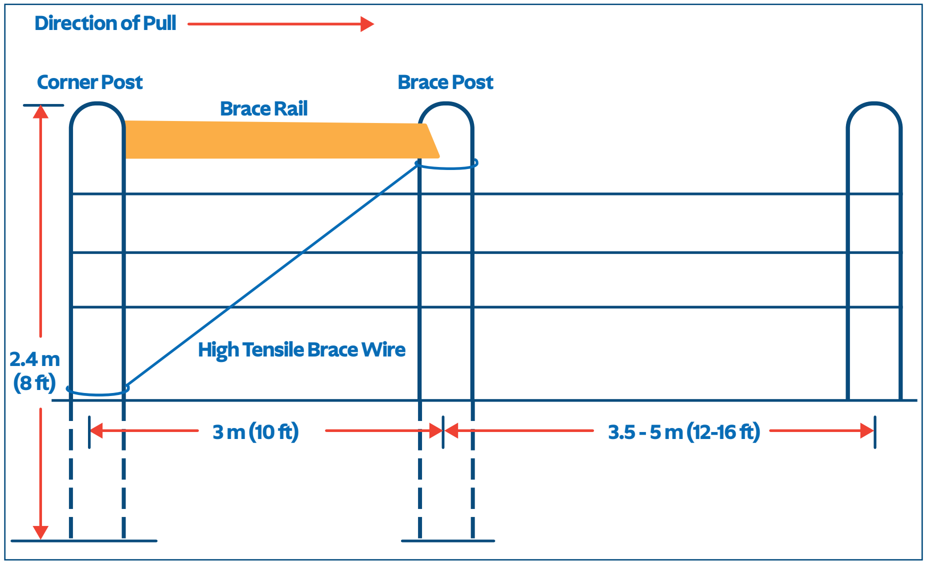



Figure 3.8 The "H" brace is the most common type of corner bracing.

All posts should be 2.4 m (8 ft) long
corner and brace post: 15 cm(6 in) top diameter posts along fenceline: 12.5 cm (5 in) top diameter brace rail: 10 cm (4 in) top diameter, notched and spiked into brace and corner posts brace wire: twist at 2 locations (can insert fence tightener) to make tighter

## Gates

Gates should be 25% wider than the widest tractor and implement that must pass through. Gates should be placed at corners or fence intersections since livestock tend to follow the fence when herded out. This location will also reduce the total number of braces that will need to be built.

## Comparison of Types of Fencing

Table 3.1 summarizes the characteristics of the most available types of fencing for easy comparison. Although fence costs may change, the table illustrates the relative costs of several fencing types.

Table 3.1 Comparison of Different Fencing Types.

| FENCE TYPE | ADVANTAGES | DISADVANTAGES | RELATIVE COST | BEST FOR |
|---|---|---|---|---|
| Barbed wire | • Easy to install | • Animal injury possible<br>• High maintenance<br>• Not predator proof<br>• Not movable | • Medium | • Cattle in combination with other fencing |
| Electric high tensile | • Inexpensive<br>• Long life<br>• Easy to install<br>• Predator control | • Maintenance<br>• Some training required | • Initially, medium to high<br>• Wire cost is low | • All classes of livestock |
| Electric poly wire | • Inexpensive<br>• Easy to install<br>• Easy to move | • Not predator proof<br>• Short life<br>• Less durable | • Low | • For all classes as interior or temporary fencing |
| Electric netting | • Psychological and physical barrier<br>• Predator control<br>• Easy to install<br>• Easy to move | • Expensive<br>• Animal injury of concern<br>• Less durable | • High | • Small livestock and temporary fencing of small areas |
| coloPage wire | • Physical barrier<br>• Predator control | • Expensive<br>• High maintenance<br>• Not movable | • High | • All classes for permanent fencing |

## LIVESTOCK WATERING

Direct livestock access to streams or ponds has been the traditional method of watering. While this method may be suitable for low-density use, both animal and environmental problems may arise.

Impacts on livestock include reduced health, production and rates of gain and a greater chance of injuries. Impacts on the environment include erosion of banks, siltation of watercourses, loss of vegetation and habitat, nutrient build-up in water, and increased growth of algae and bacteria, which can all have negative effects on aquatic life and water quality. More information can be found in Chapter 7 - *Creating an Environmentally Responsible Pasture System*.

**Figure 3.9 Pumping water into a tub protects water sources and improves animal performance.**

### Effects of Poor Water Quality

Livestock can be significantly affected by high levels of coliform bacteria (especially E. coli, which indicates septic waste or manure in the water). Cattle weight gain can be reduced by 20-30% with the consumption of contaminated water. Livestock generally prefer clean water over contaminated water and cool water over warm or icy water. Several studies have shown that cattle prefer drinking from water troughs rather than streams or ponds, and calf gains are greater (Willms et al., 2002). Ramps and crossings can be used to reduce riparian damage, provided they are well-designed and constructed.

### Water Requirements

Table 3.2 gives water requirements for several types of livestock. (To calculate per-hour herd intake, multiply the given number by the herd size and divide by 24.)

**Table 3.2 Average daily water intake by livestock.**

| LIVESTOCK TYPE | INTAKE§ | |
|---|---|---|
| | Litres | Gallons |
| Cow-calf pairs | 55 | 12 |
| Dry cows (both dairy and beef) | 45-55 | 10-12 |
| Growing cattle* (150-350 kg) | 20-40 | 5-10 |
| Growing cattle* (350-550 kg) | 30-55 | 7-13 |
| Dairy cows | 75-95 | 12-20 |
| Sheep, goats | 10 | 2 |
| Horses | 30-45 | 6-10 |

**§ On days over 25oC, intake can increase by 50-100%.**
***Finishing cattle may require more**

### Alternatives to Watercourse Access

There are many ways to provide water for livestock while preventing them from entering water sources. There may be several options for a particular system, so before choosing a watering site, there are some details that should be considered.

**To determine the right system for you, know: daily total**

- water volume required per # of livestock
- distance from barn water or electrical supply (accessibility) water source
- specifications (type and location)
- pasture location(s) and conditions (remoteness, topography, riparian features)
- grazing intensity (intensive or extensive)
- time available for labour (maintenance, reliability of system) financial feasibility

## TYPES OF WATERING SYSTEMS

### Pipeline from the Well

This is the preferred method of watering livestock in Nova Scotia. The source of water usually feeding a pipeline system (Figure 3.10) is a drilled or dug well. However, any other source can be used if there is electricity available for a pump to move the water. Wells can provide high volumes of quality water, are very reliable, and pipe can be laid out over a long distance, depending on the rise in elevation.

**Figure 3.10 Pipeline system: consists of the main line with connectors to tubs in paddocks.**

The waterline diameter is usually 1 in, but if pumping uphill, reduce the pressure loss by using a larger waterline. Waterlines can either be buried below the frost line or kept above ground, but then need to be emptied before freezing. In rotational grazing systems, plan the layout of the paddocks to best accommodate the waterline and insert several quick disconnect couplings so that a water tub can be quickly emptied and moved to the next paddock. The cost will depend on the distance of the waterline installed and any excavation costs associated with burying the line.

### Gravity Flow

This is a simple system in which the force of gravity is used to bring water from the source to the watering site and into a water tub. Since no power is required, this system can be used with almost any surface water source, and anywhere there is adequate slope (the source should be at least 1.5 m higher than the water tub; this increases as the distance increases).

The pipeline should be as straight and level as possible to prevent air locks, but the risk of air locks increases as distance increases. The diameter of the waterline should be at least 1.25 in for grades over 1%, but if pressure drop is a problem, then up to 1¾ in diameter may be required. The daily volume is completely dependent on the source (i.e. flow from the spring or volume of the pond). These systems may have a water valve to control flow but are often designed to overflow with a return line to the stream so the water in the tub is always fresh.

## Solar Powered Pumps

Solar-powered pump systems use solar energy to either charge batteries which run a 12-volt pump (Figure 3.11), or as a direct system which operates the water pump directly. The intake of the water hose can be placed in a stream, pond or shallow well, and the outlet should run to a water tank. Three days' worth of reserve in either batteries or as a water reservoir is recommended for extended periods of cloud; solar panels can recharge during cloud cover but at a much-reduced rate. The water tub can be fed by gravity from the water tank or reservoir.

**Figure 3.11 A simple setup of a solar panel, batteries and a submersible pump. The pond is barely visible in the background.**

Suppliers can help with the system design, including panel(s), batteries (optional), pump, controller and float switch. This system also has the potential to power an electric fence at the same time it is powering a water pump. Solar direct systems are at least double the cost of battery-operated systems. There is a large range of system sizes. Systems can pump as little as 200 L/hour (4,000 L/day) to as much as 5,000 L/hour (120,000 L/day) or more (the latter was tested at an 8-foot vertical lift and 16 foot horizontal with a 102-watt solar panel). In general, 100 watts is the minimum wattage of a panel required to operate a pump with sufficient volume. If higher flow rates of water are required, panels can easily be added to the system to increase its power output and drive a larger pump. This system works well in more remote areas since the water reserve only needs to be checked every few days. Theft or vandalism may become an issue. The panel, batteries and water tank may be permanently installed or placed on a trailer and moved to another area of the farm.

More information about solar-powered watering systems can be found in the Perennia factsheet Installing a Solar Powered Livestock Watering System.

## Wind-Powered Pumps

Both mechanical and compressed air pumps are used. However, the latter is more economical and requires less maintenance. The intake of the water hose can be placed in a stream, pond or shallow well, and the outlet should run to a water tank. A water reservoir holding three days of water supply may be necessary in case of several calm days. However, normally, very little wind is required to drive the pump. The water tub can be fed by gravity from the water tank or reservoir. Since there is only one moving part, there is almost no maintenance required other than to check on water levels in the trough or reservoir.

One manufacturer of compressed air windmills reports a maximum of 16,000 L/day pumped at a 10 ft lift (horizontal or vertical) and 6,000 L/day at a 21 ft lift, with 5-8 km/hr winds. When tested with a 75 ft horizontal and 6ft vertical lift, the windmill could pump at least 300 L/hr (7,200 L/day). Most regions of Nova Scotia regularly have enough wind. There is an automatic shut off at wind speeds higher than 35 km/hr.

## Nose Pump

This diaphragm pump is powered by livestock and yields 0.5 to 1 L per stroke. The maximum number of cattle that each nose pump can water is 20 cow-calf pairs. Nose pumps are easily set up by placing the intake hose into the water source, like a stream or pond. When the cattle are moved, simply haul the hose out of the water and take the nose pump with them. Winterized versions cost more. A two-day training period is required to allow cattle time to become familiar with the pump. Where nose pumps are permanently fixed, installing a pad or trough underneath the pump can reduce mess and can provide water to very young calves that otherwise could not operate the pump.

As hose length increases, so does the force required, so a distance of 6-10 m is considered maximum for best results. The amount of lift will depend on hose length but is generally not more than several metres. Other than occasionally needing to prime the pump, there is little maintenance required. These pumps are very reliable and can be used in more remote locations.

## Water Powered Pumps

Both the ram pump and the sling pump are powered by water. Neither is used much in Nova Scotia because they require specific water source conditions. The ram pump requires a minimum of 1 m fall to drive it, while the sling pump needs a minimum water depth of 40 cm and a current speed of 0.6 m/s to operate. Water source factors such as flow rate, fall and lift requirements will all determine the amount and rate of water delivered. Both pumps have been reported to pump up to 6,000 L/day or more, and the ram pump can lift several hundred feet, depending on the initial fall.

## Hauling Water

Hauling water consists of a tank mounted on a trailer or vehicle that supplies water by gravity to a water tub. The flow of water is then controlled by a float valve. Tanks generally hold several thousand litres of water, so they only need to be refilled once every couple of days (Figure 3.12). This system is practical when no other water source is available in the grazing area. It can be used with a rotational grazing system by moving the trailer at the same time as the animals are moved. Like smaller troughs, algae can grow inside tanks, especially in the hottest part of the summer.

**Figure 3.12 Typical tank used to haul and store water in more remote fields. Photo from Alicia and Danny King.**

## Pumps Powered by Battery and Fuel Generators

There are many types of pumps that can be run by portable batteries or gas engines. They are useful as backup power sources or when providing water in remote areas. However, these can be more labour-intensive as the power source needs to be attended to regularly. Theft may also become an issue. Here again, a water tank can store water and then feed a water tub by gravity. An alternative to having the batteries or generator constantly running a pump is to routinely visit the site with the power source and fill a water tank that can store a large quantity of water.

## System Costs

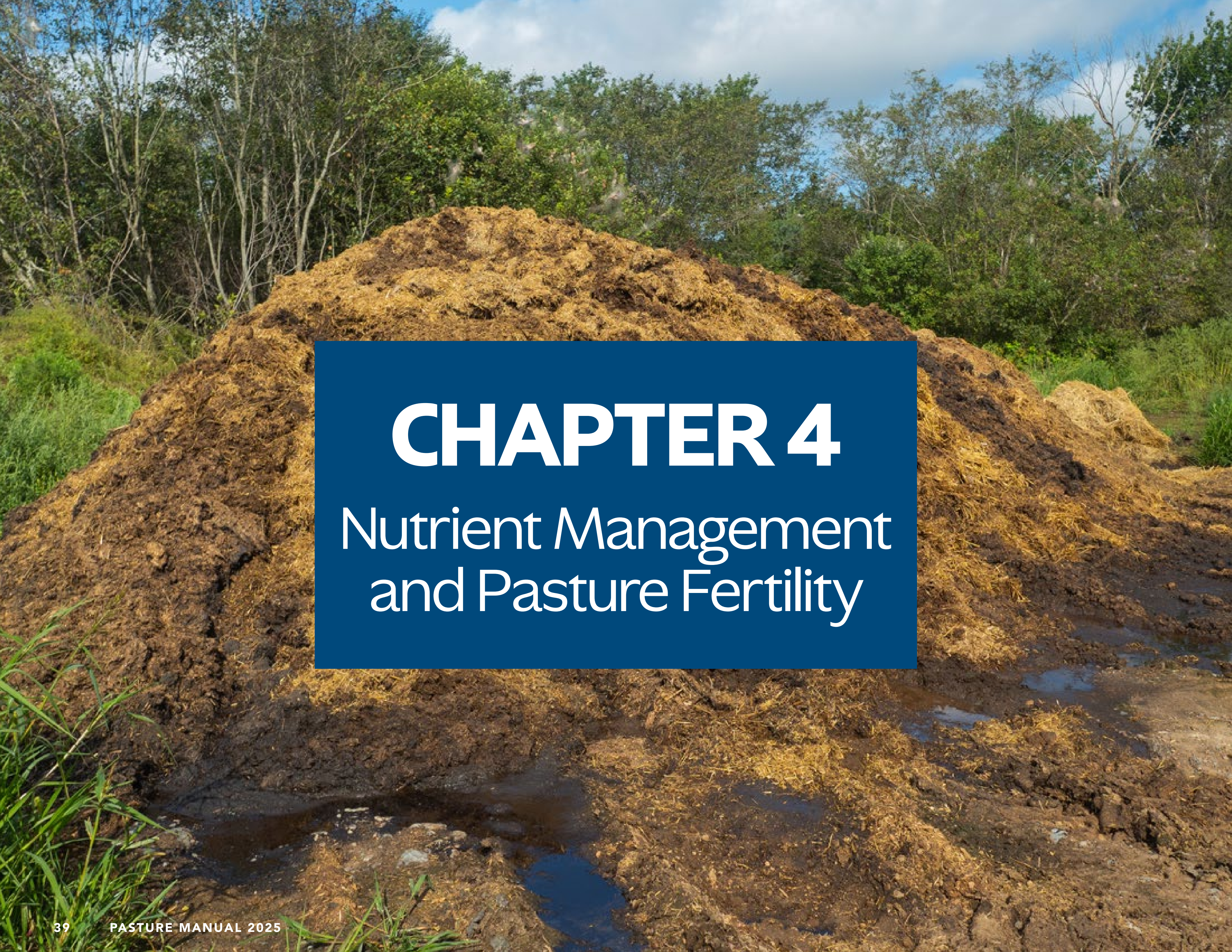
Table 3.3 shows the cost ranges for each system. The costs include the pump and all immediately associated components of the pumping system; they do not include water troughs, floats or any pads that may be required at the watering site. There is also the possibility of excavation costs, which will depend on the size of the task, as well as the soil type that is worked on. Large water tanks or reservoirs to store several days' worth of water will also add to the total cost of the system.

**Table 3.3 Cost of alternative watering systems.**

| TYPE | COST OF SYSTEM ($) |
|---|---|
| Well | 3,000 - 20,000 |
| Pipeline | *1,000+ |
| Gravity flow | *1,000+ |
| Nose | 400-500 |
| Solar | **1,500+ |
| Wind | **1,500+ |
| Ram pump | 500+ and fuel |
| Gas engine generator<br>Battery powered | Batteries and Charging system |
| *Cost depends on the total distance of the system.<br>**May have to add the cost of a reservoir. | |

Costs associated with a pipeline system include a float (under $20) and plastic tubs, which range from $150 to $250 depending on the size, while metal tubs can cost $100 (or less for used) and waterline (less than $1.50 per foot for 100 psi pipe).

The section on livestock watering systems has been reprinted with permission from the Soil & Crop Improvement Association of Nova Scotia.



# CHAPTER 4

## Nutrient Management and Pasture Fertility

# CHAPTER 4
# Nutrient Management and Pasture Fertility

Soil fertility is an important factor in pasture production. It helps determine the yield and quality of the crop and directly affects the species composition and longevity of the stand. In addition to water and sunlight, maintaining pasture fertility through the input of nutrients and beneficial management practices (BMPs) is key to supporting healthy plant growth. Nutrient balance in pastured forage may also affect the health and productivity of the grazing animals.

Many nutrients are supplied to the plant by the soil, but not all soils are equal in their capacity to supply nutrients. Soil parent material, which soils are formed from, may have inherently low fertility or nutrient stores may have been depleted by decades of grazing without any fertilizer to replace what has left the farm. Nitrogen (N), phosphorous (P), and potassium (K) are the most common limiting nutrients, although micronutrients may occasionally limit production. It may be necessary to add nutrients through the application of manure, chemical fertilizer, or seeding legumes to fix N.

A healthy, productive pasture cannot be maintained by nutrients alone. For pasture plants to capitalize on the nutrients from the soil, the plants must have a healthy root system. Overgrazed plants with small, weak root systems cannot take advantage of improvements to soil fertility (Leahy & Robinson, 2000). Therefore, it is necessary to manage grazing and the nutrient status of the soil to maintain productive pastures. Refer to Chapter 2 (*Grazing Systems*) for more information about grazing management and systems.

## NUTRIENT CYCLING

There are seventeen essential elements for plant growth. Of these, carbon (C), hydrogen (H), and oxygen (O) are supplied primarily by air and water. The remaining fourteen elements are mineral elements supplied by the soil, except N can also be supplied from the air. Macronutrients include N, P, and K, while sulphur (S), calcium (Ca), and magnesium (Mg) are often referred to as secondary nutrients, and the rest which include boron (B), copper (Cu), iron (Fe), nickel (Ni), manganese (Mn), and molybdenum (Mo) are micronutrients (Table 4.1). Both macro and micronutrients are essential, but macronutrients are required in higher amounts.

There are also nutrients that are beneficial for plant growth but not proven to be essential or contribute to animal nutrition. These include silicon (Si) (contributes to stalk strength), sodium (Na) (which can partially substitute for K), cobalt (Co) (which is essential for N-fixation by Rhizobia) and selenium (Se) (which is essential for animal nutrition).

Additionally, soil microorganisms are essential to the soil ecosystem and directly influence the cycling of nutrients within the soil environment. Microorganisms are responsible for the decomposition of organic matter, which involves the mineralization and release of plant nutrients. For more information on nutrient cycling and insights to the role of soil microorganisms see Chapter 7 - *Creating an Environmentally Responsible Pasture System*.

The cycling of all nutrients through the soil and plants is affected by soil pH (acidity or alkalinity) and soil organic matter concentration. While not strictly nutrients, these soil properties are important to understand as part of managing the nutrients in your soil.

**When you think about nutrient cycling and nutrient uptake it is important to remember that in order for plants to take up nutrients:**

1. Nutrients need to be in an available form (e.g., ammonium ($NH_4^+$) or nitrate ($NO_3^-$) for nitrogen)
2. Nutrients need to be in soil solution (the water between soil particles)
3. Nutrients need to be in relatively close proximity to the root
4. Have appropriate timing

**Table 4.1 Plant macronutrients and micronutrients.**

| MACRONUTRIENTS | SECONDARY NUTRIENTS | MICRONUTRIENTS |
|---|---|---|
| • Phosphorus (P)<br>• Potassium (K)<br>• Nitrogen (N) | • Sulphur (S)<br>• Calcium (Ca)<br>• Magnesium (Mg) | • Boron (B)<br>• Iron (Fe)<br>• Zinc (Zn)<br>• Copper (Cu),<br>• Manganese (Mn),<br>• Nickel (Ni),<br>• Chlorine (Cl),<br>• Molybdenum (Mo) |

## Soil pH

Soil pH is a measure of the acidity or alkalinity of the soil. Soil acidity is caused by the presence of hydrogen ($H^+$) ions in soil solution. As the presence of $H^+$ ions increase, the soil becomes more acidic. pH is measured on a scale from 0-14, with a neutral pH (neither acidic nor alkaline) at 7.0, with values below 7 indicating acidic conditions and above 7 indicating alkaline conditions. The pH values typically found in agricultural soils range between 4.5-8.0.

Soil pH is impacted by other soil properties such as cation exchange capacity (CEC) and the relative number of acid cations ($H^+$ and $Al^{3+}$) and basic cations ($Ca^{2+}$, $Mg^{2+}$, $Na^+$, and $K^+$). The surfaces of soil particles carry a negative charge, but these are most concentrated in clay minerals and soil organic matter. The amount of this charge is a measure of the capacity of the soil to hold positively charged ions (cations), known as the CEC. Cations are divided into basic and acidic classes. The basic cations include many important plant nutrients, but over time they can be leached from the soil. As this occurs, they are often replaced by acidic cations ($H^+$ contributes directly to acidity, and $Al^{3+}$ releases $H^+$ when it combines with water). This process reduces soil fertility and increases acidity (Advisory Committee on Soil Fertility). Acidification occurs fastest where there is high rainfall combined with low CEC.

Soil pH indicates whether a soil will benefit from added lime or not, but it will not tell you how much lime is needed. Soils differ in the amount of acidity held on the soil surfaces, and this reserve acidity must also be measured. See the section on liming for more information.

Many agricultural soils in the Canadian Atlantic region are highly acidic. Both natural and anthropogenic factors (caused by human activity) affect soil acidity and may be caused by:

- Natural soil environment
- Organic acids released from plant roots or microorganisms and organic decomposition
- Precipitation, which is naturally slightly acidic (due to dissolved carbon dioxide ($CO_2$) forming carbonic acid); air pollutants like sulphate can increase this acidity
- The underlying parent material can be naturally acidic
- Anthropogenic inputs and management practices
- Ammonium-based fertilizers will generate $H^+$ ions as soil bacteria nitrifies the ammonium molecule to $NO_3^-$ decreasing pH
- Harvest can remove basic cations from soil, increasing acidity

## Why Manage Soil pH

Soil acidity can have a considerable influence on the productivity of pastures. For the following reasons, the control of soil acidity should be incorporated into pasture management:

- **Nutrient availability:** Soil pH affects nutrient availability by impacting the solubility of nutrients. Typically, at pH levels below 5.5, the plant essential nutrients (N, P, K, S, Ca, Mg) may become less available, potentially limiting normal plant growth. In contrast, the micronutrients (Fe, Mn, Cu, Zn) may become more available at lower pH levels yet can potentially increase to toxic concentrations (Figure 4.1). Keep in mind that nutrient availability does not exclusively depend on pH, but it is affected by soil structure, management and climate as well.
- **Solubility of Phosphate Minerals:** Phosphorus in plants is essential for energy transfer, root growth, protein synthesis, and crop maturity. The soluble (i.e., plant available) forms of P are orthophosphates ($H_2PO_4^-$ or $HPO_4^{2-}$). The soil pH for optimum P availability to plants is around 6.5. At pH levels below 6.0, aluminum ($Al^{3+}$) and iron ($Fe^{3+}$) can attach with soil P to form insoluble P compounds. At pH levels above 7.0, $Ca^{2+}$ and $Mg^{2+}$ can attach with soil P to form insoluble P compounds. This reduces the availability of P to plants and limits normal plant growth.
- **Al and Mn toxicity:** At lower pH, $Al^{3+}$ and $Mn^{2+}$ become more plant available and can increase concentrations levels and adversely affect normal plant growth (Advisory Committee on Soil Fertility).
- **Fertilizer use efficiency:** Fertilizer use is less efficient in acid soils. At a pH of 6.0, the fertilizer use efficiency is 80%, but at pH 5.0, it is less than 50%. This is particularly significant for phosphorous fertilizer (Table 4.2).
- **Plant sensitivity:** Many pasture species are sensitive to acidic soil conditions and are most productive at a pH between 6.0 and 7.0 (Advisory Committee on Soil Fertility) (Table 4.3).

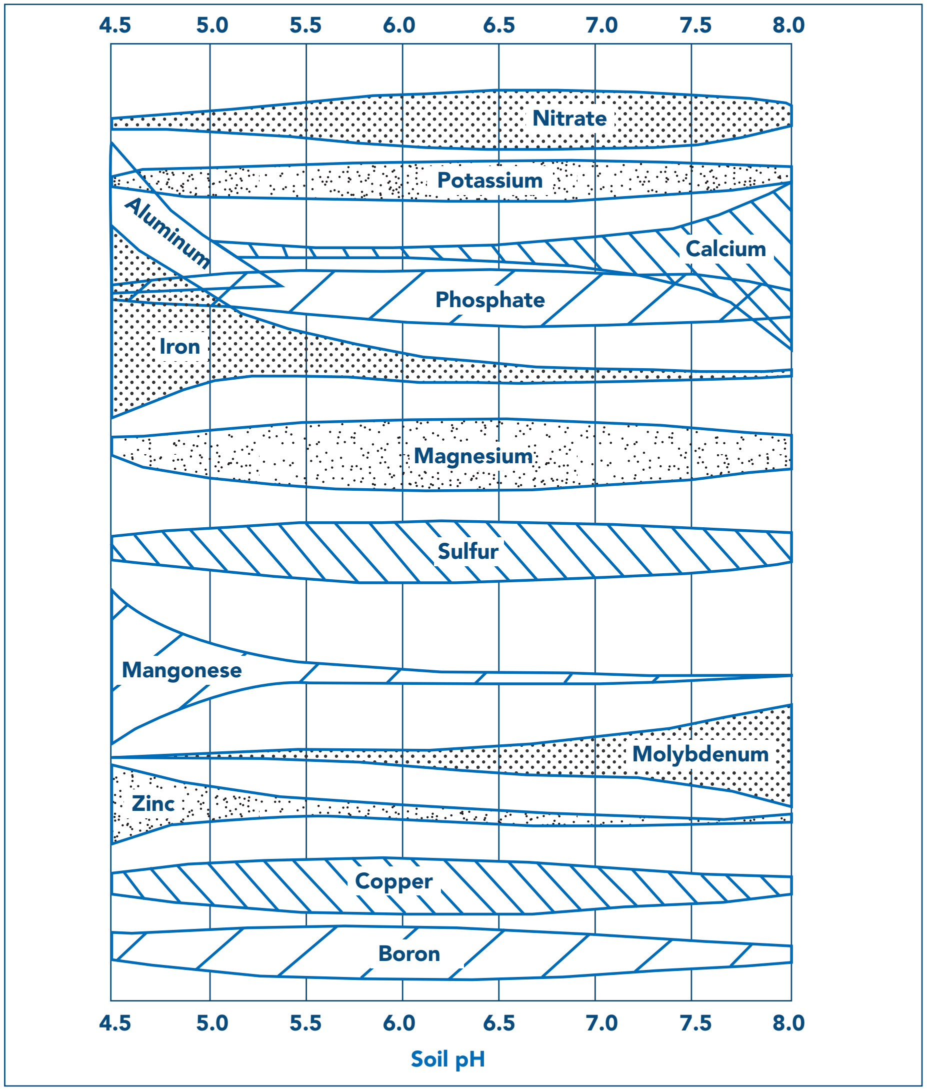



Figure 4.1 Nutrient availability and pH (OMAFRA, 1994).

Table 4.2 Fertilizer efficiency at various soil pH levels (Advisory Committee on Soil Fertility. Atlantic soils need lime. Publication No. 534-84, Agdex No. 534. Atlantic Provinces Agricultural Services Co-ordinating Committee).

| | pH = 6.0 | pH = 5.5 | pH = 5.0 | pH = 4.5 |
|---|---|---|---|---|
| Nitrogen efficiency | 89% | 77% | 53% | 30% |
| Phosphorus efficiency | 52% | 48% | 34% | 23% |
| Potash efficiency | 100% | 77% | 52% | 33% |
| Overall efficiency | 80% | 67% | 46% | 29% |

Table 4.3 Forage species sensitivity to soil pH (Forage and Corn Variety Evaluation Task Group).

| SENSITIVE TO ACIDITY (prefers soil pH ≥ 6.5) | LOW TOLERANCE TO ACIDITY (prefers soil pH ≥ 6.0) | MODERATE TOLERANCE TO ACIDITY (prefers soil pH ≥ 5.5) |
|---|---|---|
| Alfalfa | Kentucky bluegrass | Alsike clover |
| Smooth bromegrass | White clover | Birdsfoot trefoil |
| Sweet clover | Orchardgrass | Meadow fescue |
| | Red clover | Redtop |
| | Ryegrass | Reed canarygrass |
| | Timothy | Tall fescue |

- **Weed tolerance:** Several weeds can tolerate low soil pH and will take advantage of openings in the stand as more desirable species die out. Acidic soil conditions may result in an increased presence of weeds in the pasture (Table 4.4).

Table 4.4 Weeds that tolerate low pH levels and may indicate acidic soil conditions (Singh 2006).

| INDICATOR WEEDS | | | |
|---|---|---|---|
| Coltsfoot | Eastern bracken | Knapweed | Plantain |
| Common mullein | Field horsetail | Moss | Prostrate knotweed |
| Curled dock | Garden sorrel | Nettle | Sheep sorrel |
| Dandelion | Hawkweed | Ox-eye daisy | Silvery cinquefoil |

- **Response to nitrogen:** Plant response to N depends on adequate supplies of K and P. Both P and K enable a plant to utilize N and produce higher yields and more protein. The reduced availability of P and K at low pH levels means the plant will be less able to respond to N (Thomas, 2001).

- **Activity of microorganisms:** Many of the microorganisms responsible for nutrient transformations in the soil are not well suited to acidic environments. The natural supply of nutrients may, therefore, be inhibited at acidic pHs.

## Soil Organic Matter

Soil organic matter (SOM) refers to the portion of soil composed of biological (plant and animal) matter and can be considered anything living or dead in the soil. The major contributors of SOM are plant roots, plant residues, and macro and microfauna. In pasture systems, the more SOM the better, as it helps with nutrient cycling water management and improves soil structure.

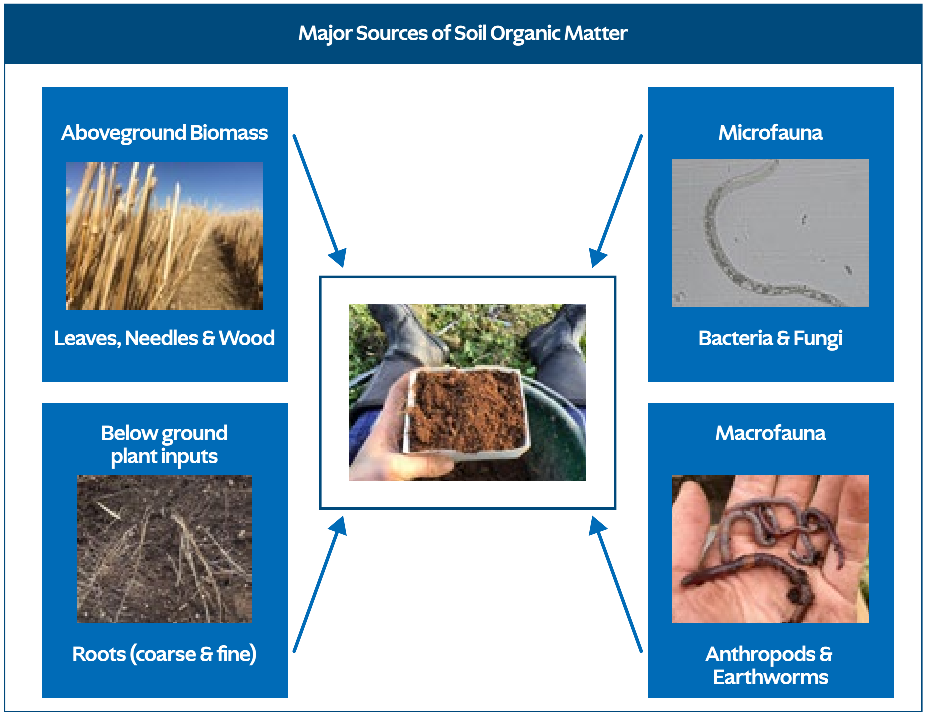



**Figure 4.2 Major sources of soil organic matter.**

Organic matter plays two key roles in nutrient cycling in soil. First, nutrients are held within the SOMs chemical structure. Secondly, the molecules in SOM carry a much higher negative charge than other soil particles and so have a much higher CEC. Soils with depleted organic matter will be less able to retain nutrients and supply them to plants than soil with high organic matter content. Pasture soils are often well supplied with organic matter because of the year-round plant cover and cycling of organic material back to the soil as plant residues and livestock feces. The exception is pastures with a history of chronic over-grazing; with inadequate top growth on the pasture for most of the grazing season, there is not enough leaf area to photosynthesize and replenish soil organic matter reserves. Low SOM levels on a pasture soil test typically indicate poor management in the past.

## NITROGEN

Why is Nitrogen (N) Important?

- It is an essential component of protein, which is necessary for healthy plant growth
- It is an important component of chlorophyll, which is essential to photosynthesis
- It is a component of nucleic acids, which contain the genetic information of the plant
- It aids in the uptake of other nutrients

In the soil, N primarily occurs as *organic N*. Organic N is unavailable for plant uptake and commonly is found in organic residues (undecayed and partially decayed plant and animal residues) such as manure and unmineralized SOM or humus. Smaller amounts of N occur as *inorganic N* forms such as nitrate ($NO_3^-$) and ammonium ($NH_4^+$) which are available for plant uptake and found in mineralized SOM. The decomposition of organic residues such manure, *biological N fixation*, and the application of inorganic N fertilizers can add these plant available forms to the inorganic pool. Microorganisms convert organic N to $NH_4^+$ and $NO_3^-$ through the processes of mineralization and nitrification. Biological N fixation in which bacteria (Rhizobia) living in a symbiotic relationship in the roots of legumes convert atmospheric nitrogen ($N_2$) to $NH_4^+$ and organic N in exchange for carbohydrates. Biological N fixation is an important process as it can supply N to both legumes and non-leguminous plants.

Nitrogen can be lost from the system through several different transformations. Nitrogen may be lost to the atmosphere through $NH_4^+$ volatilization and denitrification, lost to the groundwater through $NO_3^-$ leaching, or lost by surface runoff and/or erosion. Harvesting a crop, grazing by animals and immobilization also remove N from the system. Figure 4.3 and Table 4.5 describe the N cycle and includes the inputs of N, its processes (e.g., transformations), and its losses.

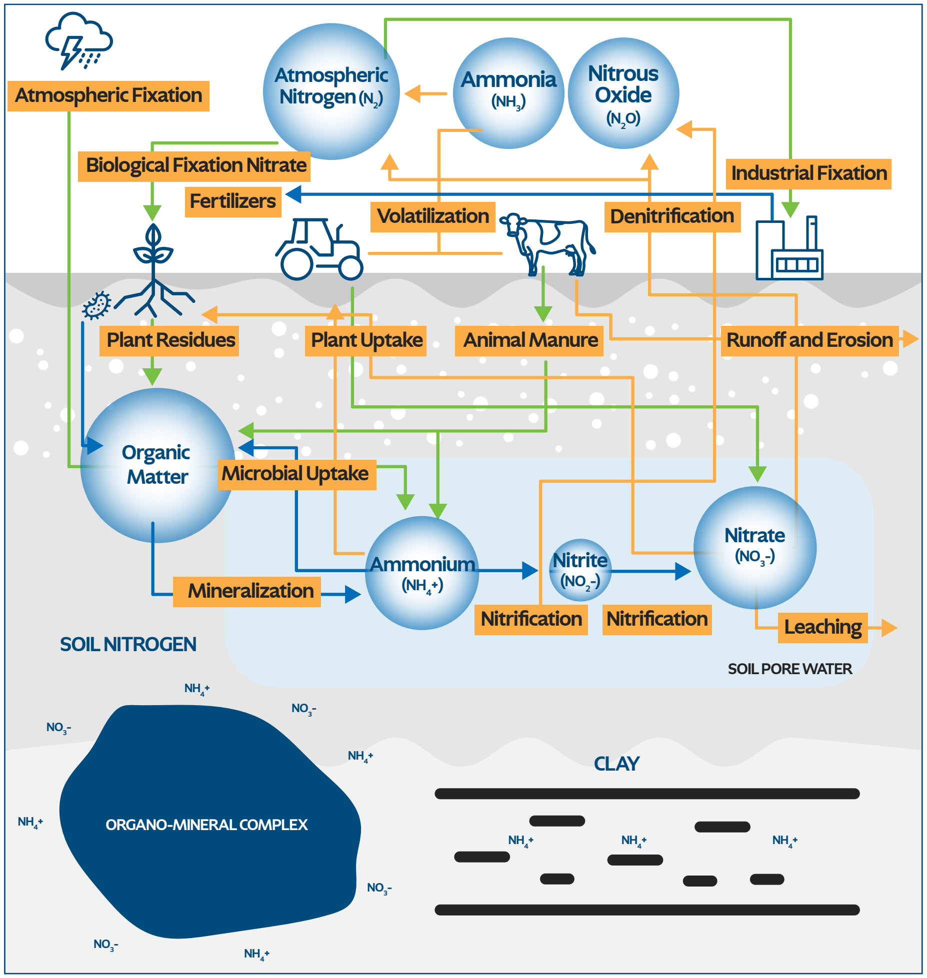



Figure 4.3 Nitrogen Cycle.

Table 4.5 Nitrogen cycling.

| |
|---|
| **N mineralization:** soil microorganisms convert organic N to inorganic N in the form of $NH^{4+}$. The majority of N is supplied to plants through mineralization. |
| **Nitrification:** soil microorganisms convert $NH^{4+}$ to nitrite ($NO_2^-$) and finally to $NO_3^-$. At pH levels below 5.5 and when $O_2$ is limiting (in wet or waterlogged soil), nitrification is inhibited. Cold soil can slow nitrification. When nitrification is slowed or inhibited, $NH^{4+}$ accumulates, and the supply of $NO_3^-$ to plants is limited. |

| |
|---|
| **N fixation:** Rhizobia bacteria at the roots of legumes convert atmospheric N to ammonium and organic N. Industrial N fixation combines the hydrogen from natural gas with $N_2$ to produce ammonia, which is then processed into other N fertilizers. |
| **Ammonia volatilization:** the loss of gaseous N through the conversion of $NH_4^+$ to ammonia gas ($NH_3$). Ammonia volatilization is pH-dependent, occurring more quickly under high pH conditions. Nitrogen loss via ammonia volatilization is usually associated with surface-applied manure or surface-applied urea fertilizer. |
| **Denitrification:** The loss of gaseous N as soil microorganisms convert $NO_3^-$ to $N_2$ or $N_2O$. Denitrification occurs in wet or flooded conditions where oxygen is limited (anaerobic conditions). |
| **Nitrate leaching:** $NO_3^-$ is very water-soluble and may be lost as water moves through the soil profile to the groundwater. Nitrate leaching becomes prevalent when high $NO_3^-$ levels in the soil are combined with rainfall levels that exceed the soil's water-holding capacity (usually in fall and winter). |
| **N immobilization:** soil microorganisms convert $NH_4^+$ back to organic N. |

The N cycle in the soil is dynamic and is influenced by several factors. Mineralization, nitrification, N fixation, denitrification, and immobilization are biological processes; therefore, they are influenced by such factors as soil pH, temperature, oxygen, and moisture. Profitable N management for pastures strikes a balance between supplying enough N to ensure vigorous pasture growth while avoiding excess that could be lost to the environment. The following points can help to optimize your N use on pasture:

- Establish legumes as the base for the pasture mix and manage the pastures to maintain a reasonable proportion of legumes.
- Acid soils will inhibit N fixation by legumes; add a liming agent to soils if the soil pH is low.
- If supplemental N is required, apply the recommended rates. It is also helpful to calibrate fertilizer and manure-spreading equipment so that applications are more accurate, and N is not over-applied.
- Implement split applications of N to pastures to match the time when grasses will be actively growing and to avoid high N concentrations in the soil that could be lost to the environment or impair forage quality.

Timing of N applications can, to some extent, even out the supply of forage to grazing livestock, but it will not be able to overcome the lack of moisture in mid-summer. Beneficial management practices for manure application should be employed to reduce N loss to the environment.

Proper rotational grazing will help distribute nutrients across the pasture more evenly, reducing the occurrence of high N concentrations that could potentially be lost to the environment.

For organic producers, industrially fixed N fertilizer is not an option. As with conventional pastures, the first consideration should be maintaining enough legumes in the pasture to supply adequate N. If supplemental N is required, options include pelletized poultry manure and certified organic manure or compost. In certain situations, non-organic manure is permitted. It is important to note that graziers who don't use N fertilizer are exporting N from their farms, just like everyone else, in the form of meat protein. It is an important part of an organic plan, and any farm plan, to establish where the plant-available N is coming from in the system.

## LEGUMES

Legumes are valuable species in a pasture not only because they are a good source of protein for grazing animals but also because of their symbiotic relationship with Rhizobia bacteria. Rhizobia bacteria form nodules at the roots of leguminous plants to fix atmospheric N. The N that is fixed is available to the host legume, as well as nearby non-leguminous plants. Legumes supply the nearby non-leguminous plants with N primarily as the nodules and legume residues decompose (Havlin et al., 1999). There is also evidence of N transfer through root exudates and mycorrhizal fungi (Thilakarathna et al., 2016).

Legumes such as red or white clover (Figure 4.4), alfalfa, or trefoil (Figure 4.5) can typically fix about 100 kg N/ha per year (Havlin et al., 1999). In a pasture with a healthy population of legumes, the fixed N is a valuable supply of N, reducing or eliminating the need for additional N fertilizer. The differences in N fixing potential among the various legume species are less important than maintaining a high enough proportion of legumes in the stand, so the choice of legume should be dictated by adaptability to your soil conditions (drainage, pH) and grazing management.

**Figure 4.4 Red Clover in pasture.**

**Figure 4.5 Birdsfoot trefoil, a common pasture legume.**

The following considerations should be taken into account when incorporating legumes into a pasture system:

- The nutrient requirements of legumes differ from those of grasses. In a pasture with 30% legume content or more, additional N fertilizer is unnecessary and will suppress N fixation by the legumes if added. In Atlantic Canada, it is recommended to maintain 30% legume content in the pasture, although this can be difficult. Despite legume content, a fertilizer application of 20 kg N/ha in the spring might benefit the grass content of the pasture (Thomas, 2001).
- Using less fertilizer N can promote legume content in a pasture, and less N reduces the competitive nature of grasses. Dry matter yield will likely be reduced because of suppressed grass growth; however, in addition to savings in fertilizer, forage quality and animal performance can be improved.
- Legumes require higher amounts of P, K, Ca, S, B, and Mn than grasses. The root systems of legumes are such that they are less efficient at extracting soil nutrients than grasses and, therefore, are more prone to nutrient deficiencies. When these nutrients are deficient, N fixation will be limited.
- Phosphorus is often the nutrient limiting the growth of legumes. To encourage the growth of legumes, adequate P levels must be maintained, which may require manure or fertilizer applications. In Atlantic Canada, B may be deficient, and this deficiency should be addressed to promote legume content. Generally, B may be required at a rate of 1 kg B/ha every two years. Sulphur and molybdenum are generally sufficient, and soil testing is recommended to monitor these nutrient levels.
- Soil pH will also affect the N-fixing activity of legumes. Many legume species and Rhizobia bacteria are sensitive to acidic conditions. To maintain a productive stand of legumes in the pasture, soil pH should be monitored and maintained at a level between 6.0 and 6.5 (or above 6.5 for alfalfa).
- Legumes require specific species and strains of Rhizobia bacteria for N fixation. Using the proper inoculant for the legume at the time of seeding will promote N fixation by helping make sure the proper Rhizobia bacteria for the legume is present in the soil. In many cases, legume seed is pre-inoculated with the appropriate bacteria.

For information on how to add legumes to a pasture, see Chapter 5 – *Pasture Renovation and Establishment*.

## PHOSPHORUS

### Why is Phosphorus (P) Important?

- It is an essential component of the compounds that store energy in plant cells and is critical for plant processes such as photosynthesis
- It is important for enhancing root growth and development
- It is a structural part of all cell membranes and other cellular components

Phosphorous occurs in the soil as organic P, dissolved P in solution, and insoluble inorganic P compounds. Plants take up soluble P in the forms of orthophosphates ($H_2PO_4^-$ and $HPO_4^{2-}$). The amount of P in solution at any time is small compared to plant requirements and must be continually replenished from the organic and inorganic P pools.

Dissolved P reacts with many elements and compounds in the soil, converting into forms of varying levels of insolubility. Like N, there is cycling back and forth between dissolved P and the organic pool. Organic P is mineralized to release dissolved P, which is then immobilized back into organic forms by microbial assimilation. Unlike N, the organic pool is a relatively small part of the total P in the soil, and the size of the organic pool does not appear to expand as P is added to the soil.

Inorganic P makes up a larger part of total P in most soils; P can be adsorbed to the surface of clay minerals or organic matter or precipitated as insoluble P compounds. These reactions are pH dependent, with precipitation as iron ($Fe^{3+}$) or aluminum ($Al^{3+}$) phosphates dominating in acidic soils while calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$) phosphates dominate in alkaline soils. The greatest availability of $H_2PO_4^-$ in the soil solution is between pH 6-7. This mineral P can be desorbed or dissolved to replenish what is removed from the soil solution by plant uptake. Figure 4.6 and Table 4.6 describe the P cycle.

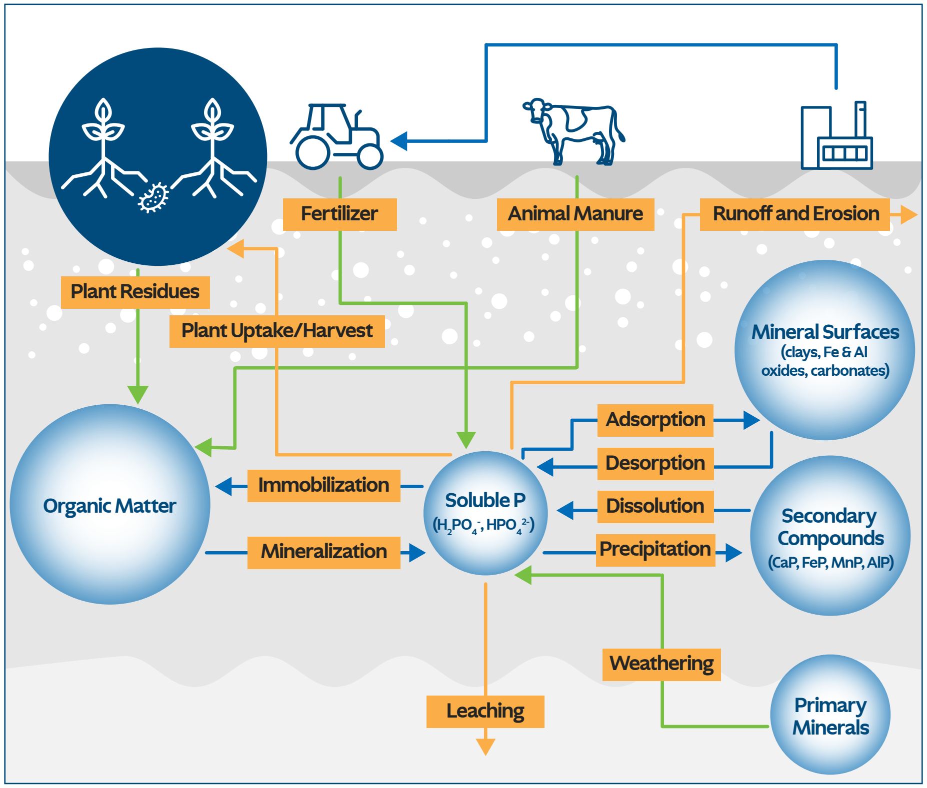



**Figure 4.6 Phosphorous Cycle.**

**Table 4.6 Phosphorus cycling.**

| |
|---|
| **Phosphorus immobilization/mineralization:** P cycles between inorganic ($H_2PO_4^-$ and $HPO_4^{2-}$ ) forms, which are immobilized in organic forms by soil microorganisms and then mineralized back to inorganic P. |
| **Phosphorus adsorption/desorption:** Inorganic P binds to the surfaces of clays, minerals, or organic matter and then is slowly desorbed into the soil solution, where it becomes available for plant uptake. |
| **Phosphorus precipitation/dissolution:** Inorganic P reacts with calcium ($Ca^{2+}$), iron ($Fe^{3+}$) or aluminum ($Al^{3+}$) to form insoluble compounds that precipitate out of solution. These compounds can slowly dissolve to replenish the dissolved P pool. |

Soils on organic farms and other low-input situations can sometimes be problematically low in P. Rock phosphate is permitted in organic production, but it is not very available to plants – only about 3% available (Hammermeister, 2023). Industrially produced P fertilizers like triple superphosphate (TSP) and monoammonium phosphate (MAP) are not allowed in organic. Although they also originate from mineral phosphate, the mineral source undergoes industrial processes that produce and add phosphoric acid, making the P more than 90% plant-available (water-soluble).

Phosphorus is removed from pasture soils by plant uptake and subsequent intake by grazing livestock or by erosion and runoff. Much of the P that grazing livestock consume will be deposited back in the field as urine and feces, so removals are modest compared to many field crops. Phosphorus additions to the soil can be in the form of mineral fertilizer, livestock manure or biosolids. An indirect P addition is buying feed from off-farm that is added to the fields via manure.

Soluble inorganic P is taken up by plants by diffusion from the soil solution to the plant roots. However, the diffusion of P to the root can be slow. Mycorrhizae are plant root fungi that can translocate P to the plant root. In this way, the root fungi essentially increase the length and surface area of the plant root and thus increases plant-available P. These fungi remain active at a lower pH than bacteria (Weil & Brady, 2017). In low-P situations, mycorrhizal fungi can extract more P from organic matter, making it available to the plants (Schneider et al., 2019).

Phosphorus is lost to the environment primarily through surface runoff and erosion. Excessive losses of P to the environment are of concern due to the potential for the eutrophication of surface water. It is important to always base P applications on a soil test to reduce the occurrence of overapplications of the nutrient. Soil erosion is seldom a concern in well-managed pastures, but there are risks for “hot spots” for dissolved P runoff if livestock congregate in one area for access to water or supplemental feed; this can be managed by moving feeders or water troughs regularly. Trampling of streambanks can also release sediment into surface water along with the P it carries; fencing livestock away from riparian areas will avoid this.

## POTASSIUM

### Why is Potassium (K) Important?

- It is involved in the activation of enzymes that are responsible for many physiological plant processes
- It plays a role in nutrient and sugar transport within the plant
- It is essential for water regulation within the plant
- It is essential for increased winter hardiness of legumes

The forms of K in the soil and the cycling of this nutrient differ substantially from those of N or P. In the soil, K occurs as the soluble cation $K^+$, exchangeable $K^+$ held on the surfaces of clay and soil organic matter particles, and non-exchangeable $K^+$ tied up between the layers of clay minerals. Plants take up soluble $K^+$ from the soil solution in large quantities. As the plant takes up $K^+$, exchangeable $K^+$ is released from clay surfaces to supply more soluble $K^+$. Non-exchangeable $K^+$ is not readily plant available. The weathering of clay minerals makes this non-exchangeable form available to plants over a period of years. Conversely, by the process of fixation, soluble and exchangeable $K^+$ may become unavailable and held as non-exchangeable $K^+$.

Potassium can be lost from the soil by crop uptake and leaching, but leaching losses are generally small. Although not often lost through leaching, K deficiencies can arise from an overabundance of other nutrients, such as Ca. Potassium has an antagonistic relationship with $Ca^{2+}$, $Mg^{2+}$, and $NH_4^+$, and these can often outcompete $K^+$ on soil exchange sites and root hairs.

Potassium has not been shown to be an environmental risk, but there can be consequences for livestock diets. Excessive levels of K in grazed forage can interfere with the cation:anion balance in the rumen, predisposing pregnant livestock to milk fever (hypocalcemia) when they give birth. This is not a problem for growing livestock, but K levels in soils where dry cows or pregnant ewes are grazing should be monitored carefully.

The most common K fertilizer is potassium chloride (KCl) (muriate of potash), much of which is mined from large deposits in western Canada. Other options which may be considered, depending on the need for other nutrients as well as cost and availability, are sulphate of potash-magnesia (11% Mg, 22% K, 23% S) or potassium sulphate ($K_2SO_4$). Livestock manure often contains significant quantities of K, but this should be confirmed with testing.

Deficiency of K may be visible on pasture plants, for example, as white spots on the leaves of alfalfa plants (Kaiser and Rosen, 2018). Figure 4.7 describes the potassium cycle.

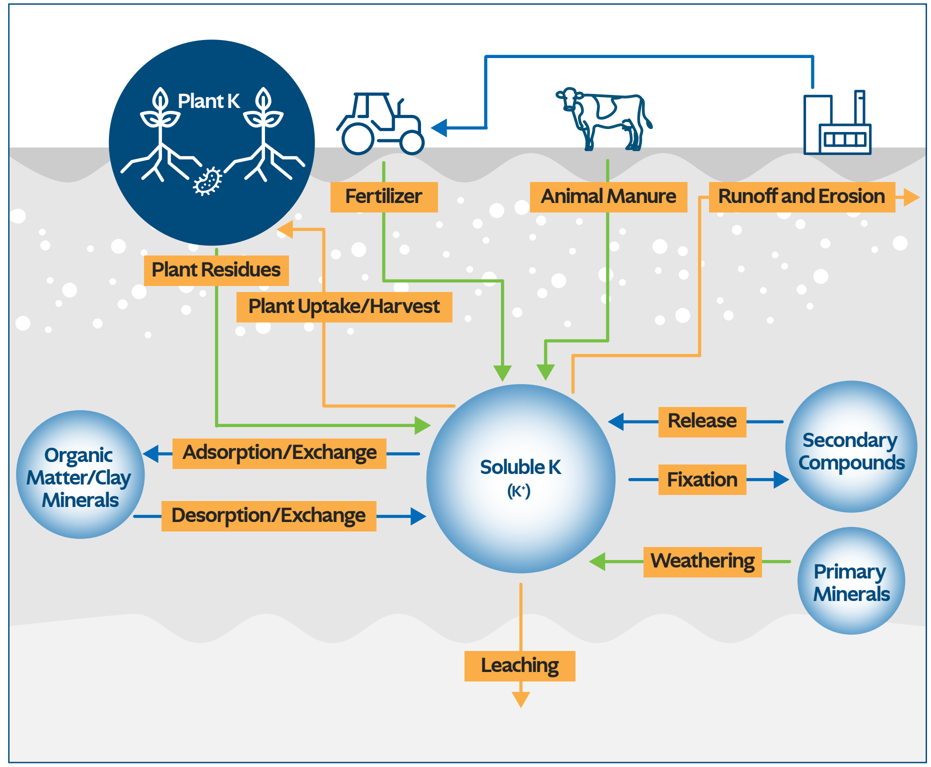



**Figure 4.7 Potassium Cycle.**

## SULPHUR

### Why is sulphur (S) important?

- It is important for N metabolism within the plant and the formation of amino acids and proteins
- An essential part of plant structural components
- A pivotal part of N fixation and the activation of vitamins and enzymes within the plant

Sulphur is a nutrient that plays an essential role in plant metabolic functioning and is often overlooked. It can be considered the fourth most important nutrient behind N, P and K. The S cycle is very similar to the N cycle, and in areas with high annual precipitation and sandy soils, S is readily leached from the soil. Until recently, most of the S required by plants was either deposited from the atmosphere or derived from organic matter. The various versions of the Clean Air Act in the United States and Canada have led to a decrease in the amount of S deposited in precipitation that was previously available to plants. This reduction in atmospheric S is a reason for producers to monitor soil S levels and consider adding S as part of a nutrient management plan. When soils are saturated, bacteria will use the oxygen in sulphate ($SO_4^{2-}$) and produce hydrogen sulphide ($H_2S$) (a gas lost through volatilization).

Sulphur levels in pasture soils are directly linked with N use efficiency, so plants deficient in S will be less efficient at assimilating N into plant tissues. Soils should be able to supply at least one part S for every eight parts of N. Increasing N in the soil without modifying S can lead to symptoms of S deficiencies in pasture plants. Legumes with S deficiencies will have light green leaves and stunted growth. Because they fix their own N, clovers and other legumes may show more consistent responses to S than grasses; lack of S may significantly reduce the winter survival of some legumes.

Non-atmospheric sources of S may include fertilizers such as ammonium sulphate (24% S, 21% N) and Sul-po-mag. Gypsum (calcium sulphate; $CaSO_4$) and wood ash (see calcium section) also contain significant amounts of S. These sulphate forms of S are immediately plant available. Elemental S can also be used as an amendment, but it will be slowly available because the S must be oxidized to sulphate by bacteria before plants can absorb it. The above-mentioned S sources are acceptable for organic production except for the ammonium sulphate, as long as the source and production methods are consistent with Table 4.2 of the Permitted Substances Lists (CGSB, 2020). For example, mined gypsum is acceptable, but $CaSO_4$ produced with sulfuric acid is not allowed.

## CALCIUM

### Why is calcium (Ca) important?

- All plants require Ca to regulate cellular functions, leaf development and protein synthesis
- An important component in the cell wall structure
- Important for animal health

Calcium is the dominant basic cation in most soils, so Ca concentration in the soil is typically related to soil pH. As Ca is removed from the soil by plant uptake or leaching, it is often replaced with $H^+$ ions, and therefore, low Ca is often accompanied by increased acidity. Calcium deficiencies are rare if the soil pH is adequate for crop production. Legumes, including clover, alfalfa, and birdsfoot trefoil, are heavy Ca consumers, which explains their preference for alkaline soils. On average, the level of Ca that is ample for grasses is the lower limit of what is required by legumes.

Not only is Ca essential to plants, but animals also require large amounts of Ca as part of a healthy diet. Calcium is essential for animal health, particularly in the formation of bones and teeth. It is also needed in large amounts by growing, pregnant, and lactating animals.

As Ca is immobile within the plant, it is important to have an adequate supply in the soil so that newly forming leaves will not be limited. Adding dolomitic or calcitic limestone to soils with low pH can provide adequate amounts of Ca. If Ca is required, but there is no need to increase soil pH (e.g., salt-affected soils or soils where pasture is grown in rotation with potatoes or blueberries), gypsum (17% S, 22% Ca) will provide significant amounts of Ca without changing soil pH.

## MAGNESIUM

### Why is magnesium (Mg) important?

- It is important for animal health
- It is the center of the chlorophyll molecule and is essential for photosynthesis
- Essential component in enzyme functions and controls respiration at the cellular level
- Involved in the translocation of starch and the formation of proteins and lipids

Although Mg is rarely the limiting nutrient for plant growth, it is required by plants in roughly the same proportions as P and S. When Mg is limited in the plant, animal health may be affected (see "hypomagnesemia" in the animal health section of this manual). Magnesium, unlike Ca, can be translocated within the plant. Sources of Mg include dolomitic limestone (<5% Mg, <30% Ca), Sul-po-mag (11% Mg, 22% K, 23% S), magnesium sulphate (Epsom salts) (10% Mg, 10% S). Application of Mg to pastures should be made based on soil tests.

## MICRONUTRIENTS

Micronutrients are rarely limiting to pasture growth in Atlantic Canada because of the acidic nature of most soils (availability of Fe, Cu, B, Mn, and Zn are greater in acidic soils) and because the soils are relatively young in geologic terms. Reduced pasture productivity from deficiencies in any of the macronutrients would mask micronutrient deficiencies, so profitable responses to micronutrients would only be expected where the management of all other aspects of pasture production is excellent. There are circumstances, however, where pasture micronutrient requirements should be considered.

Boron (B) is an essential plant nutrient but is only required in small amounts, and legumes have a much higher requirement for B than grasses. Boron may be required for legumes; use a soil test to determine whether B applications are required. Over-fertilizing B is problematic because adequate B levels for some plants can be toxic to others (Perennia, Forage Production Guide, 2021).

Levels of Cl, Fe, Mn, molybdenum (Mo) (Cl and Mo are not on the NS standard soil test report), and Zn are usually adequate, but Cu may sometimes be deficient. Over-fertilizing with Cu can be toxic to livestock, particularly sheep. Regular soil testing to monitor micronutrient levels is recommended as there may be a benefit to micronutrient applications if deficiencies exist.

### What about Wood Ash as an Amendment?

Wood ash is a by-product of power cogeneration from large pulp and paper mills. Wood ash adds Ca, S, and appreciable amounts of other nutrients, including P and K. Research in Nova Scotia vineyard soil has found that wood ash produced by power generation has a $CaCO_3$ equivalence of 22% to 64%, depending on the wood ash source and soil type (Sharifi et al., 2013). Before applying wood ash as a pH conditioning amendment, soil tests may be necessary to determine if K and P levels are sufficient to prevent nutrient loading in pasture soils. Limited research applying wood ash to pastureland in Nova Scotia has found no significant decrease in pasture condition score (MacEachern 2012). However, depending on the wood ash source, the concentration of aluminum and the heavy metals arsenic, cadmium, chromium, and lead can increase in soil and plant tissue within one year following application. Analysis of the wood ash prior to application is important to avoid possible contaminants. Ash is acceptable as a soil amendment in organic production provided that it is from plant or animal sources, not manure, minerals, or plastic that was burned, and that it does not exceed safe levels of arsenic, cadmium, chromium, lead and/or mercury.

## EFFECT OF GRAZING ANIMALS ON NUTRIENT CYCLING

Nutrient cycling in a pasture differs from that in non-grazed cropland due to the influence of grazing animals. In addition to regular nutrient transformations and cycling, nutrients are taken up by the grazing animal in the herbage it consumes and returned in the form of urine and dung. Grazing animals will recycle about 75-85% of the nutrients they consume (Bellows, 2001). Returned nutrients are partitioned differently between urine and dung. Potassium is primarily excreted in the urine, and P, Ca, Mg, Cu, Zn, Fe, and Mn are primarily excreted in the dung. Nitrogen, Na, Cl, and S are excreted in urine and dung (Haynes & Williams, 1993).

**The Magic of Manure:**

Manure is a valuable source of nutrients for pasture. For example, Thomas (2001) has calculated that in 24 hours on pasture, 100 grazing cows can deposit dung and urine equivalent to 20 kg N/ha, 4.5 kg $P_2O_5$/ha, and 16 kg $K_2O$/ha.

**Table 4.7 Estimates daily nutrient returns from a lactating dairy cow, a beef feeder, and a mature sheep (US Department of Agriculture Natural Resources Conservation Centre, 1992).**

| | ANIMALS PER 454 KG ANIMAL UNIT (AU) | TOTAL N (kg/day per AU) | TOTAL $P_20_5$ (kg/day per AU) | Total $K_2O$ (kg/day per AU) |
|---|---|---|---|---|
| Lactating dairy cow (625 kg) | 0.7 | 0.28 | 0.07 | 0.14 |
| Beef feeder (350-500 kg) | 1.1 | 0.14 | 0.11 | 0.13 |
| Mature sheep (60 kg) | 7.5 | 0.20 | 0.07 | 0.18 |

Although a significant source of nutrients, the manure deposited by grazing animals is not distributed evenly throughout the pasture, as grazing animals tend to congregate in particular areas such as water sources, supplemental feed troughs, or in shaded areas. For example, manure deposited from cattle grazing on a 0.44 ha pasture at a stocking density of 5 steers/ha resulted in a zone of nutrient enhancement near a water source (located in one corner of the pasture) and extending 10-20 m into the pasture (West et al., 1989). In another example, Franzluebbers et al. (2000) found nutrient concentrations for a 0.7-0.8 ha pasture to be the greatest within a 30 m radius around the water and shade sources. When nutrients from the grazing areas are transported to the congregation areas, fertility distribution across the pasture becomes uneven.

Recognizing that grazing animals do not evenly distribute nutrients will enable management decisions to better use nutrients returned by the grazing animal. The following management strategies will help ensure a more uniform distribution of nutrients across the pasture:

- Management of intensive grazing, clipping and harrowing, and measures to prevent grazing animals from camping in particular locations will improve the distribution of nutrients within the pasture (Thomas, 2001).
- Locating water, shade, or supplemental feed sources in different pasture areas will reduce the animal congregation that might occur if they are all located in the same area (Bellows, 2001).
- Using a portable water source that can be periodically relocated in a pasture may help to distribute nutrients from dung and urine more evenly (Bellows, 2001). The same thing can be done with portable shade structures, which some local producers are now using.
- Locating a water source in an area known to be low in nutrients may help to offset any deficiencies (Bellows, 2001).
- Subdividing larger pastures may help better distribute nutrients as congregation areas will be distributed among several pastures (Bellows, 2001).
- Leaving longer grass behind when grazing animals are rotated out of the pasture will enable excess nutrients in an area of congregation to be taken up by the vegetation still present (Thomas, 2001) and increase soil organic matter.

### Effect of Urine and Dung Deposits

Dung and urine patches result in increased grass growth in the surrounding area. The high concentration of N in urine favours grass growth, as do the nutrient concentrations of dung. The effect of urine may last several months, while the impact of dung may last as long as two years (Haynes & Williams, 1993). Dung patches generally kill underlying vegetation, resulting in bare soil areas that can allow weeds to creep in (Haynes & Williams, 1993). Urine patches may scorch or burn vegetation (Leahy & Robinson, 2000).

The breakdown of dung is by both physical (rainfall and animal treading) and biological processes; therefore, both the climate and stocking rate will affect the breakdown rate (Haynes & Williams, 1993). Intensive rotational grazing will speed up the physical breakdown of dung by trampling. Harrowing will also enhance the physical breakdown and spread the dung to distribute nutrients more evenly (Leahy & Robinson, 2000).

Rejection of herbage (not eaten by animals) around dung patches can be a problem as the vegetation near the patches is wasted, and the vegetation between patches may be overgrazed. Rejection is less of a problem for sheep than cattle, as sheep dung is deposited as pellets instead of one large patty (Haynes & Williams, 1993). The rejection period depends on the time for the dung to break down (Leahy & Robinson, 2000).

Intensive rotational grazing can minimize rejection and speed up the breakdown of dung. Intensive grazing forces cattle to graze closer to dung patches because of the higher grazing pressure, and the trampling action of their hooves will flatten any un-eaten forage, leaving a uniform exit height. Clipping pastures after grazing will also keep the ungrazed forage from getting over-mature, which would reinforce the avoidance of that area. Note that clipping would have to happen immediately upon removing the animals from the pasture to avoid stressing the regrowing plants. Grazing animals do not usually reject the herbage near urine patches; sheep prefer to graze in these areas (Leahy & Robinson, 2000).

## NUTRIENT MANAGEMENT PLANNING

Nutrient management planning evolved from intensive livestock and crop production areas where N leaching into groundwater systems and surface movement of P and pathogens into watercourses had significant environmental impacts. Nutrient management planning involves matching nutrient requirements to realistic crop production yield targets and understanding the nutrients available from fertilizer, manure, and soil. Effective nutrient management planning optimizes nutrient use for optimal crop production while minimizing the potential for environmental impact (Burton & Fairchild, 2003).

Developing a nutrient management plan requires knowledge of the nutrient status of the soil, the crop to be grown, and the source of the nutrients supplied (e.g., manure or chemical fertilizer). With this information, decisions can be made about which fields would benefit from additional nutrients, the amount required, and the type of nutrients to supply.

## NUTRIENT LOSSES

Often, the only nutrients a pasture receives come directly from the grazing animals; in these fields, soil fertility levels will gradually decline unless the livestock gets supplemental feed. As a rule, it is more expensive to fertilize the soil through purchased feed than purchased fertilizer; feed-grade ingredients are more expensive than fertilizer-grade, only a portion of what is fed is excreted in the manure, and losses during storage and application mean that the cost of nutrients from manure can be double or more what could be purchased as fertilizer. Some farmers prefer to buy hay as a supplemental feed, for example, rather than making it themselves, and while the fertility from this source should be considered, it is unlikely to be the economic driver. The risk of nutrient losses to the environment from fields not receiving fertilizer will come primarily from uneven distribution of urine and feces. If the pasture is receiving fertilizer or manure, the rate and timing of nutrient additions will influence nutrient losses. Ensuring proper timing, application rate, spreader calibration, and application technique will help reduce nutrient loss.

Permanent pastures reduce nutrient loss. With a permanent sod cover, plants have more opportunity for nutrient uptake and less potential for loss by erosion. Permanent sod cover allows for a long-term buildup of root mass in the soil, which helps stabilize the soil making it less prone to erosion. In addition, it can help build soil organic matter and increase nutrient retention.

Nutrient losses generally occur from urine and dung patches, where nutrient levels in the soil tend to be the highest. When these levels exceed plant demand, nutrient loss becomes a risk. Nutrient loss is likely even greater in animal congregating areas, as soil nutrient levels can become even more elevated. Nitrogen is the most likely nutrient to be lost from urine and dung patches. Nitrate levels beneath dung patches can become elevated and potentially lost to the groundwater (leaching) or the atmosphere (denitrification). Ammonium ($NH_4^+$) levels can also build up beneath urine patches and become a source of gaseous losses by ammonia volatilization. Or, if the ammonium is converted to $NO_3^-$, it may also be lost to the groundwater or the atmosphere.

Phosphorus is less mobile and less likely than N to be lost from dung and urine patches. However, if P levels in the soil become high, there is the potential for P loss by runoff and erosion. Soil P may build up if manure is regularly applied to the same fields year after year. Soil testing and using manure on fields known to have low soil P levels will help reduce P loss.

Potassium is taken up by the plant and held in soluble form in plant sap and cell contents. It is returned to the soil through urine, where it bonds to clay and organic matter. Potassium has not been identified as an environmental risk.

Maintaining a balance between nutrient inputs (manure, fertilizer, supplemental feed) and removals (harvested hay, consumed feed, animals removed) will help maintain adequate fertility for productive pasture growth and reduce nutrient loss resulting from excessive nutrient input. Taking measures to reduce animal congregation behaviour and, thus, areas of concentrated nutrients may reduce the potential for nutrient loss. Maintaining an actively growing sod will encourage nutrient uptake and reduce erosion.

## SOIL TESTING

Soil testing is critical to managing soil fertility and is also important in assessing soil health and determining the crop production potential for a field. Soil testing provides information on soil nutrient levels as well as other soil characteristics such as soil organic matter, pH, cation exchange capacity and base saturation (the percent CEC occupied by basic cations $Ca^{2+}$, $Mg^{2+}$, $K^{+}$, and $Na^{+}$). It should be noted that soil tests in Nova Scotia do not provide information about soil N levels. Historically, P in mineral fertilizer has been reported as $P_2O_5$, and K has been reported as $K_2O$; therefore, soil tests in Nova Scotia report soil nutrient levels in kg/ha of $P_2O_5$ and $K_2O$.

A soil test also provides recommendations for nutrient and lime applications. Nutrient and lime applications should **always** be made based on a soil test. Although soil testing in Nova Scotia does not currently measure soil N, a soil test report provides N application recommendations based on the general N requirements for pastures. Nutrient management decisions can be made using the soil test information and the pasture's legume content.

Soil tests extract a portion of nutrients from the soil that correlates with the amount of that nutrient a plant can take up. It is not the amount of fertilizer in the soil, even if it is expressed in those units.

To monitor soil fertility, soil testing should be done at least every three years. Most plant roots in a pasture are in the top 10-15 cm of the soil. Therefore, pasture soil samples should be taken to a depth of 15 cm to collect a representative sample. A composite sample of several individual cores or sub-samples taken from the field is the best way to provide a representative soil sample for soil testing. Table 4.8 summarizes information from Perennia about soil sampling. More information about taking a field soil sample can be obtained from Perennia's extension website: [https://www.perennia.ca/portfolio-items/soil/?portfolioCats=135](https://www.perennia.ca/portfolio-items/soil/?portfolioCats=135).

Table 4.8 Soil sampling method for pastures.

| SOIL SAMPLING FOR PASTURES | |
|---|---|
| **Necessary Equipment** | • Soil probe, shovel, or auger<br>• Bucket (plastic or non-galvanized metal)<br>• Boxes from the soil test lab (or Ziploc bags)<br>• Waterproof marker for labelling box or bag<br>• Map or sketch of the pastures identifying each sampled location |
| **Number of Samples** | • Take one composite sample per pasture. Large fields (>25 acres or 10 hectares) should be subdivided into smaller areas.<br>• Take about 20 individual cores for each composite sample, no matter how small the sampling area is.<br>• Mix the soil from individual cores thoroughly to make a composite sample to be sent to the lab for analysis.<br>• The composite sample sent to the lab should be about 500 grams (2 cups) of soil. |
| **Sampling Location** | • Samples should NOT be taken near roads, fence rows, or highly eroded areas.<br>• Do not sample in obvious dung deposits.<br>• Soil from high-yielding and low-yielding areas should not be combined in the composite sample.<br>• Areas of non-uniform slope, colour, texture, drainage, and cropping practice should be sampled separately. |
| **Sampling Depth** | • 10-15 cm for pastures |
| **Sampling Time** | • Ideally, after harvest. However, samples may be obtained at any time of the year.<br>• Fall sampling will allow results to be returned in time to plan for the upcoming season.<br>• Early fall sampling will allow results to be returned in time for fall lime application.<br>• Results from spring sampling may not be returned in time to make decisions regarding fertilizer and/or lime application for that year.<br>• Sampling at the same time each year is best. |
| **Sampling Frequency** | • Every three years for a general indication of fertility.<br>• Sample more frequently to monitor soil improvement, especially if trying to produce high-quality herbage. |

## Soil tests may be obtained through Laboratory Services of the Nova Scotia Department of Agriculture:

Nova Scotia Department of Agriculture Quality Evaluation Division, Laboratory Services 176 College Road (Harlow Institute) https://novascotia.ca/agri/programs-and-services/lab-services/analytical-lab/

## SUPPLYING NUTRIENTS TO THE PASTURE

Effective fertility management for a pasture should always begin with a soil test. Once nutrient requirements are known, nutrients may be added through manure, chemical fertilizer applications, or seeding a legume to supply N. Lime is a soil amendment that should be considered if soils are acidic, as pastures are less productive under acidic conditions.

## NUTRIENT RECOMMENDATIONS

### Macronutrient Recommendations

Pastures in Nova Scotia are predominantly grass pastures, whether seeded or native grasses. While these pastures may still have legume content, they are often at least 70% grass. The legume content of a pasture can help determine the nutrient levels required due to the N-supplying capacity of legumes and the differing soil P and K requirements of legumes and grasses. It is important to try and estimate the legume content of a pasture. This can be difficult, and experience suggests that most individuals overestimate the legume content, especially when it comes to white clover content.

Fertility recommendations are based on soil test reports; testing your soil is important and will help improve your soil fertility and potentially save money on fertilizer. Table 4.9 outlines the nutrient recommendations at different soil test ratings. Nitrogen recommendations do not change because the labs do not measure N in soil because the N cycle is variable and difficult to measure. General recommendations for N application to grass or mixed pastures in Nova Scotia is 100-150 kg N/ha, while a legume-based pasture will only require 0-20 kg N/ha. Table 4.9 is an average of the recommendations for NB, NS and PEI, so the exact recommendation on a lab report may vary from this, but it will be in the same range.

**Table 4.9 P and K recommendations for grass and mixed pastures in Atlantic Canada.**

| MEHLICH-3 SOIL TEST P | | RECOMMENDED P | MEHLICH-3 SOIL TEST K | | RECOMMENDED K |
|---|---|---|---|---|---|
| ppm P | kg $P_2O_5$/ha | kg $P_2O_5$/ha | ppm K | kg $K_2O$/ha | kg $K_2O$/ha |
| 0-5 | 0-23 | 100 | 0-20 | 0-44 | 150 |
| 6-15 | 24-69 | 80 | 21-40 | 45-88 | 110 |
| 16-30 | 70-138 | 50 | 41-60 | 89-144 | 75 |
| 31-50 | 139-229 | 25 | 61-90 | 145-216 | 40 |
| >50 | >229 | 0 | >90 | >216 | 0 |

***For legume pastures, add 20 kg P2O5/ha and 50 kg K2O/ha to the recommendations in this table. Recommendations are in kg/ha.**

The soil test gives recommendations in kg N/ha, kg $P_2O_5$/ha, and kg $K_2O$/ha. This is for ease of use for determining fertilizer amounts, and application rates will depend on the type of fertilizer used. For example, applying 60 kg/ha of N using urea (46-0-0) will require an application rate of approximately 130 kg/ha of urea.

**Estimating Legumes in Pasture:**

One way to estimate legume content that works better than simple observation is by using a quadrat and random sampling, like what was described for measuring pasture yield in Chapter 2. Use a quadrat (a square or circle that's open in the middle and can be thrown on the ground) and walk a pre-determined pattern in the pasture. Aim to estimate the legume content 10+ times on the track, stopping each time a pre-determined number of paces is reached, tossing the quadrat down to a random place and looking down at it from above. It is much easier to see the proportion of legume in a small quadrat than estimating it in the full pasture. Note the visual percent legume (how much space is taken up by legume in the square) at each stop and then take the average. The quadrat average can be compared to the estimate made by walking around the pasture without a quadrat to test for accuracy.

## Fertilizer Application Timing

Recommendations for N application:

- The soil test report in NS does not recommend split applications; however, it is recommended to split apply nitrogen for better fertilizer use efficiency. Application of N should be applied in early spring to encourage growth (50 kg N/ha), after the first cut or graze (mid-June, 50 kg N/ha), and the balance after the second cut or graze if there are good conditions for pasture growth. Nitrogen applications should coincide with the times in which the plants will be taking up the most N to avoid N losses.
- Nitrogen credits can be applied from different management practices to reduce fertilizer application. Manure application can provide some N credits, and increasing the legume content in your soil provides N credits. Considerations for nutrient application of P and K.
- Both P and K are required during seed emergence; therefore, application is recommended during spring. Additional applications for K during the season to help restock removal from harvest and grazing may be necessary, especially if initial K levels are low in the soil test. There may also be certain instances where additional P applications are required; consult with an agrologist for this.
- Potassium can build up in soil and can be released slowly over time. The ability of K to be released from this reserve and made plant available depends largely on soil type. Soils with higher clay or organic matter content have a higher capacity to hold K. Soil with low clay content has less ability to hold and release K and soil test levels can decline more quickly (Commision chimie et fertilite des sols, 2010). Quebec has adjusted K values for pasture application based on soil texture; however, this has not been done in the Maritimes. Most maritime soil is coarse-textured, and therefore, a single recommendation can be used (Heung et al., 2021).
- Phosphorous binds with aluminum in soils, especially in low pH soils, making P unavailable for plant uptake. Therefore, the amount of aluminum in the soil can determine the availability of P. Soils with greater amounts of Al may require higher applications of P for P to be plant available. The Maritimes often have higher amounts of Al, and therefore high amounts of P can be bound and not be plant available. Increasing pH in soils by liming helps to reduce the amount of Al available to bind with P.

**Table 4.10 Sample fertilizer programs. These suggested applications are for two fields with a soil test P of 20 ppm (92 kg $P_2O_5$/ha) and soil test K of 70 ppm (168 kg $K_2O$/ha). One field is dominated by grass, while the second field has 35% legume content.**

| | GRASS PASTURE | LEGUME PASTURE |
|---|---|---|
| **Total Nutrient Requirements** | 150-50-40 | 20-70-90 |
| **Early spring application** | 109 kg/ha urea (46-0-0) | 100 kg/ha 19-19-19 blend |
| **Mid-June application** | 263 kg/ha 19-19-19 blend | 226 kg 0-22-31 blend (formulated with 490 kg 0-46-0 plus 510 kg 0-0-62) |
| **Mid-August application** | 109 kg/ha urea (46-0-0) (only if there is good potential for late summer growth of the pasture) | Not required |

**Note: replacing urea with ESN or adding a urease inhibitor will reduce gaseous losses and improve N utilization by the pasture.**

## MANURE

Manure is a source of nutrients for pastures, supplying N, P, K, several micronutrients, and organic matter. The nutrient content of manure is both organic and inorganic and can be highly variable depending on the source and type. If manure is used as a nutrient source, care must be taken to ensure excessive nutrients are not applied to the soil. Excessive P loading in the soil may be a problem if manure is continually applied to the same field year after year.

Manure N occurs as plant-available $NH_4^+$ and organic N, which slowly becomes available through mineralization. The ammonium N may be lost to the atmosphere during storage, through handling practices, or at the time of spreading. The amount of manure N available to the growing crop is the amount of $NH_4^+$ that is not lost to the atmosphere and the organic N that is mineralized. The P in manure is considered to be 40% available in the year of application but will all contribute to a build-up of soil P over time. The K content of manure is readily available, with 90% available in the year of application (Burton and Fairchild, 2003).

Manure testing provides information about the nutrient content of manure, and this information helps determine where and at what rate manure should be applied. In combination with soil testing, manure testing will help make effective use of nutrients available in manure. Like soil testing, manure should be tested approximately every three years or when a major change is made to the feed ration.

When collecting a manure sample, follow the Manure Application Guidelines from the Nova Scotia Department of Agriculture (2006), the How to Take a Manure Sample factsheet (**https://novascotia.ca/agri/documents/lab-services/analytical-lab-howto-manure.pdf**) or information from the Perennia website, like the factsheet on Taking a Compost and a Solid Manure Sample and Liquid Manure Sampling (**https://ofcaf.perennia.ca/wp-content/uploads/sites/19/2023/10/Liquid-Manure-Sampling-Factsheet-FINAL-Updated.pdf**):

- A manure sample should be a composite of several individual samples.
- Agitate liquid manure in storage before collecting a sample.
- Do not collect samples from the surface of a solid manure pile, as the sample will not be representative of the rest of the manure.

If the manure has yet to be tested, nutrient approximations may be made based on the information in Table 4.11.

**Table 4.11 Nutrient content of stored manures (Burton & Fairchild, 2003).**

| ANIMAL | MANURE TYPE | DRY MATTER % | TOTAL N | AMMONIUM-N KG/TONNE (as applied) | $P_2O_5$ | $K_2O$ |
|---|---|---|---|---|---|---|
| Beef | Semi-solid | 13 | 2.7 | 0.8 | 2.3 | 5.3 |
| | Solid | 21 | 4.3 | 1.0 | 1.6 | 4.6 |
| | Average | 17 | 3.5 | 0.9 | 1.6 | -- |
| Dairy | Liquid | 9 | 3.1 | 1.5 | 3.0 | 5.8 |
| | Semi-solid | 16 | 4.4 | 1.9 | 2.3 | 4.7 |
| | Solid | 22 | 5.0 | 1.5 | 5.5 | 3.1 |
| | Average | 15 | 4 | 1.6 | -- | -- |
| Sheep | Solid | 50 | 7 | 2.9 | 4.6 | 12 |
| Poultry | Semi-solid | 17 | 7.7 | 4.2 | 19.2 | 11.5 |
| | Solid | 32 | 15.2 | 6.6 | 31.1 | 8.4 |
| | Litter pack | 71 | 33.9 | 8.4 | 57.5 | 19.2 |
| | Average | 51 | 25 | 6.4 | 43.5 | 14.4 |
| Swine | Liquid | 5 | 2.5 | 1.7 | 1.8 | 1.1 |
| | Semi-solid | 15 | 5.3 | 2.4 | 5.0 | 2.2 |
| | Solid | 24 | 7.6 | 3.0 | 4.8 | 5.4 |
| | Average | 15 | 5.1 | 2.4 | 3.9 | 2.9 |

The effectiveness of manure as a nutrient supply for pastures depends on when it is applied, the rate of application, and the uniformity of the application (Leahy & Robinson, 2000). Manure application in early spring is optimal because of the plant's demand for nutrients at this time. However, this is often not practical as grazing animals tend to reject herbage, where manure has been spread during the grazing season. Therefore, it is often more advantageous to spread manure in the fall. In addition, fall application of manure on upland grasslands in NS was found to be preferential, showing that semi-solid manure applied in the late summer and fall results in greater N uptake (Rodd et al., 2021).

The following guidelines should be followed when applying manure:

- Avoid applying manure between October 1 and April 1 due to the high potential for nutrient loss through surface runoff and erosion.
- Avoid spreading manure on frozen or snow-covered ground, as nutrient losses can easily result through surface runoff.
- Avoid spreading manure on very wet soils.
- Avoid spreading manure on areas of exposed bedrock.
- Only apply manure on land with less than a 10% slope. There is a high chance of nutrient loss through surface runoff when manure is spread on steep slopes.
- Ideally, manure is incorporated after application; however, this is not possible when applied to unbroken pasture sod. For liquid manure, injection or the use of toolbars on the back of spreaders can reduce losses.
- Calibrate manure spreaders to improve the accuracy of nutrient application.
- Spread manure as evenly as possible.
- Manure should not be spread within 30 m of a drilled or dug well on clay loam soil or within 60 m on sand or gravel soil.
- Manure should not be spread within 3 m of a ditch.
- Manure should not be spread within 5 m of any water bodies.

## LIME

There are two forms of soil acidity: active and reserve acidity, shown as pH and buffer pH on the NS soil test report. Active acidity is the measure of $H^+$ ions in the soil solution, and Reserve acidity is the measure of $H^+$ ions bound by clay surfaces and/or soil organic matter. Both active and reserve acidity factor into how much lime will be needed to neutralize the soil (Advisory Committee on Soil Fertility). When the pH of the soil is too low, it can be raised with the addition of lime. Soil with high clay and/or organic matter will require more lime than sandy soil because of the higher reserve acidity of the soil (Advisory Committee on Soil Fertility).

### About Lime

Liming materials vary in their ability to neutralize acidity, depending on the chemical composition, neutralizing value, and fineness of grind; this is often called the effective calcium carbonate equivalents (ECCE). Pure calcium carbonate ($CaCO_3$) has a neutralizing value of 100; agricultural limestone will have a lower neutralizing value due to impurities or coarse fragments. The fineness of the grind determines how fast the lime will act in the soil. Limestone with a finer grind has more surface area in contact with the soil and will act faster (Advisory Committee on Soil Fertility).

Agricultural limestone is typically calcitic (calcium carbonate; $CaCO_3$) or dolomitic (calcium magnesium carbonate; $CaMgCO_3$) limestone. Calcitic lime adds Ca and increases soil pH; dolomitic lime adds Ca and Mg and increases soil pH. When the Mg content of the soil is low relative to the Ca content, dolomitic limestone should be used (Advisory Committee on Soil Fertility).

### Applying Lime

Always apply lime based on a soil test. In Nova Scotia, provincial soil tests indicate the amount of lime recommended to raise the soil pH to 6.0 or 6.5, depending on the crop. Lime is slow-acting; therefore, the timing of the application is important. Lime can be applied at any time of year, but it is often recommended to be applied in the fall before the growing season. Lime applied in the spring will still have some benefits. Lime will most likely be surface applied to an unbroken sod in pasture production. In this case, more frequent light applications of lime are better than one heavy application. Higher amounts of lime may be incorporated at ploughing and re-seeding.

When applying lime, follow these guidelines from the Advisory Committee on Soil Fertility:

1. Always apply lime based on a soil test
2. Do not apply more than 4 tonnes per ha (t/ha) (1.5 t/acre) of lime per year to unbroken sod
3. Lime applications equivalent to 0.5 t/ha per year are required to maintain a desired pH
4. Use dolomitic limestone if the Mg content of the soil is low
5. Applications should be spread over several years if there is a high lime requirement
6. If ploughing a field where the lime requirement is more than 6 t/ha, plough down half and incorporate the rest into the surface soil

## SUMMARY POINTS

- Soil test at least every three years to monitor the fertility of the soil.
- Base all nutrient applications (fertilizer, manure, lime) on soil test information.
- To reduce potential nutrient loss, apply recommended rates of nutrients.
- Employ best management practices for manure application to reduce N losses to the environment.
- Calibrate fertilizer and manure-spreading equipment to make applications more accurate.
- Time nutrient applications with plant demand to encourage plant uptake rather than loss to the environment.
- Maintain an actively growing pasture sod to help reduce nutrient losses to the environment.
- Although manure is a valuable nutrient source for pastures, grazing animals do not evenly deposit nutrients across a pasture; recognizing this enables management decisions to make the best use of nutrients returned by the grazing animal.
- Nitrogen is often the most limiting nutrient in pastures.
- Split applications of N will improve N use efficiency and will reduce the occurrence of excess N in the soil, which may be lost to the environment.
- Grasses require more N than legumes. As the legume content of a pasture increases, the need for applied N decreases.
- If the legume content of the pasture is 30% or more, it is not necessary to apply additional N. Applied N will suppress N fixation by the legumes.
- Legumes require more soil P, Ca, and K than grasses; therefore, adequate K and P are important for maintaining legume content.
- Manage the pH of the soil to promote P availability; P is most available to plants between pH 6.0 and 7.0.
- Fertilizer use efficiency is pH-dependent, declining rapidly as the soil pH drops below 6.0.
- The addition of lime can help increase your pH and nutrient use efficiency; the choice of liming materials and the amount applied should be based on a soil test report.

# CHAPTER 5
## Pasture Renovation and Establishment

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Productive pastures do not just happen, they are created by careful management. Grazing management can go a long way to maximizing the returns from the forage that is there, but there are times when more intervention is needed. Introducing more productive grasses or legumes, or adjusting soil fertility or pH, can revive "run out" pastures and increase the profitability of the grazing operation. This may be done by adding to the existing sward (renovation) or terminating the existing pasture and starting fresh (re-establishment). Additionally, producers may need additional pasture, whether they are just starting production or need to expand, which may require establishing fields on land not previously in pasture.

## PASTURE RENOVATION

Taylor and Barczewski (1998) define pasture renovation as a series of actions that lead to a permanent or long-term change in the botanical composition of a pasture. The changes are designed to improve the species composition or to increase the population of a selected species in the pasture, which leads to an overall improvement in pasture quality and yield (Lawson, 2004). The key to a successful renovation is to plan all aspects well before the planting date.

The following questions should be asked when planning a renovation (adapted from Undersander et al., 2002):

1. What is the current condition and species composition of the existing pasture?
2. What are the current soil pH and fertility levels, especially P and K?
3. Does the pasture have weed issues that need to be controlled?
4. When will weed control happen?
5. Are tillage and/or herbicides acceptable options?
6. How long can the pasture be out of service?
7. How much money and effort should be spent?
8. What type of equipment is accessible?
9. What renovation technique will give me the best results?
10. When should renovation occur?
11. What is the maximum acceptable waiting period for a good establishment?
12. Which legume or grass species and which cultivars are best for the growing conditions and production goals?

## ASSESSING CURRENT CONDITIONS

Is renovation the answer to improved pasture productivity? Depleted pastures are often the result of improper grazing management, poor soil fertility or poor drainage. If forage species are introduced without addressing the other underlying issues, then the success of renovation will be short-lived and limited. Renovation should be part of a long-term solution that includes improving grazing management and soil fertility.

Good soil fertility is the foundation of successful pasture renovation. Soil testing early in the planning process is important as the results will show the current status of the pastures sampled. This will include information like the pH of the soil, nutrient levels of a range of important macro- and micro-nutrients, recommended rates to apply for some nutrients to meet production goals and liming requirements to correct soil acidity. Each of these factors is important as they can affect any attempt at improving the pasture.

To improve forage establishment, growth and the maintenance of a desirable pasture stand, a pH range of 5.8 to 6.5 is considered most beneficial. Careful consideration should be given to the choice of legume used in soils with a pH of less than 6.0, as acidic soils can impact N fixation in some species. Lower N fixation can limit the growth of the sward and may require supplemental N applications to improve forage growth and yields. Pastures with pH less than 6.0 may be more suitable to grasses and acid-tolerant legumes like red and alsike clover or birdsfoot trefoil. Some species typically not tolerant of acidic soils may have cultivars with improved tolerance.

If an application of lime is needed and re-establishment of the pasture is necessary, then lime should be incorporated before seeding during seedbed preparation. However, when looking to rejuvenate established pastures or in no-till systems, surface applications of lime need to be applied. Surface applications are slower acting and will need to be applied one year to six months in advance, or if large amounts of lime are required, annual applications may need to be made for several years. A surface application of lime is unlikely to be effective in strongly acidic soils as the pH adjustment will be confined to a shallow layer at the surface.

Adequate soil P is required for good seedling establishment and root development. This is especially important when overseeding or in no-till seeding. Additionally, adequate K levels are important in maintaining strong root systems and healthy, winter-hardy plants.

The grass/legume balance can be significantly affected by P and K fertilization. Low N rates and high P and K rates can increase the proportion of legumes (either volunteer or seeded legume species) in the existing sward. With this in mind, it is very important that mixed grass/legume pastures receive sufficient lime, P and K fertilizer to establish and maintain the sward's legume component.

See Chapter 4, *Nutrient Management and Pasture Fertility*, for specific information on pasture fertility requirements.

## TYPES OF RENOVATION

Pasture renovation can be classified into two groups:

1. Rejuvenation by adding new seed to a pasture through overseeding practices while maintaining the existing sward
2. Stand termination and re-establishment

Overseeding methods use little or no tillage and include frost seeding, seeding with a no-till drill and livestock seeding. Stand termination and re-establishment can rely on tillage as well as no-till methods.

Producers should weigh the pros and cons of each method discussed below. The method chosen will depend on financial means, equipment availability, production and environmental goals, acceptable time frames and acceptable risk.

Rejuvenation methods can be completed in a short time frame but may require multiple attempts over multiple years as success may be incremental. Each seeding attempt may be less costly whether in labour, equipment costs or fuel burned and will be more environmentally friendly as minimum tillage or no-till methods will keep the currently sequestered carbon in the ground and not release it into the atmosphere, can minimize the impact on earthworms and reduce erosion by maintaining the permanent sod. Termination and re-establishment are generally more successful than rejuvenation methods but are expensive, equipment intensive, environmentally damaging, and there is a loss of pasture productivity in the short term.

### Rejuvenation

The first method of pasture renovation is improvement through rejuvenation: seeding new species into the existing stand. Most commonly, legumes are introduced this way into declining pasture swards, but the techniques can also be used for grasses. This is known as overseeding or sod-seeding. Successful pasture renovation by overseeding depends on reducing the competition from the existing vegetation while the new seedlings are established. Few pastures are so "run out" that there won't be a flush of spring growth. This clashes with the optimum time for seedling germination, leading to competition for light and space. Managing the competition from existing plants can be accomplished by suppressing the existing pasture stand through herbicide applications, mowing, or grazing. Some methods of overseeding include frost seeding, no-till seeding and livestock seeding and will be discussed further below.

**Herbicides can either be non-selective or selective. Non-selective herbicides target a broad range of weeds from both the grasses (monocot) and broadleaf weeds (dicot) families. Some selective herbicides target either grasses or broadleaf weeds while having minimal impact on the other family.**

**Non-selective herbicides can be useful when all plants within an area must be terminated while selective herbicides can be useful to clean up broadleaf weeds before rejuvenation. Both types of herbicides can be used for spot spraying depending on the type of weed, the weed's growth stage or size, the number of weeds, area covered by weeds and density of weeds.**

Planning is needed since the first step is to manage existing growth either by mowing, grazing or applying an herbicide spray to the paddocks to be renovated. This can occur in the fall or spring of seeding. A wider window to manage the existing biomass may be available in the fall compared to the spring but will depend on weather and soil saturation. In preparation for rejuvenation efforts in the spring, producers should target an average sward height of 5-10 cm going into winter or should target this height in spring prior to seeding. This will improve the chances of seed to soil contact and reduce competition from the established sward. Research in Eastern Canada shows that suppressing the sod at the time of seeding can be successful (Seguin et al., 2001; Kunelius & Campbell, 1984). In a study completed in Quebec it was found that at one of the sites selected, mowing or grazing to 5 cm not 10 cm prior to seeding was sufficient to improve clover populations comparable to that seen with herbicide suppression while the second site in the study only saw improvements in clover population when fall management was also used along with mowing or overgrazing of the established sward to 5 cm prior to seeding (Seguin et al., 2001). More recent research has used mowing or grazing of an established paddock in the fall to an average height of approximately 5-7 cm before frost seeding in the upcoming spring (K. Glover, 2024). Two to three weeks after seeding it may be necessary to mow or graze the paddock to reduce competition from the established plants and allow light to reach the seedling forages. After this, the recommended rest, entrance and exit heights should be followed for the species present.

Supressing the established sward through the use of contact herbicides is an option. Contact herbicides with no residual effects can be used two weeks prior to seeding (Seguin et al., 2001) until the time of seeding (Kunelius, H.T., and A. J. Campbell, 1984). Herbicide sod suppression has been shown to be an effective method when sod-seeding legumes into an existing stand, often providing the greatest number of legumes established compared to other methods. However, chemical sod suppression does have trade offs including providing opportunities for weeds to establish and lower yield in the year of seeding (Seguin et al., 2001). Chemically suppressed paddocks should not be mowed for at least 30 days. Follow the label regarding post application wait periods on when the paddock can be grazed or the mowed forage can be used as feed.

Success with rejuvenating an existing pasture comes in many forms and can depend on a number of factors including time of seeding, weather, soil moisture availability, competition from the already established sward or weeds, and species chosen for the renovation. Many Some desirable species, like birdsfoot trefoil, can be difficult to establish, and others, like red clover, establish well but are short-lived. weeds may be managed through regular grazing practices however others, like biennial weeds (i.e., burdock or thistles) that become an issue during the early stages of establishment of the new forages can be clipped to remove the stalk at the onset of flowering which will be highly beneficial to reduce weed competition and future weed problems. Some of the desirable species chosen for rejuvenating pastures, like birdsfoot trefoil, can be difficult to establish and may have fewer newly established plants but are expected to be long-lived while others, like red clover, may establish more easily, have higher initial new plant counts but are short-lived.

**Figure 5.1 Forage Seeds. From wrist to fingers: Red Clover, Timothy and Orchardgrass seed.**

In order to maintain a good pasture composition it is necessary to regularly overseed the pasture every few years. Another strategy that some producers use is to intentionally let their pastures go to seed to establish a seed bank of desirable plants (Duynisveld, 2023). This technique can be used in the years following a renovation to encourage the continued presence of newly seeded species. There will be a trade off in pasture quality, but it is an example of a different pasture management goal that may make sense in certain situations. Producers working with multiple pastures and paddocks should rotate which pieces will be allowed to naturally re-seed to balance production needs with rejuvenation efforts. For continuously grazed pastures, animals can be kept out of sections using temporary fencing.

## REJUVENATION METHODS

### Frost seeding

Frost seeding is generally most successful with aggressive species such as red clover, white clover and tall fescue, or with species with an extended germination period like birdsfoot trefoil and consists of broadcasting the seed onto the existing sward. This should be done in late winter/early spring in the early morning when frost is still in the ground. The daily thawing and nightly freezing action will open small cracks in the soil into which the seed will fall. Moist springs and several frosty nights will be most favourable for success. Broadcasting of seed can be done with a variety of tools, whether by hand, a broadcast spreader mounted to an ATV or other vehicle or tractor, or there has been recent interest in the use of drones.

### No-till seeding

No-till drills are best used when little disturbance of the soil and existing sward is desired. The drill inserts the seed into a small slice that the drill has made, increasing the seed-to-soil contact and improving the chance of seedling grass and legume establishment. The establishment of new seedlings into live swards can be improved by managing the pasture for the new seedlings. This can be achieved by mowing or grazing after seeding to reduce competition and shading by taller plants. Tests have shown good success using a no-till drill for red and white clover, as well as grasses like annual ryegrass, orchardgrass, meadow fescue and Kentucky bluegrass.

**Figure 5.2 No-till seeding into an established pasture.**

### Livestock seeding

In livestock seeding, untreated seed is fed to livestock by mixing it into free-choice mineral or a grain ration. Only the hard seed will pass through the animal's digestive tract and will come through in 24-72 hours, so some planning is required in order to renovate the correct pasture. Using livestock to seed legumes into a pasture is a slow process, often taking several years to see a benefit. However, this method may be the only choice for land not accessible by equipment. Untreated seed is fed to livestock by mixing it into free-choice mineral or a grain ration. Only the hard seed will pass through the animal's digestive tract and will come through in 24-72 hours, so some planning is required in order to renovate the correct pasture. A study in Ontario found that of the hard seed that is passed through the digestive system, about 10% will germinate (Winch, 1960). Also, the distribution of the seed will not be consistent, especially in more extensively grazed systems. The seeds that do germinate, however, will benefit from being in an area of enhanced soil fertility and where competition from the native vegetation is suppressed.

### Rejuvenation timing

The ideal time to seed is early spring (late March to mid-May) as there is more likely to be adequate soil moisture, and the seedlings have the full summer to establish before the next winter. Late summer (mid-August to early September) seeding can also be done, but results are less predictable since moisture levels can vary and winter survival of fall established seedlings can be poor. Grasses (timothy and bromegrass in particular) are more likely than legumes to establish successfully with late summer seeding. The upside of seeding in late summer is soil temperatures are higher, so seed will germinate more quickly if there is adequate moisture.

## STAND TERMINATION AND RE-ESTABLISHMENT

This second method of renovation involves the termination of the existing sward with the intention of seeding a new stand and usually involves primary tillage. Stand termination and re-establishment is a costly method for renovating a pasture and should only be done if other methods cannot meet the required levels of fertility and/or productivity. It is recommended in situations where substantial amounts of amendments (i.e. manure, fertilizer or lime) need to be incorporated to correct fertility or pH issues that limit pasture productivity. For example, if P, K, soil organic matter or pH are in the "Low" to "Low to L minus" range, according to a soil test, then it is recommended to have corrective soil amendments incorporated into the soil, making tillage the preferred method. Stand termination and re-establishment may be the only viable option if the pasture has been overrun by perennial weeds and there is a need to grow a completely different crop that provides flexibility in weed control options before reseeding the pasture.

When choosing to do a complete renovation of a pasture, it may be advantageous to seed in a **break crop**. A break crop is an annual crop such as annual ryegrass, a brassica (turnip or kale) or an annual grazing mixture that "breaks" disease cycles while also adding organic matter, reducing weed populations, and allowing for the incorporation of nutrients or lime, if large quantities are needed which should be applied to the field over multiple seasons.

When considering a renovation there is no silver bullet, and multiple methods can be applied. A more economical method may be to do a partial renovation which includes renovating only areas of the pasture where there is poor yield or significant damage from winter injury, drought, or where flooding has occurred.

In cases where weeds are a primary concern, but soil fertility levels and pH are optimal and the pastureland would not benefit from or is not suitable for primary tillage, the area can be burned (e.g., sprayed) down with a chemical herbicide in the fall. The following spring, the pasture can be reseeded using a no-till drill. This method will reduce the cost associated with primary tillage, and, provided the sod is completely killed by the burndown, successful stand re-establishment is often achievable.

## Pasture establishment

The establishment of vigorous and resilient forages that provide complete ground coverage is essential for any producer relying on pastures in their production system. Producers need to consider their field conditions, soil characteristics, growing environment, goals, equipment, and costs to have success in pasture establishment. These are not items that should be left to the last minute, as failure to consider these issues may lead to lost time, lost productivity, or financial losses. For the successful establishment of new pastures, producers should start planning up to 18 months in advance and should be able to answer the questions listed at the beginning of this chapter before beginning. An additional question to answer when a new pasture will be established is, "How will the seedbed be prepared, and what are the seeding depths?" Some of the information in the final sections of this chapter are not specific to stand termination and new pasture establishment and can also apply to rejuvenating pastures.

## Soil Fertility and pH

Soil fertility and pH issues are two pasture characteristics that are difficult to address once a pasture has been established and should be corrected before establishment.

As in the case of pasture rejuvenation, testing the soil will identify fertility or pH issues within the field. The Nova Scotia provincial lab offers soil testing services and provides a report that identifies current nutrient levels, pH and other important soil factors. They can also provide a recommendation for fertilizer requirements for forages as well as the lime requirement of $CaCO_3$ in tonnes/ha needed to bring the soil pH up to 6.5. A pH range of 5.8 to 6.5 is recommended for a good growing environment for forages and to improve nutrient availability during establishment and production periods. Legumes are more sensitive to low pH than grasses, and soil pH will decline over time, so the target soil pH should be higher than the minimum required for the most sensitive species in the mix. Lime reacts slowly with acidity in the soil, so liming materials should be incorporated at least 6 months prior to seeding.

## Weed control

Weed control is important in both rejuvenating and newly established pastures. It's important to manage weeds to reduce competition from annual grass and broadleaf weeds after planting and reduce or eliminate perennial weeds that can infest the pasture once it is established. This is particularly important if there is a history of weeds that are toxic (e.g., lupin, tall buttercup) or unpalatable (e.g., knapweed, thistles) to livestock.

When considering weed control, remember that the goal is to create a plan that is efficient, cost-effective and one that reduces the weed population to a level that is not economically damaging. Plans focussing on complete weed removal may be too expensive to pursue. Weed control should be done through more than one method to improve the chances of success. Methods can include chemical, mechanical/physical or through cultural practices (ACCPCFC, 1991). In Atlantic Canada, pastures are often planted with both grasses and legumes (mixed stands) in combination. Controlling weeds through herbicides in established mixed stands is difficult as attempts to apply herbicide for either grass or broadleaf weeds may lead to the loss of the desired species. Controlling perennial weeds in advance of planting is the most effective method.

To reduce the weed population, non-selective herbicides can be applied in late summer or fall of the year prior in preparation for the upcoming year's seeding. Non-selective herbicides can be applied shortly before planting, whether in spring or late summer of the establishment year and help create a stale seedbed to no-till the new stand into. Timing is crucial for this method but can conserve soil moisture compared to a tilled seedbed. For established perennial weeds, there may not be enough top growth for the herbicides to be fully effective. The time between pre-planting herbicide application and sowing of the field should follow label recommendations. Herbicide selection is important regardless of the timing of the application as some products may have residual effects that can cause poor establishment of a newly seeded pasture.

Mechanical methods of weed control can include mowing/clipping, cultivation, or tillage. These methods are appropriate in certain situations and for those who want to avoid herbicides, such as organic producers. Timing of these activities is important and should happen before the weeds set seed. Mechanical control can spread and/or bury the problem in the form of seeds until a later time. In the year prior to establishing a new pasture, mowing or clipping of weeds is recommended. Clipping can weaken the established weeds and, if done before seeds develop, can limit the amount of new weeds that may establish in the future.

Tillage can be used to kill emerged weeds; however, it may also bring new weed seeds to the surface, allowing them to emerge and compete with the newly seeded forages. The depth and intensity of tillage must be appropriate for the weed species being targeted. Light, shallow tillage will be most effective against small annual weeds, while established perennial weeds with deep roots or extensive rhizomes will need deeper, more aggressive tillage to have any effect. However, be aware of the risk of tillage spreading problem weeds to different parts of the field rather than eliminating them.

If weed emergence is significant prior to seeding but after seedbed preparation, the prepared field can be lightly cultivated to disturb any small or young weeds; however the seedbed will need to be firmed up using a cultipacker or roller before seeding. This additional cultivation may impact moisture availability and affect forage establishment.

If weed pressure is an issue post-forage emergence, clipping the tops of weeds can be effective if cutting height is kept high enough to minimize cutting of the forage while removing the tops of weeds. Clipping can remove the flowering portion of some weeds, may weaken them and may provide more sunlight to establishing forages.

Planting a companion or nurse crop can help to reduce the competition from annual weeds, particularly annual grasses. However, the companion crop will also compete with the establishing forages for nutrients, water, and light. Timing of companion crop removal is critical to reduce the chance of thinned stands in the new pasture. See the below section on underseeding for more information.

Weed control in established forages switches from annual weeds to perennials that grow within the forage stand. Annual weeds growing in a pasture are an indication that grazing management needs careful review since an established forage stand will usually suppress annual weed germination completely. Producers should monitor the movement of biennial or perennial weeds into pastures, as a combination of methods may be needed to maintain a strong forage stand.

### Forage species selection

Information on forage species can be found in Chapter 6 along with recommended mixtures for establishing a new pasture. The information in Chapter 6 (*Pasture Species Identification and Recommended Pasture Mixes*) can also be used to choose species for rejuvenating an existing pasture.

### Planting timing

Spring planting has a much greater probability of successful seed establishment than any other time of year and should be the first choice for pasture establishment or rejuvenation (except frost seeding). Seeding should occur as early in the spring as possible when fields are dry enough to handle equipment, and there is a low risk of frost at the time of seedling emergence. Unfortunately, for those using tillage practices, this provides a short window with which to complete the many tasks related to field preparation. Luckily, some of the steps for field preparation may be completed in the fall of the year prior to the seeding year. Those following no-till practices should ensure the no-till drill is in good condition and set correctly to cut through residues left on top of the field or cut into living or weakened stands. If a crop is to be terminated or weakened prior to seeding using herbicides, planting dates should account for any pre-plant intervals required by the label.

> If a non-selective herbicide product such as glyphosate is used, there should be no residual herbicide activity, and planting can be performed that day as the sward dies down.

If mowing or grazing is to weaken a crop, mowing and planting dates should account for the time for forage seedling emergence to reduce competition from the established crop. Ensure the crop is spread evenly behind the mower to limit impacts on seedling emergence. Benefits of spring seeding include allowing seeds to germinate at a time when soil moisture is unlikely to limit germination; lower temperatures, which are ideal for seedlings to emerge and establish before hot temperatures cause heat and water stress; and the full growing season to allow plant establishment before winter.

If choosing a late summer planting timing, be aware that moisture availability and higher temperatures may impact the germination of the seedlings; however, competition from annual weeds may be lower, and there may be more flexibility with fewer competing on-farm activities. Sown-by dates vary across Atlantic Canada, but enough time should be given for plant and root development and to build up energy reserves for successful overwintering (a minimum of eight weeks before the date of normal fall frost is recommended). If not given enough time to establish themselves, late summer plantings can be at risk of winterkill. Grasses are more likely to establish from a late summer seeding than legumes, and clovers are more likely to establish than trefoil.

## Seedbed preparation and seeding

When starting with bare soil, an ideal seedbed is one that is fine, smooth and firm. It will improve seed placement and seed-to-soil contact as well as help ensure proper seeding depth. Cultipackers and rollers can be used to firm up a seedbed if soils have been overworked or if larger cultivation equipment is used in preparing the field (ACCPCFC, 1991). If using no-till methods, the no-till drill should have the weight, sturdiness and capabilities to handle residues on top of the field as well as cut into compacted soils or existing sod and, therefore, preparation can focus on termination or weakening of existing crop stands.

Forage seeds tend to be small and round or thin. Seeding depth is species specific however, in general, a seeding depth of 0.64 cm to 1.28 cm (1/4 in to 1/2 in) is recommended and allows for quick and even emergence. If fields are dry, a depth of 1.92 cm (3/4 in) may be used to find moist soil; however, deeper seed placement may lead to slow, poor and/or uneven emergence of the forages. If broadcasting seed onto bare soil, the seeds should be packed after seeding and, ideally, have light soil cover. One of the leading reasons for poor pasture establishment and longevity is a failure to properly prepare the seedbed along with improper seeding depth or poor soil cover, which leads to thin stands with lower productivity and increased risk of weed encroachment.

On cultivated fields, seeding can be completed using a seed drill, cultipacker seeder or by broadcasting seed. Seed drills are more versatile as they can be used to seed other crops; they allow for deeper sowing, which is useful if moisture availability is a concern, but are of limited use in stony fields.

**Figure 5.3 A cultivated field recently sown to forage.**

Cultipacker seeders can provide a uniform seed distribution at a consistent and shallow depth, along with packing the seed after it is placed into the soil. Unfortunately, if soil moisture is a concern, seeds may not be placed deep enough and may lead to a poor stand. Cultipacker seeders may have difficulty maintaining consistent depth and soil cover on fields with larger stones.

Another option is to broadcast seed, which can be done with a tractor or ATV. When broadcasting seed, choose a day and time with low wind to improve the uniformity of seed distribution. This method is quick and reduces wheel traffic on the field, but different-sized seeds may be thrown at different distances by the spreader, resulting in uneven stands. Seed to soil contact and moisture availability is a concern, and after seeding the field should be packed using a cultipacker or roller.

Figure 5.4 Broadcast seeder mounted to an ATV.

For uncultivated fields, a no-till drill is the best option to ensure seed-to-soil contact and uniform distribution. Ensure the drill is correctly set before seeding begins, and periodically check and assess whether adjustments need to be made. Broadcasting seed can be used but is a less effective method in this situation as seed-to-soil contact is less assured due to existing residues or the existing stand and sod will limit the seed from reaching the soil even with some attachment or implement to roll over or knock down the seed.

The use of the correct seeding rate is important when establishing new pastures to ensure a strong, healthy and long-lived sward. See Chapter 6 for recommended seeding rates for forage species and recommended mixes.

To identify the actual seeding rates, the percent of Pure Live Seed (% PLS) needs to be found.
To calculate % PLS, first, identify the percentage of seed purity of the bag and percent germination of the seed found on the seed tag.

Percent of Pure Live Seed (% PLS) = % seed purity * % germination

Followed by,
Actual seeding rate in kg/ha (lb/ac) = Recommended seeding rate in kg/ha (lb/ac) ÷ % PLS

## Legume inoculation

When seeding legumes, whether new stands or for rejuvenation, always apply the correct inoculant for the legume seed being sown and follow the provided instructions. Follow storage instructions provided by the seed supplier for inoculum; however, if none are provided, packets of inoculum should be stored in a cool, dark place. Seed that has been inoculated and stored should be re-inoculated to ensure viable bacteria are on each seed at planting (ACCPCFC, 1991).

## Underseeding

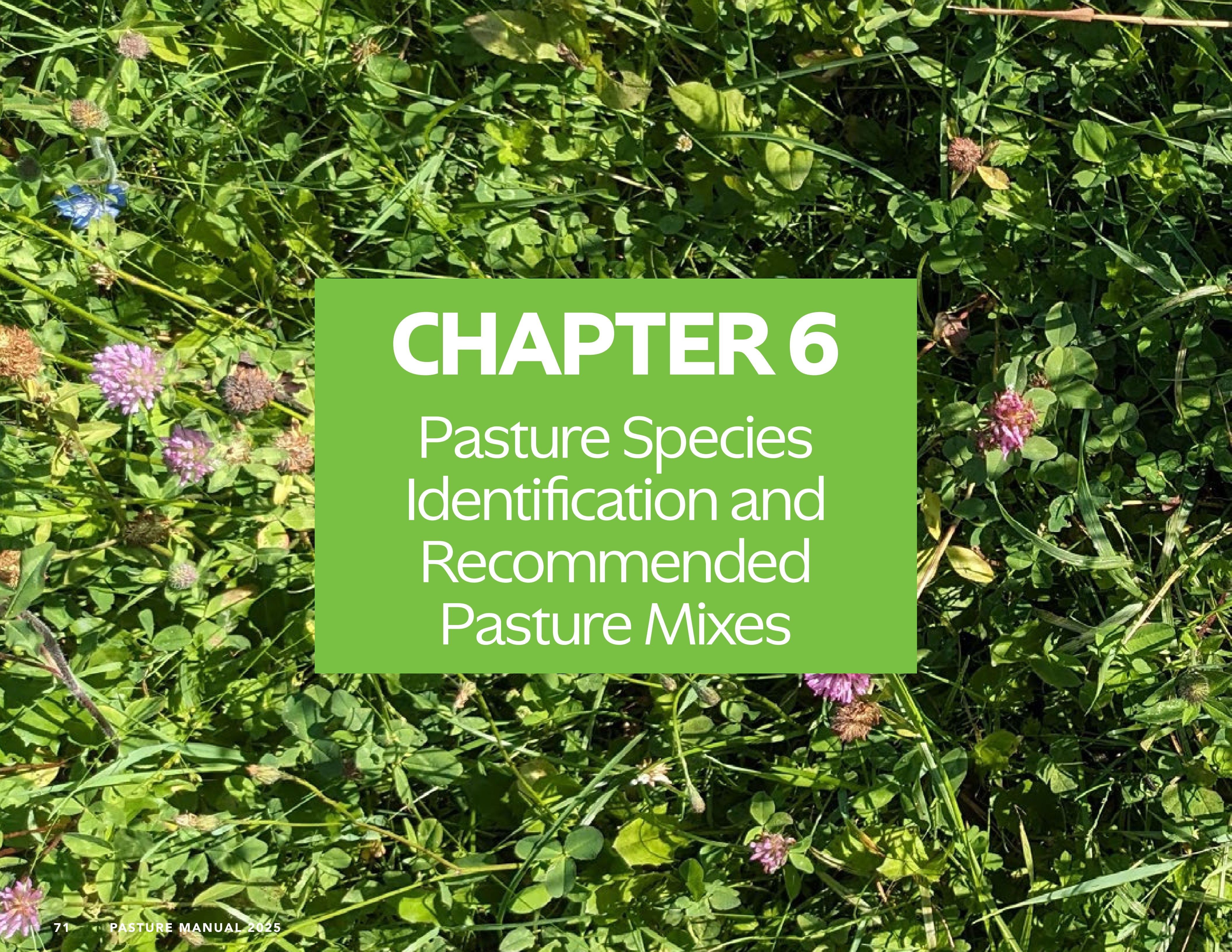
Underseeding also known as companion cropping or nurse cropping, is when a small annual grain crop is sown just prior to or with the perennial grass and legumes which will become pasture. The companion crop typically grows faster than the establishing perennial grass and legumes and can provide benefits such as soil erosion control and can also help suppress annual weeds. An additional benefit is that it can provide an earlier crop to harvest as haylage or it can be grazed, which can help lessen the loss of feed when re-establishing a new stand. Underseeding is only recommended for use in the spring and may not be recommended at all depending on the forage species chosen for the pasture. Experience has shown that red clover, timothy and ryegrasses better tolerate the competition from the companion crop compared to alfalfa and many other grasses (ACCPCFC, 1991).

Companion crops can help reduce competition with weeds however they must be carefully managed to ensure that they do not compete with the establishing pasture. To help reduce competition with the seedling perennial forages, N should be carefully managed while other nutrients should be provided to supply both the annual and perennial crops. The establishing pasture should take priority; therefore, all management considerations should favour the perennial forages. The chosen companion crop will compete with the forages for sunlight, nutrients and water and, if not managed carefully, can lead to thin and weak stands whose productivity will be impacted in future years.

To minimize competition, use a reduced seeding rate for the annual crop. Based on recommendations from Quebec, cereal companion crop seeding rates should be reduced by 30% from the recommended seeding rate of the pure grain crop (Bélanger et al., 2022). Spring cereals like oats, barley, rye or triticale or a mixture such as a spring cereal with field peas can be used as companion crops. Choose varieties that are early maturing, short and stiff strawed (Bates, D, 1970). Harvest timing of the companion crop when using a cereal is at the boot to heading stage, and the crop can be made into silage or haylage or be grazed. If grazing, do not let animals graze the field short enough that they eat the establishing grasses and legumes. Leaving the companion crop to mature for grain harvest will adversely affect the establishment of the forage stand.

**Figure 5.5 Forage field established with companion crop. Early season growth (left) beside later season growth (right).**

While there are many factors to consider with underseeding, it has been used successfully by farmers. Grain producers in PEI successfully use this method to incorporate pasture into their rotation. They underseed oats, the final cash crop in their rotation, with their pasture mix that includes red clover and alfalfa. Not only do they harvest the oats as a grain crop, they also harvest the straw and have had very successful pasture stands. This is an organic operation, so the soluble N is likely quite low at this point in the rotation, underlining the point that applying too much N might make this practice unworkable. They have used this method for 17 years, and only once did one crop fail: in 2023, a very high moisture year, the pasture species outcompeted the oats (Bernard, 2023). Furthermore, in a study conducted at the Nappan Experimental Farm, when barley was sown as a companion crop to alfalfa, there was no significant impact on the establishment of the alfalfa. While the amount of alfalfa in the barley/alfalfa stand was somewhat lower in the seeding year this was not statistically significant and subsequent production years were similar to alfalfa sown without the companion. Total forage yield was significantly higher in the seeding year in comparison to alfalfa grown without barley, however forage quality was reduced in the first cut. (Dr. Glover, 2024).



# CHAPTER 6

## Pasture Species Identification and Recommended Pasture Mixes

# CHAPTER 6
# Pasture Species Identification and Recommended Pasture Mixes

## RECOMMENDED PASTURE MIXES

Identifying the species present in a pasture and understanding their growth habits and seasonal growth patterns are important for the effective management of pastures. This chapter will outline methods of identifying the major species of grasses and legumes found in Atlantic Canada.

It is important to note that there are various cultivars of each forage species - Kentucky bluegrass and white clover are excellent examples, as they each have various related cultivars. These cultivars should follow the species identification characteristics outlined below. This chapter does not focus on cultivar differences within species as the availability of cultivars changes over time. The use of certified seed for named cultivars can provide improvements to naturalized species within a pasture. These improvements can include higher yields, faster establishment, longevity (i.e., persistence), changes in maturity timing, seed production for reseeding, and tolerance to grazing.

## CHARACTERIZATION OF PASTURES

Researchers in Nova Scotia, New Brunswick, Prince Edward Island and Newfoundland have independently collected data on pasture composition since 1921 (Butler et al., 1993). Based on the species present, pastures can be divided into two categories: 1) naturalized pastures and 2) tame pastures. In Atlantic Canada native pastures are uncommon due to the extensive use of introduced grasses and legumes more familiar to settlers during colonization. Some of these introduced species have become naturalized to Atlantic Canada and are still commonly seen in abandoned or minimally managed pastures. As these naturalized and tame species make up the greatest proportion of forages used in Atlantic Canada, they will be the focus of this chapter.

Naturalized pastures generally contain higher amounts of such species as bluegrass, bentgrass, white clover, quackgrass and creeping red fescue. Tame pasture species include timothy, orchardgrass, meadow fescue, tall fescue, improved Kentucky bluegrass, red clover, white clover, birdsfoot trefoil and alfalfa.

Pastures can also be categorized based on whether they are improved or unimproved. These terms are associated with the management of the pasture. Improved pastures are those that have received additions of lime or fertilizer or have had new species or varieties of species sown into the field. They may also have had some form of weed control or a more intensive grazing system in place. Unimproved pastures are more common in the Northern plains and Western Prairies in Canada where livestock are grazed on native grasslands that have persisted for thousands of years prior to colonization.

## PARTS OF GRASSES AND LEGUMES

Vegetative and reproductive structures (seed heads) can be used to identify grasses and legumes. However, because the reproductive structures are removed through grazing, often just the vegetative structures remain and, therefore, must be used to identify the species.

The figures on the following page will help to identify grass and legume species based on both their physical and physiological characteristics. First, determine the growth habit such as whether the grass growth is a bunch-type or sod-forming, or upright or prostrate. Also, check to see if it has any rhizomes (i.e., below-ground horizontal stems) or stolons (i.e., above-ground horizontal stems).

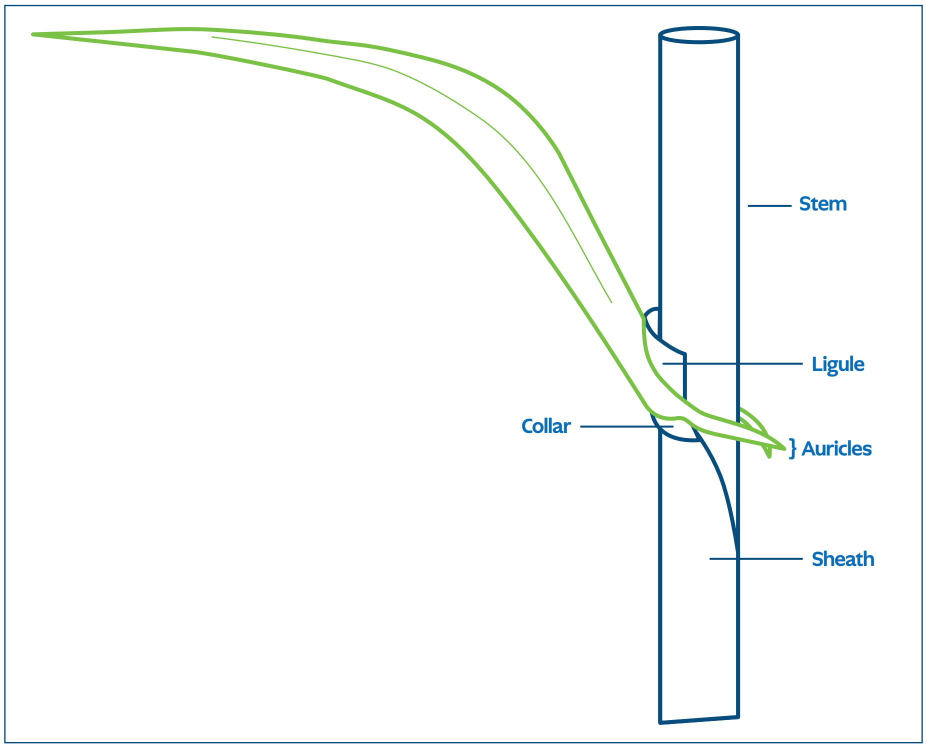



**Figure 6.1 Parts of a grass plant that can assist in identifying different grass species.**

In the case of grasses (see Figure 6.1 above), look to see if the leaves growing from the bud shoot are rolled or folded. The physical characteristics of the leaf blade, such as its colour (light, dark), texture (ridged, smooth, hairy, shiny), shape (wide, narrow, tip shape) and structure (flat, curved) are also distinguishing characteristics. To narrow down species differences, look at the collar area (the area of the joint at the base of each leaf blade) structures such as the ligule and auricles. Determine if hairs are present. The collar of grasses is light green and varies in size and shape according to species (Figure 6.2, below).

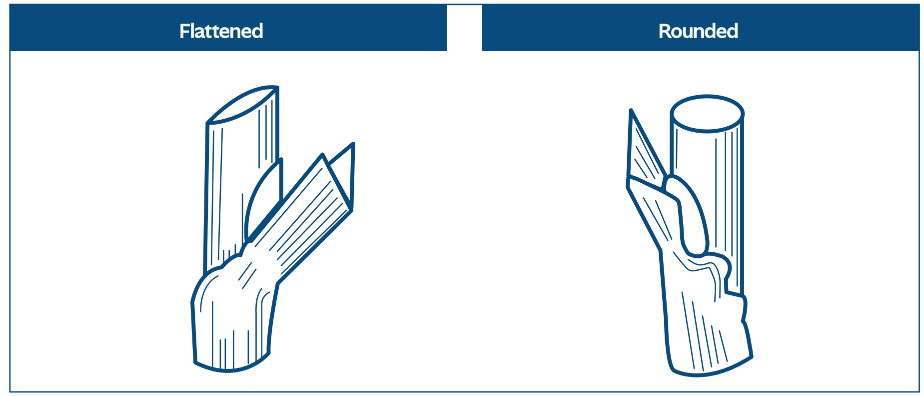



**Figure 6.2 Different shapes of collars for grass species. The collar also varies in size.**

The ligule (Figure 6.3) is found at the inner base of the leaf and is a translucent membrane that can differ in size (large, small), texture (hairy, ridged, smooth) and shape (crown, collar) or be absent. On some grasses, the ligule can be less than 2mm in length, such as Kentucky bluegrass, while on others, it can be much longer (reed canary grass).

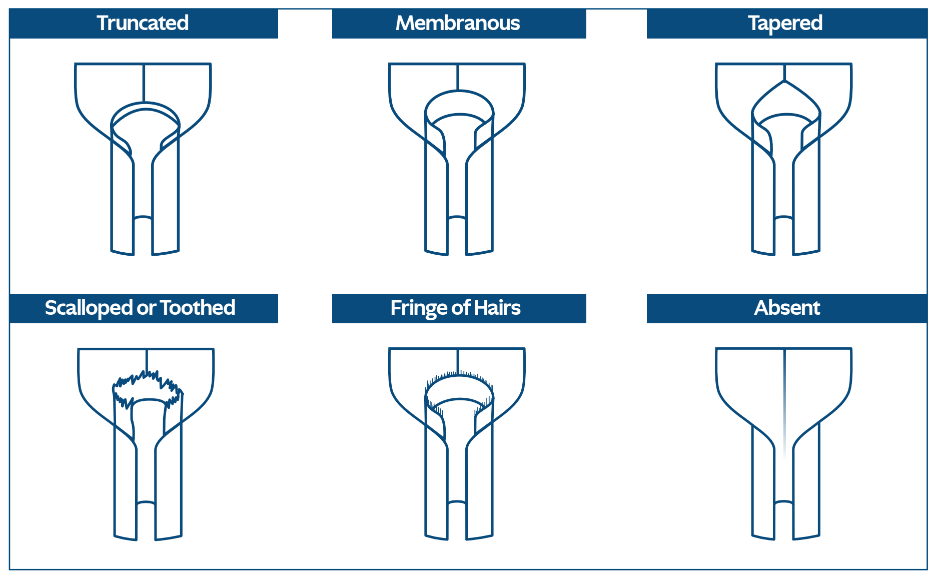



**Figure 6.3 Examples of ligules.**

Auricles are claw-like structures found at the junction of the leaf blade and sheath that may be present or absent depending on grass species and can differ in size and shape (blunt, long) (Figure 6.4). The type of opening of the leaf sheath that wraps around the stem can be closed and split or overlapping and can also help identify the grass (Figure 6.5).

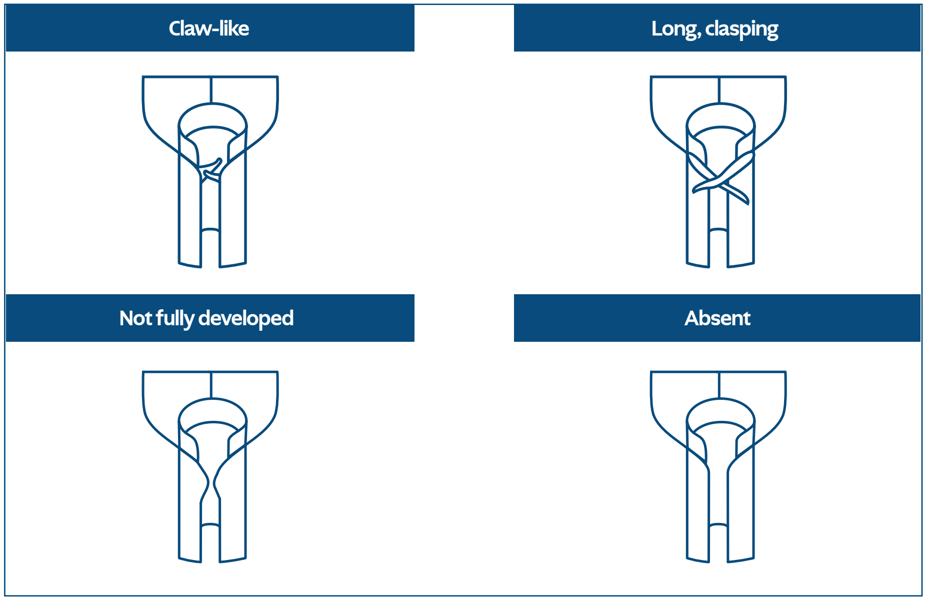



Figure 6.4 Examples of auricles.

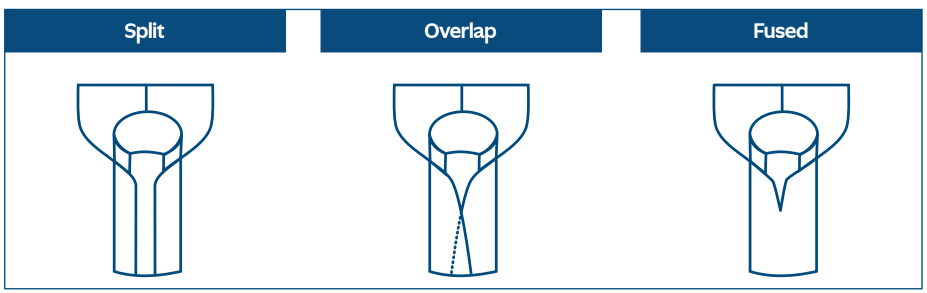



Figure 6.5 Examples of leaf sheaths.

In legumes, look at where the leaves join the stem; there may or may not be small, leaf-like structures called stipules (Figure 6.6). Typical pasture legume species have either three or five leaflets, which make up the leaf. The stalk connecting the leaf to the stem is called the petiole. The petiolule is the extension of the petiole to the leaflets.

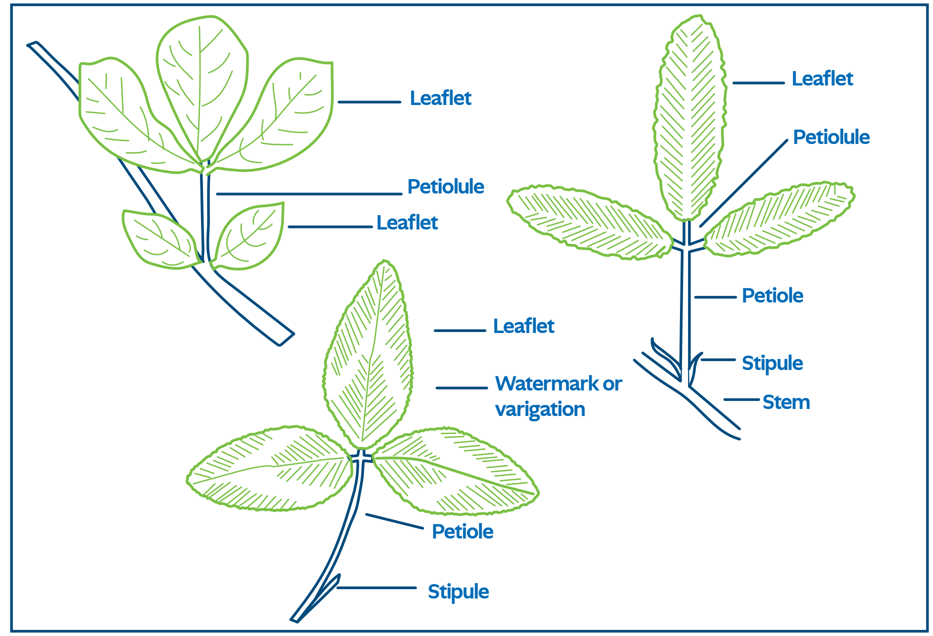



Figure 6.6 Examples of characteristics that can assist in identifying different legume species.

## TILLERING

Another way to differentiate grass species is to look at their tillering ability. Tillers are leaves that develop from the leaf axis on the main shoot or from other tillers during vegetative growth. Some bunchgrasses, like orchardgrass, produce only a few short tillers, making the plant look like a distinct clump with open spaces between plants. On the other hand, sod-formers such as Kentucky bluegrass and smooth bromegrass often have rhizomes or stolons and tiller much more. In these grasses, the tillers grow sideways and may come out a little bit away from the main stem, causing them to spread and fill in open areas. This growth pattern allows them to be more adapted to close grazing because their growth points are close to the ground, unlike those on bunchgrasses, which tend to be higher.

## IDENTIFICATION KEYS FOR GRASSES AND LEGUMES

A number of classification keys have been developed for grasses. Two classification keys for common pasture species in the Maritimes, one for cool season grasses (Table 6.1) and one for legumes (Table 6.2), are included in this chapter. For more detailed information on specific grasses and legumes, see individual species descriptions included in this chapter.

Table 6.1 Identification Key for Common Pasture Grasses in the Maritimes.

| SPECIES AND SCIENTIFIC NAME | GROWTH HABIT | LEAVES | LEAF SHEATH | COLLAR |
|---|---|---|---|---|
| Bromegrass, meadow; ***Bromus riparius*** Rehm**.** | • bunchgrass,<br>• many basal leaves,<br>• some vegetative spreading | • rolled in budshoot, mostly basal growth and presence of hairs | • hairy, closed near top | • narrow, divided at midrib |
| Bromegrass, smooth; ***Bromus inermis Leyss.*** | • open sod-forming,<br>• erect growth | • rolled in budshoot, wide and flat, dull green. First leaves may have hairs present but later leaves are hairless. "W"-shaped marking near the centre of the leaf | • margins joined for almost whole length, hairless | • narrow, divided at midrib |
| Fescue, meadow; ***Festuca pratensis*** | • bunchgrass, limited vegetative spreading | • rolled in budshoot, 3-6 mm wide, medium green, dull upper side of leaves with shiny lower side, hairless, rough edges and sharp tip | • medium green, finely veined, hairless;<br>• split with margins overlapping near bottom | • broad, continuous |
| Fescue, creeping red; ***Festuca rubra*** | • sod-forming,<br>• many basal leaves,<br>• erect growth | • folded in budshoot, basal growth, very narrow, hairless, bristly, always somewhat folded up | • closed margins, joined almost to top, fine hairs,<br>• base of younger sheaths usually red while aging sheaths are brown | • narrow, continuous |
| Fescue, tall; ***Festuca arundinacea*** | • bunchgrass, limited vegetative spreading as it has short rhizomes, sod-forming under intensive grazing | • rolled in budshoot, basal growth, thick and wide (4-12 mm), hairless mature leaves, finely haired on newly formed leaves, dark green, sharp pointed tip, rough margins, dull topside with shiny under surface | • split with margins overlapping, hairless, thick,<br>• older sheaths at base of plant and are slow to decay | • broad, divided, yellowish, wrinkled on edges |

| AURICLES | LIGULE | RHIZOMES | STEM | INFLORESCENCE | DISTINGUISHING CHARACTERISTICS |
|---|---|---|---|---|---|
| • absent | • membranous, short | • short, stout rhizomes or none | • hairy, erect | • open panicle, similar to smooth bromegrass | • distinguishable from smooth bromegrass by presence of hairs on leaf blades and sheaths, many drooping basal leaves |
| • absent | • membranous, very short | • robust, long | • hairless, erect | • erect and branched panicle, branches slender with long smooth spikelets, 2 short awns on floral pieces | • "W" in centre of most leaves. Only first leaves are hairy, later growth is hairless |
| • present, small, may be claw-like, hairless | • membranous, very short | • short | • hairless, erect | • elongated panicle of spikelets up to 20 cm (8 in.) long | • rough leaf edges, short ligules and clasping hairless auricles |
| • absent | • membranous, very short | • short, few in number | • hairless, erect | • long panicle with few branches, spreads out at flowering, turns purplish | • dark-green, very slender, bristle-like leaves, young leaf sheaths can be reddish while old/dead basal leaf sheaths are reddish brown |
| • present, claw-like, yellowish, finely haired | • membranous, short | • very short | • hairless, erect | • open panicle, 15-30 cm long, short awned | • shiny underside, coarse growth, leathery, prominently ribbed leaves, slightly hairy auricles, fines on newly formed leaves |

| SPECIES AND SCIENTIFIC NAME | GROWTH HABIT | LEAVES | LEAF SHEATH | COLLAR |
|---|---|---|---|---|
| Festulolium (annual ryegrass x meadow fescue), ***Festulolium braunii*** | • characteristics can take after annual ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or meadow fescue. Review parent characteristics. |
| Festulolium (annual ryegrass x tall fescue), ***Festulolium pabulare*** | • characteristics can take after annual ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or tall fescue. Review parent characteristics. |
| Festulolium (perennial ryegrass x tall fescue), ***Festulolium holmbergii*** | • characteristics can take after perennial ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or tall fescue. Review parent characteristics. |
| Festulolium (perennial ryegrass x meadow fescue), ***Festulolium loliaceum*** | • characteristics can take after perennial ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or meadow fescue. Review parent characteristics. |
| Kentucky bluegrass, ***Poa pratensis L.*** | • sod forming, many basal leaves, erect growth | • folded in budshoot, hairless, narrow, shiny underside, blueish or dark green, central vein bordered by 2 long grooves, boat-shaped tip | • young leaf sheaths appear flattened, closed when young, mature sheath splits | • broad, yellowish-green, slightly divided by the midrib |
| Orchardgrass, ***Dactylis glomerata*** | • bunchgrass, many basal tillers, erect growth | • folded in budshoot, hairless, flat and wide, dull green, rough edges, central vein prominent, v-shaped in cross section near base becoming flat towards the tip | • flattened, hairless, split part way, green on the top, pale green/ white on lower part | • broad, yellowish-green, divided by the midrib |

| AURICLES | LIGULE | RHIZOMES | STEM | INFLORESCENCE | DISTINGUISHING CHARACTERISTICS |
|---|---|---|---|---|---|
| • characteristics can take after annual ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or meadow fescue. Review parent characteristics. |
| • characteristics can take after annual ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after annual ryegrass or tall fescue. Review parent characteristics. |
| • characteristics can take after perennial ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or tall fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or tall fescue. Review parent characteristics. |
| • characteristics can take after perennial ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or meadow fescue. Review parent characteristics. | • characteristics can take after perennial ryegrass or meadow fescue. Review parent characteristics. |
| • absent | • membranous, very short | • numerous, forming dense networks | • hairless, erect, medium height | • open panicle, triangular, often tinted purple | • canoe-shaped tip |
| • absent | • membranous, very long, pointed | • none | • hairless, flat, erect | • panicle open at base and closed at tip, spikelets in one-sided clusters | • flat stem, pronounced V-shape of base of leaf, pronounced clumps in fields |

| SPECIES AND SCIENTIFIC NAME | GROWTH HABIT | LEAVES | LEAF SHEATH | COLLAR |
|---|---|---|---|---|
| Quackgrass, ***Elymus repens*** | • sod-forming,<br>• aggressive,<br>• erect growth | • rolled in budshoot, pale yellow to green in colour, hairless to sparsely hairy, flat | • sparsely hairy near base of plant, hairless further up stem; split with margins overlapping | • broad, pale, continuous |
| Redtop, ***Agrostis gigantea*** | • sod-forming | • rolled in budshoot, mostly hairless, vary in length, elongated, a bit stiff, flat, and pointed at tip | • split, with overlapping margins | • v-shaped, pale green, large |
| Reed canarygrass, ***Phalaris arundinacea L.*** | • sod-forming,<br>• erect growth | • rolled in budshoot, leaves wide (6-20 mm), flat with rough margins and pale green colour | • hairless, split with overlapping margins | • narrow, continuous, pale green or yellow |
| Ryegrass, annual; ***Lolium multiflorum*** | • bunchgrass with many tillers,<br>• erect growth | • rolled in budshoot, hairless and thin, bright green colour, keeled, very ridged on the upper surface with midrib and shiny smooth underside | • split and overlapping margins | • broad, yellowish-green |
| Ryegrass, perennial; ***Lolium perenne*** | • bunchgrass with many tillers,<br>• erect growth | • folded in budshoot, hairless and bright green, narrow, short and v-shaped in cross section and a shiny underside, a bit stiff | • pale green, closed or split; red or purple near base base of stem | • narrow |
| Timothy, ***Phleum pratense L.*** | • bunchgrass with limited tillers,<br>• few basal leaves,<br>• erect growth | • rolled in budshoot, hairless, dull green, erect, variable length, rough margins | • split and overlapping margins, hairless | • broad, continuous, may have hair on margins |

| AURICLES | LIGULE | RHIZOMES | STEM | INFLORESCENCE | DISTINGUISHING CHARACTERISTICS |
|---|---|---|---|---|---|
| • present, claw-like | • membranous, very short | • pale, sharp-pointed, far-reaching 8-15 cm deep | • usually hairless, exept sometimes at the base, erect | • elongated narrow spike (like ryegrass) | • auricles; straw-coloured, long rhizomes; aggressive growth and spread |
| • absent | • membranous, very long, pointed | • short, shallowly buried | • shoots usually hairless, usually erect, sometimes prostrate to soil | • first greenish and closed then reddish fine panicle | • single seed florets, leaf blade has prominent ridges on upper side, tall ligule |
| • absent | • membranous, long | • short, thick, scaly | • erect, round, stiff, tall | • panicle tinted with purple, initially open like orchardgrass but then closes | • wide leaf blades, tall erect growth, edges of the blade constricted 5 cm from either the tip or the collar |
| • present, starting with 3rd or 4th leaf, long and claw-like and usually longer and more prominent than perennial ryegrass | • membranous, short | • none | • erect, hairless, base of young plants appears somewhat reddish | • flattened spike, alternating spikelets edgewise to stem | • shiny underside, keeled leaf, more prominent auricles than perennial ryegrass |
| • present, starting with 3rd or 4th leaf, small and claw-like | • membranous, short, toothed near top | • short | • erect, hairless, shorter than annual ryegrass, base of young plants appears somewhat reddish | • flattened spike, alternating spikelets edgewise to stem | • shiny underside of leaves, auricles |
| • absent | • membranous, medium, upper edge pointed and notched on sides | • none, base of stem swollen (culm) | • erect, round, hairless, bulb-like swelling at base, sometimes reddish | • cylindrical, spike-like panicle | • onion-like bulbs (corms)at base of stems |

## INDIVIDUAL PASTURE GRASSES

### Kentucky Bluegrass

**Figure 6.7 Kentucky Bluegrass seedling. Boat-like leaf tip (left). Folded in budshoot, no auricles, prominent midrib (right).**

Kentucky bluegrass (*Poa pratensis*) is a perennial grass species most commonly found in naturalized pastures, likely due to its ability to survive close grazing (Butler et al., 1993). It is palatable, lush and grows close to the ground. Bluegrass is slow to establish but will persist for five or more years (OMAFRA, 2002). It is a winter-hardy grass that can grow in soils with a pH greater than 5.5 but performs best when soils have a pH between 6.0 and 6.5, and also have good fertility. Developed cultivars are higher yielding than the naturalized type and also handle grazing well. Due to its shallow roots, Kentucky bluegrass goes dormant when conditions are hot and dry in midsummer, but productivity returns with moisture. Its sod-forming nature can help limit damage to the pasture in high-traffic areas like laneways and makes it practical for use in pasture mixes to fill in bare spots around other forages, which can help limit soil erosion and provide competition for weeds. Bluegrass is most readily identifiable by the "boat tip" shaped end of its blades.

### Reed Canarygrass

**Figure 6.8 Reed Canarygrass. A young plant (left). Leaves (center) and long ligule (right).**

Reed canarygrass (*Phalaris arundinacea*) is a perennial grass species that gives an excellent yield on variable drained and dry soils. Established plants are tolerant of flooding; however, seedlings are vulnerable. It is moderately tolerant of acidic soils and can grow on soils with a pH as low as 4.9. It has good regrowth, responds well to N and is a very winter-hardy grass. However, it is slow to establish and rapidly loses quality and palatability once the inflorescence emerges. Low-alkaloid varieties have overcome many of the issues with palatability and poor livestock performance, and regrowth generally stays vegetative. It has a low tolerance to close grazing and frequent cutting and fits better into a less intensive rotational grazing system (Bittman, 1988). Recently sown stands are vulnerable to weed encroachment; however, once established, reed canarygrass can aggressively spread and may outcompete other desirable forages. Due to its aggressive nature and ability to thrive on wetter soils, it has been a problem in ditchways and wetlands.

## Tall Fescue

**Figure 6.9 Tall Fescue. Rolled in budshoot (left). Hairless leaf sheath. Dull green, ribbed, hairless leaves (right).**

Tall fescue (*Festuca arundinacea L.*) is a deep-rooted perennial grass with growth habits of a bunchgrass but which, under frequent grazing, may also form a sod through rhizomes. It is adaptable to a wide range of climates ,soil types and conditions. Tall fescue tolerates poor drainage, is somewhat drought tolerant and is winter hardy. Due to its heat tolerance, it can often grow later in the summer than other cool-season grasses but will eventually become dormant as well. It has good fall growth and maintains greenness and nutritional quality better than some other cool-season grasses during autumn, making it an option for stockpiling feed for extended grazing.

As fescue matures, the leaves become coarse and less palatable, which may decrease animal intake through animal avoidance. Breeding efforts have also been used to produce varieties with "softer" leaves, which improve palatability. Tall fescue has been previously cast in a negative light due to its symbiotic relationship with ergopeptine alkaloid-producing endophytes. The ergopeptine alkaloids may cause a range of animal health issues, which have been broadly labelled fescue toxicosis. Endophyte-free varieties of tall fescue are available and do not cause animal health issues (Casler et al., 2008). Producers should ensure the purchase of endophyte-free tall fescue varieties.

## Meadow Fescue

**Figure 6.10 Meadow Fescue. Auricles (left). Potted plant. Shiny underside of leaves (right).**

Meadow fescue (*Festuca pratensis L.*) is similar to tall fescue; however, its leaves are finer and less coarse, improving palatability. Meadow fescue has better digestibility than tall fescue, but it has lower yields. It is tolerant to frequent grazing and is easy to establish. It has good spring growth, allowing earlier grazing compared to some other cool-season grasses. It is tolerant to variably drained soils and a range of growing conditions. It is more drought tolerant than timothy but is more sensitive to high summer temperatures than tall fescue. Meadow fescues grow well late into the fall. Meadow fescue also has a symbiotic relationship with an endophyte; however, the endophyte does not cause health issues in animals but instead improves the tolerance of meadow fescue to adverse growing conditions (Casler et al., 2008).

## Creeping Red Fescue

Creeping red fescue (*Festuca rubra*) is more commonly grown as a turf than pasture grass, but its fine leaves are highly palatable and can produce reasonably well in the cool conditions of spring and fall. It tends to go dormant during hot, dry weather. It establishes quickly from seed, and as the name implies, creeping stolons will allow this grass to fill in bare spots in the pasture and form a dense sod that is somewhat tolerant to hoof traffic.

## Perennial Ryegrass

**Figure 6.11 Perennial Ryegrass. Young plant. Reddish purple colour near base of stem (left). No auricles on first few leaves but auricles present on newer leaves (right).**

Perennial ryegrass (*Lolium perenne*) establishes quickly and has excellent quality and palatability. It has vigorous spring growth and can also withstand close grazing. However, it has poor drought and heat tolerance and does best in mild temperate climates. It prefers wetter climates but has poor tolerance for variable drainage. In some areas of the Maritimes, it is generally sown as an annual or short-lived perennial because of its poor winter hardiness. The risk of winterkill is higher when perennial ryegrass has too much growth in the fall before snowfall, as it can cause matting and increased disease risk. Paddocks may need to be grazed or cut in the fall to manage excessive plant growth. However, even with proper management of growth, losses may still occur depending on the winter conditions, as perennial ryegrass does not tolerate ice well. Before purchasing seed, verify whether the cultivar available is suited for grazing: different varieties have been developed to target different purposes, whether pasture, hay or turf.

## Annual Ryegrass

**Figure 6.12 Annual Ryegrass. Keeled leaf. Clawlike auricles (left). Inflorescence emerging in year of planting for Westerwold types (right).**

The term annual ryegrass (*Lolium multiflorum*) refers to two different types of ryegrass. Westerwolds ryegrass is an annual bunchgrass, while Italian ryegrass is a biennial bunchgrass. Italian ryegrass may overwinter depending on fall and winter conditions but will often winterkill. Italian ryegrasses are more suitable for grazing as they are leafy with many tillers, while Westerwolds ryegrasses are more upright and may be more suitable for stockpiling (Kuneluis, T., 1991).

Annual ryegrasses fit in pasture systems as supplemental forage for grazing during late summer when other cool season forages are dormant and fall when perennial forages are in the critical rest period. They are high-yielding with good quality. Annual ryegrasses have historically performed well in Atlantic Canada growing conditions. They grow in a range of soil types but grow best in soils with a pH of 6.0 or greater and good fertility (Kuneluis, T., 1991).

A weed-free seedbed is important as seedlings are not competitive; however, once established, they can outcompete weeds and other forages when grown in a mixture. Reduce the ryegrass seeding rate if establishing it with other forages to improve the persistence of the mixed stand. Adding a legume to the stand will help offset N requirements for regrowth. Be cautious if adding N fertilizer, as toxic levels of $NO_3$- may accumulate. See Chapter 10 (*Animal Health on Pastures*) for more information on the risk of accumulated $NO_3$-. Annual ryegrasses are best suited for a rotational grazing system due to their rapid regrowth.

### Festulolium

Festulolium (*Festulolium spp.*) is a group of hybrid grasses created by crossing perennial ryegrass or annual ryegrass with tall fescue or meadow fescue. The hybrids are then selected for those cultivars that best combine the palatability and quick regrowth of the ryegrasses with the stress tolerances, winter hardiness and productivity of the fescues. Physical characteristics and growing condition suitability can either resemble the ryegrass or fescue parent. Therefore, producers should review those descriptions to ensure their fields can meet a given cultivar's needs. Careful selection of varieties is important to ensure they meet production practices and local growing conditions. Each cultivar will have varying degrees of ryegrass or fescue characteristics, including varying levels of winter hardiness (Casler et al., 2008).

## BROMEGRASSES

### Smooth Bromegrass

Smooth bromegrass (*Bromus inermis*) is a leafy, sod-forming perennial grass used mainly as a hay crop but may also be used for pasture. It has excellent spring and fall yields. However, regrowth can be slow and adequate rest time is required as it cannot withstand close or frequent grazing. It is a palatable species that retains its palatability through maturity. If an inflorescence develops prior to grazing or harvesting, the regrowth will be vegetative and will not produce a new inflorescence. It is very winter-hardy and drought-tolerant because of its deeper root system. However, seeding may be a challenge, as its seeds are large and light.

### Meadow Bromegrass

Meadow bromegrass (*Bromus riparius*) is a perennial bunchgrass and is a reduced creeping type of bromegrass. It is a high-producing and palatable pasture species. Meadow bromegrass has more uniform seasonal production, with earlier spring growth and better growth in July and September than smooth bromegrass. It can also withstand grazing better than smooth bromegrass and has good re-growth and faster initial re-growth. However, it is more difficult to establish than smooth bromegrass. It has larger seeds requiring a higher seeding rate than smooth bromegrass and has a lower ability to fill in stands. It is very winter hardy but less so than smooth bromegrass. It is not tolerant to wet soils or in soils where water will accumulate and is sensitive to flooding. It yields similarly to orchardgrass, timothy or tall fescue. (Knowles et al., 1993).

### Orchardgrass

**Figure 6.13 Orchardgrass. Flat leaf in bud (left). V shaped leaf. Long ligule (center). Inflorescence (right).**

Orchardgrass (*Dactylis glomerata*) is an aggressive perennial bunchgrass that is easy to establish and has excellent re-growth after cutting or grazing. It can tolerate drought and will have better regrowth during the warmer temperatures of summer than timothy grass. It prefers moderately- to well-drained soils and does not tolerate wet soils or flooding. Orchardgrass can tolerate close grazing, except in the fall, and responds well to N application. It has poor tolerance to icing and is less winter-hardy than timothy.

In spring, it will produce an inflorescence earlier than many other cool-season grasses, and the inflorescence matures quickly. Unfortunately, the palatability and nutritive quality of orchardgrass decreases rapidly after seedhead emergence. This can cause issues in some pasture mixes as other forages may not be ready to be grazed when orchardgrass is ready. Fortunately, the regrowth of orchardgrass is generally vegetative as long as tillers develop an inflorescence before being grazed or mowed. The vegetative growth in later cuts maintains palatability and quality better than the losses seen when the inflorescence emerges.

In order to manage these traits, choose a late-maturing cultivar when using orchardgrass in a mixture with other forages. Orchardgrass may require different harvest options (hay or silage), particularly in the spring, in order to minimize quality and palatability losses if many paddocks contain orchardgrass. If there are a few orchardgrass-dominant paddocks, it is a good idea to prioritize grazing them early in the spring, moving through them quickly.

## Timothy

**Figure 6.14 Timothy. Split and overlapping leaf sheath. No auricles. Pointed ligule (left). Bulbous corms (right).**

It has been stated that timothy (*Phleum pratense*) is the most important grass grown in the Atlantic Provinces due to its inexpensive seed, ease of establishment, excellent winter hardiness and good first-cut yields (Rodd et al., 1994). Timothy is a perennial bunchgrass that is not well adapted to grazing; however, it is commonly found in pastures due to its adaptability to a wide range of soil conditions, strong persistence and winter hardiness. Seed is generally readily available and inexpensive, and it can be found in many forage mixtures. It does not tolerate drought and will have limited productivity during periods of high daily temperatures seen in the later parts of summer. Timothy has good spring growth, slow regrowth post-harvest and limited fall growth (Grant & Burgess, 1978). If used for grazing, it will be more productive if managed in a rotational grazing system that provides longer rest periods.

Table 6.2 Identification Key for Common Pasture Legumes in the Maritimes.

| SPECIES AND SCIENTIFIC NAME | EASY ID | STEM |
|---|---|---|
| Alfalfa (lucerne), ***Medicago sativa L.*** | • 3 leaflets (typically) oblong in shape,<br>• leaflets are longer than they are wide,<br>• light lavender to purple flowers,<br>• seedpods are tightly coiled | • often erect but there are some prostrate cultivars,<br>• no hairs |
| Birdsfoot trefoil, ***Lotus corniculatus L.*** | • 5 leaflets per leaf,<br>• yellow flower, papilionaceous shaped (butterfly like),<br>• seed pods form shape that looks like a bird's foot | • grazing type is prostrate,<br>• well branched,<br>• minimally hairy |
| Clover, alsike; ***Trifolium hybridum L.*** | • flower stem originates from the same point off the main stalk as separate leaflet stems (different from red clover),<br>• distinguished from white clover by erect growth and dull colour of underside of leaves | • upright,<br>• branched,<br>• hairless |
| Clover, red; ***Trifolium pratense L.*** | • flowers and leaflet clusters on the same stem | • mostly upright,<br>• numerous branching stems arising from crown,<br>• hairy |
| Clover, white; ***Trifolium repens L.*** | • flowers and leaflets on separate stalks from the above-ground stem (stolon),<br>• spreads by stolons (above ground stems) | • prostrate,<br>• no hairs |

| LEAVES | FLOWER | ROOT |
|---|---|---|
| • Typically 3 leaflets per leaf but some newer varieties may have more (multifoliate),<br>• oblong-shaped leaflets around 2 cm long and 0.5 cm wide with serrated tips,<br>• hairless on top but hairs on underside of leaves | • 10-20 small pea-like flowers in a short raceme at the top of stems | • taproot, or<br>• branch root, or<br>• rhizomatous, or<br>• creeping |
| • 5 leaflets per leaf,<br>• oval or lance shaped,<br>• minimally hairy | • typically 5 yellow petals,<br>• papilionaceous (butterfly-like),<br>• pods at right angle to stem, | • deep taproot with many branching side roots near surface |
| • 3 oblong-shaped leaflets,<br>• no white "V"-shaped water markings,<br>• hairless and serrated,<br>• leaflets 2 cm long,<br>• long stipules, | • pink, rose or white colour;<br>• florets on short stalk,<br>• flower looks more open compared to red clover | • superficial taproot with many fibrous lateral branches |
| • 3 oblong-shaped leaflets,<br>• often have a white "V"-shaped watermark,<br>• hairy,<br>• leaflets 2-5 cm long (not on stalks),<br>• stipules red-veined | • red, pink, sometimes nearly white;<br>• tight group of florets | • superficial taproot with many fibrous lateral branches |
| • 3 roundish-shaped leaflets with serrations around margin,<br>• sometimes have white "V"-shaped watermark,<br>• hairless,<br>• shiny underside | • white,<br>• florets on short stalk,<br>• looks more open compared to red clover | • superficial shallow taproot with many fibrous lateral branches |

## INDIVIDUAL PASTURE LEGUMES

### Alfalfa

**Figure 6.15 Alfalfa. Trifoliate leaf (left). Individual leaflets are longer than wide. Serrated leaflet tips. Flower (right). Taproot (below).**

Alfalfa or lucerne (*Medicago sativa*) is a perennial legume that can last up to 5 seasons depending on management and growing conditions. It is generally grown as a forage legume rather than for pasture, but its high yield potential makes it attractive for intensively managed pastures. Research in Nova Scotia showed that alfalfa performed very well under rotational grazing as long as it was not grazed too short (exit heights of 10-12 cm) (Papadopoulos et al., 2005). It has excellent yield and palatability but poses a high risk of bloat in grazing animals. It requires good drainage and is less tolerant of acidic soils than trefoil or clover. Alfalfa seed will not germinate at pH < 6, and soil pH should be > 6.5 for optimum productivity. Given the acidic nature of much of Atlantic Canadian soils, lime should be applied periodically to pastures based on soil test results to maintain a pH between 6.0 and 6.5.

Established alfalfa is autotoxic to alfalfa seedlings, so stands will thin over time, and the alfalfa percentage cannot be increased without killing off the stand and reseeding after a break of at least a year. It is a deep-rooted legume that can better withstand the heat of summer and tolerate drought. It must be matched with a grass-like reed canarygrass or orchardgrass that will maintain productivity during the warm months of the summer to dilute the proportion of alfalfa consumed and manage the bloat risk. Winter survival is a concern, and soil prone to frost heave should be avoided. Grazing should be avoided during the fall rest period, as winter survival and spring regrowth will be affected (Suzuki et al., 1989). See Figure 6. 12 for the identified start dates of the fall rest periods for zones within Atlantic Canada. Do not graze short in the fall after the critical fall rest period, as this can impact overwintering or may slow spring regrowth (Suzuki et al., 1989).

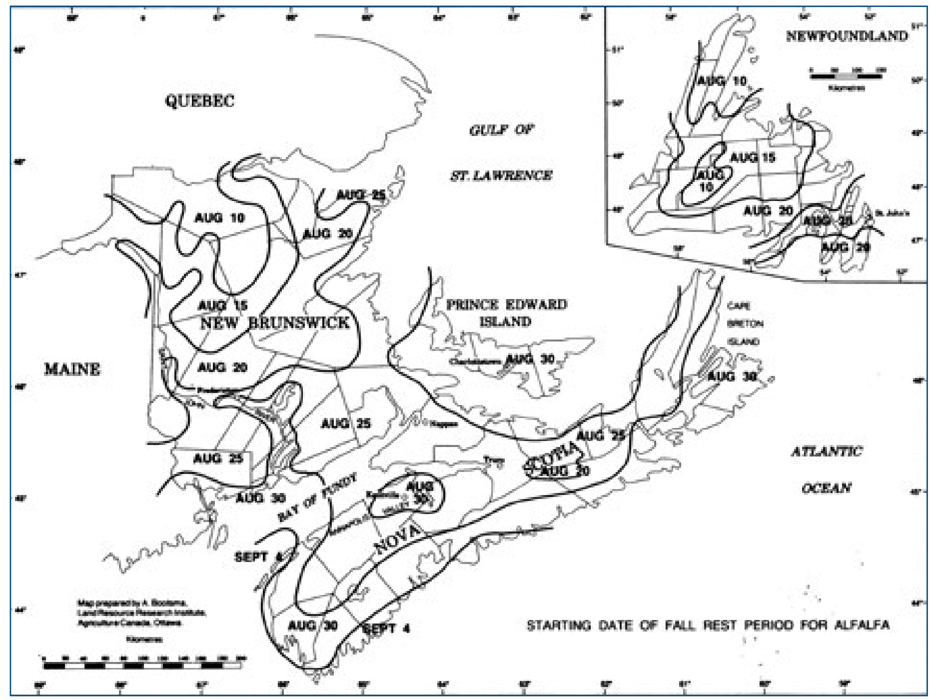



**Figure 6.16 Start date of the critical fall harvest period for alfalfa (Suzuki et al., 1989).**

## Alsike Clover

**Figure 6.17 Alsike Clover. Trifoliate leaf. No "V" shaped watermark on leaves (left). Serrated leaf margins. Hairless leaf. Pinkish flower (right).**

Alsike clover (*Trifolium hybridum*) is a quick growing perennial legume that may only survive two seasons. It withstands wet and moderately acidic soils. It can be used in soils considered too acidic for red clover. It is tolerant to flooding and is winter hardy but is not tolerant of drought. It is very palatable to livestock, but care must be taken with horses as it can cause photosensitivity at high levels of intake or enlarged liver with extended periods of intake. It can be useful for renovating pastures using frost seeding or by broadcasting seed to bare or thin areas in season. When converting wooded areas to pasture with minimum tillage, alsike clover can be used as it can establish on a range of soil types. (Elliott & Pankiw, 1972)

## Birdsfoot Trefoil

**Figure 6.18 Birdsfoot Trefoil. 5 leaflet leaf. Oval or lancelike shape.**

Birdsfoot trefoil (*Lotus corniculatus*) provides forage that is high in quality and poses no bloat hazard to grazing animals. The condensed tannins that prevent bloat with birdsfoot trefoil also improve protein utilization. They protect protein from being broken down in the rumen so that the animal gets a higher quality protein. Horses sometimes find it unpalatable in pastures due to the bitterness of the tannins, but this has not been observed in sheep or cattle. It is very adaptable to moderately acidic soil as well as soils with variable drainage. It is tolerant to flooding, provided it does not lead to ice sealing in winter. However, trefoil is slow to establish and has slow spring growth and regrowth. Newer cultivars have been bred with better seedling vigour, improving seeding success. It can fit well in a rotational grazing system for paddocks that will be grazed later. It does not tolerate close grazing without adequate recovery time. Winter survival will be poor if soil P levels are low, but otherwise, it is very winter-hardy. To improve winter survivability, sufficient rest should be given before the first frost. It can be frost-seeded or drilled into pastures to increase the legume content, provided that the competition from existing grasses is managed. Birdsfoot trefoil is a good seed producer and can reseed itself if allowed to go to seed at some point in the annual grazing rotations.

**Figure 6.19 Red Clover. Trifoliate leaf. Occasional "V" shaped watermark (left). Hairy leaves and stems (right).**

Red clover (*Trifolium praetense*) is a biennial or short-lived perennial lasting for two to three seasons. It comes in two forms: single cut or double cut red clover. Single-cut varieties flower later in the season and typically produce a single high yielding crop per season and are less preferred for grazing. Double-cut varieties flower earlier in the season and have rapid spring growth and better regrowth than single-cut varieties, allowing for repeated grazings in a season. Double-cut red clover is less winter hardy than single cut red clover. It has an excellent first-year yield; however, the stands thin after two years. It is high in quality and easy to establish, with good tolerance to acidic and variably drained soils. Red clover is better suited for acidic soils or variably drained soils than alfalfa; however, it is less tolerant than alsike clover to these same conditions (Fairey, 1977). Unfortunately, it is susceptible to a complex of crown and root rots leading to a need to reseed frequently. Because of its ease of establishment and competitive growth, it can be frost-seeded and overseeded into pastures, helping to improve the quality and yield of established pastures.

On the cautionary side, red clover can cause bloat in grazing animals. It is possible, but uncommon, for red clover's phytoestrogens to cause fertility issues in ewes if a very high-red clover content pasture is grazed around the time of breeding. Cows seem less susceptible to this issue. Local research showed that this was unlikely to be an issue at 30% red clover or lower (Graves et al., 2012).

### White Clover

**Figure 6.20 White Clover. Trifoliate leaf. Occasional "V" shaped watermark (left). Hairless stems and leaves (right).**

White clover (*Trifolium repens*) comes in three forms. Ladino clovers have the largest leaves and tallest growth; intermediate clover (common or white Dutch) have intermediate-sized leaves; and native clover (wild white or microclover) has the smallest leaves. White clover has excellent palatability and quality, but like most legumes, it may cause bloat at high concentrations. Its tolerance to soil acidity and poor drainage is intermediate between alfalfa and trefoil; however, it is not tolerant to heat or extended periods of drought or flooding. It is generally persistent from season to season if environmental conditions are met. Because the stems of white clover are prostrate, with the leaves and flowers carried on long petioles arising from the leaf nodes, it is tolerant of close grazing (down to 5 cm height). To maximize productivity while managing bloat hazard, white clover should be mixed with a forage grass that will maintain productivity during the summer (orchardgrass or reed canarygrass). Since livestock will preferentially graze the clover, pasture managers will need to watch the height of both the clover and the grasses to ensure both species are being utilized effectively; if the grasses are grazed down to the same height as the clover, they will be slow to recover. Adequate rest periods between grazing (grasses reach 20-25 cm height) are needed to maintain the productivity of both the legume and grass.

## PASTURE MIXES FOR THE MARITIME PROVINCES

To decide how to improve a pasture (grazing management improvements, rejuvenation, or complete reseeding), consult Chapter 5 – *Pasture Establishment and Renovations*. Once it has been decided to add new species into a pasture, choosing the right grasses and legumes requires some thoughtful planning. The reward for getting it right is a more efficient pasturing system, one that is more productive, has a longer season and fewer associated input and supplemental feed costs.

When choosing a pasture mixture, consideration must be given to a number of factors: forage persistence, soil drainage, grazing intensity, soil fertility, and the compatibility of plant species with one another.

Forage species have evolved or been bred to perform differently under different environments and production systems. The species chosen needs to fit the field characteristics and local weather conditions while also accounting for management and production systems. Species that do not match with the above considerations can lead to lower productivity, may impact financial returns and can be costly to correct in time and money. Additional information can be found by visiting the Beef Cattle Research Council's (BCRC) online Forage U-Pick tool, which can provide forage recommendations for Eastern Canada based on soil conditions and production system.

It is recommended that pastures contain a mixture of grasses and legumes. The physical structures of grasses and legumes can complement one another, optimizing the capture of sunlight and below-ground moisture and nutrients. The combination of the two provides a balance of productivity and high-quality feed. Choosing to grow only grasses is an option if the soil conditions (pH < 5.5) do not favour legume establishment and productivity.

**Figure 6.21 Mixture of grasses and clovers.**

Legumes are known for their ability to fix N through their symbiotic relationship with specific soil bacteria. This process can provide N for the legumes as well as nearby grasses. Typically, forage stands containing at least 50% legumes on an above-ground biomass basis can supply enough N to completely replace synthetic N fertilizer application. This is important to note for organic producers or others who choose not to use synthetic N fertilizer – it can be a challenge to maintain such a high proportion of legumes in a pasture. Stands containing more than 30% but less than 50% legumes on an above-ground biomass basis may require additional N provided through outside sources to reach full yield potential. While stands containing less than 30% legumes will benefit from N applications to improve grass yields.

See Chapter 4 (*Nutrient Management and Pasture Fertility*) for fertilizer recommendations.

Improving legume content in a pasture can reduce the need for expensive N fertilizers while also improving overall pasture productivity and feed quality. Legumes typically provide higher protein than grasses and perform better during the hot and dry summer months. They can help provide feed for animals when cool-season grasses are dormant from the heat. Persistence can be an issue as animals prefer legumes to grasses, and if given the opportunity, animals will re-graze a young legume before it has fully recovered. This can require reintroduction of legumes to pastures if rest and recovery periods are inadequate.

Mixtures do not need to be complicated, and a combination of 3-5 species can provide balanced growth and production throughout a season. More complex and multifunctional "cocktail mixes" may also be used. However, mismatches in the ideal time for harvesting, the timing of maturity, the suitability of species to the field, and the persistence of different species may leave holes in the stand that the recommended mixtures below are made to avoid. Using complex mixtures across a pasture can allow species suited to the different growing conditions within a field to establish and perform in conditions best suited to them. Producers take on the risk that not all species within the mix may establish, perform or persist within the field and are, therefore, paying for seed that will not perform.

Recommended species will change depending on the choice of pasture management system, and not all paddocks necessarily need the same mix of species. A well-drained south-facing slope, for example, might be seeded to an orchardgrass-white clover mixture for early grazing in the spring, while a poorly drained field might be better with a trefoil-based mix even though the pasture regrowth will be slower. Timothy is not generally recommended for grazing due to its slow regrowth in mid-summer. However, it will establish easily, and so might be included in mixes as "insurance" against bare spots.

Table 6.3 lists some cool-season species options for the Maritime Provinces and the characteristics that should be taken into consideration when deciding which ones are best suited to a specific pasture. Seeding rate information can also be found in Table 6.3.

Table 6.3 Characteristics of perennial cool-season grasses and legumes as a potential for pastures.

| SPECIES | * WINTER HARDINESS | DROUGHT TOLERANCE | POOR DRAINAGE | LOW PH TOLERANT | PERSISTANCE | PALABILITY | TOLERANCE TO FREQUENT GRAZING | ** SEEDING RATE (KG/HA) | EASE OF ESTABLISHMENT | **** RELATIVE MATURITY |
|---|---|---|---|---|---|---|---|---|---|---|
| **Bromegrass, meadow** | H | H | M | L | H | H | H | 12 | M | E |
| **Bromegrass, smooth** | H | H | L | L | M | H | L | 12 | L | M-L |
| **Fescue, meadow** | H | H | H | H | H | M | H | 15 | M | E |
| **Fescue, creeping red** | H | H | H | M | H | N/A | H | 12 *** | H | E |
| **Fescue, tall** | M | H | H | H | H | M-L | H | 15 | M | M |
| **Festulolium (annual ryegrass x meadow fescue)** | H-L | H-M | H | H-M | H-L | H-M | H | 20 | H-M | E |
| **Festulolium (annual ryegrass x tall fescue)** | M-L | H-M | H | H-M | H-L | H-L | H | 20 | H-M | M |
| **Festulolium (perennial ryegrass x tall fescue)** | M-L | H-M | H-L | H-M | H-L | H-L | H | 15 | H-M | M-L |
| **Festulolium (perennial ryegrass x meadow fescue)** | H-L | H-M | H-L | H-M | H-L | H-M | H | 15 | H-M | E-M-L |
| **Kentucky bluegrass** | H | L | L | M | H | H | H | 8 *** | M | E |
| **Orchardgrass** | M | H | H | L | H | H-M | H | ‘8-10 | H | E |
| **Quackgrass** | H | H | H | H | M | H | H | N/A | L | E |

| SPECIES | * WINTER HARDINESS | DROUGHT TOLERANCE | POOR DRAINAGE | LOW PH TOLERANT | PERSISTANCE | PALABILITY | TOLERANCE TO FREQUENT GRAZING | ** SEEDING RATE (KG/HA) | EASE OF ESTABLISHMENT | **** RELATIVE MATURITY |
|---|---|---|---|---|---|---|---|---|---|---|
| **Redtop** | H | H | H | H | H | H | H | 10 *** | L | E |
| **Reed canarygrass** | H | H | H | M | H | M-L | M | 12 | L | E |
| **Ryegrass, annual** | L | M | H | M | L | H | H | ‘25-35 | H | ***** |
| **Ryegrass, perennial** | L | M | L | M | L | H | H | 12 | H | M-L |
| **Timothy** | H | L | H | M | M | H | L | ‘8-10 | H | E-L |
| **Alfalfa (lucerne)** | M | H | L | L | M | H | M | ‘10-12 | M | M |
| **Birdsfoot trefoil** | M | M | H | M | H | H | H | 9 | L | L |
| **Clover, alsike** | H | M | H | H | M | H | M | 9 *** | H | E |
| **Clover, red** | H | M | M | M | M | H | L | 11 | H | M |
| **Clover, white** | H | L | L | M | H | H | H | 5 *** | M | L |

* Winter hardiness H=high, M=medium, L=low
** Recommendation is for seeding a pure stand; when seeding in a mixture or into an established sward, reduce the seeding rate by 1/3 or more depending on complexity of mixture
*** Not recommended to seed as a pure stand
**** Relative maturity E=early, M=medium, L=low
***** Italian type (annual ryegrass) is recommended as it remains vegetative in year of seeding

Variation in growing patterns occurs over seasons as well. The following table (Table 6.4) outlines which species perform best over different portions of the growing season.

**Table 6.4 Species that perform best in the given season.**

| EARLY SPRING | LATE SPRING |
|---|---|
| Meadow bromegrass | Meadow bromegrass |
| Orchardgrass | Orchardgrass |
| Kentucky bluegrass | Kentucky bluegrass |
| Red fescue | Reed canarygrass |
| White clover | Perennial ryegrass |
| | Red fescue |
| | White clover |
| **EARLY SUMMER** | **MID-LATE SUMMER** |
| Meadow bromegrass | Meadow bromegrass |
| Orchardgrass | Orchardgrass |
| Timothy | Meadow/tall fescue |
| Meadow/tall fescue | Reed canarygrass |
| Reed canarygrass | Alfalfa |
| Perennial ryegrass | Red clover |
| White/Red clover | Birdsfoot trefoil |
| Birdsfoot trefoil | |
| **EARLY FALL** | **LATE FALL** |
| Kentucky bluegrass | Kentucky bluegrass |
| Tall fescue | Tall/meadow fescue |
| Reed canarygrass | Reed canarygrass |
| Red clover* | Red clover* |

***Grazing legumes during the fall rest period is detrimental to their persistence.**

Given the great variability of soil types and topography across Atlantic Canada, complex mixtures of several grasses are recommended to take advantage of the different conditions that may exist within a single pasture. The following table (Table 6.5) gives some recommended mixtures for different grazing management systems, from good through to poor drainage conditions. Producers can either bring these suggested mixes to a local seed supplier and have them recommend specific varieties suited for the producer's needs, or they can order pre-made mixes from seed suppliers.

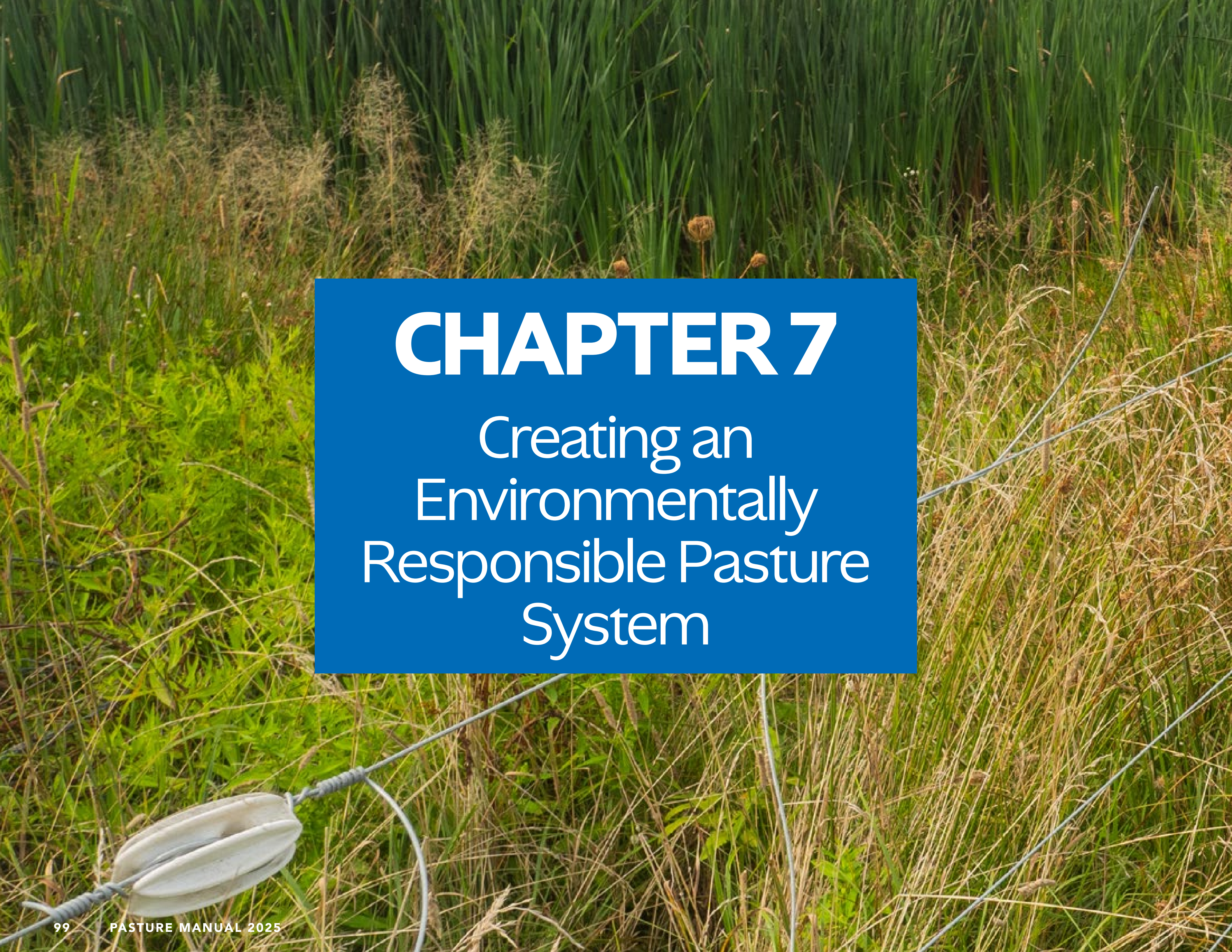

Figure 6.22 Cow eating forage mixture.

**Table 6.5 Recommended mixtures for Atlantic Canadian pastures of varying drainage and grazing intensity. Recommended seeding rate for each mixture is 15-20 kg/ha.***

| | CONTINUOUS GRAZING<br><6 paddocks | ROTATIONAL GRAZING<br>6-12 paddocks | INTENSIVE ROTATIONAL<br>>12 paddocks |
|---|---|---|---|
| GOOD DRAINAGE | • Kentucky bluegrass (35%)<br>• Meadow bromegrass (25%)<br>• Perennial ryegrass (25%)<br>• White clover (15%) | • Orchardgrass (20%)<br>• Perennial ryegrass (20%)<br>• Tall fescue (15%)<br>• Meadow bromegrass (15%)<br>• Alfalfa (20%)<br>• White clover (10%) | • Orchardgrass (25%)<br>• Meadow fescue (25%)<br>• Kentucky bluegrass (25%)<br>• Reed canarygrass (10%)<br>• White clover (15%) |
| | • Timothy (30%)<br>• Kentucky bluegrass (25%)<br>• Meadow fescue (25%)<br>• White clover (20%) | • Timothy (30%)<br>• Kentucky bluegrass (25%)<br>• Meadow fescue (25%)<br>• White clover (20%) | • Timothy (25%)<br>• Meadow fescue (25%)<br>• Perennial ryegrass (20%)<br>• Meadow bromegrass (15%)<br>• White clover (15%) |
| | • Kentucky bluegrass (40%)<br>• Reed canarygrass (40%)<br>• White clover (20%) | • Timothy (40%)<br>• Kentucky bluegrass (40%)<br>• White clover (20%) | • Timothy (20%)<br>• Meadow fescue (20%)<br>• Kentucky bluegrass (20%)<br>• Alfalfa (25%)<br>• White clover (15%) |
| | | • Kentucky bluegrass (30%)<br>• Reed canarygrass (30%)<br>• Birdsfoot trefoil (30%)<br>• White clover (10%) | • Orchardgrass (40%)<br>• Meadow fescue (40%)<br>• White clover (20%) |

| | CONTINUOUS GRAZING<br><6 paddocks | ROTATIONAL GRAZING<br>6-12 paddocks | INTENSIVE ROTATIONAL<br>>12 paddocks |
|---|---|---|---|
| IMPERFECT DRAINAGE | • Timothy (30%)<br>• Kentucky bluegrass (30%)<br>• Birdsfoot trefoil (30%)<br>• White clover (10%) | • Timothy (25%)<br>• Reed canarygrass (20%)<br>• Kentucky bluegrass (20%)<br>• Birdsfoot trefoil (25%)<br>• White clover (10%) | • Timothy (20%)<br>• Reed canarygrass (15%)<br>• Kentucky bluegrass (15%)<br>• Meadow fescue (20%)<br>• Birdsfoot trefoil (20%)<br>• White clover (10%) |
| | • Tall fescue (35%)<br>• Kentucky bluegrass (30%)<br>• Birdsfoot trefoil (25%)<br>• White clover (10%) | • Tall fescue (30%)<br>• Kentucky bluegrass (20%)<br>• Timothy (20%)<br>• Birdsfoot trefoil (25%)<br>• White clover (10%) | • Timothy (20%)<br>• Kentucky bluegrass (20%)<br>• Meadow fescue (25%)<br>• Birdsfoot trefoil (25%)<br>• White clover (10%) |
| | | • Timothy (30%<br>• Kentucky bluegrass (30%)<br>• Birdsfoot trefoil (30%)<br>• White clover (10%) | • Tall fescue (35%)<br>• Timothy (30%)<br>• Birdsfoot trefoil (25%)<br>• White clover (10%) |
| | | • Timothy (30%)<br>• Reed canarygrass (30%)<br>• Birdsfoot trefoil (30%)<br>• White clover (10%) | • Tall fescue (35%)<br>• Meadow fescue (30%)<br>• Birdsfoot trefoil (25%)<br>• White clover (10%) |
| POOR DRAINAGE | • Tall fescue (25%)<br>• Timothy (20%)<br>• Kentucky bluegrass (25%)<br>• Birdsfoot trefoil (30%) | • Tall fescue (25%)<br>• Timothy (20%)<br>• Kentucky bluegrass (25%)<br>• Birdsfoot trefoil (30%) | • Tall fescue (25%)<br>• Timothy (20%)<br>• Kentucky bluegrass (25%)<br>• Birdsfoot trefoil (30%) |
| | • Timothy (20%)<br>• Reed canarygrass (20%)<br>• Kentucky bluegrass (30%)<br>• Birdsfoot trefoil (30%) | • Timothy (20%)<br>• Reed canarygrass (20%)<br>• Kentucky bluegrass (30%)<br>• Birdsfoot trefoil (30%) | • Timothy (20%)<br>• Reed canarygrass (20%)<br>• Kentucky bluegrass (30%)<br>• Birdsfoot trefoil (30%) |

***Adapted from McElroy, M., B. Thomas and Y. Papadopoulos. "Pasture Mixtures for Atlantic Canada". Center for the Advancement of Pastures (CAP), Nova Scotia Agricultural College, Truro, NS, 2009.**



# CHAPTER 7

## Creating an Environmentally Responsible Pasture System

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# Creating an Environmentally Responsible Pasture System

When designing pastures, there are several factors to consider that will impact the environmental load. A well-designed, well-managed pasture can provide several ecosystem services, including carbon sinks, wildlife habitat and sensitive area protection. A poorly managed pasture can increase greenhouse gas emissions (GHGs), pollute watercourses and damage soil. In addition, poorly managed pastures will likely lead to poor profits; all efforts should be made to decrease the environmental footprint of our pastures.

Pastures get a mixed review for their environmental performance, particularly in regard to GHGs. The precise impact on GHG emissions will depend on local conditions and pasture management. Still, it is clear that well-managed pastures will provide a wide range of environmental benefits, particularly when compared to row crops. Perennial plant cover protects the soil from erosion and allows better water infiltration than cropped soils. The root exudates support a large and diverse microbial population in the rhizosphere, leading to improved soil structure and C sequestration. Pastures also provide habitat for a wide range of beneficial insects and a number of grassland birds like the bobolink and plover.

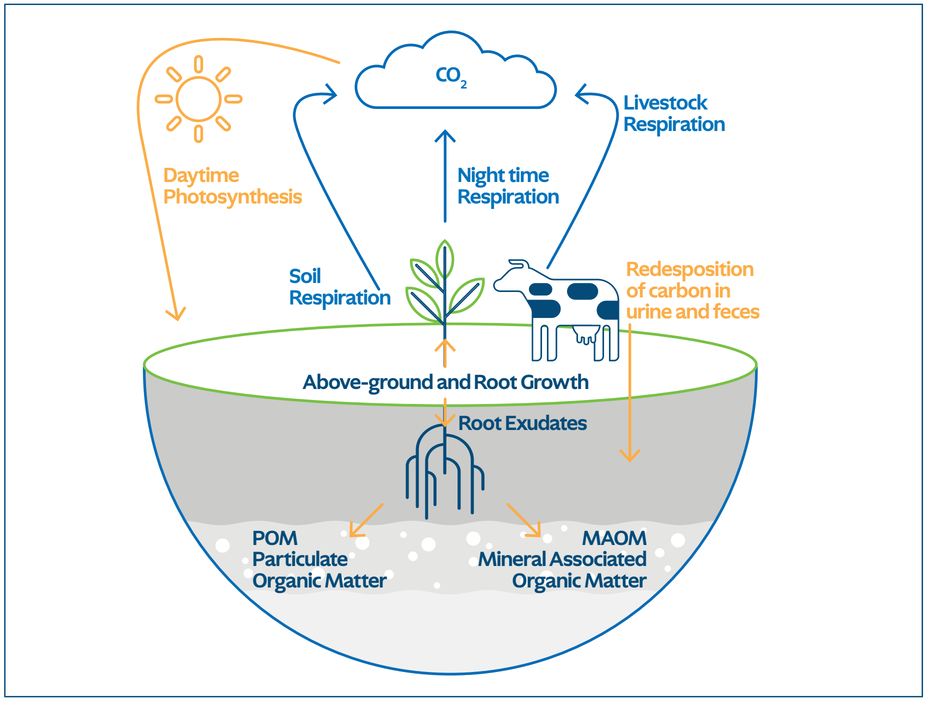



**Figure 7.1 The carbon cycle in pasture systems.**

To realize these benefits requires careful management, and poorly managed pastures can negate these benefits and add additional environmental risks. Over-grazing doesn't leave enough vegetation to provide adequate ground cover and opens the canopy to allow weedy species to establish. Cattle grazing in riparian areas can damage the integrity of streambanks as well as defecate directly into the stream causing bacterial contamination. Sound management of pastures will balance productivity with environmental benefits. This chapter discusses how you can lighten your ecological footprint while improving your bottom line.

## PROTECTING SURFACE WATER QUALITY

Keeping surface water clean involves two practices: grazing management within the paddocks and riparian area management. These are complementary but require different approaches.

### Paddock Management

The most visible symptom of surface water impairment is sediment leaving the field from soil erosion, and this runoff can also carry nutrients and bacteria, which are equally harmful if less visible. The more water that soaks into the soil rather than running off, the fewer contaminants can be carried off the field during a rainstorm or spring thaw. A side benefit is that the slower travel of groundwater to the stream will maintain stream flows during dry periods with cooler water, improving fish habitat.

The enemy of water infiltration is poor soil structure; in pastures, this is created by excess hoof traffic combined with weak aggregation of the soil. The first line of defence is to build the resilience of the soil aggregates so they are not as easily broken down by hoof traffic. The way to build strong soil aggregates is to maintain a healthy cover of vegetation; the root biomass mirrors what is happening above ground.

When plants are actively growing, there is more photosynthesis, so carbohydrates are available to be sent down to the roots, and the plants use these to grow more roots to support the need for water and nutrient uptake by the plant. The roots also excrete some of the photosynthate to support microbial populations in the surrounding soil. During grazing or clipping, part of the top growth is removed so there is less photosynthate to feed the roots and the plant will slough off root biomass. These dead roots become food for fungi, bacteria and other soil organisms. Under a rotational grazing system, the recovery period of the pasture allows new top growth that leads to a flush of new root growth. All of this biological activity creates the lattice of fungal hyphae and dead roots combined with the sticky compounds in microbial exudates to build stable aggregates.

For organic producers, the Canadian Organic Standard (CGSB 2020) requires "construction and management of pasture ... to avoid soil degradation, long-term damage to vegetation and the contamination of water" (Clause 6.7.1 j) and that manure management practices in pastures "shall be implemented in a manner that minimizes soil and water degradation" (Clause 6.8.1). These clauses mean that the organic inspector can ask how surface water quality is being protected; it must be included in a producer's organic plan. However, it doesn't always specify how it needs to be done - the methods will be the same as what is described in this chapter, it is a matter of documenting and demonstrating it each year.

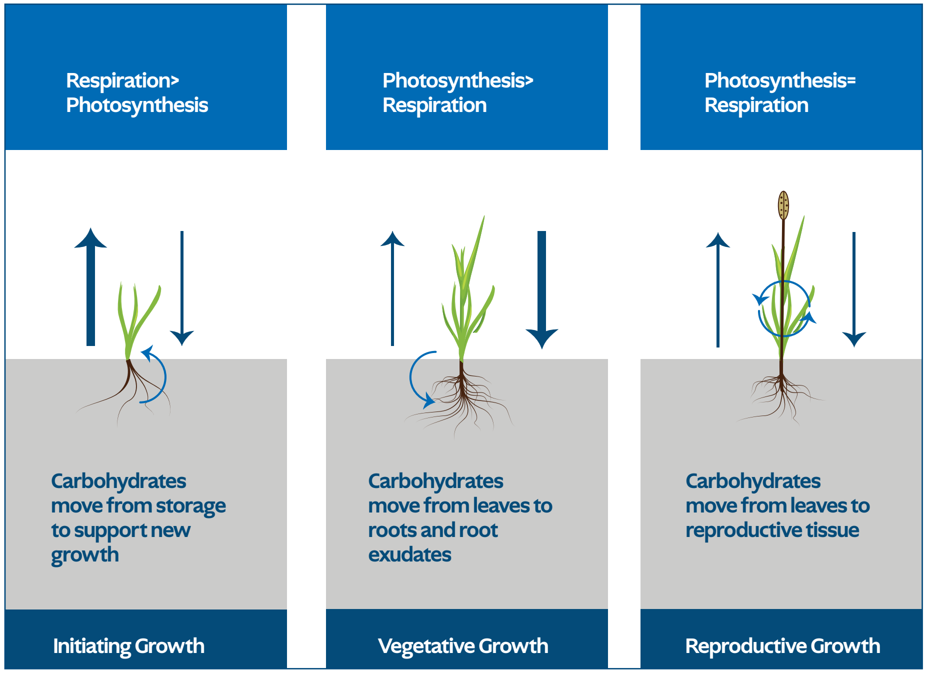



**Figure 7.2 Carbon dynamics of pasture maturity. This movement of carbon can be manipulated through careful grazing.**

In contrast, continuous over-grazing limits root regrowth. The pasture is not only susceptible to drought stress and poor nutrient uptake because of inadequate roots, but the soil aggregates will be weaker, breaking down when there is heavy rain or hoof traffic. The principles of adaptive rotational grazing not only improve the productivity of the pasture but the environmental sustainability as well.

Even with strong soil aggregates, excessive hoof traffic can destroy soil structure, particularly when the soil is wet. Areas where traffic is concentrated are particularly vulnerable to pugging: laneways, gateways into paddocks, and around waterers or feeders. Once the soil structure has been destroyed, plants have a hard time re-establishing, and drainage is slowed, so the damage is repeated each time there is rain.

Ideally, livestock would be excluded from pastures whenever the soil was too wet to support them, but this is seldom practical, particularly as wet soil conditions often coincide with rapid pasture growth that needs to be eaten before it gets over-mature. Experienced graziers will shorten the length of time the animals are left in a paddock and/or increase the size of the paddock in wet conditions. This is a key part of management-intensive grazing: adapting to the conditions. Although there will be a trade-off in future pasture quality if a paddock is grazed more lightly, it is worth it to protect the pasture and the surrounding environment. Some of the risks can also be mitigated when laying out the paddock system, so gates and water troughs are located in well-drained areas rather than in hollows where water accumulates. Hay or mineral feeders in the paddocks should be moved regularly to allow the vegetation to recover.

**Are you treating your soil like a pottery factory?**

One of the tools for preparing clay for making pottery is a pugging mill, which repeatedly punches and mixes the moist clay to homogenize it. This is exactly the same action a herd of cattle or sheep will do to a wet soil, destroying the network of pores that would allow the soil to drain and plants to grow. It is unclear if pugging in pastures got its name from the mill in the pottery factory, or vice versa, but it is clear that this is something to avoid.

Providing a "sacrifice paddock" is also an option, where the area that receives the worst damage is limited, and the other paddocks are spared. Since runoff will be increased from these sacrifice areas, keep them away from surface water to limit the movement of sediment and nutrients from the pasture into streams or lakes. For organic producers, who are generally required to give livestock access to pasture in season and to the outdoors year-round, there is an exception that animals can be brought inside temporarily if the conditions are threatening soil, water or plant quality (Clause 6.7.2c, CGSB, 2020). But they also need to show that they are taking measures to enable year-round outdoor access if it is under their control.

Maintaining good vegetative cover and stable soil structure will reduce the amount of runoff from pastures by increasing infiltration, but it will not eliminate it completely. Manure, either spread on the field or deposited directly by livestock, is a source of nutrients and bacteria; the risk of transport is greater from a concentrated source, so managing to avoid manure buildup in small areas (e.g., feeders or water sources) by moving them regularly can help to mitigate this. Similarly, avoid over-application of fertilizer or manure that could create nutrient buildup and lead to runoff. Fortunately, the year-round plant cover in a well-managed pasture is an effective erosion control, but over-grazing can lead to the risk of soil loss and sediment transport.

If you are applying supplemental fertilizer or manure to a permanent pasture, it is difficult or impossible to incorporate the material into the soil. A concentrated source of nutrients sitting on the soil surface will increase the risk of nutrient runoff under conditions of heavy rain or snowmelt. Limit nutrient applications to what the plants need so there is not a lot of extra vulnerable to runoff. Choose the timing of nutrient applications carefully. Nitrogen, if needed, should be applied close to when the grasses are actively growing so it is absorbed immediately. Phosphate fertilizer should be applied when the risk of runoff is low, during the period from late spring to mid-summer, giving the fertilizer a chance to react and bind with the soil before the fall rains.

The organic standards require producers to document the details of manure, compost and other amendment applications. They need to demonstrate that they are following responsible nutrient management and, specifically, that they are applying manure when the soil is "sufficiently warm and moist to ensure active bio-oxidation" (Clause 5.5.2.3, CGSB, 2020). Organic producers aren't permitted to apply manure at a rate or time of year that would lead to significant runoff into waterways, and the annual inspection will check their records to make sure.

## RIPARIAN ZONE MANAGEMENT

### What is a riparian zone?

A riparian zone is a transitional area separating aquatic ecosystems (including lakes, rivers, streams, ponds and wetlands) and upland terrestrial ecosystems (Cameron, 2001; Gregory et al., 1991), in this case, pasture. Riparian zones play diverse and valuable functions within an ecosystem. In general, a riparian zone protects the watercourse and increases its sustainability as an ecosystem and as a source of quality water. Several key functions include acting as a barrier to human activity, providing wildlife habitat and protecting the watercourse and water quality by filtering nutrients and bacteria (Cameron, 2001).

Many human activities in upland areas can harm the ecological integrity of watercourses, and while agricultural studies have shown that pasture is less damaging to watercourses than annual or perennial cropping systems (Clark, 1998), there is still a risk to be mitigated.

The benefits of riparian buffer zones are diverse and far-reaching. First and foremost, riparian areas increase the water quality of a watercourse and maintain the integrity of the stream channel so it can function properly. The various levels of vegetation within the riparian zone help to maintain water quality by trapping sediments and filtering out harmful pollutants. The same vegetation strengthens streams and riverbanks by binding soil with the roots, shielding banks from erosion, and repairing annual damage with sediment deposition (Platts, 1991; Platts, 1990; Thomas et al., 1979). Streambank vegetation stabilizes the streambank and helps prevent streams from widening or changing course (Bellows, 2003). This also reduces the need for implementing expensive shoreline protection. The shade provided by the riparian zone plant life keeps the water cool. Overhanging vegetation provides shelter for fish and other aquatic organisms. The contrast between the riparian area plant community and the surrounding upland range vegetation adds to structural diversity over the landscape (Thomas et al., 1979). Riparian areas also act as carbon sinks, with the vegetation storing carbon. Once well established, part of the riparian zone can provide a highly productive forage supply for livestock (Fitch & Adams, 1998).

Keeping livestock away from the watercourse has a positive impact on animal health. When livestock are contained in pasture, out of riparian zones, they spend more time feeding and less time in muddy and wet conditions, which results in a reduced incidence of mastitis, fewer injuries and less foot rot (Cameron, 2001).

Healthy riparian areas are well-vegetated with a diverse group of plants that have a deep binding root mass and have the age classes of vegetation that allow for regrowth. The species found in a riparian zone vary depending on the location of the riparian zone and the water body on which it borders.

The health of a riparian zone can be measured through the number of native species growing in the zone, the abundance of shade-providing trees, the presence of multi-age plants, the presence of wooded debris and the lack of bare ground. Conversely, riparian zone health can also be measured by the lack of specific characteristics. AAFC (2003) has listed the characteristics of unhealthy riparian zones as outlined in Table 7. 1.

**Table 7.1 Unhealthy Riparian Zone Characteristics (AAFC, 2003).**

| CHARACTERISTIC | CAUSE | EFFECT |
|---|---|---|
| **An abundance of weeds and non-native plant species** | Removal of native vegetation | • Less deep binding root mass<br>• Stream banks become unstable and erode |
| **A lack of shade providing trees** | Logging of trees | • Promotes greater sunlight penetration, leading to warmer stream temperature and decreased capacity to hold dissolved oxygen<br>• Increase algal growth<br>• Decrease abundance of aquatic organisms |
| **A lack of tree saplings** | Over-grazing | • Mature trees are not replaced |
| **Large areas of bare ground** | Trampling by livestock | • Slumping and erosion of bare ground<br>• Increases sediments in stream, reducing water quality |
| **A lack of large woody debris** | Removal of woody debris | • Limits habitat for fish and other aquatic organisms |

There is often more than one source that contributes to riparian degradation, and they tend to interact with one another, making it difficult to isolate what is causing the harm. Cultivation, timber harvest, water management, urban development, flood and erosion control, in addition to livestock grazing, may all negatively impact a water course.

## Managing riparian zones adjacent to pastures

Grazing livestock affects the soils and vegetation which they have access, both through trampling and eating the biomass. The severity of this impact will depend on the amount of grazing pressure and the sensitivity of the grazed area. Riparian areas may be more sensitive to disturbance because the soil tends to stay wetter, and they may also receive selective grazing pressure during hot, dry weather as upland pasture productivity declines and livestock may prefer shaded areas near streams.

Allowing livestock free access to riparian zones can result in the following:

1. Damage to the stream channel form and structure, and soil stability and structure in the riparian zone. The water column is altered by increasing water temperatures, the addition of nutrients and suspended sediments and alterations in the timing and volume of flow. Soil compaction on the floodplain from hoof action decreases infiltration rates and leads to increased runoff, accelerated erosion and higher sedimentation rates.
2. Decreased vigour and biomass of vegetation, an alteration of species composition and diversity and losses of some vegetation components, especially trees and shrubs.
3. A decrease in fish and wildlife species and numbers following overgrazing of riparian areas.

Much of the current literature on livestock impact on watercourses pertains to the arid and semi-arid zones of western North America. In regions with higher rainfall, herd behaviour may differ, such as the frequency of drinking, duration of lounging near a water source and the degree of reliance on the riparian zone (Clark, 1998). Agouridis et al. (2005) reviewed the literature pertaining to livestock grazing impacts on water quality and found a wide range of responses depending on the interaction between grazing management and climate. A study done by Bremner (2008) in Nova Scotia compared two scenarios: cattle having full access to waterways, versus cattle with restricted access to waterways, using special structures to limit their access. Results varied with each situation and structure; however, they suggest that providing controlled access could reduce bacterial load to the water course if the access location is properly sited, designed, and managed. For more information, see the Soil & Crop Improvement Association of Nova Scotia and the Nova Scotia Environmental Farm Plan's factsheets titled "Providing Water with Limited Access Ramps", "Water Quality Impact of Cattle Access to Watercourses," and "Do Limited Access Ramps Improve Water Quality?"

The Nova Scotia Department of Agriculture has defined minimum setbacks from watercourses to be five metres for spreading manure. Biologists suggest a setback of 10 to 15 m to create a healthy and biodiverse riparian zone.

Appropriate management of the riparian areas, then, will depend on the grazing intensity:

- Low-intensity extensive grazing (less than 0.5 animal units (AU) per acre. Impacts on stream water quality and riparian vegetation are likely to be minor and temporary in most cases.
  - » Avoid grazing during the "shoulder seasons," when soils are more likely to be wet, leading to an increased risk of compaction. If supplemental feed is supplied, keep feeders away from riparian areas and move them regularly to allow vegetation in those areas to regenerate.
- Moderate intensity grazing (0.5 – 1 AU/ac). Grass riparian zones may tolerate this grazing pressure, but forest cover is unlikely to regenerate. Sloughing of stream banks may become evident, along with increased sediment load to streams.
  - » Limit access of livestock to the stream, particularly stream crossing. This may take the form of fencing along one side of the stream or both. Areas with access to watering should have hardened surfaces. Provide access to water as well as shade and supplemental feed away from the water to discourage livestock from congregating near the stream. Streambed-level livestock crossings should have hardened surfaces to prevent the suspension of sediment in the stream water.
- High-intensity grazing (> 1 AU/ac). Uncontrolled access to riparian areas is likely to cause severe damage to vegetation and streambanks. Fouling of stream water with urine and feces is likely.
  - » Livestock should be excluded from riparian areas, with alternative sources of water provided. The exclusion zone should be wider if the livestock are under continuous rather than rotational grazing, as the amount of nutrients and sediment to be filtered out of runoff water will be greater. Livestock crossings should be over culverts or bridges to maintain the integrity of the streambed.

With any of these systems, monitoring of the condition of the riparian zone is essential, so if damage is occurring the livestock can be excluded to allow the vegetation to regrow. Trees and shrubs will be more sensitive to grazing and trampling damage than grasses.

### Is riparian zone grazing appropriate?

A common objection to excluding livestock from riparian zones is the loss of grazing land, especially if the stream meanders so the only practical fencing design encloses a significant area. Can this "lost" forage be used without destroying the riparian zone? The answer appears to be a qualified "yes", provided some rules are followed:

- Soils must be dry enough to support the weight of the livestock without pugging, so the available grazing period will be shorter than for upland pastures.
- The goal is to harvest the forage rather than provide a playground, so a high stocking rate for a short time period is ideal.
- Leave adequate top growth on the forages (minimum of 4") to allow rapid regrowth.
- Monitor closely to ensure livestock are not damaging trees or shrubs.

One caution is that riparian areas may have plant species growing in moist soils or woodlands that are toxic for livestock. Animals with nothing else to eat will consume plants they would normally avoid; one more reason to avoid over-grazing riparian areas.

### Protecting Groundwater Quality

The contaminants of concern for groundwater are $NO_3$- and bacteria, both of which impair drinking water quality. With increased water infiltration under pastures, there is more potential for transport of these materials to groundwater. Still, fortunately, the source of these contaminants in most pasture systems is low enough that they are not a concern. It is only in a few exceptional areas that caution is needed.

The exception for $NO_3$- is where there is application of high rates of N, either as mineral fertilizer or manure. Actively growing grass will absorb a lot of N, so the $NO_3$- concentration in pasture soils is generally very low. Still, N applications late in the season can leave N in the soil when the plants are not actively absorbing it, leading to N leaching over the winter. Be sure the N application timing matches plant requirements.

Soil is a very effective filter for bacteria, but the filtering capacity is limited in shallow soils over fractured bedrock. Bacteria deposited in feces during the summer die off quickly, but they survive much longer when the temperature cools down. Avoid grazing paddocks with shallow soils late in the fall to minimize the risk that these surviving bacteria can seep into groundwater.

## PASTURES FOR GREENHOUSE GAS REDUCTIONS

Cattle are major sources of methane ($CH_4$) production in agriculture due to the enteric fermentation process in their rumen. As a result, they are frequently used as an icon of climate destruction by the media. However, grazing cattle on improved pastures can provide several environmental services when done thoughtfully. Proper management of permanent pastures sequesters carbon from the atmosphere into stores in the soil.

It is complex to figure out the greenhouse gas emissions of pastures because it is a dynamic system that combines the influences of soil, plants and animals. The ruminant livestock that graze pastures do produce methane as they digest the grasses – this is unavoidable – but improved feed quality from good grazing management has been shown to reduce (but not eliminate) the amount of methane produced (Fredeen et al., 2013). Nitrous oxide can be produced from N fertilizer applications to grass pastures and from the dung and urine patches left by grazing livestock. Seeding legumes as part of the pasture mix will avoid the emissions from fertilizer application (Rochette & Janzen, 2005), but the impact on dung and urine is less straightforward (McAuliffe et al., 2020). Perennial forages are generally assumed to build up soil organic matter (Conant et al., 2017), although there is a wide range in how much is added to the soil each year. The forage management system has a big impact on carbon accumulation, with managed intensive grazing showing consistently greater soil organic matter gains than continuous grazing, mowing, or unharvested grass, particularly in humid climates (Phukubye et al., 2022; Oates & Jackson, 2014).

### Net GHG emissions count more than any single indicator

The three main GHG are carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$), and every ecosystem will be emitting or absorbing these compounds to various degrees. Each has a different effect as a GHG, so the balance is expressed as the equivalent amount of $CO_2$. Changes in pasture management will affect all three, so the important number to watch is the net $CO_2$ equivalent ($CO_2$-eq).

**Carbon-sequestering practices** may enhance the profitability of farming systems by increasing yields or reducing production costs. Pastures can function as "carbon sinks" by storing excess carbon dioxide sequestered from the atmosphere. Plants remove carbon dioxide from the atmosphere as part of their growth process. When plants are grazed, part of the root system dies off, trapping organic carbon in the soil. Allowing sufficient rest periods permits those root systems to regrow, converting more atmospheric carbon into organic carbon. By using conservation tillage or no-till practices when renovating pastures, soil is conserved, and carbon dioxide can be trapped in the humus of agricultural soil, thus removing carbon dioxide from the atmosphere. Improved farming practices can remove one to three tonnes of carbon per hectare from the atmosphere during a 10-20 year period (AAFC, 2003).

Cattle consuming high-fibre diets produce more $CH_4$ per litre of milk or kilo of liveweight gain than cattle consuming low-fibre diets with less forage and a higher grain component. However, the production of higher quality pasture, in particular legumes, may result in lower emissions, along with lower fossil fuel use and increased sustainability (Fredeen et al., 2001). The overall impact of pasture management on greenhouse gas emissions is a combination of all the components in the grazing system, encompassing the inputs to the soil, the pasture biomass production, and the emissions from the grazing livestock. Methane emissions alone are a poor predictor of the greenhouse gas impacts of pasture systems (Fredeen et al., 2013).

The impact of managing intensive grazing (MIG) on greenhouse gas emissions was examined using the Atlantic Dairy Sustainability Model, which was developed by Mike Main in 2001. Three systems were compared for producing 500,000 kg of fluid milk per year:

- **Seasonal MIG dairying:** A novel system where cows are freshened in spring and fed entirely through Management Intensive Grazing (MIG) for almost 6 months, followed by confinement feeding through late lactation and the dry period. Almost no supplements are fed, with an annual production of 5,800 kg milk /cow/y from a milking herd of 86.
- **MIG, high forage:** Cows were fed through MIG for just over 5 months, and about 85% of the milking herd diet is forage; annual production is 6,900 kg/cow/y from a milking herd of 73.
- **Confinement, high concentrate:** Cows are fed entirely in confinement and only about 55% of the milking herd diet is forage; annual production is 10,300 kg/cow/y from a milking herd of 49.

Table 7.2 outlines the predicted carbon dioxide equivalent ($CO_2$-eq) emissions per year.

**Table 7.2 Greenhouse gas emissions and other sustainability measures of high pasture-based versus confinement feeding.**

| | SEASONAL MIG DAIRYING | MIG, HIGH FORAGE | CONFINEMENT, HIGH CONCENTRATE |
|---|---|---|---|
| $CO_2$ from fossil energy use | 0.11 | 0.14 | 0.21 |
| $CH_4$ emissions | 0.77 | 0.70 | 0.53 |
| $N_2O$ emissions | 0.21 | 0.24 | 0.36 |
| $N_2O$ from off-farm feed production | 0.01 | 0.01 | 0.05 |
| Soil C sequestration/loss | -0.28 | -0.13 | -0.04 |
| Net total (kg $CO_2$-eq per kg milk) | **0.82** | **0.95** | **1.10** |
| Hectares needed | 190 | 180 | 105 |
| Grain fed (tonnes) | 4 | 53 | 170 |
| Chemical fertilizer | no | no | yes |
| Farm soil organic matter (% increase in 20y) | 0.51% | 0.23% | 0.15% |
| Average $NO_3$- leaching (N, kg/ha/y) | 2.0 | 2.7 | 8.2 |
| Net margin (uniform milk price) * | $83,000 | $50,000 | $47,000 |

*The Net Margin represents the profit after the cost of production (gross income minus total costs). The costs vary with cow numbers, total milk production, use of pasture, feed costs and crop inputs.

In the overall analysis, it was found that high forage and pasture diets have lower net emissions because of lower emissions associated with energy use and $N_2O$ production and because of $CO_2$ trapped in the higher soil humus content under forages. These factors more than offset the higher $CH_4$ emissions from a high-forage diet. This comparison did not include a continuous grazing system, where the $CH_4$ emissions would be even higher and the soil C sequestration much less, so the net total would be higher than the other pasture systems (and possibly the confinement system). A recent New Zealand analysis has predicted the same results (Robertson et al., 2002). Greenhouse gas emissions from Canadian milk production in 2001 have been estimated to average 1.02 kg $CO_2$-eq per kg milk (Verge et al., 2007).

Soil carbon sequestration is important even though the % change in soil organic matter levels is quite small since the mass of the soil is so large (2,000,000 kg/ha to 15 cm depth). Also, forage crops typically have low $N_2O$ emissions or $NO_3$- leaching losses because, unless heavily fertilized, grass crops tend to scrub $NO_3$- from the soil. However, if pastures are heavily fertilized with N, there can be large $N_2O$ emissions, and/or $NO_3$- leaching because of N overload where cows urinate. Also, when forage legumes are used as the main N source, much of the N is tied up in organic forms and is less available for $N_2O$ production or $NO_3$- leaching until the land is tilled (Rochette & Janzen, 2005).

The analysis also suggests that high-forage systems using MIG are more broadly sustainable than confinement systems. Fossil energy use is lower, $NO_3$- leaching is lower, soil organic matter levels are higher, and it appears to be a more profitable approach. Another benefit is that soil erosion is a non-issue under well-managed forages. Of course, forage-based seasonal milk production is not currently an option within the current Canadian system, but there are demonstrable efficiencies in this approach if future markets would allow it. Meanwhile, there are clear benefits to forage-based systems, especially when MIG is optimally used, and this will only become more important as grain prices rise.

### An Interesting Local Example

An interesting local example of a pasture-based dairy is the Hunters' Knoydart Farms in Nova Scotia. It is an organic farm, meaning that the cows must get at least 30% of their dry matter intake from pasture in the grazing season. Fraser Hunter has developed a system that does much more than that. They strip-graze their dairy herd, moving them once per day on high-legume content pastures (alfalfa, birdsfoot trefoil, red clover – paired with fescues and timothy). This system has allowed them to decrease the amount of land they use to produce forages over time for the same size herd by increasing the productivity of that land (Hunter, 2023).

## PASTURE BIODIVERSITY

Ecologists universally accept biodiversity as desirable in natural systems, but it is worthwhile to consider that agroecosystems are a special case where the management of the system is focused on the production of food, feed and fibre. In this context, biodiversity, for the sake of stability of the system may not be the most desirable outcome as it would come at the expense of productivity. There are, however, many opportunities for maintaining or enhancing the diversity of plants, animals and microbial life within agricultural systems, and there are advantages to doing so.

### Why is biodiversity important?

**Intrinsic value:** diversity for the sake of diversity; protection of endangered species, value is not in terms of direct benefits to humans.

**Relational value:** cultural or aesthetic benefits, supporting quality of life for humans.

**Instrumental value:** improving biomass production (or stability of biomass production) or providing ecosystem services to support human life (habitat for beneficial insects, replacement of purchased inputs, reduced pest pressure).

Biodiversity's value exists both intrinsically and through its contribution to ecosystem stability and processes. These contributions include providing habitat for beneficial insects, reduced weed incursion, reduced pest and disease pressure, and N fixation by legumes. In a pasture system, where conservation and production can be at odds, careful management can build a bridge between economic production and ecosystem protection.

Pastures already possess more diversity than any annual cropping system by virtue of the presence of both plants and animals in coexistence and because it is a perennial system. In addition, this biodiversity is overlain on soils and topography that is not suitable for annual crop production due to steep slopes, shallow soils, excess stoniness, or moisture, etc. Grazing livestock is a way to turn resources that are lower value (ex. marginal lands, grass) into desirable food products while maintaining ecological integrity. The focus of this section is how to manage the pastures for improved biodiversity.

Diversity can occur over different spatial or temporal scales. Farmers are familiar with crop rotation as a way to increase diversity across time, and adding pastures into the crop rotation brings another dimension to this. There is a great deal of potential to add pastured livestock into cropping systems, adding not only diversity in the rotation and another "cash crop" – meat or milk – but also improving the soil with organic matter.

Pastures also add diversity across the landscape, providing patches of habitat for grassland birds like bobolink or upland plover and nectar sources for bees and other insects that are not present in either cropped fields or dense forests. The choice of management practices to support enhancement of biodiversity within pastures will heavily rely on production goals and knowledge of desirable habitats for species of concern. Conservation practices have the most success when producers address production and conservation goals at the same time.

Within pastures, there can be significant differences in plant species across gradients in soil moisture or pH, as the plants best adapted for specific conditions come to dominate in those areas.

## Pastures as Unique Ecosystems

In a pasture ecosystem, the plant and animal biodiversity depends critically upon the level of grazing. Too much grazing may lead to land degradation and the loss of biodiversity. Too little grazing may lead to the change from grassland to woodland and the loss of grassland habitat. The timing and frequency of grazing and the animal species involved are also important factors (Watkinson & Ormerod, 2001).

Several challenges exist for the farmer to develop and maintain a balanced pasture ecosystem. The judicious addition of nutrients, drainage and reseeding will increase herbage production, but it may lead to a decrease the plant diversity (King & Blesh, 2018; Finney & Kaye, 2017).

Balancing the stocking rate with pasture growth is important. Higher stocking rates without appropriate grazing management will result in land degradation and invasion of weed species (Watkinson & Ormerod, 2001). Leaving the pasture ungrazed will reduce biomass production and contribution to soil carbon by reducing the time the forage is actively growing (Oates & Jackson, 2014), which in turn will reduce the food available for soil organisms.

Current research (at the time of publication) is examining the biodiversity resulting from the interaction of factors like manure and fertilizer application and livestock behaviour such as defecation and grazing patterns.

### How much diversity is enough?

This is a question that generates much debate and little clarity, with some experiments testing various mixtures with up to 60 different species. If this is diluting the productive species in the mix with much less productive ones, the net result of this diversity is going to be lower yield, which is not a desirable outcome. It is better to think about functional diversity, so there are plants in the mix that carry out different roles. A mix of grasses and legumes is simplest. The grasses are very good at growing fibrous roots for soil stabilization and soil carbon supply, while the legumes supply N to support the grass growth. Additional factors are tolerance to poor drainage or soil acidity, so the mix may contain species like trefoil and canarygrass that will do well in wet areas along with white clover and orchardgrass that will do much better in the dry areas. The species chosen must also be palatable to livestock and productive in your climate conditions, so a mix of 4-10 species is a reasonable range to aim for.

**Figure 7.3 Many pasture species are visible in this stand including grasses, legumes and forbs. Photo courtesy of Margaret Graves.**

## The Soil Food Web and Biologically Active Soil Environment

Diversity in the plant and animal communities above the soil surface is mirrored by a vast network of life in the soil. The soil life needs feeding and nurturing, just like the livestock grazing above ground. People are starting to think of soil life as "soil livestock", reflecting the importance of managing so that they thrive. The soil food web is a network of dynamic interactions among soil organisms as they decompose organic materials and transform nutrients. Soil organisms include a variety of species ranging from bacteria to earthworms, as shown in Figure 7.4.

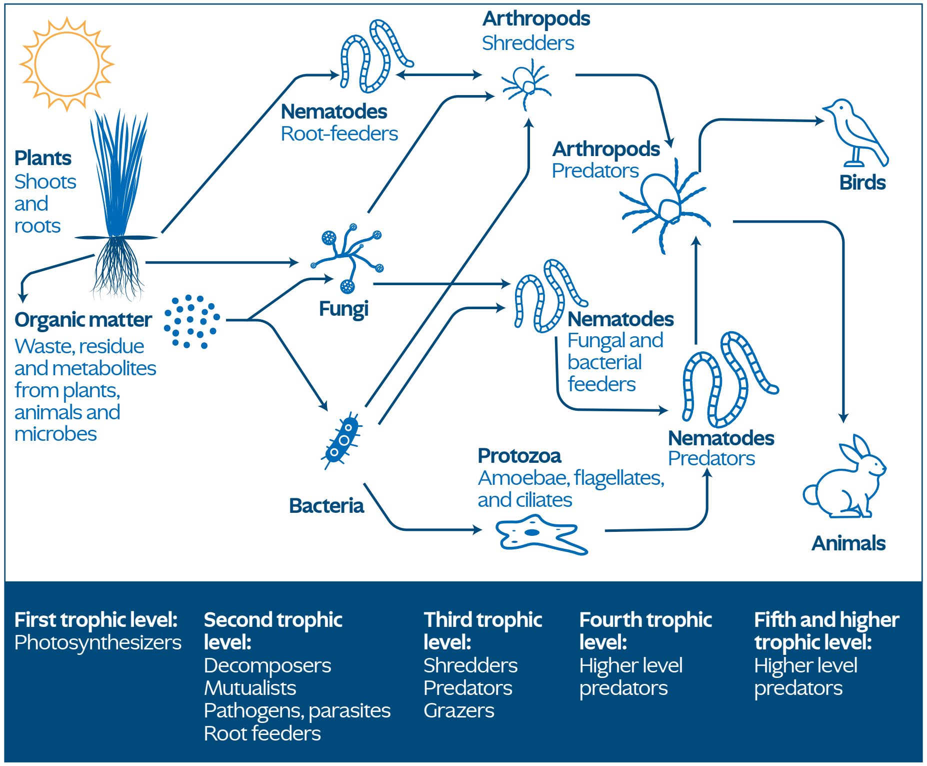



**Figure 7.4 Food web of grassland soil.**

The source of food for the soil food web, as for all life on earth, is photosynthesis, which converts the sun's energy into organic compounds. Wherever plants grow, some of these compounds are transported into the soil, some for root growth and some excreted by the roots into the surrounding soil, along with the dead plant parts that form the litter on the surface of the soil. These form a rich source of energy for soil organisms that have their own complete ecosystem.

These cycles are modified in pasture systems. First, the grazing animals harvest the top growth of the plants, modifying this material through digestion and returning a large part of it back to the soil as feces and urine. This represents a source of energy and nutrients that is not present in most cropped fields. Second, when pastures are rotationally grazed, there are alternate flushes of root growth as the leaves are actively growing and then die back following grazing until a fresh round of growth can start. The result is a continuous source of food for soil biota throughout the growing season.

The microbes in the soil are eager to use everything that comes their way, and they will grow rapidly to use all the available food supply. Bacteria will use the most easily degraded materials, both fresh from the plants and the by-products from other soil life. Some species of bacteria form symbiotic relationships with legume roots, making nodules that fix N from the air. Bacteria drive the N cycle in the soil, converting organic N compounds to $NH_4^+$and then $NO_3^-$, as well as to nitrous oxide. Some species of bacteria will use pesticides and other harmful chemicals as food, detoxifying them in the process. Exudates from bacteria act as glue to help bind soil particles together into aggregates.

Fungi specialize in breaking down the tougher material, as their hyphae excrete enzymes that digest stuff that is too tough for bacteria. This feature makes some fungi pathogens, as they can digest the cell walls of living plants to infect them, but this is only a small part of the diversity of fungi. Mycorrhizal fungi form associations with plant roots that function as extensions of the root systems, assisting in the absorption of nutrients and water from the soil and even the transfer of N from legumes to grasses. These mycorrhizae take time to develop, so a perennial pasture will have far more of them than any annual crop field. Fungal hyphae form a lattice in the soil that helps to strengthen and stabilize soil structure.

Earthworms, arthropods and insects play a key role as well, grazing on plant residue and dead roots and breaking them down into finer pieces that are accessible to bacteria and fungi. They also mix the organic materials through the soil and help to form soil aggregates as they move around.

There is another group of soil organisms that feed on bacteria and fungi. These include protozoa, microscopic mites and insects and nematodes. This feeding is important for nutrient cycling, as it releases the nutrients that the microbes have absorbed back into soluble and plant-available forms. These predators are, in turn, eaten by larger predators that become food for birds and soil-dwelling mammals.

Nematodes occupy many of these ecological niches, with some species specializing in eating plant roots, some grazing on bacteria and fungi, while others are predators that feed on other soil animals. These microscopic worms include some species that are plant pests (e.g., root knot nematode, root lesion nematode, soybean cyst nematode), but this is only a small part of the diversity in nematodes. The conditions under a pasture are suitable for a wide range of nematode types that help to keep things in balance and prevent the plant-parasitic species from dominating.

This diagram of the soil food web captures only a small part of the complexity of soil life. There are fungi and actinomycetes that excrete antibiotics to allow them to compete with bacteria for resources. There are carnivorous fungi that trap and digest nematodes. Bacteria living in the rhizosphere (the soil immediately surrounding the roots) can excrete plant hormones that help the plants respond to stress. There is a constant cycling of nutrients and energy between the organisms living in the soil and the plants growing there.

Once established, a healthy food soil web must be managed to maintain a healthy soil environment. The management schemes necessary for maintaining a healthy soil food web are outlined below in Table 7.3.

**Table 7.3 Maintaining a Healthy Soil Food Web (adapted from Bellows, 2001).**

| | |
|---|---|
| **Provide soil organisms with a balanced diet** | • Adding organic material such as manure and a continuous supply of root exudates as provided by perennial pastures provides food for soil organisms.<br>• Nitrogen-rich materials decompose faster than older, woodier materials with less N. |
| **Provide soil organisms with a favourable environment** | • Soil is well aerated.<br>• Moist, easily decomposed materials are available to decomposer bacteria.<br>• Carbon-rich, complex organic materials are available to decomposer fungi.<br>• Continuous plant growth takes place (active roots provide a nutrient-rich habitat for soil organism growth).<br>• Maintain adequate but not excessive soil fertility to support plant growth. |
| **Use practices that favour the growth of soil organisms** | • Maintain a balance between intense grazing and adequate rest or fallow time. Leave enough top growth to encourage rapid regrowth.<br>• Encourage grazing animals to move across pastures to feed, to distribute manure evenly and to break up manure patties.<br>• Maintain a diversity of forage species to provide a variety of food sources and habitats for a diversity of soil organisms.<br>• When required, add lime to help acidic soils move toward a more neutral state. |
| **Avoid practices that kill or destroy soil organism habitat** | • Avoid the use of ivermectin deworming medications, soil-applied insecticides and concentrated fertilizers (i.e. anhydrous ammonia and superphosphate)<br>• Minimize tillage and cultivation practices<br>• Minimize practices that compact the soil (ex. grazing wet soils.) |

Pasture health should be monitored regularly, with adjustments to management practices as needed to maintain healthy pasture soil. An index of pasture soil health (or a soil health card) is explained in Table 7.4 and is a tool to determine pasture soil health. While a given pasture may score low on some points and high on others, the purpose of the card is to get an overall score that will determine the state of biodiversity within the pasture's soil.

**Table 7.4 Pasture Soil Health Card (adapted from Bellows, 2001).**

| PASTURE SOIL HEALTH INDICATOR | GOOD SOIL HEALTH | MEDIUM SOIL HEALTH | POOR SOIL HEALTH |
|---|---|---|---|
| **Pasture Cover** | Complete cover of forages and litter over entire pasture. | Limited bare patches; no extensive bare areas near drainage areas. | Extensive bare patches, especially near watering or other congregation areas. |
| **Plant Diversity** | Diversity of plant species, including forbs, legumes and grasses; differences in leaf and root growth habitats. | Limited number of plant species and diversity of growth habitat; some weeds present. | Less than three different plant species, or weeds, are major components of the plant mix. |
| **Plant Roots** | Abundant vertical and horizontal roots. | More horizontal roots than vertical | Few roots, most are horizontal. |
| **Soil Life (macro-organisms)** | Many dung beetles and earthworms present. | Few dung beetles and earthworms present. | No dung beetles or earthworms present. |
| **Soil Compaction** | Wire flag enters soil easily; does not encounter hardened area at any depth. | Can push wire flag into soil with difficulty or encounter hardened area at 15-20cm depth. | Cannot push wire flag into soil. |
| **Erosion** | No gullies present, water running off pasture is clear. | Small rivulets present, water running off pasture is somewhat muddy. | Gullies present, water running off pasture is very muddy. |
| **Soil Aggregation** | Soil in clumps that hold together when swirled in water. | Soil breaks apart after gentle swirling in water. | Soil breaks apart within one minute after being in water. |
| **Water Infiltration** | Water soaks in during moderate rainfall, little runoff or ponding on soil surface. | Some runoff during moderate rainfall, some ponding on soil surface. | Significant runoff during moderate rainfall, much water ponding on soil surface. |

## CONSEQUENCES OF MANAGEMENT ON BIODIVERSITY

### Insect Habitat

The global decline of insect populations, especially pollinators, has been in the spotlight (Janicki et al., 2022). Some of the causes are habitat decline due to both urbanization and agriculture and pesticide use. Pastures can help provide a refuge for insects if the right conditions are created. Producers may choose to let areas of their fields flower and go to seed periodically to create a seed bank of desirable pasture species as well as provide food for pollinators. Fencelines, field margins and riparian areas can help, too, by housing flowering species that aren't harvested.

Restricting the use of insecticides is important to encourage insect populations. Permanent pastures are unlikely to need insecticide applications, making them inherently safer places for insects than annual crops.

### Wildlife Habitat

In the Maritimes, a wide variety of ecozones are present, ranging from cropland to mixed wood and coniferous forest to wetlands. The influence of agriculture on wildlife habitat is less here than in major agricultural ecozones. However, in river valleys and most of PEI, where farmland is concentrated, wildlife is affected.

There are land management practices that favour wildlife use. These practices include rotational grazing systems, planting shelterbelts and hedgerows, management of riparian areas, conservation of wetlands and wetland buffers and the conservation of remaining natural (native) lands.

Organic farmers have to show that they are invested in creating habitat and diversity on their farms. The standards say that organic farms must have at least one of the following: pollinator habitat, insectary areas, wildlife habitat, and maintenance or restoration of riparian areas or wetlands (Clause 5.2.4, CGSB, 2020).

The Kern Family Farm in Granville Ferry, Nova Scotia, is a local example of resource management and its effect on the environment and wildlife habitat. An economical, gravity-driven watering system for cattle was installed to draw water from a pond and was installed in conjunction with the improvement of pastures in the pond area.

To maintain the pond's water quality and prevent erosion of embankments, the pond and traditional watering area were fenced off from livestock. On the inner slope of the pond berm, red fescue and birdsfoot trefoil were planted to control erosion. On the external slope of the pond berm, wildlife food and cover and natural vegetation were planted. These included white pine, red spruce, autumn olive, dogwood, nut and berry trees, honeysuckle, cranberry, oak and birch. Watercress was planted along the pond's edges, and the pond was stocked with trout. Wildlife inhabitants included deer, bears, great blue herons, ducks, sandpipers, pheasants and songbirds (Kern, 1994).

Practices to promote soil quality, control erosion and protect water quality are compatible with promoting wildlife use of agricultural habitats.

Grassland bird habitat is another area that can be explored to improve on-farm biodiversity and support wildlife. The Bobolink (*Dolichonyx oryzivorus*) grassland bird population has been declining largely due to the loss of breeding habitat and poor reproductive output. Hayfield mowing periods often overlap with the peak of the bird's breeding season (mid-late June), and higher stocking densities of livestock increase the likelihood of nest trampling. There are general guidelines that may support the conservation of grassland birds, such as the bobolink; suitability varies from farm to farm.

**Figure 7.5 The Bobolink is a vulnerable species that nests in grasslands and hayfields.**

Firstly, the larger the field, the better for grassland birds – typically, they will avoid fields less than 10 acres and will be attracted to fields that are round or square rather than narrow. This is largely due to avoidance of edge habitat, as it provides travel routes for predators. The optimum habitat for grassland birds will be a mix of 60 to 80% grasses of species of varying heights, comprising 25% or less of alfalfa and avoidance of fescue grasses.

Secondly, to help minimize mortality during harvesting, there are several strategies that can be applied:

- Scout out where the birds occur, and avoid cutting these areas until mid-July, or cut these areas last
- Awareness of fledging dates (can be as early as mid-June or as late as mid-July)
- Cutting the perimeter of hayfields and leaving the interior for later cutting

Thirdly, to minimize mortalities due to grazing management:

- Rotational grazing can be beneficial, given that grasses are not grazing below 4 inches in height, and half of the pasture area is maintained at longer heights (12+ in) from May to early July
- Including a bird "refuge" or "biodiversity" paddock that remains un-grazed until after July 15 (should be located in the center of the field)

Lastly, maintenance of old fields to avoid the encroachment of woody plants will help provide a more suitable habitat for grassland birds. Heavy growth of tall herbaceous species like knapweed or goldenrod will crowd out grass cover and reduce habitat value.

For more information on these guidelines presented by Nature Canada, reference the booklet (Cheskey & Kirkpatrick, 2019), which provides information for producers who wish to learn more about supporting grassland birds on their farms.

## Soil Health in Grazing Systems

A healthy soil is able to maintain good productivity, now and into the future while providing essential ecosystem services like water infiltration, carbon sequestration and nutrient cycling and retention. Soil biota is a big part of this picture, but it does not exist in isolation; the physical structure of the soil, along with the chemistry of the soil minerals, provides a habitat for life in the soil, while the life in the soil modifies and stabilizes soil structure and chemistry. This continual interaction is the heart of a properly functioning soil, and so managing healthy soils requires managing all of the various components simultaneously.

Fortunately, this is not as daunting as it sounds, particularly in pasture systems, and good grazing management is good soil health management. The permanent forage cover provides protection from soil erosion and food for soil organisms. Extensive root growth and lack of disturbance by tillage helps create good soil structure, which allows rapid infiltration of rainwater or snowmelt. Rhizobia bacteria associated with the legumes in the mix fix N out of the air to share with the other plants, and the mycorrhizae that develop under perennial plants assist in nutrient and water uptake by plants.

The organisms are already there, and they multiply to take advantage of the habitat created by the pasture plants.

The main risks to soil health in pasture systems come from poor management. Low soil fertility or acid soils will limit forage growth, cutting off the food supply for the soil life. Soil testing is a good first step to check if supplementation is needed. Low nutrient levels will compromise the longevity of the pasture plants as well as their yield and may translate to poor mineral nutrition of the livestock grazing that land.

Over-grazing also hurts the "underground economy", as plants with little top growth don't have enough leaf area for photosynthesis. Match stocking rates to forage supply and allow adequate time for recovery between grazings.

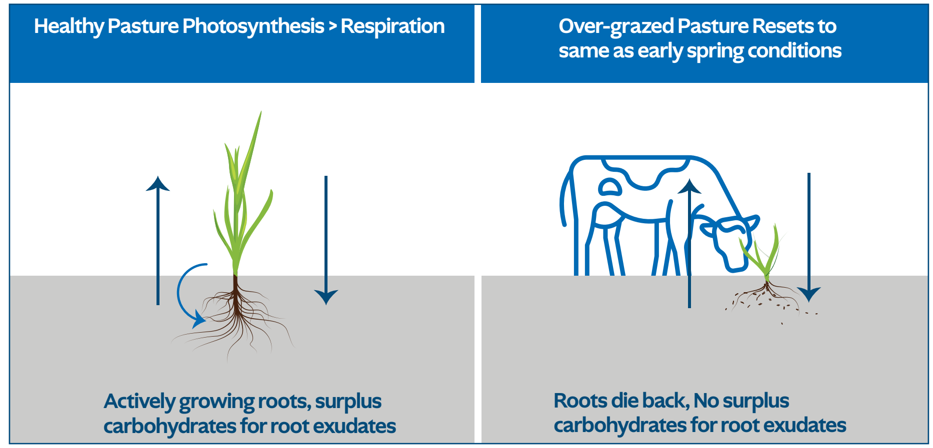
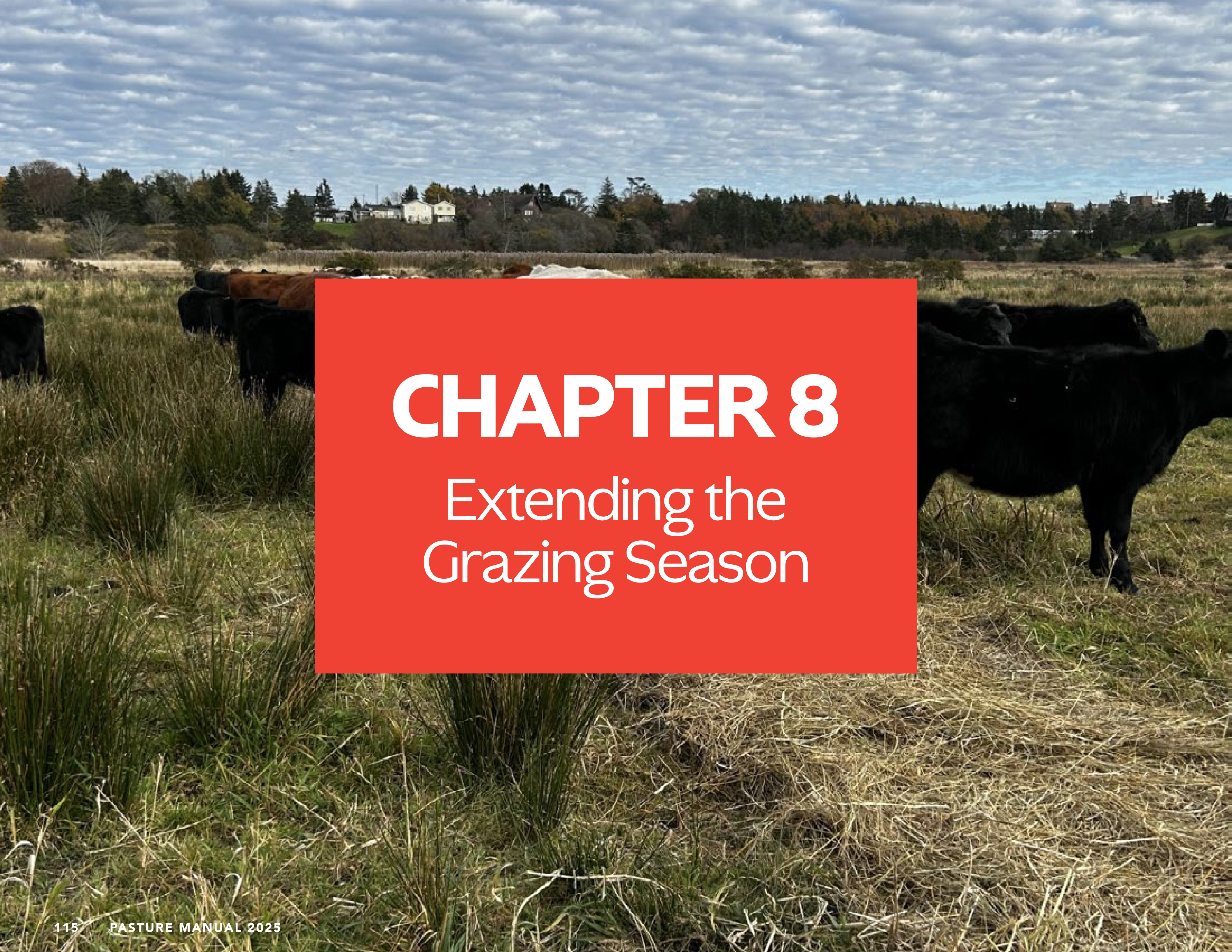



**Figure 7.6 Overgrazing affects plant pasture dynamics.**

**Figure 7.7 Overgrazed pasture- note the bare patches and weeds present.**

Soil compaction by excess hoof or wheel traffic, particularly when the soil is wet, limits soil aeration; some microbes thrive in anaerobic conditions, but these are generally not as desirable for nutrient cycling, and some may be pathogenic (e.g., clostridium). Soil compaction can become a vicious cycle, as compacted soils do not drain as readily, and so are more susceptible to further compaction. This underlines the importance of watching soil conditions around feeders or waterers and being prepared to move these to different areas before the damage to the soil is permanent.

These actions may incur some expense and will certainly take some time to manage properly, but they will reward you with soils that function better and will support much greater pasture growth.



# CHAPTER 8

## Extending the Grazing Season

# CHAPTER 8
# Extending the Grazing Season

On conventional beef and sheep farms in Atlantic Canada, overwintering livestock accounts for 60-80% of the cost of production. The cost of putting up stored forage is a major component of that cost. By extending the grazing season, producers can provide livestock with an economical feed of adequate nutritional value in the months before and after the traditional grazing season. Extending the grazing season also reduces the costs associated with housing animals such as handling of bedding and manure (Teno et al., 2017). To be successful, producers must focus their efforts on providing suitable, well-drained pastures that can be grazed late into the fall and even winter (Duynisveld, 2008).

Strategies for extending the grazing season are presented in this chapter by order of expense. The first step will be improving the management of existing pastures to avoid early removal of livestock from "run out" pastures in late summer. Generally, stockpiling is considered the cheapest method for extending the season beyond the growing season, followed by grazing annual crops, then bale grazing (McGeough et al., 2018) – and all of them are considered less expensive than feeding cows in the barn (Teno et al., 2017). These strategies aren't all applicable for the whole winter, but combined approaches may considerably extend the grazing season (assuming acceptable weather).

## MANAGING FOR EXTENDED SEASON GRAZING

As with any change in management, some considerations must be addressed; keeping livestock on pasture requires less expense and labour than confinement systems, but that does not mean zero expense. There must be planning for a supply of fresh water that does not freeze during cold weather and for a supply of salt and mineral supplements. The livestock may also require some form of shelter or wind protection for their comfort and productivity. Depending on the quality of the pasture or stored forage provided, supplemental feed may be required to provide adequate energy and protein to the livestock. Because there is manure being deposited on pasture during freeze-thaw cycles, there is some risk of runoff of N, P and bacteria, so the pastures used should be carefully chosen. Concentrating manure in small areas should be avoided, so the location of minerals and any supplemental feed should be planned accordingly. Addressing these issues at the outset will ensure that extending the grazing season will be beneficial.

### Controlled Grazing

Controlled grazing techniques extend the grazing season by increasing plant productivity over the season. Controlled grazing methods such as "put and take", rotational grazing and strip grazing keep pastures more productive throughout the season. By keeping pastures healthy, they grow better and last longer. Pastures grazed with management intensive grazing develop better root structure that increases growth in dry periods and overall. Ongoing research at the AAFC Nappan Research Farm shows that it allows for more grazing days in the season (Duynisveld, 2023).

### Early Weaning

Early weaning will allow cows to improve their body condition prior to winter. An improved body condition in the early fall may allow a longer winter grazing period with less supplemental feed. Cows in good body condition will have a reduced daily nutrient requirement making it easier to match forage quantity and quality, leaving more forage available for other cows (Lardner, 2003).

### Stockpiling

Stockpiling pasture is a management system that allows for grazing late in the fall after the pastures have ceased growing for the year. To stockpile a pasture, the pasture is allowed to grow from July or early August with no further defoliation until after the first killing frost. The stockpiled areas are grazed after the other pastures have run out of available forage. Economically, stockpiling is the cheapest way to feed cattle and sheep in the late fall and winter (many studies confirm this, a good example being McGeough et al., 2018).

Depending on the amount of pasture stockpiled, livestock can graze these areas as long as weather conditions allow. It is important to plan ahead to ensure a forage sward height of 20 to 30 cm is available at the first killing frost. This grazing management system works best if the stockpiled forage is not allowed to become overmature, as selective rejection will occur due to poor plant palatability. The idea is to have the frost stop plant development while it is in the vegetative growth phase so that the best quality is preserved by the cold (Duynisveld, 2008). This will not match the quality of actively growing pasture but should be adequate to meet the needs of dry cows, backgrounding cattle or pregnant ewes in early gestation (Hedtcke et al., 2002). It is possible to submit forage samples of stockpiled pasture for lab analysis, but submitting forage samples from pasture is not often practical due to the turnaround time (usually 5-10 days).

There is a tradeoff between the yield and quality of stockpiled forage (Gerrish, 2004). Better quality can be obtained by stockpiling for a shorter length of time. Grazing or cutting the forage later in the season (for example, in mid-August rather than July) and stockpiling the regrowth will result in better-quality stockpiled forage. Of course, the less time allowed for the stockpile to accumulate, the lower the yields. Depending on moisture and the condition of the pasture, waiting too long to start stockpiling would result in no stockpile at all.

Strip grazing or block grazing are excellent ways to increase the utilization of the stockpiled forage. Controlled grazing reduces the animals' selectivity, forcing them to eat what is available.

Good fertility and adequate fall moisture are both important to successful pasture stockpiling. If N is limiting, an application of 50 kg/ha of N to the stockpiled pasture in late August will help increase forage yield.

Snow can certainly be a challenge to the grazier, but despite this, there are opportunities to pasture in the winter months. Hardy species, such as fescues, have been shown to maintain quality through the cold and freeze-thaw cycles of Atlantic Canadian winters. Cattle are able to successfully graze through up to 15 cm of loosely packed snow, while sheep can paw through nearly 30 cm. Snow conditions need to be carefully monitored as ice (from either freeze-thaw cycles or livestock tramping) will interfere with the animal's ability to access the forage.

Wand et al. (1998) explored the feasibility of using stockpiled perennial pastures for dry, pregnant beef cows grazing in late fall and early winter. They divided 40 dry cows into four pasture groups, with two groups on a grass pasture and two groups on a legume/grass pasture. There were also 10 cows (in barn) fed round-bale hay as a control group. Grazing was allowed from October 3 to December 18. All pasture was strip grazed with the poly wire fencing moved daily. There was no back fence. The results showed that the grazing cows and barn-fed cows had similar weight gains and increases in backfat up to three weeks before the trial ended. The grazing cows then lost weight, possibly due to the snow accumulation reducing their feed intake. There were no statistical differences between the grazing and indoor cows for pregnancy weight, calf weight and calving ease (Wand et al., 1998).

The economics of alternative management practices for beef-cow enterprises was studied by Gao et al. (2001). They compared the economics of traditional winter calving versus summer calving and confinement feeding versus extending the grazing season. They found that the revenue was similar between each comparison, but in both situations, the alternative management practice had a lower cost, which resulted in a higher net return. The most profitable combination of management practices was summer calving combined with extending the fall grazing season and then retaining the feeders up to the finishing stage.

## Best Species for Stockpiling and Fall Grazing

Grass species recommended for fall stockpiling include frost-tolerant species such as tall and meadow fescues, orchardgrass and annual ryegrass. Tall fescue is remarkably well adapted for stockpiling because of its uniform distribution of growth over the season. It continues to grow well into late summer and fall, and its stiff, waxy leaves seem to hold up well over the winter.

A study on stockpiling summer tall fescue pasture for late summer and fall grazing showed that early stockpiling improved forage yields by 0.5 – 1 tonne/ha. A N application in late summer or including a legume like alfalfa in the mix improved the yield and the crude protein content of the fescue (Buchanan-Smith et al., 2008; McGeough et al., 7017). Gerrish (2004) and Duynisveld (Forsythe, 2018) both state legumes are fine for stockpiling early in the season but lose feed quality more rapidly than grasses, especially tall fescue. Gerrish suggests using legume/grass pastures earlier in the stockpile season and keeping N-fertilized grass pastures for later.

To be utilized most effectively, orchardgrass must be uniformly grazed to no lower than 8 cm (3 in) at a high animal stocking rate for a short grazing period (3 days). Leaving an 8 cm stubble height and a short grazing period will reduce the chance of winter kill or injury.

Some species of grass are not well suited for fall stockpiling because winter survival and productivity in following years can be impaired. A study by Hall et al. (1998) in Pennsylvania found that tall fescue and perennial ryegrass tolerated fall grazing well, but prairie grass had significant winterkill and died out completely after the second year of fall grazing. They also found that the early spring growth of the fescue and ryegrass was reduced after stockpile grazing but that total production over the year was equivalent to conventional grazing. This opens the opportunity for managing the spring flush of growth with a combination of regular and stockpiled paddocks.

Table 8.1 lists the productivity of various perennial pasture species throughout the growing season.

**Table 8.1 Productivity of various perennial pasture species throughout the growing season.**

| EARLY SPRING | LATE SPRING |
|---|---|
| • Meadow Bromegrass<br>• Red Fescue<br>• Orchardgrass<br>• White Clover<br>• Kentucky Bluegrass | • Meadow Bromegrass<br>• Perennial Ryegrass<br>• Orchardgrass<br>• Red Fescue<br>• Kentucky Bluegrass<br>• White Clover<br>• Reed Canarygrass |
| **EARLY SUMMER** | **MID-LATE SUMMER** |
| • Meadow Bromegrass<br>• Reed Canarygrass<br>• Orchardgrass<br>• Perennial Ryegrass<br>• Timothy<br>• White/Red Clover<br>• Meadow/Tall fescue<br>• Birdsfoot Trefoil | • Meadow Bromegrass<br>• Alfalfa<br>• Orchardgrass<br>• Red Clover<br>• Meadow/Tall fescue<br>• Birdsfoot Trefoil<br>• Reed Canarygrass |
| **EARLY FALL** | **LATE FALL** |
| • Kentucky Bluegrass<br>• Reed Canarygrass<br>• Tall fescue<br>• Red Clover | • Kentucky Bluegrass<br>• Reed Canarygrass<br>• Tall/Meadow fescue<br>• Red Clover |

## Alternative Fall Crops

Annual fall crops can also be used to extend the grazing season (Table 8.2). Annual ryegrass seeded in early spring produces large amounts of high-quality forage into the fall, so it may be an option. It can produce feed within six to eight weeks of planting and will remain productive well into late October. It can be seeded with a Brillion or no-till seeder but requires adequate fertility for high yields.

Brassicas, such as kale, rape, and stubble turnip, are another option for late summer to early winter grazing. They tolerate frost and grow well into October. Choosing which type of brassica to use depends on several factors, such as time of seeding, desired time of grazing and the class of livestock.

Kale is seeded earliest (late May to early July) and can be used between October and early January. Rape and stubble turnips should be seeded between mid-June and late July and are ready for use by late August or early September through November. Yields range from five to 10 t/ha for kale and 3 to 8 t/ha for rape and stubble turnips but will suffer significant reduction if planting is delayed to early August (Villalobos & Brummer, 2016). Grazing management is the key to the successful use of brassicas. Strip grazing has been shown to be an effective method of getting good utilization of these crops by reducing wastage. Consumption is about 1 kg/head/day of dry matter (DM) for lambs and 4.5 kg DM/head/day for cattle allowing for about 20% wastage (Thomas & Goit, 1986).

**Figure 8.1 A cover crop containing brassicas was seeded in late August and grazed into December.**

A note of caution: brassicas are very high in protein and energy but low in fibre and they also can reduce the uptake of iodine when consumed in excessive amounts (Arnold & Lehmkuhler, 2014). These problems can be avoided by limiting the intake to less than half of the diet; this could be done by seeding other annuals in a mixture (ex. Oats, fall rye) or by feeding hay. It is recommended to provide supplemental iodine, 2-4 times above the normal requirement, to animals consuming brassicas (Nickel, 2015).

Cereals like fall rye and oats can also be used to extend the grazing season until snow limits grazing. Seed fall rye by mid-August for mid-October grazing. If seeded early, fall rye can be cut for haylage and then grazed in the fall. With its early spring growth, fall rye is a useful early pasture. Oats can be seeded any time during spring or summer and are ready for grazing 6-8 weeks after seeding. Oats can be used as a companion crop when establishing a forage stand. Provided the ground is not too soft, oats are ready for early summer grazing at 20 cm tall. The oats can be grazed to a height of 5 cm. To reduce competition with the establishing crop, the seeding rate of the oats is lowered to 30 to 40 kg/ha. See Chapter 5 for more information on this practice.

Another option to consider is grazing cattle on standing corn after summer pastures become unsuitable or snow becomes too deep to access other crop species. Corn provides energy and roughage to animals, stands up well to snow accumulation, and may offer shelter from prevailing winds. The protein levels also match the nutritional requirements of dry cows up to mid-gestation.

**Figure 8.2 Corn grazing is one option for winter grazing.**

Grazing cattle on standing corn requires close management and limiting access to corn in order to ensure all parts of the corn plant are consumed. If too much corn is available to cattle at once, cattle will selectively eat the grain and can become at risk of developing acidosis, also known as grain overload. Corn should be strip-grazed to limit the corn available to cattle at once. It is often recommended to provide hay bales to cattle in addition to grazing corn. Fences can be moved every day to every few days, depending on the condition of the animals and how quickly they can clean up a paddock.

Cattle must be trained to respect fences before attempting to graze standing corn. Back fences are not necessary, especially if the water source is stationary. Place fence posts before the ground freezes. Cattle should begin grazing corn once the ground is frozen to prevent too much corn from being trampled in the mud. During thaws, cattle may have to be moved more frequently to prevent the ground from becoming compacted.

Cattle also must be trained to eat corn. Young cattle unaccustomed to grazing corn will try to graze grass surrounding the fence line before attempting corn. Mature cows who are used to grazing corn will often eat the cob first before eating the leaves and finally the stalk. Before letting cattle into corn, make sure they have recently eaten and consider leaving some poor-quality bales in with the corn to prevent too much grain from being consumed too rapidly.

Minerals and salt should be provided to cattle in addition to grazing corn.

A protein supplement will be necessary if late-gestation cows or feeders are being pastured. The article *Understanding Your Protein Supplement* by University of Saskatchewan beef nutritionist John McKinnon is a useful resource for all producers (McKinnon, 2016).

Organic producers are much more limited in their choices of protein supplements. Acceptable supplements cannot contain meal from genetically modified canola or soybean, or non-protein N like urea.

Corn variety and planting time should be selected to target a killing frost at the half-milk stage. Later than this will result in more starch being present in the kernel. Silage varieties are better suited to grazing than grain varieties as they are more palatable to cattle.

Extending the grazing season into the fall carries the risk of wet soils, particularly in a Maritime climate. Care must be taken to avoid pugging or compaction in muddy times to avoid future yield reductions; the savings in feed cost this winter could be lost next summer in reduced production. In perennial forage fields, tramping damage in muddy conditions may also lead to the encroachment of weeds into the stand.

Organic producers must meet some additional requirements for annual crops to extend the grazing season:

- The seed must be organically certified unless it can be shown that organic seed is unavailable
  - » Non-organic seed must not be treated with non-permitted substances
- Genetically modified varieties must not be used (most often a concern for corn)
- Supplemental nutrients for the crop, if required, can be manure or compost from on-farm or other appropriate source
- Minerals and salt for livestock are generally acceptable for organic, but if there is any doubt, it is always wise to check with the certification body

Table 8.2 Potential annual crops to be used to extend the grazing season.

| CROP | PLANTING DATE | SEEDING RATE (KG/HA) | ROW SPACING (CM) | SEEDING DEPTH (CM) | FERTILITY *(KG/HA) | GRAZING TIME |
|---|---|---|---|---|---|---|
| **Annual Ryegrass** | late April-mid May | 25 for diploid; 35 for tetraploid | broadcast or no-till; a good place to incorporate manure | 1 | at planting, 17-17-17 at 300; after each grazing, 34-0-0 at 125 | 6-8 weeks after planting, grazed every 30 to 45 days thereafter |
| **Kale** | late May-early July | drilled: 2-4; broadcast: 4-6 | 15-70 | 1.5 | Total N 80-120<br>P2O5 65<br>K2O 65 | 120 days |
| **Rape** | mid-June- late July | drilled: 2-4; broadcast: 5-7 | 15-30 | 1.5 | Total N 80-100<br>P2O5 65<br>K2O 65 | 90-100 days |
| **Stubble turnips** | mid-June- late July | drilled: 2-4; broadcast: 3-6 | 15-30 | 1.5 | Total N 100<br>P2O5 135<br>K2O 135 | 80-90 days |
| **Fall oats** | mid-August | 80-100 | 15-18 | 2 | at planting, 17-17-17 at 350 | 45-60 days |
| **Fall rye** | mid-August | 150 | 15-18 | 2 | at planting, 17-17-17 at 350 | 45-60 days |
| **Grazing corn** | late May to mid-June | 30,000 seeds/acre | 35-75 | 5 | incorporate 40 t/ha manure, then in a planter: 25-25-0 at 200 | mid-October onward |

*These NPK recommendations are appropriate for pastures with low fertility (i.e., no recent applications of fertilizer or manure); soil testing will provide more precise P&K recommendations. Required fertility can be provided by mineral fertilizer, manure, or a combination.

### Bale Grazing

When the snow is too deep or packed too hard for animals to graze through, feed can be made available in other ways. One method is **bale grazing** which allows the animals to graze from bales of hay placed in the field. This can help reduce labour and fuel costs by eliminating the need to move feed and bedding in and manure out of the barn. It also adds nutrients to the pasture for spring plant growth. The nutrients returned to the soil from bale grazing are particularly effective when bales are spaced to provide an even distribution of manure. Generally, bale grazing involves setting the bales out in rows in advance – it is not the same as feeding out a few bales at a time in feeders. The animals can be strip-grazed through the bales, which minimizes damage to the soil and allows flexibility in how long they stay in a particular strip. Rather than putting posts for the temporary fence in the ground, they can be stuck horizontally into bales in the next row. A back fence is not needed.

**Figure 8.3 Bale grazing in Wallace, Nova Scotia, in January. Photo courtesy of Margaret Graves.**

There is evidence from Western Canada that this is a particularly effective method of pasture rejuvenation, adding substantially more organic matter, N and P, than feeding cows in the barn and then spreading the manure on pasture (Jungnitsch et al., 2011). Cattle should not be wintered in the same field year after year or bale grazed in an environmentally sensitive area. Cattle have been bale grazed at the AAFC Research Farm in Nappan, NS, for over ten years, dispelling a common myth that our winters in Atlantic Canada are unsuitable for bale grazing. Due to our freeze-thaw cycles, it is recommended that bales be placed on their sides rather than the ends to prevent moisture from being wicked up the cores and freezing.

Depending on the quality of the bales, it may be necessary to provide a protein or energy supplement. Sampling the bales for forage analysis will confirm if this is necessary. The same cautions apply to organic producers as mentioned above.

**Figure 8.4 Posts can be placed into bales when the ground is frozen. Photo courtesy of Margaret Graves.**

## EARLY SPRING GRAZING

Most of this chapter has focused on adding grazing days to the end of the pasture season, but the benefits are similar for getting livestock onto pasture earlier in the spring. This can be part of a controlled grazing system or by grazing the early growth of winter cereals.

### Controlled Grazing

Well-drained pastures with south-facing slopes will warm up and begin growth earlier than other fields in the area, so if these are planted to a grass-legume mix that grows rapidly in early spring, livestock can be grazing these paddocks a few weeks earlier than normal.

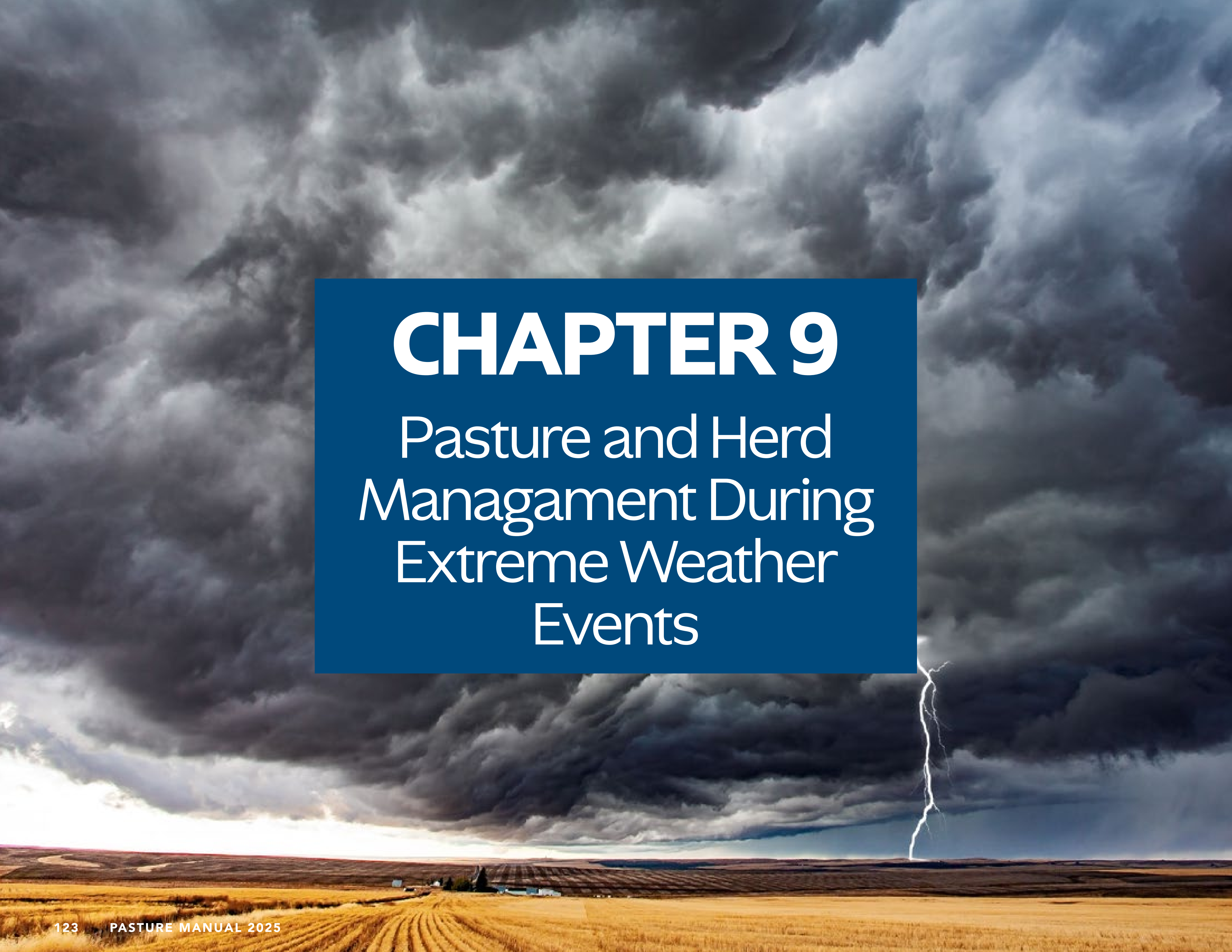
### Winter Cereals

Fall rye or winter triticale will begin regrowth early in the spring and can provide significant quantities of high-quality forage for grazing (Phillips et al., 2021). An application of N fertilizer (40-60 kg N/ha) may be required in early spring to increase growth if there is not a significant supply of residual N. Grazing can begin when the rye stem is 15 cm (6") tall. This forage will be very high in protein and low in fibre, so hay should be available free choice. As with any other grazing system, access to clean water, salt and minerals must be supplied.

Figure 8.5 Winter wheat, no-tilled in at the end of summer, is just visible in the existing stand of pasture in October.

## CONCLUSIONS

There are challenges to extending the grazing season in Atlantic Canada, but if these are overcome, there are also opportunities for reducing costs and improving returns to the livestock operation. Farmers should approach extending the grazing season incrementally, as the management of livestock out of doors in cold weather is different from in a barn or feedlot. Taking the time to learn each new management system before moving on to the next will minimize the risk of setbacks that could affect animal comfort or productivity. This will also allow you to develop a system that best matches your soils, climate, equipment and management style.



# CHAPTER 9

## Pasture and Herd Managament During Extreme Weather Events

# CHAPTER 9
# Pasture and Herd Management During Extreme Weather Events

Many of our Maritime soils are susceptible to drought conditions. How producers manage drought events can significantly impact their farm's profitability. The major impact of drought is a reduction of forage yields and pasture regrowth. Improperly handled, the impact of drought can be far-reaching to both the pasture and the livestock. Overgrazing of drought-stressed paddocks can leave them open to winterkill or encroachment of weedy species. Livestock may also become more likely to eat poisonous weeds when forage availability is low (see Chapter 10 for more information on toxic weeds). Poor animal body condition resulting from reduced forage quality and feed availability can reduce animal fertility. Poor animal body condition in the fall can increase winter feeding costs, reduce conception rates, decrease milk production, and depress immune function – all resulting in decreased weaning weights and longer calving or lambing intervals.

Strategies for maintaining healthy pastures also allow for dealing with pasture drought, as a healthy pasture will withstand drought better than a pasture in poor condition. In the long term, a planned grazing system, which includes drought management strategies, should be developed to adapt to flexible management under a variety of conditions. Producers should review drought management strategies for their farms each spring to prepare for possible drought events. A well-thought-out plan involving reducing stocking rates or early livestock weaning and sale can provide significant savings and reduce stress on the livestock, pasture and producer.

Other factors will also reduce the effect of a drought on an operation. For example, stockpile extra forage. In a normal year, aim to have 1.5 years' worth of forage stored in the fall. This practice of banking forage for lean years has been practiced for hundreds of years in farming and has particular relevance for drought. The type of livestock raised will also have an impact. Simply put, big cows eat more. A 680 kg (1500 lb) cow will eat 17% more feed than a 570 kg (1250 lb) cow. Optimally, producers should aim to raise cows that are economical to keep and raise a big calf. A minimum target for beef producers is weaning 50% of cow weight.

A drought management plan not only involves pastures and livestock but should also incorporate finances and people. Key factors to the financial section of a drought management plan include working toward a better equity position, involving your financial planner or advisor for the leaner times the year after you liquidate. A plan should be in place to aid in your decision to destock – which animals, at what time and where. Producers should accept drought as a normal part of farming and reduce their stress by sharing their concerns and burdens.

This section provides information on techniques to plan for drought events and mitigate the impact of those events on your farm. Information is provided on:

- Managing forages under drought
- Management tips for beef producers during drought and feed shortages
- Making an informed decision on creep feeding
- Reducing stocking rates
- Supplemental feeding strategies
- Body condition scoring

## MANAGING FORAGES UNDER DROUGHT

### Grazing Management

The best way to prepare for drought is to manage pastures for deep-rooted plants, high organic matter content and good soil structure. This is why controlled grazing practices are promoted as a climate change adaptation strategy and a way to pull carbon out of the air. There is a good chance that producers using continuous grazing will have to provide supplemental feed before using rotational grazing, as the pastures have good root reserves and taller, deeper-rooted plants. These plants will make better use of soil moisture and produce more biomass for grazing.

To keep taller, deeper-rooted species in the sward, higher exit heights are needed. Over time, if the pasture is repeatedly grazed to 10 cm or lower, especially if it is not given sufficient rest, it will select for short, shallow rooted species (bluegrass and white clover). Using deeper-rooted legumes, in particular, is a good idea – for example, alfalfa and red clover. This is why Gerrish (2004) recommends varying the exit heights throughout the season. It encourages different species to fill in the above-and below-ground space, capturing more sunlight, more nutrients and more water.

Many of our grasses are weakened by drought through the lack of plant growth and the low level of stored carbohydrates in the root system. Under dry conditions, it is important not to graze pastures too short. Close, continuous grazing under drought conditions reduces root biomass, leaving plants even more susceptible. Leaving no less than 10 cm (4 in) of stubble helps shade the soil reducing evaporation losses and will aid in the recovery of plant growth once rain returns. The important part is to leave some leaves behind. If the animals have been pushed to eat all the leaves and start grazing the stems, there will be little to shade the ground. There will be no leaf area left to photosynthesize, so the plant will be forced to draw on root reserves to recover. During a drought year at the University of Missouri's Forage Systems Research Center, they found that paddocks grazed to a shorter residual height took 50-60 days to recover while paddocks grazed to a higher residual height recovered in 35 to 40 days (Gerrish, 2004).

## Use Drought Tolerant Species

The use of drought tolerant species of grasses will reduce the impact of drought on pasture. Ryegrass, orchardgrass, and bromegrass are known to have some drought tolerance, whereas pasture species such as bluegrass and timothy are known to be drought intolerant. Though bluegrass, with its shallow roots, goes dormant during dry periods, however, it does recover relatively quickly with moisture. Studies in the Northeastern US show that more diverse forage mixtures that contain a greater number of species are more productive in drought years (e.g., Sanderson et al., 2005). They highlighted chicory as a good forage plant that will fill in gaps during dry periods. Chicory is an interesting pasture plant in any case, but in dry years, it really stands out because of its deep taproot.

## Grazing Hayland

Care must be taken when grazing hayland. Overgrazing can cause serious long-term damage to red clover, alfalfa, timothy and other species. Block grazing or strip grazing using temporary electric fencing will help control grazing, reducing trampling and prevent overgrazing. The time spent on a hay field should be long enough to graze the area off evenly but short enough to prevent the grazing of any regrowth. As a general rule, seven consecutive days is the maximum length of time animals should be left on a hay field paddock. Observing the plants in previous paddocks in the rotation can give a producer a good idea of how fast the plants are regrowing and allow adjustment of the length of stay.

## Set Mowers High to Encourage Quicker Regrowth When Moisture Returns

Forage mowers for hay and silage in legume-grass mixtures should be set to leave at least 10 cm of stubble, especially during hot, dry periods. Cutting a plant too short reduces the plant's ability to regrow and exposes the ground to greater drying.

## Manage Over-mature Pastures

Following the drought, over-mature pastures can be clipped and fertilized to effectively respond to the much wanted moisture. Clipping grasses to a 10 cm height will stimulate regrowth and increase utilization by the cattle and sheep.

Alternatively, this can be managed by using adaptive management-intensive grazing. Move the animals through the paddocks quickly at high stocking densities so that they can be selective in what they eat and trample the rest. This can allow the animals to maintain good protein and energy intake while stimulating good regrowth and putting the residues in contact with the ground, where they can break down quickly. A good way to monitor cattle to ensure they are getting good quality feed in this scenario is to watch their manure. The cow patties should not be liquid, nor should they be solid. The ideal cow patty, according to Dr. Allan Williams, a US grazing consultant and farmer, is circular with a dimple in the middle and is the consistency of thick pancake batter. He has a great video demonstrating how to "read" the manure of grazing cattle (" Adaptive Grazing 101: What Should a Cow Pie Look Like?", Wallace Center, 2019).

## Cereals for Fall Grazing

Provided there is sufficient fall moisture, cereals such as oats, barley, and fall rye can be seeded in late August to provide grazing approximately six to eight weeks from planting. Oats have the fastest growth and are tolerant of light frosts. Care should be taken if grazing oats as they tend to accumulate $NO_3$- at early growth stages. The recommended seeding rate for oats is 120 kg/ha. Fall rye is very tolerant to frost and its regrowth is superior to other cereals. Fall rye can also be grazed very early the following spring, long before any other pasture is available. If using bin-run seed, ensure the seed has proper germination and is clean of weed seed.

## Nitrate Poisoning

High $NO_3$- levels in forage can poison livestock, causing symptoms ranging from reduced feed intake to laboured breathing, frothing at the mouth, convulsions and death. Hay or silage harvested during or immediately after a drought can be high in $NO_3$-. Other factors that can cause high levels of $NO_3$- are the high levels of fertilization and other conditions that interrupt the plants' ability to convert $NO_3$- into protein, like hail and frost. More information on $NO_3$- poisoning can be found in Chapter 10 - *Animal Health on Pastures*.

As a precautionary measure (especially if the forage makes up the bulk of the ration), hay, grass and corn silage harvested during or immediately following a drought should be tested for $NO_3$-. Forage can be tested for $NO_3$- levels at the NS Department of Agriculture Analytical Lab in Truro, NS. A $NO_3$- concentration in the feed of less than 0.15 % on a DM basis is considered safe for all conditions and livestock (Cash et al., 2007). If the $NO_3$- level is high, then delay the harvest or grazing for one to two weeks and retest.

## Nitrogen Fertilizer

Once the rains return, if required, regrowth on forage fields and pastures can be increased with an application of urea ammonium nitrate (28-0-0) or urea (46-0-0). Response to N application is usually rapid if moisture conditions are favourable. It is important to allow at least three weeks between application and harvest or grazing. It is not economical to apply N fertilizer later than early September.

For organic producers and those who do not wish to use synthetic fertilizers, an application of manure can help.

# BEEF MANAGEMENT TIPS FOR PRODUCERS DURING DROUGHT AND FEED SHORTAGES

The following are tips designed to provide producers with ideas in a year of feed shortages. They are focused on simple management tips, not cropping options (Firth, 2001). Think about one or more combinations of the following options if the cows look like they are going to be thin in the fall or if the pastures are not regrowing:

## 1. The Use of Creep Feed

Creep feeding is an economic decision. Creep feeding should be used before the pasture has been depleted and when feed is cheap, and calf prices are high. The general methods for creep feeding are:

- Traditional grain in creep feeders
- Pasture creep – calves graze new pasture or other feed exclusive of the cow but have access to the cows

### Creep Feeding Rules of Thumb:

1. Each kilogram of creep feed will replace 0.5 – 1.0 kg of forage DM eaten. If a calf consumes 90 kg (200 lb) of creep feed throughout the summer, there is a savings of about 68 kg (150 lb) of forage DM. This represents an additional animal unit per month of pasture for every four calves being fed.
2. Average feed conversions with creep feed are 5:1 to 8:1 kg (lb) of creep feed consumed per kg (lb) of calf gain.
3. Use caution with barley and corn – irregular intakes can lead to digestive problems.
4. The entrance to the creep area should be 0.4 – 0.5 m (16-20 in) wide and 0.75 – 1.0 m (30-42 in) high. A feeder space for two or three calves to feed at once is required, and each space should be about 0.3 m (12 in) wide. The feeders should be placed close to where cattle loaf (near shade, water, mineral feeder, etc.).

Organic producers should choose feed in the following decision-making order: first would be feed produced on-farm, then certified organic feed purchased from off-farm. Non-organic feed is only permitted in certain limited and serious conditions like "extraordinary weather conditions." Consult Clause 6.4.7 in the standards for details (CGSB 2020). This is really at the core of organic systems – if organic feed isn't being used, the animal isn't organic because the meat has been grown from non-organic nutrient cycles and inputs and has had a different impact on the environment.

### Calculating Cost Effectiveness of Feed

Some simple mathematics will determine if it is cost-effective to use creep feed.

Follow the sample ration below and using grain prices FOB Truro October 2023. A sample calf creep feed ration from Firth (2002) with 15% crude protein is below.

Table 9.1 Sample of common rations and their average weigh in ration.

| ITEM IN RATION | % BY WEIGHT IN RATION |
|---|---|
| Oats | 47 |
| Barley | 46 |
| Soybean Meal | 5 |
| Limestone | 1.3 |
| Trace Mineral Salt | 0.4 |
| Vitamins A, D & E | 0.1 |
| TOTAL | 100 |

****If using commercial protein source, use a non-urea source.**

Table 9.2 Grain prices FOB Truro (Statistics Canada, January 2023).

| ITEM IN RATION | INGREDIENT PRICE |
|---|---|
| Oats | $430/tonne |
| Barley | $440/tonne |
| Soybean Meal | $860/tonne |
| Limestone | $1.00/kg |
| Trace Mineral Salt | $1.00/kg |
| Vitamins A, D & E | $2.50/kg |

| | |
|---|---|
| Cost of grains in one tonne of ration | $490.00 |
| + cost of mixing one tonne | $ 40.00 |
| Total cost per tonne | $530.00 |

The total cost for barley and mixing at $530/tonne is equivalent to $0.53/kg or $0.24/lb The $0.24 lb feed at an 8:1 conversion ratio = $1.92/lb of calf gain

Add $0.18 per lb gain for the equipment and labour - $1.92/lb of calf gain + $0.18 = $2.10/lb gain.
If the expected feeder price meets or exceeds $2.10/lb, consider creep feeding.

### Quick Tips to Consider for Creep Feeding

**Feed Efficiency:**

- The feed efficiency of young animals fed creep feed will average 7:1 to 10:1 with free choice access to the creep
- A better feed efficiency can be obtained (5:1) if calf access is limited
- Calf creep feed intake can be limited to 0.9 kg/day (2.0 lb/day) by adding salt to the ration
- 13-15% crude protein is adequate for creep feed. Use in conjunction with a high-quality forage

**Creep Mixes:**

- There are as many creep feed mixes as there are grain types.
- Rations based on corn or grain plus protein are available upon request. Be flexible and adjust creep feed as the pasture conditions change. Feed a protein creep when forage or pasture quality is low.
- Protein will increase forage intake by 15% and digestibility by 20%
- Feeding a high energy creep when forage quantity is low will decrease forage intake

**When to Use Creep Feeding:**

- The most obvious use of creep feed is when pasture quality and quantity decline. Use creep feeds in the absence of top-quality preserved forage for fall-calving herds.
- Creep feeds can be used 3-4 weeks preweaning as part of a preconditioning program to decrease the incidence of stress-related illness due to weaning.
- Using creep feed when there is a high percentage of first or second-calf dams will reduce the nutritional demand on the dams, and the addition of creep feed will help the calves.
- When grain prices are low relative to current or anticipated calf prices.

The use of creep feed can complicate which animals to select as replacement stock if heifer calves are being selected as replacements. The rule of thumb is to select the largest heifer calves for replacement stock. The maternal ability of the cow is not clear if the calf has been fed creep feed, as it becomes difficult to determine if the calf growth is coming from the genetics of the cow or from the creep feed itself. Calves will sometimes be discounted as feeders if they flesh out too much from the creep feed. Many feedlots will shy away from creep-fed calves because of the loss of compensatory gain advantage (the calves are not "green").

## 2. Sell Now Option

Producers can decrease stocking rates by selling culls in the drought period (or before) that would normally be sold in the fall. Culls sold earlier in the year are often sold for a higher price than those sold in the fall. For example, assume heifers and cows weighing 1000 lb and up are trading at approximately $1 per live lb This price will decrease by 10-15% by October or November. On a 1300 lb cow, that is a decrease of $195/cow, so selling earlier is an economical option. Cows should be pregnancy checked by mid to late summer or earlier to identify all non-pregnant animals. For cows bred between April 25 and June 28 for a February 1 calving, veterinarians can accurately pregnancy check as early as August 7 (40 days post-breeding).

Table 9.3 A mathematical example showing the net gain of selling open and cull cows early.

| | TIME FOR SELLING | |
|---|---|---|
| | Late Summer | Fall |
| Cow Weight (lb) | 1300 | 1250 |
| Cow Price ($/lb) | 1.00 | 0.85 |
| Return ($) | 1300 | 1063 |
| Pregnancy Check ($) | -10 | -10 |
| Additional Feed Cost* | | -41 |
| Net Value | 1290 | 1022 |
| Difference | $268 less for cows in fall than late summer | |

*Feed cost = 30 days x 20lb @ $150/T

**Points to Consider:**

- Cows will eat feed and lose weight between late summer and October
- Cull bottom 15 % of cows if necessary and all open cows
- Sell by late summer, not later in the fall, for maximum return

## 3. Remove the bull from pasture 60 days post-calving

The simple practice of removing the bull from the pasture 60 days post-calving, coupled with pregnancy testing in the fall, will allow you to make easy culling decisions. These are valuable practices in any year but are especially valuable in drought years.

Ship any cows that are not bred. With later calving cows, the spring flush of grass is over and rebreeding time could increase if adequate nutrition is not available.

## 4. Early Weaning

Early weaning accomplishes two things:

- It decreases the pressure on pasture and
- It maintains cow condition for the upcoming fall and winter

### 5. Consider selling your calves

- Consider selling the calves in the fall to reduce the reliance on stored winter feeds. Know the local price for calves and be aggressive in identifying buyers.
- Choose replacement heifers early and try to choose the oldest (they should be the biggest). Then, decide if you will sell the remaining heifers as feeders.
- Consider having the calves custom-fed at a local feedlot.

### 6. Test Feed Early

Testing the feed early allows you to be better prepared for winter feeding. Knowing the nutrient levels in the feeds allows time to plan your feeding program well in advance.

- Feed the poorest quality feed first, providing the cows are in adequate condition coming off pasture and save the best feed for just before and after calving.
- Consider some processing of the poorer quality forage. Grinding increases the intake of poorer quality feeds but does not replace feeding adequate protein and energy
- Remember to always provide adequate supplements (protein, minerals and vitamins).

**Figures 9.1 Feed testing early is always a good practice.**

### 7. Supplemental Feeding

Supplement feeding the entire cow herd on pasture will decrease grazing pressures and can be a valuable practice to get through a drought situation.

- Supplemental feed can be hay, straw, grain or other opportunity feeds. To decide if supplemental feeding is an option, first take a feed inventory.
- If you have more forage than you need for this winter, then feed it as supplemental feed while the animals are on pasture. A cow needs 5,500 lb of as-fed hay for the winter (12 only 4x4 bales or 7 only 5x4 bales).
- Consider feeding vegetable waste if it is available.
- Straw can be used, but cows will lose body condition.
- The use of straw plus grain is another alternative to consider.
- Grain can also be fed, but the intake should be limited by adding salt or restricting the amount fed.

### 8. Investigate Alternative Feeds

Economical, nutritious feed may be available as a by-product, depending on your location.

- By-products suitable for use as alternative feeds can include apple pomace, cull potatoes, cull carrots, vegetable processing waste (beans, peas, cabbage, etc.), bakery waste, brewer's grains and even cranberry and grape by-products.
- Straw is suitable to replace the fibre component of forage, which is needed for rumen function, but it is not a sufficient source of protein, carbohydrates, vitamins, and minerals, so it can't be fed on its own. The high fibre content can reduce how much an animal can eat because of its bulk and slow passage through the rumen. There are good resources out there about feeding straw, for example, factsheets provided by the provinces of Ontario and Manitoba (OMAFRA, 2022; Manitoba Agriculture, no date).
- These feeds can compensate for shortages of forage and may provide an economical alternative to grain supplementation.
- Contact a ruminant nutritionist for information regarding any special feeding considerations before deciding to use by-products as a feed source.

## 9. Monitoring the Cows and Body Condition Scoring

Body condition scoring is a management tool that can help the cow/calf producer better utilize a year-round feed supply and achieve better reproductive and calf-rearing performance. Body condition scoring is a relatively objective method of determining the overall body fat covering of an individual animal. A number between 1 (very thin) and 5 (very fat) is assigned to the animal depending on its body fat covering. In the mid-1970s, several researchers in Scotland created a system of condition scoring for application to beef cows. The system consists of five grades determined by an appraisal of the fat cover over the loin area between the hook (hip) bone and the last rib (Figure 9.3). See Table 9.4 for *Body Condition Scoring Descriptions*.

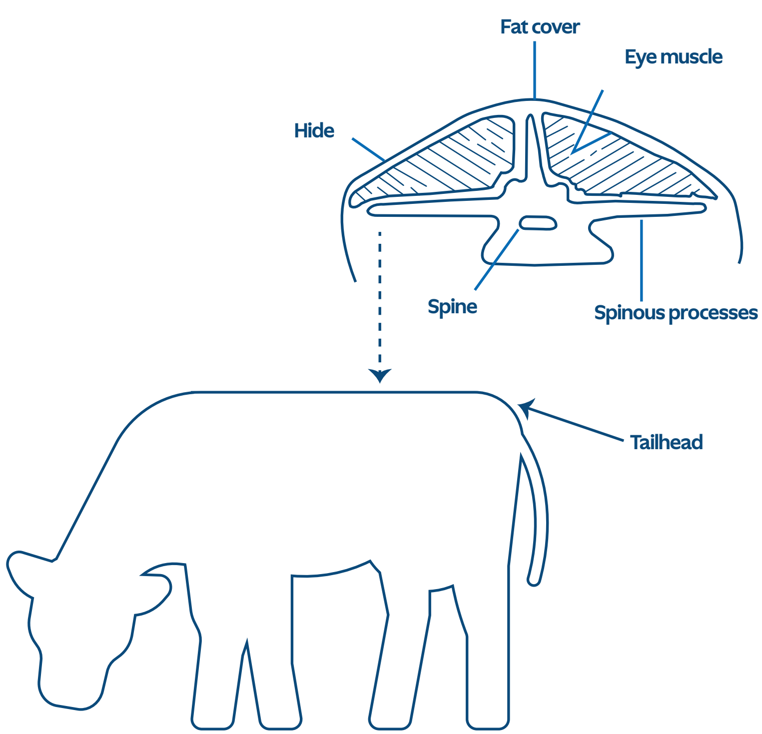



Figure 9.2 Areas to handle in assessing condition score.

Table 9.4 Body Condition Scoring Descriptions.*

| SCORE | DESCRIPTIONS |
| --- | --- |
| 1 | The outline of the spine is very prominent, and individual short ribs are sharp with no fat cover. Individual ribs and tail head are prominent. |
| 2 | Short ribs have a rounded look but can still be felt. Individual ribs and tail head have some fat cover. |
| 3 | Short ribs are felt with firm pressure, tail head has a fat cover that is easily felt. |
| 4 | Short ribs cannot be detected even with firm pressure; fatty deposits around the tail head are quite obvious. |
| 5 | Characteristic bone structure is no longer noticeable; flesh hangs from the tail head, and mobility may be impaired. |

*Body condition scores may fall between these values; if so, assign an intermediate number (e.g., 2.5).

## Body Condition Scores and Optimum Production

Beef cattle body condition scores for optimum production, based on calving season, are as follows:

**Winter Calving – February:**

Generally, winter-calving cows can be bred at a lower body condition score than those calving in autumn. Cows calving in winter are bred on a rising plane of nutrition. The target body condition score for cows calving in winter is 2.5 and not below 2.0 at breeding. Early calving cows should not be allowed to lose any body condition between calving and pasture turnout. At weaning, these cows should have a body condition score of 3. See Table 9.5.

Table 9.5 Winter Calving-February.

| | FEBRUARY CALVING | APRIL BREEDING | NOVEMBER WEANING |
|---|---|---|---|
| **Condition Score** | 3.0 | Cows 2.5<br>Heifers 3.0 | 3.0 |

**Spring Calving – May:**

The major difference between this group and the winter-calving cows is that the body condition score can be 2.0 - 2.5 (instead of 2.5) at calving. By July (breeding season), the cows have regained their body fat reserve to the point where they should have a body condition score of 3.0. At weaning and housing, these animals usually have a body condition score of 3.5. A fall body condition score of 3.5 enables feed levels to be reduced during the latter stages of pregnancy. See Table 9.6.

Table 9.6 Spring Calving-May.

| | MAY CALVING | JULY BREEDING | NOVEMBER WEANING |
|---|---|---|---|
| **Condition Score** | 2.0 – 2.5 | 3.0 | 3.0 – 3.5 |

**Fall Calving – October:**

Body condition scoring is especially applicable to fall-calving cows. A body condition score of 4.0 for fall-calving cows is the maximum to avoid calving difficulties. A body condition score of 2.5 is adequate for rebreeding but may be difficult to obtain due to poor winter feeding conditions. A balance between body condition scores at calving and rebreeding must be obtained. Once pregnant, fall-calving cows may be allowed to lose body condition scores reaching as low as 1.5 - 2.0 until pasture turnout. See Table 9.7.

Table 9.7 Fall Calving (October – November).

| | OCTOBER - NOVEMBER CALVING | JANUARY BREEDING | AUGUST WEANING |
|---|---|---|---|
| **Condition Score** | 2.0 – 2.5 | 3.0 | 3.0 – 3.5 |

Remember that good nutrition from post-calving to rebreeding is vital if cows are to conceive within the desired 60-day breeding period.

## Practical Application

The establishment of an objective body condition scoring system eliminates the use of broad terms such as "thin" and "fat". The body condition scoring system applies across breeds and herds. Individual animal body condition scoring records can be kept on a year-round basis to determine the success of feeding or general management changes.

Body condition scoring will increase awareness of winter feeding programs and the impact of body condition on reproductive management.

Body condition scoring can be used as an indicator of management. Producers should become aware of why individual cows or the whole herd are thin (body condition score 2.0 or less) or fat (body condition score 3.5 or greater). Look at causative factors in the management system and know what the potential problems with each body condition will be. Above all, strive to make positive management changes.

Remember that body condition problems will impact not only performance this year but will affect the calf and cow's performance in the long term.

# EXTREME FLOODING

Managing fields during extreme flooding events can be equally as challenging as droughts, although it poses unique challenges. This section provides information on managing flooded pastures and managing flooded hayfields.

## Managing flooded pastures

Animals should be immediately removed from flooded areas. A primary concern with flooded fields is silt contamination- silt can contain harmful, toxin-producing bacteria that can create animal health concerns and impact the stored forage fermentation process. Fields should be considered on a case-by-case basis, and management decisions will vary depending on plant height and flood levels.

Flooded pastures should be cut to a height of 10 cm once water levels recede, and the field is dry enough to support equipment. The cut forage should be left to decompose, and animals should be kept off the field until it has fully decomposed, and the regrowth is at least 20-25 cm tall (Rayburn et al., 2022). Ensure all animals are vaccinated against Clostridial diseases (see Chapter 10 for more information on vaccination).

## Managing flooded hayfields

The amount of the plant submerged, the movement of water and forage type are important to consider. Plants that were not completely submerged are more likely to survive and have less risks of bacterial and fungal diseases. Standing water is more damaging than moving water.

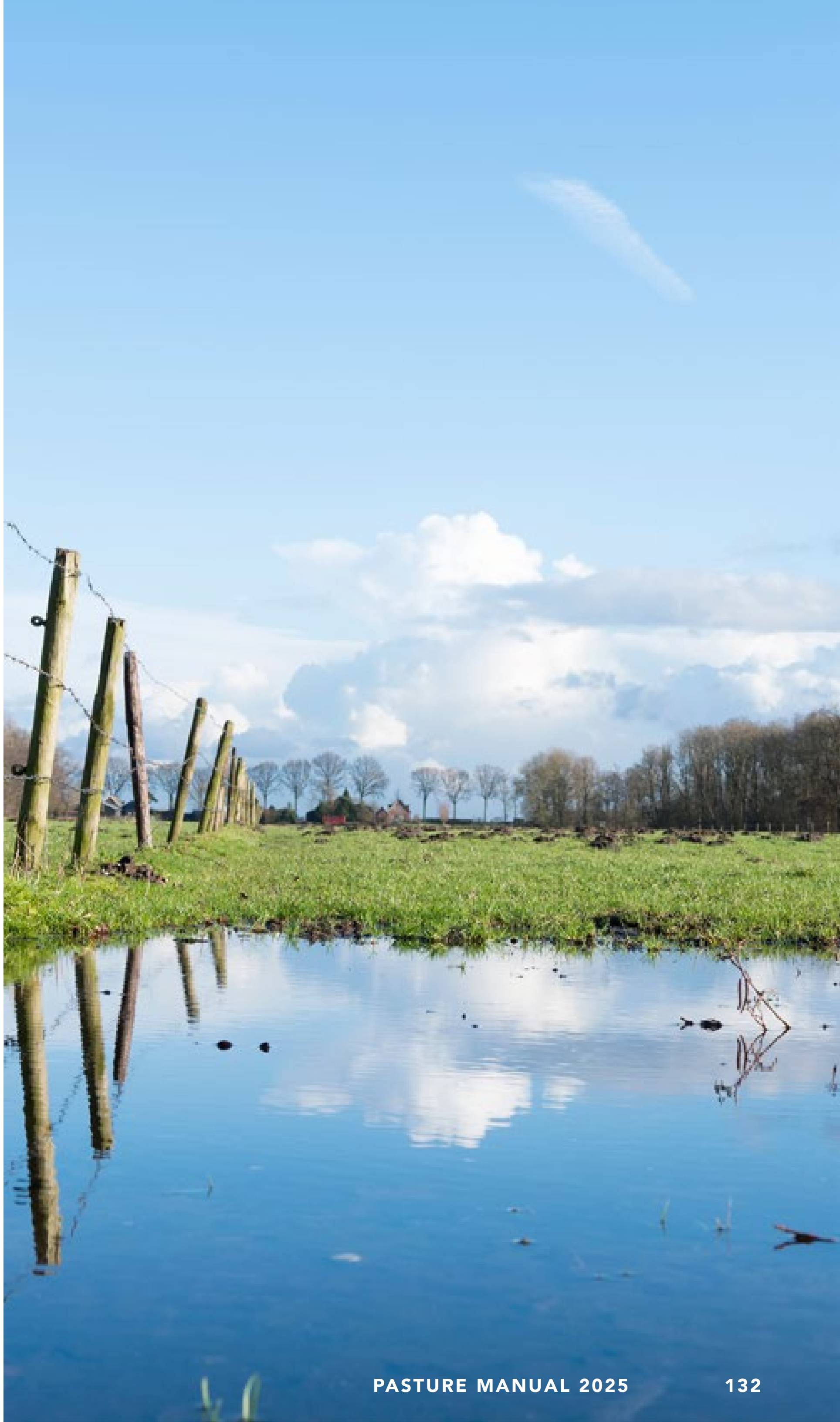
If the field was not submerged for too long (up to three or four days for alfalfa; up to seven days for grasses), an application of fertilizer will help stimulate regrowth after cutting. Some N, even for legumes, is acceptable. However, if a field has a high percentage of alfalfa (or other legumes) and was underwater for close to four days, wait one month to assess root rot in advance of fertilizing. A few plants should be dug up at different points in the field to see if the roots have been damaged. If roots have rotted off, the field should be terminated. Unfortunately, waiting one month may lead to challenges in reseeding the field to something usable this year or next season, depending on the time of year.

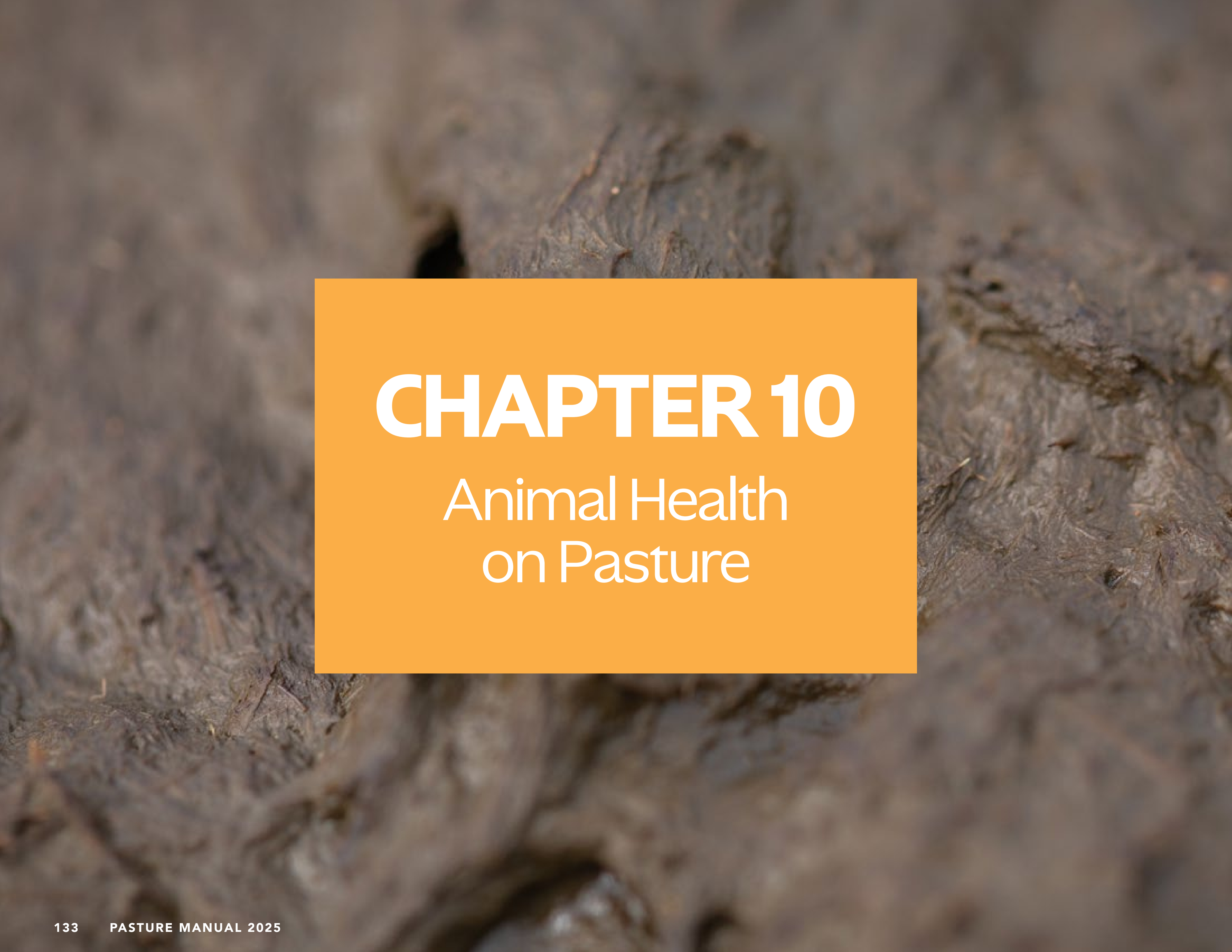
If a field has a considerable amount of silt contamination, plant height will determine its management. If there is a significant amount of plant matter in the field, the forage will need to be cut and removed. Too much biomass may affect the regrowth of the next cut. For fields that were recently cut or are short, it's possible rainfall may wash off silt, and it may be diluted with more plant growth before harvesting. Alternatively, fields should be cut, and plant material may be left to decompose.

If you are going to accept some risk and plan to harvest for feed, and if you believe the crop is not too silty then forages **should be** stored separately from any forages harvested from fields not impacted by the flood. The risk of soil contamination and poor ensiling is high; this management decision will allow for easy identification later in the season.

It may be a better option to produce dry hay from flooded forages instead of ensiling, given the risk of poor ensiling. Water may have caused stem and leaf damage, which can impact the dry-down rate and forages may dry quicker than expected. Leaf damage or loss can also affect the quality of the final product. **Be cautious: it's possible they go through the entire harvesting and storage process and still end up with unusable forage.** If you decide to ensile these forages, following best management practices for ensiling should improve the chances of success. The appropriate inoculants should be applied to the harvested grass/legume forage to assist with the ensiling process.

**Samples should be taken and sent to a lab for mycotoxin testing and nutrient analysis before feeding.**





# CHAPTER 10

## Animal Health on Pasture

# CHAPTER 10
# Animal Health on Pasture

Animal health is an essential component of a profitable grazing system. Animals in good health produce to their full potential and minimize veterinarian and medication costs. Good grazing management can promote animal health by providing high-quality, cost-effective feed, access to clean air, exercise, better footing, and will allow animals to behave more naturally. However, a good health management program is critical and should be developed in cooperation with your veterinarian.

**This chapter introduces the topics of parasites, vaccination, mineral supplementation, bloat and poisoning as it relates to pastured livestock—it does not replace the information that can be provided by your veterinarian specific to your farm and livestock.**

## PARASITES

Two main groups of parasites affect pasture animals: internal (such as roundworms and flukes) and external (including fleas, ticks, lice, and mange). Controlling the parasite load on animals can be done through management based on an understanding of the parasite life cycle and using the appropriate prescribed treatments.

Economic losses from parasites can be significant. The effects of parasites on livestock include reduced feed conversion, weight loss and increased susceptibility to disease and death. The first effect of parasitism is appetite suppression, resulting in altered grazing behaviour. Even very low levels of larval challenge will result in reduced food intake. The second effect is the generation of an immune response by the livestock to the incoming larvae. Generating an immune response requires energy and protein, and both of these needs are met at a cost to production: body weight gain, wool growth or milk production. These effects cause production losses before clinical symptoms like scouring are visible. (Meat and Wool New Zealand Ltd, 2006).

### Internal Parasites

Internal parasites can be further classified into two groups: *gastrointestinal nematode* (GIN) and *non-nematode* parasites. GIN parasites, also known as roundworms, are a challenge for many livestock farmers. Limited access to appropriate anthelmintic (i.e., dewormer) drugs and the development of worm resistance to anthelmintics are significant issues around the world. As anthelmintic resistance in parasitic worms increases, the issue of parasite control is becoming more challenging for livestock producers. Control depends on the producers understanding of the parasite life cycle, the animal class or age, grazing management and appropriate use of anthelmintic drugs.

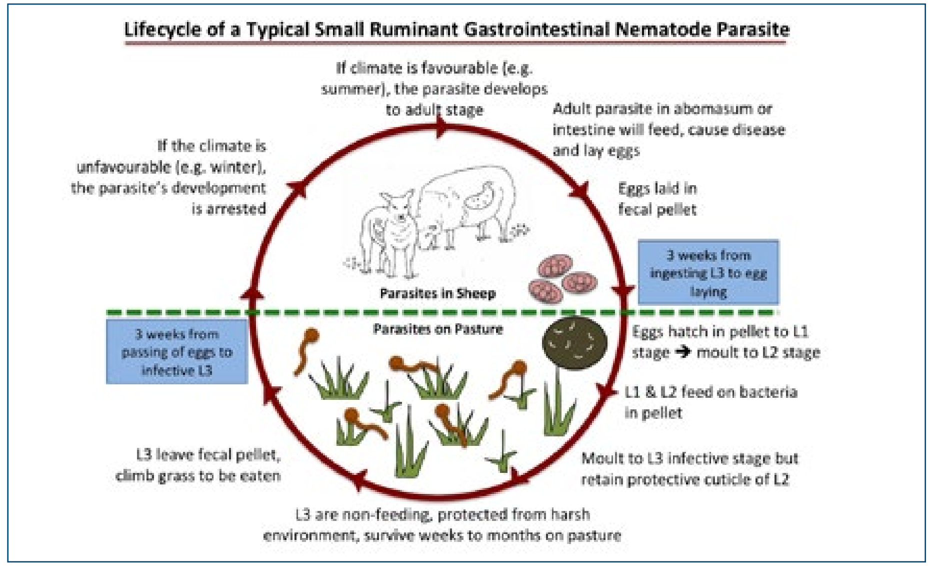



**Figure 10.1 Gastrointestinal Nematode (Roundworm) Life Cycle from The Parasite Handbook (University of Guelph, 2019).**

Most GIN species have four larval stages (Figure 10.1). The first three stages of development take place on the pasture and are called the "free-living stages". The third larval stage, referred to as L3, is the infective stage of the lifecycle. The L3s migrate out of the feces in moisture films from soil moisture, dew and rain. As the pasture is warmed by sunlight and in the presence of moisture (i.e., dew or rain), the L3 migrate up the grass blades where they are most likely to be eaten by livestock. When an animal eats the L3, they undergo another moult to become an immature worm or the L4 larva. Inside the animal, the L4 larvae moults once more and matures into the adult worm, which feeds on its host.

The female worm mates inside the host animal and produces eggs in about 21 days. The eggs pass out in the manure, and the life cycle begins again. Female worms produce large numbers of eggs over their lifetime, and the population of eggs and larvae on pasture can build rapidly if not managed properly.

Some of these parasites can survive over the winter on pasture during larval stages, surviving in the fecal pat or pellets, on the grass or in the soil. They can also survive as the L4 larva in the animal's gut, which can put its development on hold during the winter.

## Barberpole Worm

**The barberpole worm**, *Haemonchus contortus*, deserves special mention because it is detrimental to the sheep industry. These worms drink blood from the abomasum of sheep, amounting to a blood loss of 0.05 mL per worm per day. To put that into perspective, if an animal were to be infested with 5000 worms, they would experience a blood loss of 250 mL per day. This would result in severe anemia rapidly. Once infected, the treatment of Barberpole worm can be difficult. This is mostly due to an abundance of anthelmintic drug resistance. These worms do not survive well on pasture over winter due to the climate in Nova Scotia. However, they are able to lay dormant within the ewes throughout the winter and emerge in the spring when temperatures become more favourable. When ewe flocks are blanket-dewormed in the winter, the worms that survive are the ones to infect the pastures in the spring, leading to drug-resistant parasite populations in just a few seasons. In addition to this, the Barberpole worm is capable of producing up to 10,000 eggs per day, making it difficult to control the spread of the parasite if they are present in large numbers. There is Nova Scotia-specific research about the barberpole worm that can be accessed at the Sheep Producers' Association of Nova Scotia website.

Monitoring sheep for *Haemonchus* is important and can be done using an assessment of anemia called the FAMACHA, scoring the colour of the inner eyelid from 1-5. Animals with anemia should be treated with a dewormer known to be effective against *Haemonchus*. Ewes that need repeated treatment should likely be culled. Other signs to look for are failure to thrive, weight loss, submandibular edema (bottle jaw) and weakness.

## Other Stomach Worms

**Brown stomach worms** (*Teladorsagia circumcinta*) and **stomach hairworms** (*Trichostrongylus axei*) are other GIN species that cause similar symptoms to Barberpole worms. In fact, it is often difficult to distinguish between GIN species outside of a laboratory setting. However, there are some differences in host symptoms, parasite life cycles and time of year that can suggest which parasite is present. Brown stomach worms damage and feed on glands of the abomasum (fourth stomach chamber); symptoms include diarrhea, weight loss/reduced rate of gain and reduced feed intake. Damage to the abomasum can result in unthrifty animals even after deworming. They are primarily associated with causing disease in the late summer into fall. Stomach hairworms also live in the abomasum and are associated with disease during the same time of year. Symptoms are similar to brown stomach worms but can also include bottle jaws.

## Intestinal Worms

**Thread-necked worms** (*Nematodirus battus*, *Nematodirus filicollis*, *Nematodirus spathiger*) and **black scour worms** (*Trichostrongylus colubriformis*) are important GIN species that colonize the intestines. Trichostrongylus severely damages the intestinal walls and causes bottle jaw, weight loss, reduced feed intake and dark diarrhea. The disease is associated with late summer and into fall. *Nematodirus* are usually associated with causing disease in early summer and may be distinguished from other GIN species using a fecal float because their eggs are significantly larger than other species. Symptoms include watery yellow diarrhea, which causes severe dehydration.

**Other nematode species exist outside of the gastrointestinal system- a few relevant species to pasturing in Atlantic Canada are introduced below.**

## Lungworm

**Nodular lungworm** (*Muellerius capillaris*) is more commonly seen to cause significant infection in goats than other ruminant species. This parasite requires a mollusc (slug or snail) intermediate host to complete its lifecycle. The parasite will first infect the mollusc, and then once the mollusc is ingested and digested by a ruminant, the larva is released and begins its travel from the digestive system to the lungs of the host. Damage can be cumulative over several years and can eventually cause breathing problems, pneumonia and lung damage. Lung tissue becomes necrotic when the worms die. Due to its lifecycle, the nodular lungworm will be more commonly found in wet, low-lying areas. Therefore, it is recommended to fence off or avoid grazing ruminants in these areas.

## Central Nervous System Parasites

**Deer meningeal worms** (*Paralaphostrongylus tenuis*) are worth noting as several parts of Atlantic Canada have significant deer populations-- the whitetail deer is the host species of the worm, but it can infect other ruminant species, including moose and domestic species. This parasite is responsible for "moose sickness," which occurs when the parasite is consumed by moose and enters the brain, causing erratic behaviour. In domestic ruminants, it can cause hind-end paralysis and staggering, blindness and death.

## Non-Nematode Internal Parasite Species

Non-nematode parasite species include protozoa species (including coccidia and *Cryptosporidium*), tapeworms and liver flukes. **Coccidia** are single-celled organisms that can cause significant production losses or mortality if untreated. Youngstock with underdeveloped immune systems are most susceptible. Coccidiosis damages intestinal cells and causes watery diarrhea that can quickly dehydrate animals and cause reduced rates of gain; animals who have encountered coccidiosis may continue to have reduced gain even after treatment due to damaged intestinal walls and poor absorption of nutrients. Although crowded, unsanitary conditions are the usual culprit, coccidiosis can also be seen on pasture when animals are experiencing stress. The most practical way to deal with coccidiosis is through prevention rather than treatment—clean living environments, good ventilation, adequate space, and appropriate nutrition play a large role in preventing outbreaks. Coccidiostats may also be given as a preventative measure but should be discussed with your veterinarian.

**The liver fluke** has a complex life cycle. Adult liver flukes live in the hosts' bile ducts, producing eggs that subsequently leave the host in its feces. If the eggs are dropped in a wet area, they hatch and release the larvae called miracidia. The miracidium finds a snail (*Lymnaea truncatula*) that acts as an intermediate host. The miracidia bores into the snail and uses the snail to multiply and develop into tadpole-like creatures; this takes two to three months. If the miracidium fails to find a snail within 24 hours, it runs out of energy and dies. Once developed, the tadpoles leave the snail and swim to a plant, climb out of the water and encyst onto the plant. When a mammal eats the plant and cyst, the larva will emerge from the cyst and infect the new host. It burrows through the intestinal wall and then through the liver to the bile ducts, where it will mature to the adult stage. Egg production occurs about eight to ten weeks after initial infection.

Liver fluke infestations can be reduced by limiting livestock access to wet areas in pastures. Alternatively, the wet areas can be drained to reduce potential habitat for the snails that act as intermediate hosts for the liver flukes, interrupting the liver fluke life cycle and significantly reducing the risk of infecting the livestock.

## Internal Parasite Control

Parasites are a fact of life for graziers. The reality is that eliminating intestinal and stomach worms is unlikely. Furthermore, trying to completely eliminate them will lead to the rapid development of parasite resistance to anthelmintic drugs. Learning to live with parasites means deworming strategically and using a variety of practices to minimize the impact of parasites on the animals. A general rule of thumb with parasites is that 70% of the parasites occur in 30% of the animals; it is usually effective to treat only the affected animals to significantly reduce the number of eggs being deposited on the pasture.

Producers must be aware of the kind of parasites and the level of infestation before deciding what parasite control strategy to use. Collecting and submitting fecal samples for analysis will provide the producer with accurate information on the parasite burden on their farm. Keen producers can learn to do fecal egg counts (FEC) on-farm for at-home monitoring (University of Rhode Island, 2014). This information, coupled with monitoring of production measures such as the livestock's body condition the rate of gain and, for sheep, the colour of their inner eyelids (FAMACHA score for anemia), can tell a producer what effects parasites are having on the livestock. It should be remembered that fecal samples are an indication of what was happening on the pasture when the livestock ate the parasite eggs. This could be 21 to 28 days earlier, as this is how long it takes for the larva to mature and the host to start shedding eggs. The weather and other pasture factors can have a dramatic impact on the current parasite conditions.

There is a big difference between managing parasites for cattle and sheep. For sheep and goats, parasite loads are more damaging. Consult the *Handbook for the Control of Internal Parasites of Sheep & Goats*, produced by research veterinarians in Ontario, for the latest recommendations (University of Guelph, 2019). The University of Rhode Island has great resources about FAMACHA scoring available online.

The weather has a significant impact on larva numbers on pasture. Warm, moist weather in the spring and early summer promotes and speeds up the life cycle of the worms. Hot, dry weather in later summer kills off eggs and larvae. Cooler fall weather results in fewer eggs and larvae. Therefore, there is a buildup of parasites through the spring and early summer, with levels typically falling off as the season turns colder and fall changes to winter.

Producers should discuss their parasite control programs and strategies with their veterinarians. The limited number of anthelmintic drugs and the increasing problem of anthelmintic resistance is making parasite control a more complex and important issue.

Animals that are suffering from poor nutrition or that are stressed by either their production cycle (i.e., gestation or lactation) or disease are more susceptible to parasites. Our Atlantic climate can also create significant stress for livestock-- fluctuating temperatures during early or late winter plus high humidity levels can compromise livestock immune systems and make gastrointestinal parasitism and pneumonia more likely. It is vital to maintain a good level of nutrition, including appropriate access to species-specific minerals. Supplemental protein is shown to improve livestock's ability to thrive in the presence of parasite infections (see Arsenos et al., 2007 for more information). Healthy animals maintain a healthy immune system and can respond effectively to all challenges, including parasites. In an overgrazed pasture, the animals have less to eat and are placed under nutritional stress, weakening their ability to defend themselves against pathogens. Overgrazing creates two problems that can compound each other. In an overgrazed pasture, the animals have less to eat and are placed under nutritional stress, weakening their natural defences as a result of reduced immunity. At the same time, they are being forced to consume more larvae because the grass is short. It is, therefore, important not to overgraze, both for the good of the pasture and the animal's health.

Females that are in late pregnancy and early lactation have a temporary drop in immunity and can release more worm eggs onto pasture. This results in the peripartum rise in egg production that occurs later in the animal's lactation period, leading to a significant increase in parasite burden. Any other stressor that impedes the animal's ability to initiate an adequate immune response can result in increased parasite activity and egg shedding by the affected animal. This increased egg shedding can result in parasite build-up in that animal and other livestock. This phenomenon suggests that ewes benefit from sufficient, good-quality protein around the time of lambing to help them boost immunity to parasites as well as meet their nutritional needs.

## Strategic Deworming Procedures

Anthelmintic-resistant parasites pose a significant threat to grazing livestock—especially sheep. Appropriate use of dewormers will prevent or help delay the rate of resistance from developing in your parasite population and ensure that the dewormers we have continue to work as we need them to.

**The recommended plan of action, The 5-Star Worm plan, was developed at the University of Guelph and tackles parasite management as an integrated approach. The 5-Star Worm plan can be found online in the Parasite Handbook or on the Perennia website under the "Sheep" section.** A superficial summary of the plan is outlined below; producers looking for information on strategic deworming are strongly encouraged to consult the Parasite Handbook.

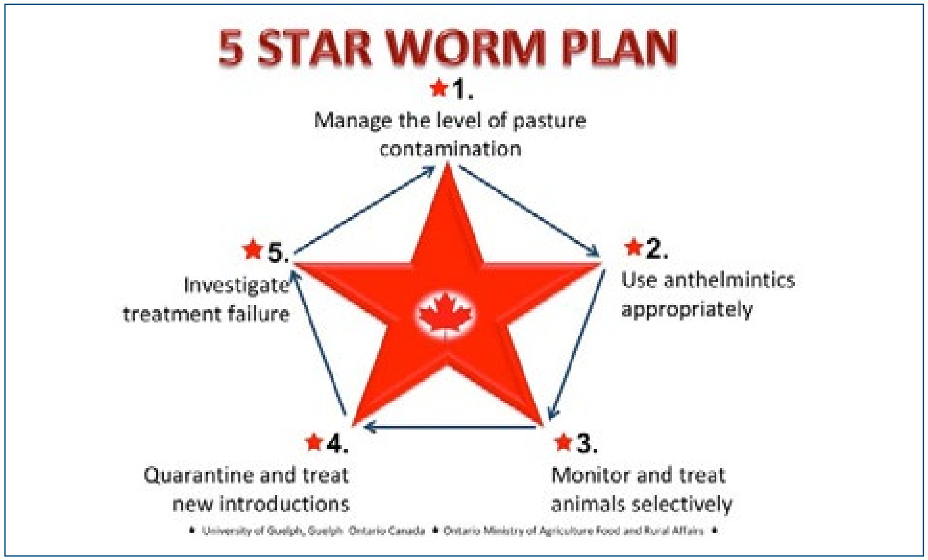



Figure 10.2 The 5-Star Worm Plan (University of Guelph, 2019).

There are five facets of management covered in the 5-Star plan. Managing the level of pasture contamination can be done by closely managing the biggest source of pasture contamination (youngstock and adult females in late gestation and lactation), modifying grazing based on temperature and humidity, modifying grazing based on sward height, removing access to wet spots on pasture, rotating grazing with other species, resting heavily contaminated pastures, using low-risk pastures for youngstock, and using evasive grazing are just some of the possible strategies covered in the 5-Star Worm plan specific to managing level of pasture contamination.

**Pasture and livestock management** can have a significant impact on parasite levels. Young livestock are more susceptible to worms than mature animals. Sheep and cattle (but not goats) develop a level of immunity to worms. Sheep develop this immunity during their first two years on pasture. It is, therefore, important that younger animals be watched closely for signs of parasite infection. By the time signs like scouring appear, there can already have been significant losses of production (scouring can be caused by things other than parasites; it is important to make sure that you are treating the right problem).

Young stock can be grazed before older animals to avoid parasites in a rotational grazing system. Clean pastures, like hay aftermath and newly seeded pasture or annual pasture crops, can be reserved for susceptible animals like lambs. These practices allow areas with the lowest worm burden to be grazed by the animals most at risk.

The highest numbers of worm larvae are found in the first 2cm of pasture height and rarely migrate to 6cm height (Callinan & Westcott, 1986). Therefore, animals grazing pasture with longer grass or not grazing too close will consume fewer worm larvae than when the pasture is shorter. This must be balanced with the animals' grazing habits and the growth pattern of the grass. Rotational grazing is an important practice for parasite management. Using the recommended exit heights for pasture recovery (10 cm) and letting the pasture rest sufficiently before it's grazed again will decrease the accumulation of worms over the season.

The choice of pasture plants is important. Parasite larvae behave differently on different species of plants. This can be because of the physical structure of the plant or its chemical properties. Parasite larvae migrate up grasses the most, so including legumes and forbs (like chicory) in the mixture is immediately beneficial. The supplemental, good-quality protein provided by these plants helps the animals' immune response and resilience to parasites. Compounds like the condensed tannins in birdsfoot trefoil may damage the larvae and inhibit eggs from hatching. Good drainage in pastures helps to prevent and reduce all parasite problems. Watering areas should be well drained and kept dry if possible. By keeping high-traffic areas where livestock accumulate dry, the buildup of parasites and other problems such as foot rot is decreased.

It is possible that species like cattle that are less susceptible than sheep could be grazed before sheep to clean up some of the parasites. Goats would be a poor choice to clean up the pasture because they are susceptible to similar parasites as sheep.

**Using anthelmintics appropriately** means following proper drenching procedures, rotating through dewormer classes no more than once a year, and using combination dewormers when appropriate, such as for new arrivals on a farm or when resistance is suspected.

It is vital to make sure the livestock are receiving the appropriate dose of dewormer. Weigh a representative number of animals (about 10%) to calculate dosing for the heaviest animal in your group. Knowing the weights of the animals that you are treating is essential to calculate the appropriate dose. In addition, the deworming gun or syringe should be calibrated to ensure that it is delivering the dose that you intend to use. This can be done by setting the deworming gun to the desired delivery rate, filling the deworming gun and then squirting it into a measuring cylinder or cup. The amount in the cup should be equivalent to the setdose times the number of squirts that you place in the container. (For example, if you have the drench gun set to deliver 10 cc and you deposited 10 squirts, there should be 100 cc in the container).

**Monitoring and selectively treating animals is another critical piece of parasite management.** Producers should consider the time of year, animal groups, animal health status and farm history in their decisions. When deciding to treat individuals rather than groups, decision-making tools like FAMACHA scores, fecal egg counts, presence of diarrhea, body condition scores and weight gain are all things producers can consider. Genetics and culling decisions are also critical. There is ongoing research into parasite resistance in livestock. Some breeds are known to be more susceptible than others. For example, in New Zealand, Merino sheep are generally more susceptible to worms than Romney or composite breeds of sheep. In the future, it may be possible to do genetic testing for worm resistance as it is currently possible to test for resistance to foot rot in sheep. A basic measure on any farm would be to cull animals that repeatedly need to be treated for parasites. They cost the producer more and contribute more parasite eggs to the pasture.

**Another facet of parasite control is managing new stock**- this is recommended to be done in consultation with your veterinarian, as every situation is unique. When bringing new livestock onto your farm, regardless of the species, it is a good idea to quarantine them from other livestock for several weeks. This may involve drylotting in a quarantine pen, treating new animals with anthelmintics, and then turning onto a contaminated pasture if possible so that any resistant parasites are diluted. This will help to ensure that you do not introduce new parasites to your farm.

**The final part of the 5-Star Worm plan considers reasons for apparent failure- is there another health concern present in the flock, or is there true resistance? Is it possible to re-introduce susceptible parasites?**

With the increasing cost of drugs and the problems associated with parasite resistance to anthelmintic drugs, producers are more and more concerned about how best to make the most of their parasite control programs.

## Internal Parasite Control for Cattle

When considering parasite control programs for cattle, remember that young cattle are more susceptible to production losses due to worms than older cattle. Cattle grazing close to the ground will be more at risk, a feature of continuous grazing and overgrazing. In most cases, mature cattle will probably not need to be dewormed, and it is more beneficial to deworm the young cattle. The level of nutrition, general health status and stress level also play a role in the general health level of the cattle.

**Internal Parasite Management for Organic Producers**

Organic producers face a huge challenge when it comes to managing internal parasites, especially for sheep. Because they aren't permitted to use anthelmintic drugs routinely (only in exceptional circumstances), they must be very careful and rely on other strategies. Organic producers are permitted to use naturally sourced means of parasite control, but there is mixed evidence of the effectiveness of these and little guidance for the dosage or frequency of treatment. If treatment is necessary, the organic standards allow the use of anthelmintic drugs with strict rules explained in Clause 6.6.11 (CGSB 2020). Livestock should not be living with clinical parasitism on organic farms any more than they should on other farms.

Good pasture management, as described above, is the first line of defence. Young, susceptible animals should be preferentially grazed on the cleanest pastures available. This means the ones that have rested the longest or have been ploughed up for renovation. Be aware that spreading non-composted manure on pastures can be a source of parasites.

The worst grazing interval is 2-3 weeks. *Haemonchus* eggs can hatch in 7 days- moving animals before 7 days and not bringing them back for 3+ weeks is a starting point. However, parasite larvae can remain on pasture for the whole season, survive through the winter and reinfect animals. They will decline over time, primarily in very hot or very cold dry conditions.

Having a lower stocking density is important for organic farms. It decreases parasitism by allowing the animals to stay away from manure pats or pellets where the highest concentrations of larvae are found Breaking up manure is helpful to reduce larvae on pasture because they will dry out. A healthy population of dung beetles helps, as can harrowing.

## Economics of Internal Parasite Control

Parasite infestation can affect the profitability of a livestock operation due to the resulting weight loss in animals on pasture. Strategic deworming, consisting of treatment prior to the pasture season and 4-6 weeks after turn-out, has been suggested to achieve better parasite control (Hamilton & Gisen, 2008).

Hamilton & Gisen (2008) studied two groups of cattle yearlings on pasture, one treated with dewormer and an untreated control group. Cattle treated with dewormer had significantly higher seasonal body weight gain and average daily gain (ADG) than cattle in the control group. Treated cattle gained an average of 10.5 kg more than control cattle over the length of the trial.

**The cost of deworming was covered by the significantly higher weight gain in the animals treated in comparison to the control animals.**

Failure to effectively control internal parasites can ultimately result in loss of livestock through mortality. This is more likely to happen with sheep and goats than cattle. If an animal dies due to parasites, it is imperative that you determine the specific organism responsible for the mortality. This can be done by submitting the animal for a post-mortem examination or through fecal tests. Once the parasite has been identified, your veterinarian should be consulted to determine the appropriate course of action, which, based on fecal results, may include deworming the rest of the group with an efficacious drug.

### External Parasites

External parasites, such as ticks, mange, lice, sheep keds and flies, can also cause significant health and production losses in grazing animals). They can cause anemia, damage meat, and transmit diseases. The life cycles of external parasites are generally short, and they multiply at high rates (Table 10.1).

Table 10.1 Description and symptoms of common external parasites.

| PARASITE | DESCRIPTION | SYMPTOMS |
|---|---|---|
| **Lice** | • 3mm or less in size<br>• Dark gray/brown<br>• Wingless<br>• 3-4 week life cycle<br>• Spread by body contact | • Irritation and rubbing of infested areas<br>• Found first on shoulders and neck, back and base of tail<br>• Sometimes found on the belly |
| **Ticks** | • 3 stages: larval, nymph, adult<br>• Wingless<br>• Size depends on the species | • Weight loss<br>• Anemia<br>• Loss of condition<br>• Attach to lower half of the body |
| **Mange** | • 1/40" or less in size<br>• Cannot be seen with the naked eye<br>• 2-3 week life cycle<br>• Spread by contact | • Itching<br>• Irritation and thickening of the affected skin<br>• Sores and licking of sores<br>• Weight loss<br>• Decreased milk production |
| **Flies** | • Two types: biting and non-biting | • Biting types cause irritation and sores<br>• Non-biting types cause annoyance<br>• Wet-looking patches on the rear end of sheep (flystrike) |
| **Sheep keds** | • 7mm in size<br>• Wingless flies | • Bites on neck, shoulders, flank and rump<br>• Rubbing and itching<br>• Dirty, discoloured wool |

The most common issues associated with flies are pink eye in cattle and flystrike in sheep, which can have significant consequences. **Face flies** transmit the infectious agent causing pink eye, Moraxella bovis, and are the primary cause of the disease spread. Pink eye causes ulcers in the eyes, which are painful and more common in youngstock than mature animals. Although not common in Canada, the reportable disease anaplasmosis is also thought to be spread by flies. Even in the absence of disease risk, flies can cause considerable discomfort to livestock. **Flystrike** occurs when flies lay eggs on sheep near the anus or underside (usually on dirty wool), which hatch into maggots and burrow into the wool and skin, eating the flesh. Flystrike usually appears as wet-looking patches on affected areas and can be fatal without treatment. Moderate to warm temperatures and wet conditions are conducive to flystrike, as is dirty wool (i.e. as a result of diarrhea).

**Sheep keds** are wingless parasites that attach to sheep and suck their blood, causing significant discomfort to the host and can damage the hide and cause anemia in case of severe infestation. Youngstock and gestating ewes are most susceptible. The entire lifecycle of keds occurs on the animal, and populations usually peak during the winter and early spring when animals are in close proximity—this can include around feeding stations.

### External Parasite Control

The lifecycle of the parasite largely dictates external parasite control and can be difficult because of the feeding habits of the parasite. Many feed by biting and sucking blood for a short time; therefore, the amount of control product that is consumed is small. Insecticides and some pour-on and oral parasite control products are effective depending on the species of external parasite. The range of registered products is sometimes limited. Insecticides are not allowed in organic production. Consult your veterinarian for appropriate control measures.

When purchasing new livestock for your farm, external parasites should be considered since this can be a source of infection for other animals on your farm. Lice, ticks, and sheep keds can be easily brought onto your farm by newly purchased livestock. **Quarantining and treating new additions to a herd or flock for external parasites is more economical and easier than trying to control an infection in an entire herd**. New additions should be carefully inspected and quarantined in an area separate from their new herd or flock mates so that treatment and careful observation can occur.

Animals that are healthy, given sufficient space, and on a good nutritional plane are less likely to develop heavy external parasite loads; weaker animals are more likely to build up high levels of external parasites. Once a control measure is selected, it often has to be repeated because most treatments are only effective against the adult form of the parasite. Eggs that are laid on the host animal will hatch over a few weeks, depending on the species of external parasite. Re-infection from the environment can occur from parasites that have fallen from infected animals and survived in bedding or pasture grasses. Control products generally do not have an effective activity period long enough to cover the life cycle of most of these parasites. Depending on the species of parasite, treatment may have to be repeated in one to four weeks.

External parasites on sheep (like keds) can be very hard to control. Depending on the time of year, it might be advisable to shear the sheep before treating them. Shearing removes large numbers of eggs and adult external parasites with the wool and makes the application of the parasite control product easier and more effective. It is important to remember that reinfection can occur from the lambs. Therefore, it is also easier to control a problem before lambing or after weaning.

**Fly control** can also be an important element in controlling several diseases, including pink eye. Efforts should be made to limit the fly populations on pasture. Insecticidal ear tags, oilers and sprays can all help to reduce fly populations. Keeping high-traffic areas (around waterers and shade) dry and free of manure will also help to limit the fly population. (Kaufman et al., 2006) Additionally, for sheep shearing, crutching and tail docking at the appropriate time will also help reduce issues such as flystrike.

## VACCINATION

Consideration should be given to vaccinating animals for various diseases before they go on pasture. Young animals usually have passive immunity from their dams if they have received enough colostrum. This immunity declines as the animals mature, and by three months of age, the immunity in both calves and lambs has declined to the point that vaccination should be considered. **Vaccination against clostridial diseases is always recommended for pastured animals in Nova Scotia; vaccination of cows for Bovine Viral Diarrhea (BVD) should also be a consideration.** The most appropriate time for BVD vaccination is prior to breeding. Therefore, if breeding is going to occur on pasture, consideration should be given when to vaccinate the breeding cows. Consult your veterinarian for advice on vaccination.

Organic producers are permitted to use vaccinations to prevent disease. If there is a commercially available vaccine for the disease in question that does not use a genetically engineered substrate, producers must use that (see 5.1.2 and the “vaccine” entry in Table 5.2 of the Permitted Substances Lists, CGSB 2020).

### Clostridial vaccination

**Clostridial** diseases are caused by various species of bacteria in the genus Clostridia, which can infect animals and can cause significant losses. The bacteria are capable of living for years in the soil because of their ability to form protective spores. Clostridia can also reside in the gut of an animal without causing problems and be shed in the manure, infecting new animals. The bacteria can infect livestock with the following diseases: blackleg, malignant edema, enterotoxemia, black disease, red water disease and tetanus (lockjaw).

**Routine use of combined clostridial vaccines is recommended. Clostridial vaccines are very effective and economical.** Administration at intervals recommended by the manufacturer is required to provide adequate immunity. Currently, multiple vaccines are capable of immunizing against seven or eight separate clostridial diseases with one product.

Once infected with a clostridial disease, the animal usually dies rapidly. Early detection and treatment with antibiotics or Clostridial toxoid is sometimes effective. Dead animals should be examined via post-mortem to determine the cause of death.

Clostridial vaccines should be administered subcutaneously in the neck region. “Tent” the skin and use a needle no longer than 2.5 cm to administer the vaccine. The vaccine should never be administered intramuscularly since it can cause significant muscle damage. Reactions resulting from subsequent injections in the neck region cause very little damage and can be removed easily at slaughter. (Floyd 1994).

Currently, there are no commercial clostridial vaccines licensed for use in goats in Canada. Goat producers have used vaccines approved for use in sheep. This is an extra-label use and must be done in consultation with your veterinarian.

## MINERAL SUPPLEMENTATION

Mineral supplementation is an important part of livestock production. Feeding a mineral and vitamin supplement to livestock on pasture is an established practice. The cost of providing these required nutrients is low when compared to the losses resulting from mineral deficiencies, toxicities and imbalances. Deficiencies and toxicities can occur through inattention to feeding management or simple unavailability. These effects can be subclinical in nature, affecting weight gain and reproduction.

Minerals are normally sold according to their Ca and P content. Most feed and mineral companies have a variety of mineral mixes. Analysis of the mineral content of pasture is a valuable tool for determining which mineral package will supplement the available minerals to best meet the animals’ requirements.

Most minerals are acceptable for use on organic farms. Kelp meal is a natural and locally available source of minerals that organic producers tend to use; additionally, many organic producers believe that a healthy soil with appropriate nutrient levels, good soil organic matter content, and thriving soil life will produce forage with a varied mineral content. However, it is recommended to use a commercially available pre-mix that includes a guaranteed analysis of vitamins and minerals. This is particularly true for selenium and Vitamin E, which is essential to supplement in Atlantic Canada.

Macro minerals are required in relatively large amounts in the diet. Requirements are expressed in grams or in terms of ration percentage. Some examples of macro minerals are Ca, P, Mg, K, N and chloride (Cl). Microminerals are required in relatively small amounts and are expressed in parts per million (ppm) or milligrams per kilogram (mg/kg) of the ration. Examples of microminerals are selenium (Se), copper (Cu), zinc (Zn), iodine (I), manganese (Mn) and iron (Fe).

An appropriate mineral mix can be fed free choice in a mineral feeder on pasture along with cobalt iodized salt. Mineral mixes for cattle should not be made available for sheep because the copper level in cattle minerals is too high for sheep. If sheep consume too much cattle mineral, it will be toxic for them. Mineral feeders should be placed in a readily accessible place and protected from weather. The feeders should be well maintained, and minerals should always be available and clean (Rogers, 2001).

It is recommended to place mineral and salt stations near water access to increase intake.

The mineral content of a pasture is influenced by plant species, plant maturity, type of soil and soil fertility. Legumes, for example, are usually greater in Ca content than grass forages, which in turn are generally higher in Ca content than cereals. Mature forages and crop residues (such as corn stover) generally contain low levels of P, while cereal grains and oilseed meals are moderate to high in P. Potassium content is lower in cereals than forages.

### Grass Tetany

Lush spring pasture is often low in Mg and can result in **grass tetany**. Grass tetany (a metabolic disease caused by decreased blood Mg level) occurs most frequently following a cool period (temperatures between 7 and 16°C) when grass is growing rapidly. Though conditions for grass tetany most often occur in the spring, they can also occur in the fall. Waterlogged soils and/or high N fertilization reduce Mg uptake by the plant. This is especially prevalent in soils high in K or Al. Drainage of these soils and/or careful N use will encourage the uptake of Mg in the plant and, therefore, increase its availability to livestock. Typical signs of grass tetany begin with an uncoordinated gait and progress to convulsions, coma and death. Animals on pasture are often found dead without illness having been observed. Evidence of thrashing will usually be apparent around the animal if grass tetany is the cause of death.

The prevention of grass tetany depends largely on avoiding conditions that cause it. Graze less susceptible animals on high-risk pastures. Steers, heifers, dry cows, and cows with calves over 4 months old are less likely to develop tetany. The use of dolomite or (high Mg) limestone on pastures (if soil pH is low) and including legumes in pasture mixes will decrease the incidence of tetany in grazing livestock. In areas where grass tetany frequently occurs, feed cows' supplemental Mg. Supplementation increases blood Mg levels and alleviates much of the grass tetany problem.

## BLOAT

**Frothy bloat** can be caused by the consumption of young, rapidly growing legumes in the pre-bloom stage. It is most often associated with white clover, ladino clover and alfalfa plants. It is a severe form of indigestion marked by the collection of gas in the rumen that the animal cannot expel. The gas is primarily carbon dioxide and methane, which are normal products of the digestion process. These gases are normally released by belching. When an animal becomes bloated, the gases are trapped in a froth formed from proteins in the feed. Bloat can also occur if the esophagus is blocked by a foreign object, preventing the belching of rumen gases. This is called **"free-gas" bloat** as its mechanism is different than frothy bloat.

Symptoms of bloat include the swelling or distention of the left side of the animal and, in severe cases, open-mouthed breathing. The animal will show signs of restlessness, abdominal pain, feet stomping and kicking its belly, laboured breathing, frequent urination and defecation and collapse. Poloxalene and monensin can be used to prevent bloat in high-risk situations but are not allowed to be used on organic farms. Poloxalene is also used to treat frothy bloat as it is an anti-foaming agent. Other anti-foaming agents, such as vegetable oil and mineral oils, can also be effective. Treatment may require the services of a veterinarian, as gas needs to be freed from the rumen in a timely manner.

The risk of bloat can be significantly reduced by feeding animals hay (either before putting them on pasture or providing access to hay on pasture) or putting them on grass pasture before turning them out onto a legume pasture. Moving animals to a lush pasture should be done in the middle of the day when the forage is dry. When seeding a pasture, it is a good idea to use trefoil-based mixtures or to limit the amount of bloat-causing legume (alfalfa or clover) in the pasture mix to no more than 50% by weight. Match the legume species with grasses that will grow well throughout the grazing season. Cool-season grasses like timothy grow poorly during the warm summer months, so the mix in the pasture may be almost completely legume in mid-summer. Maintain a more consistent balance between grass and legume by including species like orchardgrass or reed canarygrass.

## POISONING ON PASTURE

### Nitrate Poisoning

**Nitrate poisoning** occurs when animals graze pastures with high levels of N. Symptoms of $NO_3$- poisoning include brownish to grayish colour of the normally pink tissues of the nose, mouth or vulva, excessive salivation, rapid, laboured breathing, abortion, muscle tremors, a loss of conditioning and weakness. The animal's blood will also have a chocolate-coloured appearance. Plants take up $NO_3$- as the plant available form of N and under normal conditions, convert it into proteins. During a drought, plant growth slows or stops, protein synthesis stops, and $NO_3$- accumulates in the plant. Nitrogen accumulation in plants can also increase after the application of manure and fertilizers high in N.

Some pasture plants, such as lamb's quarter, pigweed, and annual grains, have a higher concentration of N than others. Pastures with high populations of lamb's quarter, pigweed, and annual grains should not be grazed for two weeks after a period of drought is broken by a significant rain, as it takes about two weeks for the plants to fully utilize the readily available $NO_3$-.

Providing a mixture of different forage species (adding legumes and forbs such as chicory) within the pastures can prevent the accumulation of $NO_3$- in the plants.

### Ergot on Pasture

The presence of ergot in pasture is **caused by the growth of a mould in the seed head of grass**, and consumption of these grasses can produce alkaloid poisoning. The ergot mould primarily infects rye and some small grains and occasionally bromegrass, fescue and bluegrass. Infections on the pasture can be severe enough to make the pasture hazardous to livestock. Livestock exhibit loss of condition, poor weight gains, reduced milk production, and abortions in horses have been reported in Ontario. (Wright & Kenney, 2001).

Control of ergot in pasture can be achieved by using ergot-free seed and clipping pastures to prevent seedhead formation. Ditches and vacant land should be mowed if possible. Cool, wet weather in the spring that delays pollination of the grasses and prolongs flowering also favours the development of ergot. (Clarke, 1999).

### Poisonous Plants

There are numerous plants that can cause poisoning in livestock. Some can cause death when small quantities are consumed, while others have less dramatic effects. Not all species of livestock are affected in the same way. For instance, Tansy Ragwort (Stinking Willie) can be fatal to cattle, but sheep can be used as a control measure for the weed.

If you suspect poisoning as the cause of an animal's death or if a death cannot be explained, a post-mortem should be done. Digestive tract contents can be examined by plant experts to determine what the animal ate. This may provide answers to why the animal died.

**Death from plant poisoning often occurs at times of pasture stress when the animals are searching for feed and will consume plants they would normally avoid. Calves or lambs will be more susceptible to poisoning because they have not developed the experience to avoid novel plants and because their lower body weight provides less dilution of any toxins.** Pastures should be kept free of poisonous plants wherever possible. Table 10.2 is a list of poisonous plants that are relevant to our pastures in the Atlantic region. Most of the plants listed will not result in death if eaten but can cause animal health and production issues.

**Table 10.2 Common poisonous plants relevant to Atlantic pastures and signs of toxicity in livestock species.**

| COMMON NAME | SCIENTIFIC NAME | AFFECTED SPECIES | TOXICITY SIGNS |
|---|---|---|---|
| Bittersweet nightshade | *Solanum dulcamara* | Cattle, horses, sheep, goats, swine | Death in cattle, sheep, and goats |
| Black Eyed Susan | *Rudbeckia hirta* | Cattle, sheep, swine, and horses | Depression, anorexia |
| Blue Flag Iris | *Iris versicolor* | All Livestock | Increased salivation, diarrhea (often bloody), may also have sores on lips/ muzzle |
| Bracken Fern | *Pteridium aqualinum* | Cattle, sheep, horses, swine, goats | Anorexia, depression, blood in urine and feces, nasal and rectal bleeding, anemia, mucosal bleeding |
| Buttercups | *Ranunculus spp.* | Cattle, goats and horses | Salivation, anorexia, colic, diarrhea |
| Canada Rhododendron | *Rhododendron canadensis* | Cattle, sheep, goats | Gastrointestinal tract irritation and neurological symptoms |
| Comfrey | *Symphytum spp.* | Horses, cattle, and swine | Weight loss, poor body condition |
| Common Groundsel | *Senecio vulgaris* | Cattle (primarily), sheep, goats | Weight loss, weakness, staggering gait |
| Elder Berry | *Sambucus spp.* | Cattle, goat, sheep | Weakness, apprehension, ataxia, dyspnea, collapse, and tetanic seizures |
| Lupines | *Lupinus spp.* | Cattle, sheep, horses, goats, poultry | Agitation, hypersalivation, frothing at the mouth, depression, reluctance to move, lethargy, muscle tremors/spasms, fetal deformities (cleft palate and skeletal defects), abortion, convulsions, coma, death |
| Serviceberry | *Amelanchier spp.* | Cattle, sheep, goats | Excessive salivation, mucous membranes pink or redder than usual, nervousness, abortion, collapse, death |
| Sheep Laurel | *Kalmia angustifolia* | Sheep (most susceptible), cattle, and goats | Excess salivation, vomiting, diarrhea, bloat, tremors, convulsions, weakness and coma/death may occur |
| St. John's Wort | *Hypericum perforatum* | Cattle, goats, sheep, pigs, and horses | Restlessness, frequent scratching of head and hind limbs, redness, swelling and peeling of unpigmented skin, swollen eyelids |
| Tansy Ragwort (Stinking Willie) | *Scenecio jacobaea* | All Livestock | Lethargy, constipation, diarrhea, loss of interest in food, loss of vision (animal appears to be walking around aimlessly), eye and nasal discharge |
| Wild Cherries (Choke and Pin) | *Prunus spp.* | Cattle, sheep, goats, horses, swine | Breath has an almond odour, head turned to one side while going down, excessive salivation, nervousness, weakness, mucous membranes are cherry-red, muscle spasms |
| Winter Cress (yellow rocket) | *Barbarea vulgaris* | Cattles, horses | Gastrointestinal irritation, colic |
| Yews | *Taxus spp.* | All Livestock | Tremors, lack of coordination, collapse, diarrhea, vomiting (in some species) |

# APPENDIX

# Appendix

## USING A RISING PLATE METER

A rising plate meter is a simple but effective tool in pasture management. It estimates forage cover by measuring pasture height and density. This method can give the producer a more accurate estimate of how much available feed is in the paddock.

The rising plate meter comes in a variety of styles, from a basic design of a disk (which can be metal or plastic) that fits over a meter stick with strings attached (Figure A1) to more sophisticated designs with computerized measuring devices. Rayburn and Rayburn (1998) described how to construct a simple weighted meter. In this study, the pasture plate is made from 5.6 mm thick (0.22 in) acrylic plastic sheeting cut in a 46 cm x 46 cm square (18 in x 18 in) square with a 3.8 cm (1.5 in) hole cut in the center of the plate. A meter stick is inserted into the hole so that the plate's height above the ground is measured when it is set on the sward. The plate has an additional 24 x 3.2 mm (0.13 in) diameter holes drilled at 7.6 cm (3 in) square intervals. These holes in the plate allow the use of the plate as a point quadrat for estimating ground cover in thin stands under the plate.

To use the rising plate meter, walk through the paddock and randomly place the tip of the meter stick on the ground and allow the plate to rest on the top of the sward. Record the height at which the plate rests. The more measurements are taken, the more accurate the mass estimation. At least 30 measurements per paddock are recommended (Rayburn & Rayburn, 1998).

The rising plate meter has been calibrated on native pastures in Nova Scotia. Firth et al. (2000) tested, calibrated, and developed equations for two types of rising plate meters using data collected from several paddocks across Nova Scotia. Table A2 shows the results of this calibration work for native pastures in Nova Scotia, comparing the height of the pasture and the corresponding pasture yield at varying times over a season.

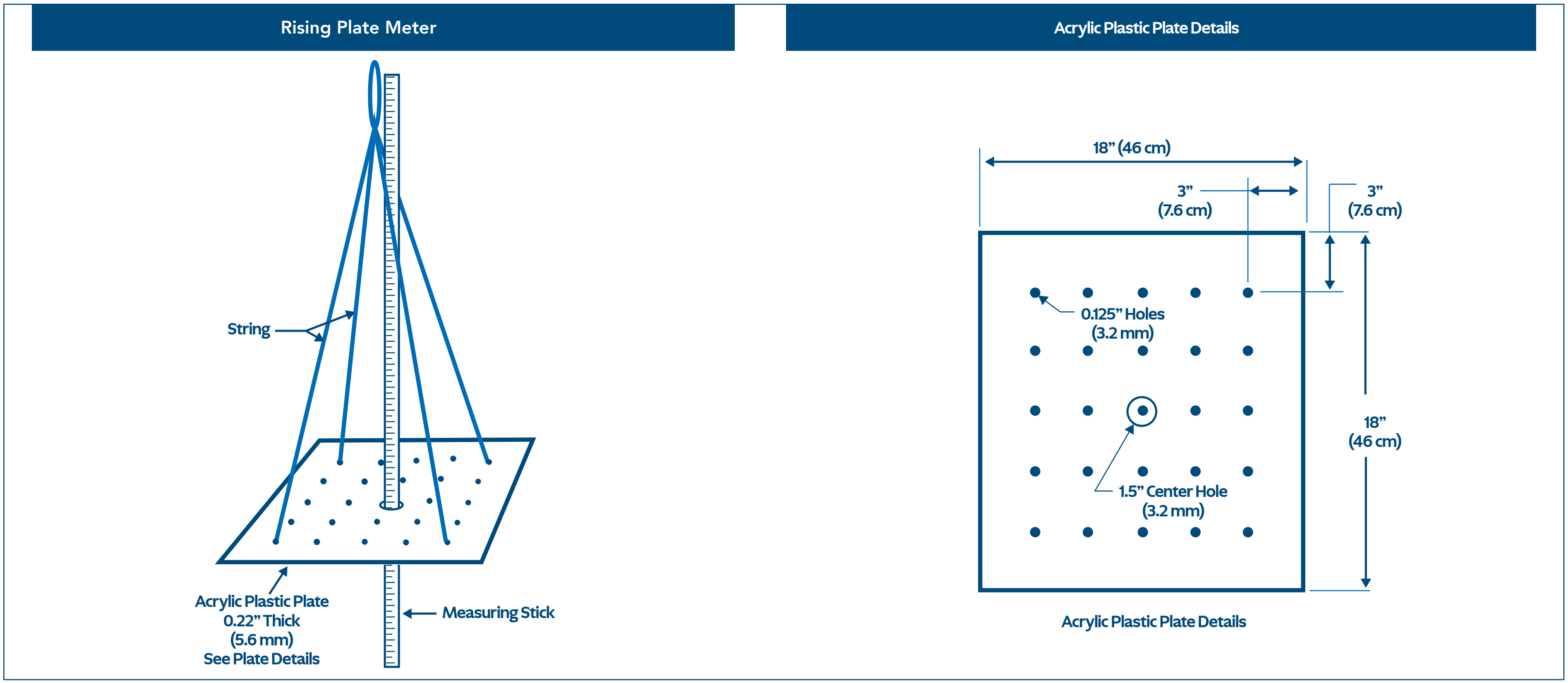



**Figure A1 A simple design to build your own rising plate meter (taken from Rayburn & Rayburn, 1998).**

Table A2 Mean predicted DM yield (kg/ha) of native pastures using a rising plate (Firth et al., 2000).

| Plant Height (cm) | MEAN PREDICTED DM YIELD (KG/HA) | | |
|---|---|---|---|
| | May/June | July/August | September/ October |
| 5 | 14 | 13 | 13 |
| 6 | 40 | 50 | 70 |
| 7 | 17 | 16 | 16 |
| 8 | 70 | 60 | 90 |
| 9 | 20 | 19 | 19 |
| 1 | 90 | 50 | 90 |
| 0 | 23 | 22 | 22 |
| 1 | 90 | 30 | 70 |
| 1 | 26 | 24 | 25 |
| 1 | 60 | 90 | 40 |
| 2 | 29 | 27 | 27 |
| 1 | 20 | 40 | 80 |
| 3 | 31 | 29 | 30 |
| 1 | 70 | 70 | 20 |
| 4 | 34 | 31 | 32 |
| 1 | 00 | 80 | 30 |
| 5 | 36 | 33 | 34 |
| 1 | 10 | 80 | 40 |
| 6 | 38 | 35 | 36 |
| 1 | 10 | 60 | 30 |
| 7 | 39 | 37 | 38 |
| 1 | 90 | 40 | 00 |
| 8 | 41 | 39 | 39 |
| 1 | 70 | 00 | 70 |
| 9 | 43 | 40 | * |
| 2 | 30 | 50 | * |
| 0 | 44 | 42 | * |
| | 80 | 00 | * |
| | 46 | 43 | |
| | 30 | 30 | |
| | 47 | 44 | |
| | 60 | 50 | |

Further testing and calibration of rising plate meters has been done at the Nappan Research Farm (Duynisveld, 2003).

The rising plate meter is being used successfully in Australia, New Zealand, Ireland and the United States. With increased research trials, the rising plate meter could become a very effective tool in pasture mass estimation in Atlantic Canada. As with all estimation techniques, it should be used in conjunction with other techniques, and with the producer's experience and knowledge of the particular pastures and forages.

## CREATING A BALANCE SHEET

Blanchet et al. (2003) also suggest using a balance sheet (Table A3) for livestock forage requirements calculations. As an animal is intended to either gain weight, or produce milk or wool, its weight and production will change on a regular basis, requiring monthly forage requirement estimates.

Table A3 Forage Requirement Sheet.

| | | | | FORAGE REQUIREMENTS (KG) | | |
|---|---|---|---|---|---|---|
| Kind/Class Livestock | # | Average Weight (kg) | Daily Utilization Rate | 1 Day | Spring 5 days | Mid-summer 8 days |
| Beef cow/calf | 35 | 545 | 0.04 | 763 | 3,815 | 6104 |
| Herd bull | 1 | 900 | 0.04 | 36 | 180 | 288 |
| Totals | 36 | | | 799 | 3995 | 6428 |

To achieve the desired production outcome, it is necessary to ensure that the animals are getting the nutrients required. The National Research Council (NRC) publishes tables of animal requirements based on breeds, production system and stage of production. These books are available to read online. Use the book that is applicable to the species you are working with.

The total available forage in a pasture can be determined by using the following formula:

**Pasture mass at entrance height – Pasture mass at exit height = total available forage**

Then, to determine the length of time a herd of animals can remain on a particular pasture use the following formula:

$$\frac{\textit{(Total available forage)}}{\textit{(Daily requirement of animals)}} = \textbf{Number of days animals can remain on pasture}$$

The use of Table 2.6 to predict the DM yield of a native pasture combined with the determination of forage requirements (Table A3) provides the producer with a very valuable tool in determining how much land is required to support a particular herd for a set period of time.

A simple log will help with tracking weekly forage estimates (Table A4).

**Table A4 An example of a visual estimates log.**

| DATE | PADDOCK NUMBER | VISUAL ESTIMATE OF DAYS OF FORAGE AVAILABLE | CALCULATED DAYS OF FORAGE AVAILABILITY (BY DM DETERMINATION) | NOTES |
|---|---|---|---|---|
| May 31 | 1 | 5 | 3 | Cows ran out of forage night before move; moved earlier than estimate |
| June 3 | 2 | 5 | 4 | |
| June 8 | 3 | 5 | 5 | |
| June 13 | 4 | 3 | 4 | |

Example: To determine the number and size of paddocks required as determined by animal units (AU) and rate of gain.

There are 25 beef cow-calf pairs, and the desired gain is at least 1.0 kg/day. A goal of 550 kg/ha with a stocking rate one cow-calf pair/acre has been set. The grazing height entry is 12–15 cm (5-6 in) with an exit height of 5 cm (2 in.).

**Step 1:** Determine the animal requirements on pasture.

Cow: 600 kg animal x 1.8% utilization rate = 11 kg DM/day required
Calf: 180 kg animal x 3.0% utilization rate = 5.5 kg DM required Total DM/day/pair = 16.5 kg

**Step 2:** Determine how many cow-calf pairs will graze and set the total days per paddock: Days in paddock = 5

Total number of cow-calf pairs = 25

**Step 3:** Using the Maritime pasture mass estimations from Table 2.8, determine the total amount of grass available.

In July, 15 cm grass will yield approximately 3740 kg DM. Using an exit height of 5 cm., this leaves 1350 kg DM. Therefore, the total amount of DM available is 3740 kg – 1350 kg = 2390 kg

**Step 4:** Calculate the amount of DM required per paddock:

(5 days in paddock x 25 pairs) x 16.5 kg DM/day/pair = 2060 kg DM required/paddock

**Step 5:** If 2060 kg/paddock is required to support the desired number of animals for a set time, and approximately 2390 kg are available per hectare in July, each paddock will need to be: 2060 kg/2390 kg/ha. = 0.85 ha/paddock.

**Step 6:** The total number of paddocks required for this rotational system would be based on the number of days a paddock is grazed and the rest period required after. In the spring, at least 15 days is required for grass to recover. Therefore, at a 5-day duration in each paddock and 15-day recovery: 15 days / 5 days / paddock = 3 + 1* paddocks in the spring. In the summer, at least 35 days recovery is required: 35 / 5 = 7 + 1* = 8 in the summer.

An example using Table A4 to calculate the biomass on a pasture is as follows:

1. The goal is to determine the available biomass in a pasture on June 30$^{th}$.
2. Using a rising plate meter, the plant height in the pasture is measured 100 times in random locations.
3. Each measurement is recorded, and an average height is calculated. For this example use an average plant height of 11.2 cm.
4. Refer to the Plant Height column in Table 2.2 and find the number closest to the calculated average number.
5. Then find the corresponding number in the appropriate month column. In this example the date is June 30th, therefore look under the column marked May/June.
6. The table shows 3170 kg/ha DM is available in the pasture.

## COMMON CONVERSIONS

Adapted from "Unités, facteurs de conversion et abréviations" 2022. Guide de production – Plantes fourragères. 2e édition. Volume 1.

| CONVERSION FACTORS FOR SOME MEASUREMENTS USED IN AGRICULTURE | | |
|---|---|---|
| **METRIC UNITS (SI)** | **CONVERSION FACTOR** | **IMPERIAL SYSTEM UNITS** |
| kilogram (kg) | × 2.204 | pound (lb) |
| tonne (t) | × 1.102 | short ton/US ton (tn) |
| hectare (ha) | × 2.47 | acre (ac) |
| gram per hectare (g/ha) | × 0.0143 | ounce per acre (oz/ac) |
| kilogram per hectare (kg/ha) | × 0.893 | pound per acre (lb/acre) |
| metric tonne per hectare (t/ha) | × 0.446 | Short ton per acre (tn/ac) |
| plants per hectare (plant/ha) | × 0.405 | Plants per acre/ (plant/ac) |
| **IMPERIAL SYSTEM UNITS** | **CONVERSION FACTOR** | **METRIC UNITS (SI)** |
| pound (lb) | × 0.454 | kilogram (kg) |
| short ton/US ton (tn) | × 0.907 | tonne (t) |
| acre (ac) | × 0.405 | hectare (ha) |
| ounce per acre (oz/ac) | × 70.06 | gram per hectare (g/ha) |
| pound per acre (lb/acre) | × 1.12 | kilogram per hectare (kg/ha) |
| Short ton/US ton per acre (tn/ac) | × 2.24 | metric tonne per hectare (t/ha) |
| Plant per acre/ (plant/ac) | × 2.47 | plant per hectate (plant/ha) |

| OTHER CONVERSION FACTORS | | |
|---|---|---|
| $P_2O_5$ | × 0.435 | P |
| P | × 2.291 | $P_2O_5$ |
| $K_2O$ | × 0830 | K |
| K | × 1.205 | $K_2O$ |
| parts per million (ppm)* | × 2.241 | kg/ha |
| kg/ha | × 0.446 | parts per million (ppm)* |

***1 part per million (ppm) = 1 mg/kg or 1 mL/L; assuming density is 1 kg/L, 1 ppm = 1 mg/L**

## COMMON CALCULATIONS

**Stocking rating:** Animal unit / area

- e.g.: 2,268 kg/2 ha = 1,134 kg per ha (5,000 lb/4.94 ac = ~1,012 lb per ac)

**Stocking density:** Animal unit / area/ per [include point in time factor]

- e.g.:. 2,268 kg/2 ha = 1,134 kg per ha per … season etc. or (5,000 lb/4.94 ac = ~1,012 lb per ac per … season etc.)
- e.g.: 9,072 kg/2 ha = 4,536 kg per ha per … or (20,000 lb/4.94 ac = ~4,049 lb per ac per …)

**Dry matter (feed intake) requirement:** access to 4% of bodyweight for ruminants

- It is expected that a ruminant animal will eat 2.5% of their body weight in dry matter per day. An addition of 0.5% should be included to account for trampling losses and an additional 1.0% dry matter should be allowed as buffer.
- Aim to provide a 544 kg cow with 21.76 kg of dry matter per day (1,200 lb cow with 48 lb of dry matter per day)

## How to calculate the forage requirements for a livestock herd:

### Estimate the daily requirement for your herd:

**Daily forage requirement = (# of animals) x (average weight) x (daily utilization rate*)**

*Daily utilization rate = 0.04. This figure is used because livestock need to have access to approximately 4% of their live weight in forage (2.5% intake, 0.5% trampling loss, and 1% buffer).

**Example:**
(25 cow/calf pairs) x (544 kg average weight) x (0.04) = 544 kg of DM/day of daily forage requirement
**or**
(25 cow/calf pairs) x (1,200 lb average weight) x (0.04) = 1,200 lb of DM/day of daily forage requirement

### Estimate the monthly and seasonal requirements for your herd:

**(daily forage requirement) x (# of days per month) = monthly forage requirement**

**Example:**
(544 kg/day) x (30 days) = 16,320 kg of DM monthly forage requirement
**or**
(1,200 lb/day) x (30 days) = 36,000 lb of DM monthly forage requirement

**(daily forage requirement) x (# of days in the grazing season) = seasonal forage requirement**

**Example:**
(544 kg/day) x (150 days) = 81,600 kg of DM seasonal forage requirement
**or**
(1,200 lb/day) x (150 days) = 180,000 lb of DM seasonal forage requirement

## How to calculate your forage production:

**Total Yield**
**(forage yield/ha) x (ha) = forage production**

**Example:**
(1,200 kg of DM/ha) x (12 ha) = 14,400 kg of forage DM
**or**
(2,500 lb of DM/ac) x (30 ac) = 75,000 lb of forage DM

### Forage Availability Per Month

**(total yield) x (% forage available by month from Appendix D) = monthly available forage**

**The minimum number of paddocks for each herd in the pasture system is equal to:**

(Rest period (days))/(Grazing period (days)+1=Minimum number of paddocks for each herd

**The required size of the paddock for average growth conditions is equal to:**

Paddock Size = ((daily herd forage dry matter requirement) x (days in grazing period))/((kg of forage dry matter available per ha))

**The following equation calculates the number of animals a particular paddock will support, and the number of days:**

**Number of animals:** ((kilograms of forage DM/ha) x ( # of ha))/((avg animal weight in kg)x (utilization rate) x (expected grazing period in days))

**Example:**
((1,344 kg DM/ha) x (3.24 ha) )/((544 kg/animal)x (0.04 utilization rate) x (4 day grazing period))= 50 head
**or**
((1,200 lbs DM/ac) x (8 ac) )/((1,200 lbs/animal)x (0.04 utilization rate) x (4 day grazing period))= 50 head

**Number of days:** ((kilograms of forage DM/ha) x (# of ha))/((Estimated total weight of herd in kg) x (utilization rate))

**Example:**
((1,344 kg of DM/ha) x (3.24 ha) )/((19,051 kg total herd weight) x (0.04 utilization rate))= 5.7 days
**or**
((1,200 lbs of DM/ac) x (8 ac) )/((42,000 lbs total herd weight) x (0.04 utilization rate))= 5.7 days

## LIST OF ACRONYMS

| | |
|---|---|
| **Ac** | Acre |
| **Al** | Aluminum |
| **B** | Boron |
| **BMP** | Beneficial management practices |
| **BVD** | Bovine Viral Diarrhea |
| **Ca** | Calcium |
| **$CaCO_3$** | Calcium carbonate |
| **$CaMgCO_3$** | Calcium magnesium carbonate |
| **CEC** | Cation exchange capacity |
| **$CH_4$** | Methane |
| **$Cl^-$** | Chloride |
| **Cm** | Centimeter |
| **$CO_2$** | Carbon dioxide |
| **$CO_2$ eq** | Carbon dioxide equivalent |
| **Cu** | Copper |
| **DAP** | Di-ammonium phosphate |
| **DE** | Digestible Energy |
| **DM** | Dry matter |
| **ECCE** | Effective calcium carbonate equivalents |
| **ESN** | Environmentally Smart Nitrogen |
| **FEC** | Fecal egg counts |
| **Fe** | Iron |
| **Ft** | feet/foot |
| **GHG** | Greenhouse gas |
| **GIN** | gastrointestinal nematode |
| **$H^+$** | Hydrogen |
| **Ha** | Hectare |
| **Hr** | Hour |
| **I** | Iodine |
| **In** | Inch |
| **K** | Potassium |
| **$K_2O$** | Potassium oxide |
| **$K_2SO_4$** | Potassium sulphate |
| **Kg** | Kilograms |
| **Kg DM/ha/day** | Kilograms of dry matter per hectare per day |
| **Kv** | Kilovolts |
| **L** | Litre |
| **MAP** | Mono-ammonium phosphate |
| **Mg** | Magnesium |
| **mg** | milligrams |
| **MIG** | Management Intensive Grazing |
| **Mn** | Manganese |
| **Mm** | millimeter |
| **Mo** | Molybdenum |
| **N** | Nitrogen Dinitrogen |
| **$N_2$** | Dinitrogen |
| **$N_2O$** | Nitrous oxide |
| **Na** | Sodium |
| **$NH_3$** | Ammonia |
| **$NH_4$** | Ammonium |
| **Ni** | Nickel |
| **$NO_3$-** | Nitrate |
| **P** | Phosphorous |
| **$P_2O_5$** | Phosphorus pentoxide |
| **PLS** | Pure Live Seed |
| **$PO_4^{3-}$** | Phosphate |
| **ppm** | Parts per million |
| **PVC** | Polyvinyl chloride |
| **S** | Sulphur |
| **$SO_4^{2-}$** | Sulfphate |
| **T** | Tonne |
| **Zn** | Zinc |

## PASTURE MANUAL GLOSSARY

**Anion:** any ion that carries a negative electrical charge. Common examples in soil are nitrate ($NO_3$-), phosphate ($PO_4^{3-}$), sulfate ($SO_4^{2-}$) and chloride ($Cl^-$).

**Auricle:** small ear-like appendages clasping the stem of some grass species opposite the leaf blade. A diagnostic feature for identifying grasses.

**Banded fertilizer:** fertilizer placed in a narrow band, generally below the soil surface. It may be with or adjacent to the seed row at planting, or between rows of emerged crops.

**Biodiversity:** the diversity of plant, animal and microbial life within an ecosystem. Ecosystems with higher levels of diversity are considered by ecologists to be more stable and more desirable.

**Broadcast fertilizer:** fertilizer spread on the surface of the soil. It may or may not be incorporated into the soil following application.

**Carbon sequestration:** the storage of carbon in the soil by increasing the amount of organic matter, which removes $CO_2$ from the atmosphere. Increasing the soil organic matter content by 0.1% will sequester roughly 3.7 T/ha of $CO_2$.

**Cation:** any ion that carries a positive electrical charge. Common examples in soil are calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$), potassium ($K^+$), ammonium ($NH_4^+$), iron ($Fe^{2+}$ or $Fe^{3+}$), aluminum ($Al^{3+}$) and hydrogen ($H^+$).

**Cation exchange capacity:** a measure of the negative charge carried by clay minerals and organic compounds in the soil, which indicates the capacity of the soil to hold positively charged ions (cations).

**$CO_{2equivalent}$:** a measure of the GHG emissions from a land area or practice that accounts for the different potency and persistence of the various GHGs over 100 years. Methane is roughly 28X as potent as CO2, while $N_2O$ is nearly 300X as potent. It is sometimes shown as $CO_2$ eq.

**Controlled grazing:** limiting access of livestock to only a portion of the total grazing area at one time, to manage utilization of the forage.

**Denitrification:** the conversion of nitrate ($NO_3^-$) into either nitrous oxide ($N_2O$), which is a potent greenhouse gas, or nitrogen gas ($N_2$).

**Dicot:** a plant with two cotyledons within each seed; members of the broadleaf plant family.

**Electric fencing:** a psychological barrier for livestock used to subdivide pastures into smaller paddocks. The fences carry a high voltage current with low amperage and duration that delivers a harmless but painful shock when touched.

**Establishment, pasture:** seeding grasses and legumes into stubble or bare ground to create a new pasture stand.

**Greenhouse gas (GHG):** gases that in the atmosphere reflect heat back to the earth's surface rather than letting it radiate into space. Carbon dioxide ($CO_2$) is the most common GHG, followed by methane ($CH_4$) and nitrous oxide ($N_2O$), all of which can be released from agricultural activities. Concentrations of GHGs in the atmosphere have roughly doubled since the beginning of the industrial revolution.

**Incorporation:** mixing of materials applied on the soil surface into the soil by tillage.

**Inoculation:** mixing the specific strain of symbiotic bacteria with the seeds of the legume species being planted.

**Legume:** broadleaf plant that forms a symbiotic relationship with specific bacterial species that fix nitrogen from the air in forms that are available to plants.

**Ligule:** a small membrane or fringe where a leaf blade meets the stem in some grass species. A diagnostic feature for identifying grasses.

**Liming:** adding a compound to the soil (commonly finely ground calcitic or dolomitic limestone) to increase the soil pH.

**Macronutrient:** nutrients required by plants in relatively large amounts. These include nitrogen (N), phosphorus (P), potassium (K), as well as calcium (Ca), magnesium (Mg) and sulfur (S).

**Management Intensive Grazing (MIG):** a type of rotational grazing characterized by high stocking intensities for short periods (often less than 1 day) to maximize the utilization of the forage in the paddock, followed by a relatively long rest period.

**Micronutrient:** nutrients that are essential for plant growth but only required in tiny amounts. These include boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn).

**Mycorrhizae:** a class of fungi that form symbiotic relationships with plant roots, either by growing into the root tissue or forming a sheath around it. These fungi receive carbohydrates from the plant, and in return extend the root system's ability to absorb water and nutrients from the soil.

**Monocot:** a plant with one cotyledon in each seed; members of the grass family.

**Nematodes:** microscopic worms that inhabit the soil (as well as aquatic ecosystems). Some species are plant pathogens, but the majority are consumers of bacteria, fungi or other organisms in the soil.

**Nitrogen fixation:** the conversion of $N_2$ gas into compounds that can be utilized by plants. This may be accomplished by symbiotic bacteria associated with legumes, free living soil organisms, or in industrial processes.

**Nitrogen immobilization:** the conversion of mineral N (ammonium or nitrate) into organic N through uptake by soil microorganisms. It is part of N cycling in the soil but is enhanced by the addition of organic materials with a high C:N ratio.

**Nitrogen mineralization:** the release of ammonium from organic materials through microbial degradation or death of microbial biomass.

**Nitrification:** the conversion of ammonium to nitrate in the soil. This is a two-step process, where Nitrosomonas sp. convert ammonium to nitrite, and then Nitrobacter spp. convert nitrite to nitrate.

**Petiole:** the stalk connecting the stem to a leaf.

**Petiolule:** a small stalk connecting the petiole to the leaflet of a compound leaf.

**Phosphorus fixation:** the reaction of phosphate ions with cations in the soil solution (predominantly Fe and Al in acidic soils, and Ca and Mg in alkaline soils) to form insoluble or slightly soluble compounds.

**Potassium fixation:** the trapping of K ions between the layers of some clay minerals where they are unavailable for plant uptake.

**Renovation, pasture:** adding seeds or amendments to the pasture to improve its composition or productivity without removing the existing pasture stand.

**Rhizome:** a rootlike underground stem that may form new roots and shoots at its nodes or tip.

**Riparian zone:** the area adjacent to a stream, river or pond which can provide protection to surface water quality if it is excluded from grazing or other agricultural activities.

**Rotational grazing:** a system of controlled grazing where livestock have access to paddocks in sequence followed by a rest period when the forage can regrow.

**Soil amendment:** a material added to the soil to change the chemical or physical properties of the soil. Lime is included in this category as it is added primarily to raise soil pH rather than supply nutrients, even though it does add significant amounts of calcium or magnesium.

**Soil pH:** a measure of the acidity or alkalinity of the soil solution on a scale from 0-14, with 7 being neutral and values below 7 acidic.

**Soil structure:** the arrangement of soil particles into larger aggregates, creating a mix of large and small pores in the soil. A stable soil structure is advantageous for water drainage, soil aeration, root growth and resilience to traffic.

**Stolon:** a horizontal stem along the surface of the soil that may form new roots and shoots at its nodes or tips.

**Tillers:** additional stems arising from the crown of the plant, at or near the ground level, to form a bunch rather than a single stalk.

**Volatilization:** the release of an element or compound from solution into the air as a gas. The compound of greatest concern in agriculture is ammonia where losses to the air can be a significant part of the total N applied.

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