Perennia

Nova Scotia's Food Development Agency



Perennial Forage Production:

Agronomic information for an intensive harvest system in Nova Scotia

NOVA SCOTIA

Information in this guide is based on and updated by Perennia from information originally published in the following guide:

Advisory Committee on Cereal, Protein, Corn and Forage Crops (1991) *Atlantic Provinces Field Crop Guide* (Publication No. 100 Agdex No. 100.32) Atlantic Provinces Agricultural Services Coordinating Committee

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Introduction

A forage program must supply high-quality feed on a year-round basis. No single forage species or mixture will supply the total forage requirement of a livestock farm. The crops grown and storage methods are unique to each farm since the choice is based on capital, equipment, land, labour, time of year forage is required, size of operation, type of livestock, and personal likes and dislikes. On most farms, the forage program will use several perennial and some annual species as silage, baleage, haylage, hay, green chop and/or pasture.

Production of good quality forages requires the perennial forage crop to be managed as intensively as other high yielding crops. Proper management of forages includes variety selection, fertilization, pest control, cutting frequency, and fall management of the forage. Good forage management must be based on the local climate and soil conditions, and end-use of the forage. A program of annual and perennial forages as stored feed and pasture provides good quality forage year-round.

This document provides information relevant to an intensive cool-season forage production system where forages are harvested three or more times in a season. It is not exhaustive of all relevant material or crop systems in the region but is intended to provide guidance for a more intensive harvest system on commonly seen perennial cropping systems in Nova Scotia. Intensifying harvest through increasing the number of cuts per year is one method to improve forage quality and potential animal productivity. Intensive harvesting for stored feed is not necessary for all ruminant production systems and is more important to backgrounding and finishing operations, dairy production or sheep flocks (especially accelerated systems).

This document does not provide information on post-harvest practices.



Forage Establishment

PLANTING TIMING

Perennial forage plants must develop sufficient size and root reserves to survive winter and regrow the following spring. Typical planting timings include spring or late summer.

In Atlantic Canada, spring plantings have a higher chance of seedling establishment than any other time of year and should be the first choice for planting timing of perennial forage species. 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. Spring seeded forages should have adequate development time to overwinter well and provide two to three metric tonnes (MT) of dry matter (DM)/ha during the seeding year.

Planting should occur early in the spring when fields are dry enough to handle equipment and there is a low risk of frost at the time of seedling emergence. For those using conventional tillage practices, some of the field preparation steps may be completed in the fall of the year prior to the seeding year to free up time in the spring. No-till seeding is also an option for fields that do not need large corrections to either their pH or soil fertility. No-till seeders should be in good working condition and set correctly to cut through crop residues 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.

When weakening a crop through mowing, the goal is to reduce competition to the establishing seedlings. Mowing may need to be completed before seeding and shortly after seedling emergence depending on regrowth. The mowed material should be widely and evenly spread behind the mower to allow sunlight to reach seedlings and reduce the risk of smothering.

For late summer plantings, 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 Nova Scotia 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. Yields in the following spring may also be lower than spring sown stands. Due to the limited time frame for establishment, a nurse or companion crop is not recommended in a late summer planting due to the increased competition for water and nutrients.

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.



Figure 1. From wrist to fingers, red clover, timothy and orchardgrass seeds.

Forage seeds tend to be small and round or thin. Seeding depth is species specific. In general, a seeding depth of 0.6 cm to 1.3 cm (1/4 in to 1/2 in) is recommended and allows for quick and even emergence. If fields are dry, a depth of 1.9 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 have light soil cover. One of the leading reasons for poor forage 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 2. 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 3. 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 get off the tractor and assess whether adjustments need to be made. Broadcasting seed can be used but is less effective as chances of seed-to-soil contact are lower due to existing plant material or existing sod limiting the seed from reaching the soil even with some attachment or implement to roll over or knock down the seed.

Correcting seeding rates for purity, germination and seeding methods/conditions

The use of the correct seeding rate is important when establishing new forage stand to ensure a strong, healthy and long-lived sward.

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 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

Additional corrections ranging from 10% - 20% additional seed can be made depending on seeding method or if sowing in less-than-ideal seeding conditions.

Final seeding rate = Actual seeding rate * (1 + additional increase for seeding method/condition in decimal form).

For example, if increasing a 10 kg of seed/ha seeding rate by 20% because seed will be broadcasted, not drilled, use the following:

Example: 10 kg of seed/ha * (1 + 0.20) = 12 kg of seed/ha

Alternatively

Example: 10 kg of seed/ha * 120% = 12 kg of seed/ha

DIRECT SEEDING

Direct seeding is when new forage seedlings are established without a companion or cover crop. Spring planted direct seeded forage will normally yield one cut the first year, although it will only be 50% of a regular production year. In good years, alfalfa planted in early May can be harvested in July and again before the recommended last date of cut. A summer planted crop may provide a harvest; however, cutting timing should account for fall rest periods. Adequate fertility, especially phosphorous, is important to direct-seeded stands. Using a seed drill to band forage seed over a fertilizer containing phosphates aids seedling growth.

UNDERSEEDING

Underseeding may also be referred to as companion or cover cropping. The additional crop(s) may be referred to as nurse crops. In this context it is when a small annual field crop is sown just prior to or with the perennial grasses and legumes. The companion crop typically grows faster than the establishing forages and can provide soil erosion control, suppress annual weeds and be harvested for stored feed, lessening the feed loss impact of 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. Experience has shown that red clover, timothy and ryegrasses better tolerate the competition from the companion crop compared to alfalfa and many other grasses.

Despite their benefits, companion crops must be carefully managed to ensure that they do not compete with the establishing forage stand. To help reduce competition with the seedling perennial forages, nitrogen should be carefully managed while other nutrients should be provided to supply both the annual and perennial crops. The establishing perennial forages should take priority, therefore, all management considerations should favour them. Remember, the chosen companion crop will compete with the seedlings for sunlight, nutrients and water and if not managed carefully can lead to thin and weak stands whose productivity will be impacted in later years.

To minimize competition, use a reduced seeding rate for the annual crop. Based on recommendations from Québec, cereal companion crop seeding rates should be reduced by 30% from the recommended seeding rate of the pure grain crop. 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. Harvest timing of the companion crop when using a cereal, whether sown alone or with peas, is at the boot to heading stage, and the crop can be made into silage, haylage or baleage. In mixtures of cereal and peas, waiting on pod formation may lead to an overall loss of forage quality as the cereal crop matures. Increase the cutting height to at least 10 cm (four inches) to limit the impact on the establishing forages. Leaving the companion crop to mature for grain harvest may negatively impact the establishment of the forage stand.



Figure 4. Forage field established with companion crop. Top: early season growth. Bottom: later season growth.

While there are many factors to consider with underseeding, it has been used successfully by farmers for years. 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.

Cool-Season Forages

In Atlantic Canada, perennial forages play a prominent role in ruminant production systems, with cool-season forages suited to the region's growing conditions. Cool-season legumes and grasses have strong growth and provide high-quality feed which can be harvested multiple times in a season and stored for use throughout the year. In Atlantic Canada, perennial forages are generally sown as mixtures of grasses and legumes instead of pure stands of either forage type.

Advantages of legume-grass mixtures can include a reduction in nitrogen fertilizer costs as legumes are able to fix their own nitrogen when grown in the right field conditions and in nitrogen limited soils. When stands contain 50% or more legumes they can supply most or all of the nitrogen needs for themselves and grasses, which leads to a substantial saving on fertilizer bills. In stands with 30% to 50% legumes, nitrogen fixation can reduce the amount of nitrogen needed to be applied to a field with increasing need for nitrogen as the proportion of legumes decreases towards 30%. Stands containing 0% to 30% legumes are recommended to have nitrogen applied. See the "Fertilizers for Forages" section for further information on recommended rates and timings.

Mixed stands have also been found to have improved yields compared to pure stands of legumes or grasses. These improved yields are due to differences in seasonal growth patterns, growing heights, leaf shape and competitiveness which allow mixed stands to maintain yields and quality across the season. The combination of different growth patterns and plant structure for mixed stands can reduce weed establishment or the types of weeds established compared to pure stands of grasses or legumes.

Additionally, legumes are shorter lived than grasses and without intervention or planning, grasses will fill in spaces left by the loss of legumes which can extend the life of the field. From an animal feed perspective, mixed stands can provide a more complete feed than pure stands with legumes able to provide higher protein and more readily available carbohydrates than grasses while grasses provide higher energy, fibre and yield.

At harvest and in post-harvest processes, the presence of grasses can act as a buffer to legumes, limiting leaf loss and may improve airflow in swaths, reducing dry down time.

Disadvantages of mixed stands are that they can be difficult to manage from a fertility standpoint. Grasses can use high amounts of nitrogen to improve yields; however, nitrogen applications can limit or stop nitrogen fixation by legumes and improve competitiveness of grasses leading to faster losses of legumes.

Another disadvantage is that despite competitiveness with weeds, when weeds do establish, there are limited chemical herbicide options to use in mixed stands and therefore cultural and mechanical methods are more relied upon.

Harvest can also be more difficult as the optimal cutting timing may not align and a compromise must be made benefiting one over the other.

Forage species selection and whether fields will be sown to single species or mixtures of grasses or legume-grasses have important management implications and should be based on animal production demands, forage quality needs, field soil characteristics, climate, harvest schedule and farm infrastructure and equipment capabilities. Choose species that work together as best as possible in terms of maturity timings, ability to withstand multiple harvests in a year, expected quality, and on-farm storage options. Below are some species that can be used in intensive forage production systems with three or more cuts taken per year.



Figure 5. A mixed stand with alfalfa, grass and clover

COOL-SEASON LEGUMES

Alfalfa (Medicago sativa)

Alfalfa or lucerne (*Medicago sativa*) is a perennial legume that can last two to five production years depending on field and harvest management and growing conditions. It is predominately grown for silage, haylage or hay and can be used in pastures. It has excellent yield and palatability and can withstand up to five harvests in a single season although this is not recommended for all regions of Nova Scotia, and it does significantly reduce the life of the stand. It

requires good drainage and is less tolerant of acidic soils than trefoil or clover. Fields should have a pH of 6.5 or greater for optimum productivity although it can grow in soils with a pH of 6.0. Given the acidic nature of much of Atlantic Canadian soils, lime should be applied prior to establishing alfalfa stands to improve longevity and productivity. Alfalfa fills an important role in crop rotations, improving soil structure and building soil nitrogen fertility for future non-legume crops.

Alfalfa autotoxicity – established alfalfa plants produce a water-soluble chemical or chemicals that, when released into the soil, can impact germination of alfalfa seeds and/or the development of the root system of newly established alfalfa. Impaired root systems can lead to poor performance of plants, lower yield and persistence issues.

Alfalfa can be grown alone or mixed with grasses. The addition of a grass to an alfalfa stand often reduces heaving, icing and lodging of alfalfa while slowing weed encroachment and providing assurance of forage production when there is severe winterkill of legumes.

Established alfalfa produces chemical or chemicals which are known to cause germination issues for alfalfa seed and/or plant development issues for newly established alfalfa plants in an already established or recently destroyed stand containing alfalfa. This self-damaging situation is referred to as alfalfa autotoxicity. Due to alfalfa autotoxicity it is not recommended to sow new alfalfa seed into a thinning stand because of the potential buildup of the chemical(s) associated with autotoxicity. Autotoxicity becomes a concern once stands reach at least one year of age, and if terminated after this point it is recommended that a one-year break be used before reseeding alfalfa back into the field. This gives time for the chemical(s) of concern to breakdown or move out of the rooting zone.

Alfalfa is a deep-rooted legume that can better withstand the heat of summer and tolerate drought. It must be matched with a grass like orchardgrass, meadow or tall fescue, or fescue leaning festuloliums that will maintain productivity during the warm months of the summer. Winter survival is a concern and soil prone to frost heave should be avoided. Harvest should be avoided during the critical fall harvest period, as winter survival and spring regrowth will be affected.

Alfalfa must be properly inoculated with the correct bacteria to take advantage of the nitrogen-fixing ability of legumes.

Red Clover (Trifolium pratense)

Red clover (*Trifolium praetense*) is a biennial or short-lived perennial lasting for two to three seasons. Red clover is difficult to make into hay and is more easily managed as silage or haylage. 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 multiple harvest systems. Double-cut varieties flower earlier in the season and have rapid spring growth and better regrowth than single-cut varieties, allowing for repeated harvests 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.

Red clover 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. Red clover can be used in mixtures with orchardgrass, tall and/or meadow fescue as well as perennial ryegrass if making silage or haylage.

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 fields, helping to improve the quality and yield of less productive stands. Best results are obtained when the red clover is inoculated with the proper species of Rhizobium bacteria.

White Clover (Trifolium repens)

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. While white clover is predominately a grazing crop, the Ladino clover form can be used in mixtures with grasses and other legumes for stored feed.

Potential grasses for mixtures include orchardgrass, meadow or tall fescue, perennial ryegrass or reed canarygrass. White clover has excellent palatability and quality. 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 harvest (down to five centimetres height).

Nitrogen Fixation and Inoculation of Legumes

One of the benefits of legumes is their ability to fix nitrogen from the atmosphere which can reduce the reliance on nitrogen from organic inputs or chemical fertilizer. However, it is not the legume which performs this process but soil bacteria, generally referred to as rhizobia. For rhizobia to fix nitrogen they must form a symbiotic relationship with the legume present and will not fix nitrogen outside of a host plant. Many species of legumes can form a symbiotic relationship but only with specific rhizobia. Successfully infected legumes have nodules on their root systems where the nitrogen fixation process occurs. If introducing a new legume species to a field or re-introducing legumes to a field, it is recommended to inoculate the legume seed before planting to help ensure the correct rhizobia are present. Fields with a history of the same legume may have rhizobia present, however, it is a cheap insurance policy to re-inoculate compared to a poorly performing stand.

It may be possible to purchase inoculant through seed companies or suppliers but ensure the correct species is chosen for each legume. It easier to purchase pre-inoculated seed from seed companies and suppliers for some legume species. Whether purchasing inoculum packets or inoculated seed, proper storage is critical for rhizobia viability. Inoculated seed or inoculum should be handled and stored based on the supplier recommendations. Improperly stored or expired inoculant should be discarded and new inoculant should be purchased. It is not necessary to discard pre-inoculated seed if the seed is still viable and in good condition. A germination test should be completed on the seed. If the germination rate is acceptable, it is recommended to re-inoculate the seed before sowing if planting will occur outside of the year of purchase. Follow manufacturer instructions when inoculating seed. Seeds should be thoroughly covered with inoculant for improved success of root infection and nodulation.

Availability and cost of inoculant varies depending on species. See below for a table of recommended rhizobia species for different legumes.

Table 1. Recommended rhizobia species for inoculation of some perennial legume species

Legume species	Rhizobia species for inoculation
Alfalfa	*Sinorhizobium meliloti*
Red clover White clover Alsike clover	*Rhizobium leguminosarum* bv. *Trifolii*
Birdsfoot trefoil	*Mesorhizobium loti*
Common and hairy vetch	*Rhizobium leguminosarum* bv. *viceae*

COOL-SEASON GRASSES

Orchardgrass (Dactylls glomerata)

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

In spring, it will produce a seedhead earlier than many other cool-season grasses, and the seedhead matures quickly. Unfortunately, the palatability and nutritive quality of orchardgrass decreases rapidly after seedhead emergence. This can cause issues in some stands as other forages may not be ready to be harvested when orchardgrass is ready. Fortunately, the regrowth of orchardgrass is generally vegetative as long as tillers develop an inflorescence before being harvested. The vegetative growth in later cuts maintains palatability and quality better than the losses seen in spring growth when the inflorescence emerges. In order to manage these traits, choose a late-maturing cultivar when using orchardgrass in a mixture with other forages.

Tall Fescue (Festuca arundinacea)

Tall fescue (*Festuca arundinacea L.*) is a deep-rooted perennial grass with growth habits of a bunchgrass but which under frequent harvest may also form a sod through rhizomes. It is adaptable to a wide range of climates, and 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.

As fescue matures, the leaves become coarse and less palatable, which may decrease animal intake. Early harvest can improve palatability and quality. 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. Producers should ensure the purchase of endophyte-free tall fescue varieties.

Meadow Fescue (Festuca pratensis)

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 harvesting and is easy to establish. It has good spring growth, allowing an earlier harvest 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.

Perennial Ryegrass (Lollum perenne)

Perennial ryegrass (*Lolium perenne*) quickly establishes, has excellent quality and palatability but requires fertile soil. It has vigorous spring growth and can also withstand close harvests. However, it has poor drought and heat tolerance and does best in mild temperate climates. Perennial ryegrass 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.

Nitrogen fertilizer should not be applied to perennial ryegrass in the fall as excessive growth in the fall increases the risk of winterkill due to matting and higher disease risk. Fields may need to be cut in the fall to manage excessive plant growth. Even with proper management of growth, losses may still occur depending on the winter conditions as perennial ryegrass does not tolerate ice well. There are many cultivars of perennial ryegrass available and those suited for stored feed should be chosen.

Ryegrasses – diploid or tetraploid, what does it all mean?

The terms diploid and tetraploid refer to the number of sets of chromosomes a cell contains. Normal ryegrasses contain two sets of chromosomes per cell and are referred to as diploid. Plant breeders have been able to create cultivars with four sets of chromosomes per cell and these are referred to as tetraploids.

Characteristics of diploids vs tetraploids:

Diploid ryegrasses tend to be denser, with more tillers than tetraploid ryegrasses. They have a less upright growing habit and better persistence as well.

Tetraploid ryegrasses have fewer tillers and more upright growth than diploids, which may pair better with other forages in mixtures. While diploids have good nutritional quality, tetraploids have higher sugar content than diploids, leading to improved palatability compared to diploids. The lower persistence of tetraploids may leave holes in stands for desirable forages and weeds to establish.

Both perennial and annual ryegrass come in diploid and tetraploid forms with both having a place in frequent cutting systems.

Annual Ryegrass (Lolium multiflorum)

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 or silage and hay production.

Annual ryegrasses maintain growth across the summer and can help add volume and quality to stands when other cool-season grasses have gone dormant. Due to its short-term nature, annual ryegrass when grown on its own can be leveraged for a harvest in the fall when perennial forages are in their 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.

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 NO3- may accumulate.

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 from those crosses 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.

SIMPLE OR COMPLEX MIXTURES

Well designed mixtures consider the nature of the different forages within the mix to provide good yields of the desired quality of forage for an acceptable length of time. Mixtures can be simple, using only a single legume and a single grass, or more complex, with four to five species grown together. Complex mixtures may not be higher-yielding or provide better quality than simple mixtures; however, they may provide more consistent growth across a season with different species excelling in different growing conditions and be more persistent from one season to the next.

Table 2. Characteristics and seeding rates of cool-season grasses and legumes.

SPECIES	* WINTER HARDINESS	DROUGHT TOLERANCE	POOR DRAINAGE	LOW PH TOLERANT	PERSISTANCE	PALABILITY	TOLERANCE TO FREQUENT HARVEST	** SEEDING RATE (KG/HA)	EASE OF ESTABLISHMENT	**** RELATIVE MATURITY
Fescue, meadow	H	H	H	H	H	M	H	15	M	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
Orchardgrass	M	H	H	L	H	H-M	H	8-10	H	E
Ryegrass, annual (diploid)	L	M	H	M	L	H	H	20-25	H	*****
Ryegrass, annual (tetraploid)	L	M	H	M	L	H	H	25-35	H	*****
Ryegrass, perennial (diploid)	L	M-L	L	M	L	H	H	12	H	M-L
Ryegrass, perennial (tetraploid)	L	M-L	L	M	L	H	H	16	H	M-L
Alfalfa (lucerne)	M	H	L	L	M	H	M	10-12	M	M
Clover, red	H	M	M	M	M	H	M-L	11	H	M
Clover, white	H	L	L	M	H	H	H	5 ***	M	L

* Winter hardiness High (H), Medium (M), Low (L)
** 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 High (H), Medium (M), Low (L)
***** Italian type (annual ryegrass) is recommended as it remains vegetative in year of seeding

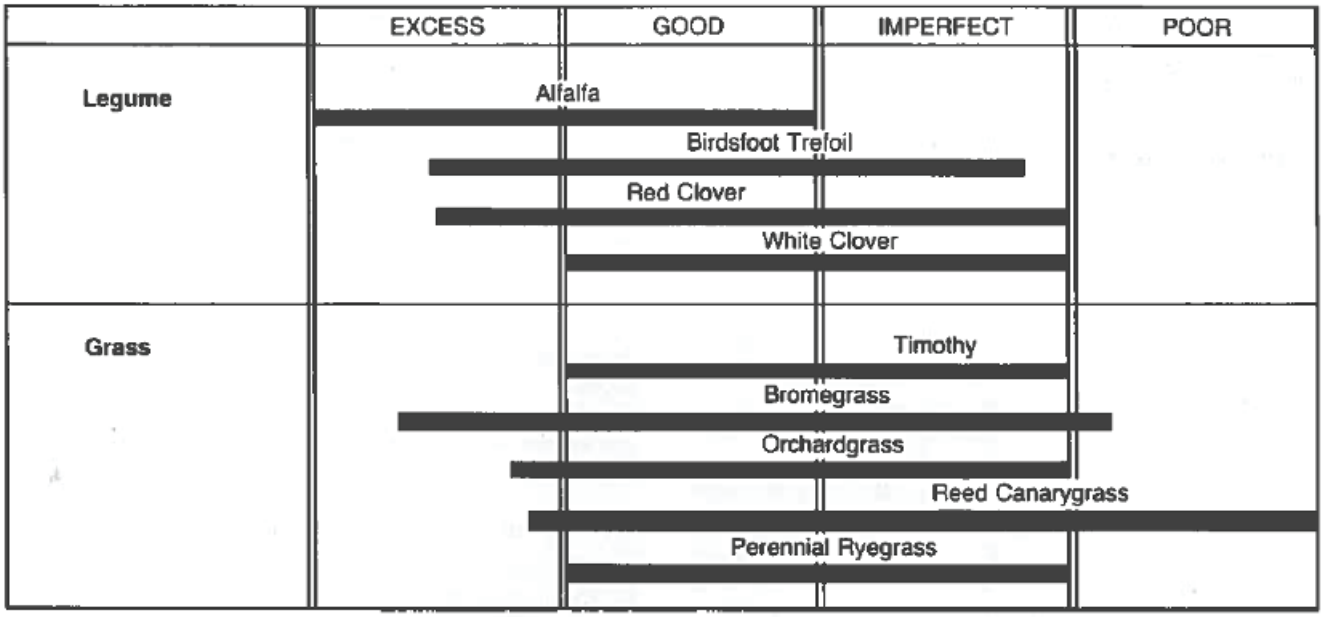

Figure 6. Drainage requirements of forage crops.

COATED SEED

Coatings used on forage seed contain various combinations of inoculating bacteria, lime, nutrients and bonding agents. Coatings are intended to improve emergence and establishment of forage stands. Coatings can be an effective measure to ensure good inoculation of legume seed. To ensure the presence of live bacteria in the year of seeding, coated seeds that are being carried over from a previous year should be re-inoculated.

Coated seeds are larger than uncoated seeds; therefore, a kilogram of coated seed contains fewer seeds than an equal weight of uncoated seed. To plant to recommended rates of seed, the seeding rate setting or dial on the seeder should be increased. The thickness of a coating may change depending on supplier and year of purchase. Adjustments to the seeding rate may need to be made each year if looking to supply a consistent number of seeds in an area. Coated seeds may help in reintroducing legumes into forage stands as the additional weight and shape of the coating can improve the chances for seed to soil contact. Some coatings may also improve moisture wicking and retention, allowing seeds to better withstand dry periods or difficult seeding conditions.



Figure 7. Uncoated (left) and coated (right) red clover seed

WEED CONTROL

Weed control is the process of limiting weed growth and infestations to allow efficient and profitable forage production. Total weed eradication is expensive and not necessary for forage production. A weed control program should be designed to reduce the weed population to a level that is not economically damaging. Weed control is an integral part of crop production and should begin the season prior to planting a perennial forage crop. Perennial forage stands in Atlantic Canada are often sown as a mixture of grasses and legumes. This mixture of grass and broadleaf plants can lead to limitations in some weed control options that are more easily applied in annual cropping systems.

A good program starts by identifying the extent of the problem. Proper weed identification helps with selection of the most effective control method. Take an inventory of the type, stage of growth and severity of weeds in the forage crop before harvest as these will be important for identifying control options.

Divide the weeds into groups such as annuals and perennials, including both grasses and broadleaf weeds. This should be done yearly as it allows evaluation of the current program and provides information that may necessitate changes to the program. In addition, indicate the severity of infestation of various weeds by using words such as rare, scattered, occasional, common and/or abundant and define these words where possible. Some weed species will require a stronger response at low population levels compared to others.

Table 3. Some common weeds found in forage fields

WEED, COMMON NAMES	WEED, SCIENTIFIC NAME	ANNUAL, BIENNIAL OR PERENNIAL
Wild Carrot, Queen Anne's Lace	*Daucus carota*	Biennial
Chickweed	*Stellaria media*	Annual
Canada Fleabane, mare's tail	*Conyza canadensis (L.) Cronq.*	Annual/winter annual
Dandelion (common)	*Taxaracum officinale*	Perennial
Curly dock	*Rumex crispus*	Perennial
Quackgrass, Common couch grass	*Elymus repens*	Perennial
Barnyard grass	*Echinochloa crus-galli* (L.) Beauv.	Annual

Weed control programs should consist of more than one type of control as relying on a single method will usually allow some weeds to escape. Types of control generally fall into four main categories: 1) mechanical or physical; 2) cultural or management; 3) biological and; 4) chemical.

Mechanical weed control is effective in new forage stands and for summer annuals. Mechanical methods include cultivation prior to seeding as well as clipping/mowing during the growing season. Get into fields early and often to scout for weeds and stay on top of weed development. Generally, clipping could occur mid-June to early July depending on location and removes the top growth and/or flowers of weeds. Clipping fields before weeds develop flowers is the safest timing as clipping when seed has started to develop, even if immature, may still result in viable seeds depending on weed species. Clipping will not provide lasting control of perennial weeds such as quack grass, dandelion (common), curly dock or milkweed.

Cultural weed control is the practice of growing a healthy, vigorous forage crop that will out-compete weeds. All practices that improve crop growth will help reduce weed populations. Choose a well-adapted variety, lime and fertilize as recommended by a soil test, plant as early as possible and fertilize older stands. A vigorously growing legume or grass crop leaves little space for weeds. Biological weed control is practiced to some extent in areas of the Maritimes to control specific weeds by introducing diseases and insects. Insects are the most effective, an example being the introduction of the Cinnabar Moth to control tansy ragwort.

Chemical weed control involves the use of herbicides that inhibit the growth of unwanted plants. Herbicides are specific in their list of weeds controlled, the susceptible weed growth stage, as well as the stage of crop it can be safely applied to. These factors can also impact the time and rate of application, as well as application method. Herbicide use and method of application are specified on the product label and must be followed. Additionally, herbicides may have harvest or grazing restrictions after application. Reading the label before using herbicides is required, however, it is recommended to review the label before purchasing to ensure any restrictions will fit the production system.

There are limited herbicide options for use in mixed grass and legume stands that maintain both grass and legumes plants. Broadleaf weeds are generally the bigger issue in mixed stands and legumes are sacrificed. Managing a weed outbreak early when there are few plants allows for more targeted herbicide control using spot applications and limits legume loss. In cases with wider scale losses of legumes, the legumes can be re-introduced to the stand through no-till or broadcast seeding, including frost seeding. Herbicides should not be the only weed control method. Use them as part of a weed control program and in conjunction with sound crop management practices that produce a vigorously growing perennial forage stand.

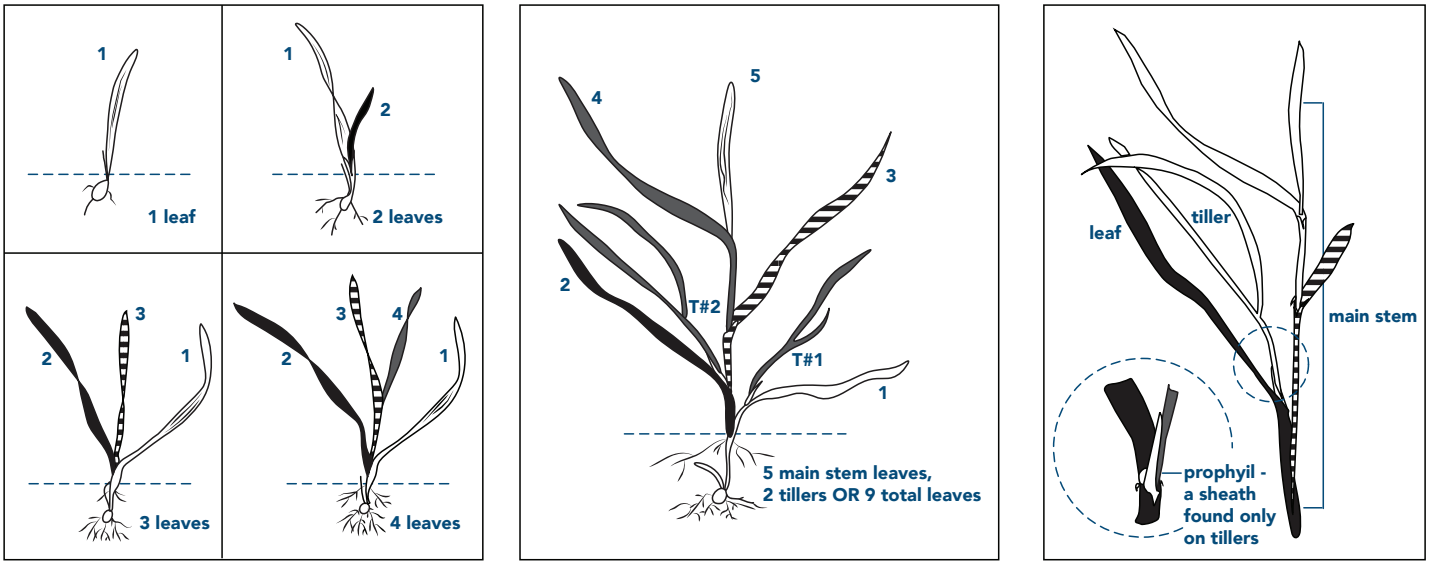

Figure 8. Identifying vegetative stages of grasses, including weeds. The left image shows how leaves are counted on young grasses. The center image shows how leaves and tillers are counted. The right image is an example of tiller development.

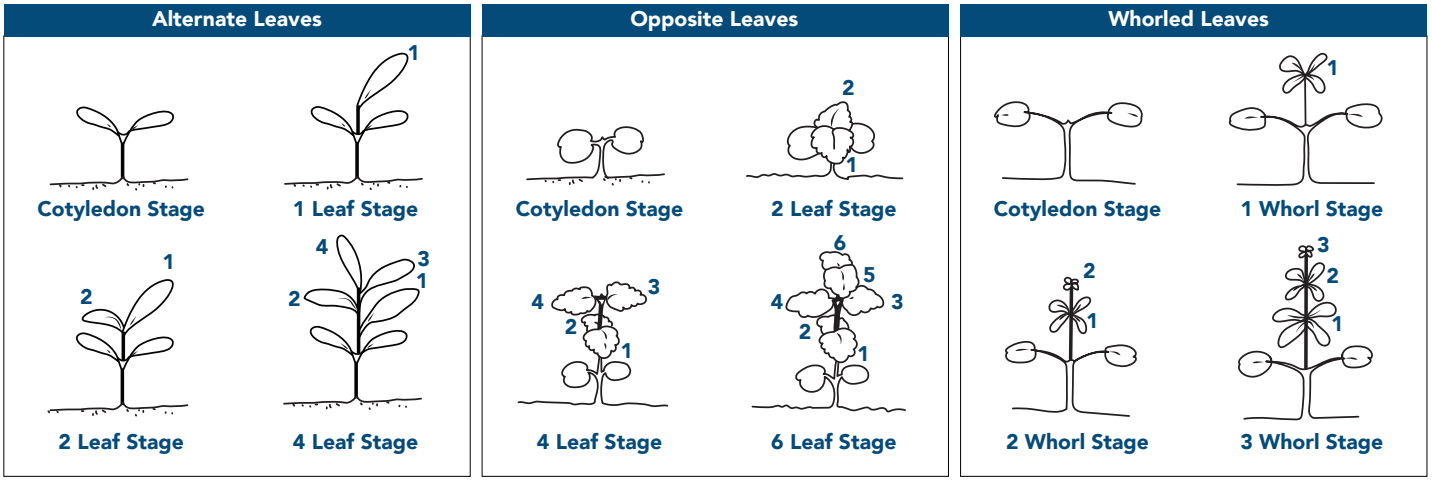

Figure 9. Counting leaves for broadleaf plants, including weeds. Each labelled diagram indicates how to identify the number of leaves for broadleaved weeds with different leaf development characteristics.

Fertilizers for Forage

GENERAL

Soil fertility is an important factor in perennial forage 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 soil fertility through the input of nutrients and beneficial management practices (BMPs) is key to supporting healthy plant growth. Nutrient balance in forages may also affect the health and productivity of 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 be depleted due to a lack of fertilizer or manure applied 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 nitrogen.

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. It is recommended to perform soil testing on fields every two to three years to assess 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^{+}). This information is essential in helping maintain healthy and productive forage stands.

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. Please contact the Nova Scotia Analytical Lab for further information on testing methods and interpretations.

It should be noted that soil tests completed by the Nova Scotia Analytical lab do not provide information about soil nitrogen levels. Historically, phosphorus in mineral fertilizer has been reported as P_2O_5 and potassium 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 report from the Nova Scotia Analytical lab provides recommendations for nutrient and lime applications. The amount of nutrients and lime applied should be based on a recent soil test. The report provides nitrogen rate recommendations based on the general nitrogen requirements for crops, not based on nitrogen content within the soil. The recommendations will change if you identify whether the current or potential crop is pure grass, mixed legume/grass or pure legume stand and whether the crops are improved or native species.

For more information on soil testing, see Perennia's "How to Take a Soil Sample" and "Soil Test Report Interpretation for Nova Scotia" factsheets.

Lime

Fertilizer cost is reduced and yields increased by liming the soil. Fertilizer use efficiency increases with a neutral pH. Research shows that forage yields are almost doubled when equivalent fertilizer is applied to soil at a pH of 6.2, compared to acidic soil with a pH of 5.4.

Table 4. 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%

There are two forms of soil acidity: active and reserve acidity, shown as pH and buffer pH on the Nova Scotia 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. 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.

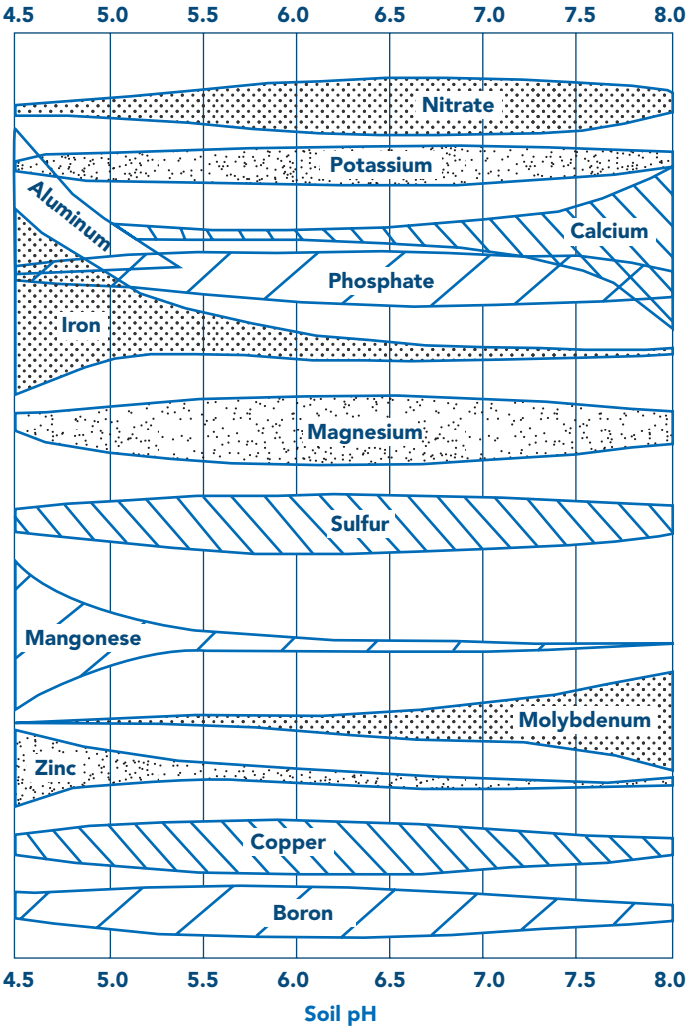

Figure 10. Nutrient availability and pH (OMAFRA, 1994).

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).

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 soils. 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.

APPLYING LIME

Always apply lime or other soil pH altering amendments 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 establishing a new forage stand in the upcoming season. Lime applied in the spring will still have some benefits. Surface applications of lime after establishing a stand are possible but will require more frequent light applications of lime, which are better than one heavy application.

When applying lime, follow these guidelines:

1. Always apply lime based on a soil test.
2. The maximum recommended amount of lime to apply at one time to a field where the lime will be incorporated is 5 tonnes per ha (t/ha) (2 t/acre).
3. Do not apply more than 4 t/ha (1.5 t/acre) of lime per year to unbroken sod.
4. Lime applications equivalent to 0.5 t/ha per year are required to maintain a desired pH.
5. Use dolomitic limestone if the Mg content of the soil is low.

6. Applications should be spread over several years if there is a high lime requirement.

7. 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.

8. If applying wood ash or other pH correcting amendment, remember to adjust the rate of application based on the CCE.

FERTILIZING FORAGE STANDS

Preparations for a new forage stand should begin the year before seeding by having soil testing completed to get a snapshot of nutrient levels going into a long-term stand. As with liming, the fall prior to establishment is a good opportunity to correct soil fertility issues whether using manure or inorganic fertilizers. Depending on the size of nutrient deficit and/or specific nutrient it may not be recommended, feasible or economical to correct all issues in the fall. Nutrients may also be applied to grass and legume stands during the growing season which can improve yields and quality of crops. In crop fertilizing timings can be found below.

MANURE

Manure can be a source of nutrients for forage fields, 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 which 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**, or information from the Perennia website like the factsheets on **Taking a Compost and a Solid Manure Sample** and **Liquid Manure Sampling**.

- 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 not been tested, nutrient approximations may be made based on the information in Table 4.

Table 5. 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

When applying manure to perennial stands, large amounts of manure can be applied prior to seeding, however, once established there are limits on when to apply manure to reduce damage and maintain yields throughout the stand's life. In-season manure applications should be limited to older legume/grass swards and those with higher grass content. Applications should occur within a few days of harvest before regrowth begins to limit damage to the stand and limit the risk of animal refusal. Manure should be spread evenly over the stand; this can limit the use of semi-solid or solid manure in-season depending on the type of manure spreader used. Be aware that the weight of the equipment and manure can cause damage to the fields and forage plants leading to yield losses. The nitrogen component of manure may reduce nitrogen fixation and improve competitiveness of grasses at the expense of legumes.

For semi-solid and solid manures, it is recommended to apply the manure in the fall after the final harvest of the season. Applications in-season may not be possible due to poor shredding of manure and/or distribution depending on the manure contents, and manure spreader type and state of repair. If clumps of manure are in the field, forages may grow through the manure, leading to increased risk of animal refusal. Clumps may breakdown slowly depending on the manure contents and weather and require a lengthened time between harvests for the manure to breakdown, if at all. Furthermore, during harvest, equipment may pick up manure and cause damage to the equipment or incorporate it into stored feed, leading to animal refusal, spoilage, and potential health issues.

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 forage sods. 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 metres of a drilled or dug well on clay loam soil or within 60 metres on sand or gravel soil.
- Manure should not be spread within three metres of a ditch.
- Manure should not be spread within five metres of any water bodies.

FERTILIZER RATES AND APPLICATION TIMING

For perennial forages, it's not only important to have a good base soil fertility when establishing stands but it is also important to apply fertilizer throughout the season to help maintain yield and quality goals. There are opportunities to provide additional fertilizer to fields during the growing season shortly after each cut and at the end of the season.

The fertilizer requirements for forages will change depending on whether the stand is newly established or is already established; based on the proportion of legumes in the stand and can also change depending on whether the species in the field are improved or native cultivars. Be sure to note the right situation and crop when submitting samples to the NSDA lab to get the correct recommendations.

Nitrogen recommendations are not based on a soil test as, at the time of writing, the NSDA lab does not measure nitrogen in the soil. Remember that legumes have the capability to fix their own nitrogen given the right soil conditions and presence of nitrogen fixing rhizobacteria. The degree of fixation is impacted by many factors including soil pH and presence of nitrogen, including from inorganic and organic fertilizers (manure). Stands containing more than 50% legumes do not require nitrogen to be applied outside of the seeding year as nitrogen fixation should be adequate to supply the stand with nitrogen. Stands with between 30% and 50% legumes may supply most but not all nitrogen required through nitrogen fixation and may require outside sources of fertilizer at specific times like during cool spring months. Stands with less than 30% legumes require nitrogen from outside sources like fertilizers and manure to meet crop nitrogen demands.

Recommendations for phosphorus (P_2O_5) and potassium (K_2O) should be based on a soil test to ensure appropriate amounts are applied to the field to build up nutrient levels or supply the crop. Over application can lead to leaching of nutrients and negative environmental impacts while also being a waste money.

General fertility recommendations can be found in the table below but a soil test should be taken to confirm actual P_2O_5 and K_2O requirements. Nitrogen applications should be split over the course of the season based on the number of harvests taken per year. Phosphorus is not a very mobile nutrient and the total requirement for the year may be applied in the spring. If large quantities of potassium need to be applied, split the total amount and apply half in the spring and half after the last cut. For smaller quantities, apply in the spring.

FERTILIZING IN THE SEEDING YEAR

Requirements for fertilizing in the seeding year depend on the amount of fertilizer applied during field preparation and whether or not the stand will be harvested. For a spring sown field, one cut may be taken in the year of establishment and fertilizer applied post-harvest to boost regrowth. It is not recommended to harvest more than once during the establishment year to allow for root development. If a second harvest needs to occur due to excessive growth, it should be planned for as close to a killing frost as possible. This reduces the amount of time available for the regrowing plants to draw down on root reserves. Fields that are sown in later summer should be left to grow unless there is excessive growth and there are overwintering concerns. Plan harvest for close to the killing frost.

Table 6. NSDA seedling nitrogen requirements based on crop type.

CROP	TIMINGS	NITROGEN REQUIREMENTS (KG OF N/HA)
LEGUME (more than 50% legume)	Prior to seeding	25
	After harvest	0
MIXED LEGUME-GRASS (30% to 50% legume)	Prior to seeding	25
	After harvest	0
GRASS (less than 30% legume)	Prior to seeding	15
	After emergence	35
	After harvest	10

*These requirements are for the seedling perennial forages. If growing a companion crop, make sure to apply enough nitrogen to feed the additional crop.

Table 7. NSDA seedling P_2O_5 and K_2O general ratings and associated nutrient requirements. Refer to soil test taken in the last three years for a more accurate rating.

CROP	TIMINGS	P_2O_5 RATINGS AND ASSOCIATED REQUIRED NUTRIENT VALUES RANGE (KG OF P_2O_5/HA)[1]	K_2O RATINGS AND ASSOCIATED REQUIRED NUTRIENT VALUES RANGE (KG OF K_2O/HA)[1]
LEGUME (more than 50% legume)	Prior to seeding	E: 0 H: 40-55 M: 70-120 L: 145-180	E: 0 H: 0-70 M: 90-160 L: 190-250
	After harvest[2]	10	50
MIXED LEGUME-GRASS (30% to 50% legume)	Prior to seeding	E: 0 H: 40-55 M: 70-120 L: 145-180	E: 0 H: 0-70 M: 90-160 L: 190-250
	After harvest[2]	10	50
GRASS (less than 30% legume)	Prior to seeding	E: 0 H: 40-55 M: 70-120 L: 145-180	E: 0 H: 40-55 M: 70-120 L: 145-180
	After harvest[2]	10	35

[1]The values within the range correspond to the following rating for nutrient levels in soil: Excessive (E), High (H+, H, H-), Medium (M+, M, M-) and Low (L+, L, L-) with higher values corresponding to lower ratings within the range.

[2] Values indicated are based on expected nutrient removal from harvest.

*These requirements are for the seedling perennial forages. If growing a companion crop, make sure to apply enough phosphorus and potassium to feed the additional crop.

Phosphorus is important for good root development and seedling establishment. Banding phosphorus two centimetres below the forage seed is beneficial if soils are low in phosphorus as it limits the need for developing roots to search for the nutrient.

Nitrogen is required for all forage seedlings. Legumes need nitrogen to promote growth until they become nodulated and can fix their own nitrogen. Excess nitrogen applied in the fall will promote winter injury and will be lost by leaching.

Potassium should be available to plants in the fall to promote good root development, storage of food reserves for increased spring yields and development of cold hardiness to promote winter survival. Plants use more potassium than any other element.

Boron can be applied to legumes in the seeding year if needed to help with establishment. It should be applied in later years as needed. Boron should not be banded at seeding but can be applied with other fertilizers. A soil test should be performed to identify the levels of boron in the soil and the required rate of application. When viewing soil test results from the NS analytical lab, the recommended range of boron for grasses: 0.5 to 1.5 parts per million (ppm); for clovers: 0.5 to 2.0 ppm; and for alfalfa: one to three ppm. Excessive boron levels in the soil can lead to toxicity issues. For established legume stands a soil application of 2.24 kg/ha of boron can be applied in alternating years.

Table 8. Deficient, sufficient and toxic plant Boron concentrations in forage legumes in the vegetative tops at 10 percent bloom.

CROP	BORON CONCENTRATION, PPM		
	DEFICIENT	SUFFICIENT	TOXIC
ALFALFA	20	20-50	100
RED CLOVER	20	20-50	60
BIRDSFOOT TREFOIL	15	30-40	70

Sulphur is required by plants for the synthesis of amino acids, which are essential components of proteins. It also contributes to the digestibility of plants to ruminant animals by narrowing the nitrogen to sulphur ratio. In the past, there was enough atmospheric sulphur contributed to the soil via acid rain to account for the needs of the plants. As those levels decrease (70% in Nova Scotia from 1990-2015, Environment Canada: 2017), there is a need for sulphur fertilizer applications to provide for plant needs. Sulphur levels in the soil can vary depending on the time of year of sampling and weather. Tissue testing is more accurate to identify whether levels are deficient/sufficient. In general, a ratio of 10 to 1 (N to S) should be targeted. At the time of writing there are no specific recommendations for the rate of sulphur to apply to forage stands in Atlantic Canada. In Québec, recent work notes that grass (less than 30% legumes) and legume (less than 30% grass) stands see a crop response when 25 kg of S/ha is applied to the stand. Given the mobility of sulphur, it may be best applied through split application with half applied in the spring and half applied after first cut. For more immediate impact, use more plant available forms of sulphur like sulphate instead of elemental S, which requires transformation by soil bacteria before plant uptake.

FERTILIZING ESTABLISHED STANDS

Forage stands lacking adequate fertilization will become unproductive, thin out rapidly and revert back to less productive native swards. To help maintain established forage stands:

1. Fertilize annually and generously with potassium, an essential nutrient in maintaining all forage stands.
2. While phosphorus is the most essential in the seeding year, a small amount may also be required annually in the maintenance fertilizer.
3. Nitrogen is required for pure grass stands or mixtures with less than 50% legume. Apply fertilizer containing nitrogen in early spring and again after each cut. With several forms of nitrogen fertilizer now available, it is commonly recommended that a urea-based nitrogen fertilizer be used for spring/first cut applications. Less volatile nitrogen fertilizers, including protected urea forms, are recommended for use during times of high potential evaporative loss (also known as volatilization) which is typically seen from late June to September. Fertilizer should be applied not less than four to five weeks before harvest to ensure proper conversion to protein in the plant.
4. Where manure is spread, reduce the rate of fertilizer to account for the nutrients provided by the type of manure and rate applied. Have manure tested before application to get a more accurate understanding of the nutrients within the manure.

For nitrogen requirements, apply nitrogen based on a cutting system. In a mixed legume-grass or grass stand (less than 30% legumes) and a three-cut system: apply 40% of nitrogen recommendation at green up and 30% of nitrogen recommendation after each cut. In a mixed legume-grass or grass stand (less than 30% legumes) and a four-cut

system: apply 25% of nitrogen recommendation at green up and 25% of nitrogen recommendation after each cut.

For sulphur, apply 25 kg of S/ha. Given the mobility of sulphur and desire for season long growth, apply sulphur at green up and after the first cut. For more immediate impact use more plant available forms of sulphur like sulphate instead of elemental S, which requires transformation by soil bacteria before plant uptake.

Table 9. NSDA established stand nitrogen requirements based on crop type.

CROP	TIMING	NITROGEN REQUIREMENTS (KG OF N/HA)
LEGUME (more than 50% legume)	At green up	20
	After each cut	20
MIXED LEGUME-GRASS (30% to 50% legume)	Four-cut system; 40% at green up; 30% after each cut	100-180[1]
	Four-cut system; 25% at green up and after each cut	100-180[1]
GRASS (less than 30% legume)	Three-cut system; 40% at green up; 30% after each cut	180
	Four-cut system; 25% at green up and after each cut	180

[1] **Use lower value for stands with higher legume content. Applied nitrogen will reduce nitrogen fixation and improve grass competitiveness against legumes.**

Table 10. NSDA established stand P_2O_5 general ratings and associated nutrient requirements. Refer to soil test taken in the last three years for a more accurate rating.

CROP	TIMING	P_2O_5 RATINGS AND ASSOCIATED REQUIRED NUTRIENT VALUES RANGE (KG OF P_2O_5/HA)[1]
LEGUME (more than 50% legume)	100% in spring	E: 0 H: 0-55 M: 65-85 L: 95-120
MIXED LEGUME-GRASS (30% to 50% legume)	100% in spring	E: 0 H: 0-55 M: 65-85 L: 95-120
GRASS (less than 30% legume)	100% in spring	E: 0 H: 0-55 M: 65-85 L: 95-120

[1] **The values within the range correspond to the following rating for nutrient levels in soil: Excessive (E), High (H+, H, H-), Medium (M+, M, M-) and Low (L+, L, L-) with higher values corresponding to lower ratings within the range.**

Table 11. NSDA established stand K_2O general ratings and associated nutrient requirements. Refer to soil test taken in the last three years for a more accurate rating.

CROP	TIMINGS	K_2O RATINGS AND ASSOCIATED NUTRIENT REQUIREMENTS VALUES RANGE (KG OF K_2O/HA)[1]
LEGUME (more than 50% legume)	50% of total in spring	E: 0 H: 0-70 M: 90-160 L: 190-250
	50% of total after first cut -or- 50% of total in fall	
MIXED LEGUME-GRASS (30% to 50% legume)	50% of total in spring	E: 0 H: 0-95 M: 115-140 L: 155-185
	50% of total after first cut -or- 50% of total in fall	
GRASS (less than 30% legume)	50% of total in spring	E: 0 H: 0-95 M: 115-140 L: 155-185
	50% of total after first cut -or- 50% of total in fall	

[1] The values within the range correspond to the following rating for nutrient levels in soil: Excessive (E), High (H+, H, H-), Medium (M+, M, M-) and Low (L+, L, L-) with higher values corresponding to lower ratings within the range.

Harvest Management

Harvest timing is critical in feed production. Generally perennial forages are harvested while balancing yield, forage quality and stand survivability for the long term. However, better forage quality has become a more important factor in ruminant production systems with higher animal productivity demands. The trade off for higher quality feed is improved nutrient availability to ruminants but there may be lower total season dry matter yield and a decrease in persistence of some forage species in stands. Given the focus of forage quality in these systems, it is critical that harvest be timed with the right crop staging to improve the chances of meeting feed quality needs. Remember that once a crop is cut, there is no going back to improve quality but instead the goal is to stabilize and maintain the quality of the feed from the time of harvest until the time it is needed.

Mixed legume-grass stands are prominent in Nova Scotia forage production systems, the decision for harvest timing is more complicated than in pure stands of grasses or legumes. In mixed stands, legumes improve protein content, provide more readily digestible nutrients than their grass counterparts while also providing nitrogen through N-fixation process. Due to their importance, harvest timing decisions can most often be based on legume growth stages in stands with high proportions of legumes (greater then 50% legumes), however, this may change in spring depending on grass species in the mixture, crop stage development and percentage of biomass contribution to the stand/field. See the "Mixed grass-alfalfa stands" section for more information. If creating your own forage mixture instead of buying a supplier designed mixture, it is important to match the maturity ratings of grasses and legumes. This can improve forage quality and potentially persistence of a species within a stand.

Changing weather patterns and growing conditions influences crop development from year to year and cut to cut. The use of crop staging, not calendar date or historical timings, is an easily identifiable and fast option that holds true in many scenarios. Alternative harvest timing systems may be based on growing degree days (GDD) or plant morphological characteristics (crop staging and plant height) and stand composition (percentage of grass). The exception for calendar date is with respect to the final harvest date. There is a recommended final harvest date based on Atlantic Canadian research which should be followed to ensure fields are not harvested when they are most at risk of winterkill. Forages must be given enough time to build up root reserves and harden to reduce the risk of winterkill. If a harvest needs to be taken after the recommended final harvest date, a time should be chosen which minimizes regrowth before a killing frost to limit the use of root reserves.

Locally, high quality forage production systems utilize a three- or four-cut system which provide a balance between yield and high-quality forage for an acceptable number of years. There is some potential for a five-cut system in certain areas of Nova Scotia but this is limited by the growing season and type of species within the stand. The addition of a fifth cut into the system must be balanced against fertility and harvest costs as well as lower stand persistence of some forage species.

The leaves of a legume forage crop contain approximately 70% of the protein. It is important that they not be lost during harvest or the storage process. Storing forage as silage is one way to improve leaf retention as silage requires wetter forage than haylage, baleage or dry hay. The presence of grasses in mixed legume-grass stands can help preserve legume leaves by acting as a buffer during the harvest and storage processes. The use of roller conditioners can reduce legume leaf loss compared to flail type conditioners. Additionally, leaf retention can also be improved by handling the harvested forages less, particularly when moisture content drops below 40%. Ways to improve drying speed without additional handling include:

1. Increasing the swath width out of the mower/mower-conditioner. Wider swaths increases exposure of harvested material to the sun and wind.

2. If using a conditioner, check to ensure it is working correctly. For roller conditioners, check to make sure the rollers are crimping the stems and if using a flail conditioner, make sure it is breaking/damaging the stem as expected. One thing to consider is that flail conditioners may lead to increased leaf losses in stands with higher proportions of legumes.

HARVEST TIMINGS

Forages are the backbone of ruminant production systems, however, not all animals need the same level of quality. Understanding the quality of feed needed is critical when establishing fields and harvest frequency which can impact forage species selection. As forages mature, changes in the leaf to stem ratio occurs with increasing fibre content developing, leading to lower digestibility of the plant. Fibre content as a percentage of total dry matter, type of fibre and fibre digestibility play a significant role in animal intake and forage quality. One variable found on forage quality tests is neutral detergent fibre (NDF), which is a term that encompasses the cellulose, hemicellulose, lignin content of cell walls, some of which can be broken down by microbes in the rumen with enough time. Target NDF for pure alfalfa stands is 38% and 50% for pure grass stands. Target NDF for mixed alfalfa-grass stands will fall somewhere between the two pure stand targets. The values mentioned are a compromise between digestibility while also providing fibre to maintain ruminant health. Ruminant animals require some fibre to maintain their health; however, excessive fibrous feeds can limit timely nutrient availability as they require time in the rumen to breakdown to have their full nutritional potential realized. While this fibre breaks down in the rumen it takes up space, of which there is a physical limit, which limits how much additional feed the animal can consume. An additional factor to consider is the digestibility of the fibre. The digestibility of NDF is termed NDFD or dNDF and is reported as a percentage of NDF. This is an estimate of digestibility based on lab processes that provides insight into how much of the NDF breaks down over a given time frame, for example within 12, 24, 30, 48 or 240 hours.

What is neutral detergent fibre?

Neutral detergent fibre is the residue left after boiling a forage sample in a neutral detergent solution. It is predominately made up of cell wall components like cellulose, hemicellulose and lignin.

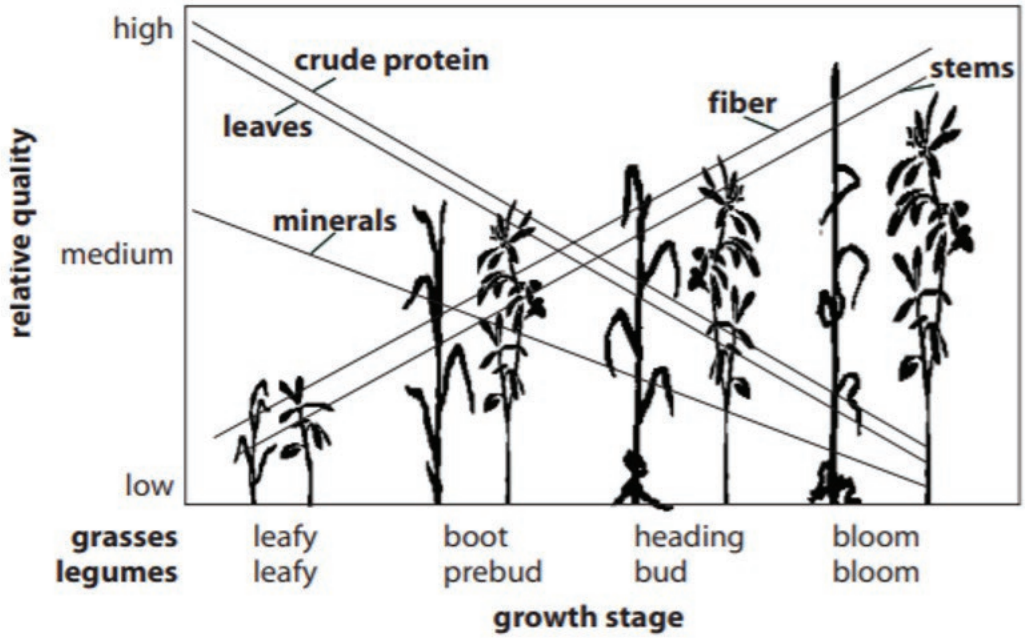

Figure 11. Effect of plant maturity on forage intake and digestibility (Ball et al., 2001).

Table 12. Chemical composition of perennial forage species by maturity (legumes). *

SPECIES	CROP STAGE	CRUDE PROTEIN (%)**	FIBER FRACTIONS	
			NDF (%)**	Lignin (%)**
ALFALFA	Late vegetative	26.9	31	5.8
	Late bud	20.4	42.6	7.3
	Mid-bloom	17.5	47.3	8.3
RED CLOVER	Late vegetative	24.5	27.2	3.2
	Late bud	18.4	34.9	4.3
	Mid-bloom	15.7	40.6	6.4
BIRDSFOOT TREFOIL	Late vegetative	25.4	26.5	5.5
	Late bud	22.4	34.1	6.4
	Mid-bloom	17	44.4	9.8

* Adapted from Hoffman et al., 1993.
**All values expressed as a percentage of dry matter (DM).

Table 13. Chemical composition of perennial forage species by maturity (grasses). *

SPECIES	CROP STAGE	CRUDE PROTEIN (%)**	FIBER FRACTIONS	
			NDF (%)**	Lignin (%)**
SMOOTH BROMEGRASS	Second node	19.5	50.3	3.9
	Boot	16.5	54.9	3.6
	Full inflorescence	12.2	63.6	6.4
ORCHARDGRASS	Second node	21.5	47.4	3.6
	Boot	16.2	49.3	3.9
	Full inflorescence	14	55.4	5.5
PERENNIAL RYEGRASS	Second node	23.3	41.5	3.2
	Boot	17.8	46.7	3.5
	Full inflorescence	12.2	58.5	4.6
TIMOTHY	Second node	23.9	49.5	4.3
	Boot	14.1	57.5	4.9
	Full inflorescence	10.6	63.5	6.8

* Adapted from Hoffman et al., 1993.
**All values expressed as a percentage of dry matter (DM).

Something to note for Tables 10 and 11 is that these values may not be the same for forages grown under different growing conditions. Additionally, when using forage morphological staging as the trigger for harvest, it is good to understand that crop staging holds better for crude protein estimation than for NDF estimation. Crop maturity is an important part of fibre development for forages as changes in the leaf to stem ratio occur with advancing maturity, however, other factors including temperature and water stress play a role in fibre development leading to higher or lower fibre content than estimated at a given morphological stage. Tables 10 and 11 can be viewed as examples in how crude protein, NDF and lignin can change as these forage species mature.

GRASS STANDS

Producers following a three- or four-cut system with pure grass stands should make their first cut once a chosen indicator grass species reaches boot to early heading stage. The chosen indicator grass species may be selected based on the proportion of the stand it represents, particularly for first cut. Grasses decrease in quality as tillers transition from vegetative to reproductive stages with reproductive stagings beginning at stem elongation. Fields harvested before stem elongation occurs may be high in quality but have insufficient yields. By harvesting at the boot to early heading stage, a compromise is made between lower but acceptable quality for higher yields. If the indicator species starts to head out, harvest should have likely already occurred if looking to achieve high-quality feed. Later harvest decisions can be based on a combination of plant staging and average plant height or just average plant height. If basing on average height, harvest when the field reaches 30 cm to 36 cm. Average crop height may need to be used instead of crop staging as fewer reproductive tillers may be present in the field after harvest depending on harvest timing and crop development at time of harvest.

Depending on grass tiller development and position of the seedhead in the sheath as well as cutting height at harvest, the growing point of the tiller may or may not have been removed. If harvest did not remove the seedhead/growing point of reproductive tillers, then those tillers may head out before enough leaf biomass has accumulated before the next harvest was to occur. A compromise between yield and quality may need to be reached depending on the proportion of the field heading out after first cut and grass regrowth.

Most grass species do not have reproductive tillers which will develop new seedheads after removal but there are some exceptions like timothy grass. Another option is to make later cuts four to six weeks after the previous cut. This can be useful in drought situations if growth has become limited.



Figure 12. Orchardgrass in early heading stage.

MIXED GRASS-ALFALFA STANDS

In spring, harvest timing for mixed alfalfa-grass stands may be dictated by grass developmental stages depending on the grass species (e.g. Orchardgrass) and their visually estimate percentage of dry matter within the stand. As mentioned above, orchardgrass and other grasses begin to lose quality as tillers transition from vegetative to reproductive with a compromise of yield and quality occurring around boot and seedhead emergence stages. In spring, these stages can occur when alfalfa has not reached its target stage triggering harvest. If grasses will make up a significant portion of the dry matter of first cut, it can be better to preserve the quality of the grasses at the expense of alfalfa. In subsequent harvests, alfalfa developmental stages are recommended to be followed with harvest coinciding when alfalfa reaches early or late bud or at early flowering depending on the target quality.

Table 14. Alfalfa developmental stages adapted from Kalu and Fick, 1981.

STAGE NUMBER	STAGE NAME	STAGE DEFINITION
0	Early vegetative	Stem length ≤ 15 cm; no buds, flowers or seed pods
1	Mid-vegetative	Stem length 16-30 cm; no buds, flowers or seed pods
2	Late vegetative	Stem length ≥ 31 cm; no buds, flowers or seed pods
3	Early bud	one to two nodes with buds; no flowers or seed pods
4	Late bud	≥ three nodes with buds; no flowers or seed pods
5	Early flower	One node with one open flower; no seed pods
6	Late flower	≥ two nodes with open flowers; no seed pods
7	Early seed pod	one to three nodes with green seed pods
8	Late seed pod	≥ four nodes with green sod pods
9	Ripe seed pod	Nodes with mostly brown mature seed pods

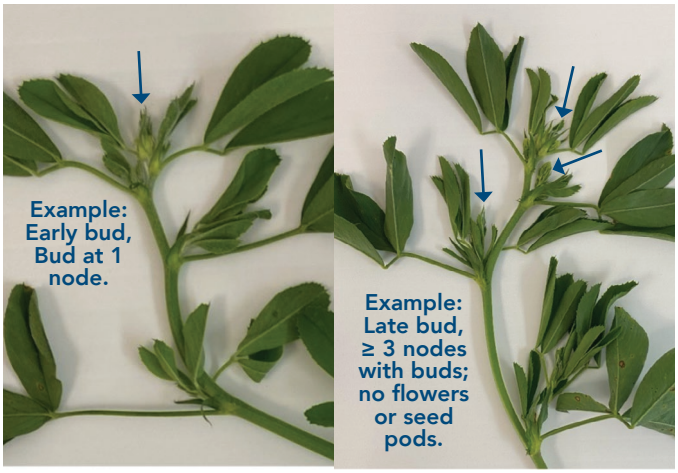

Figure 13. Alfalfa developmental stages. Left: example of early bud stage. Right: example of late bud stage.

ALTERNATIVE METHODS TO IDENTIFY HARVEST TIMING

Alternative methods for identifying harvest time for forages have been developed. One of the more widely known methods is the "Predictive Equations of Alfalfa Quality," otherwise known as PEAQ, which was developed in Wisconsin to predict NDF in standing pure alfalfa fields. Predictions are based on the crop stage of the most mature stem of alfalfa as well as the height of the tallest stem of alfalfa within a sampling area, which may not be the same stems. The PEAQ method has been evaluated in a number of studies in the United States and is in use in Manitoba and Ontario. It has been found to have an acceptable degree of prediction for helping make harvest decisions across these environments. The PEAQ model will not accurately predict alfalfa quality in mixed alfalfa-grass stands or may only predict the alfalfa portion of the stand leaving the grass quality as an unknown. This may be acceptable to some producers with fields containing high proportions of alfalfa and low proportions of grass.

In New York, additional models have been developed to estimate the NDF of standing pure alfalfa in spring. One such model relies only on the height of the tallest alfalfa stem in the sample area measured to the terminal bud and has been found to be only slightly less accurate than the model containing alfalfa maximum stage as well. Additional models out of New York were developed for use in mixed alfalfa-grass stands for predicting NDF in spring. Some of these models were assessed in Québec for accuracy but proved to not provide accurate enough predictions. New models were developed to improve accuracy. The mixed alfalfa-grass model out of New York relies on the height of the tallest stem of alfalfa and the proportion of grass within the sampling area to make NDF predictions for spring growth only. In Québec, the model predicts aNDFom (heat stable α-amylase and corrected for the ash content of the residue) using alfalfa and grass heights as well as the proportion of legume in the sample area and may be used for both first and second cut.

Another model that may be used is one based on accumulated growing degree days (GDD). For grasses and alfalfa, these models use the following growing degree day calculation:

$$\left(\frac{(\text{daily maximum temperature (°C)} + \text{daily minimum temperature (°C)})}{2}\right) - \text{base temperature °C}$$

With the base temperature being 0°C for most cool season grasses and 5°C for alfalfa. The daily GDD value is calculated and these values over a range of time are added together with negative numbers converted to zero (0). Models based on GDD have been used to try to predict NDF of alfalfa, however, this method is limited in use to spring growth as it has been found that GDD is not a good predictor of NDF in situations where moisture is limited. For alfalfa, a target of approximately 40% NDF was reached at 389-417 GDD in other studies, however, this value would need to be corroborated in Nova Scotia's growing conditions.

Fall Management

Legumes and grasses begin preparing for the winter during the fall as day length shortens and temperatures decrease. This triggers a number of physiological processes in forages, including: the build up of organic reserves like storage carbohydrates, as either starch or fructan; a reduction of water in roots and crowns; and increased concentration of potassium ions, amino acids and sucrose in cells to lower their freezing point, among other things. High levels of organic reserves, mineral ions and other solutes improve chances of winter survival of forage plants. Harvest of forages during this period of winter hardiness development can lead to the interruption of this process as plants draw on their organic reserves for regrowth and provides limited time for building reserves back up before a killing temperature occurs. This critical period lasts about four to six weeks and has been termed the "critical harvest period."

Research has identified when this critical fall harvest period begins throughout the Maritimes and the starting date for each region can be found on Figure 12. The starting dates are based on 30-year historical weather data and are the average state date from which 450 GDD were accumulated before the first day -7°C or lower was reached each year. For the best chance at a long-lived perennial stand and the fastest growth the following spring, do not cut or graze alfalfa or other perennials after the critical date in your area (Figure 4).

If additional feed is required, it is possible to harvest during this period but it must occur close to the killing temperature. Research into the impact of harvesting during the critical harvest window found that if enough GDDs have accumulated before the final cut of the year and if GDD accumulation post-harvest can be limited to 200 GDDs or less, then there is a lower risk of winterkill compared to harvesting when more than 200 GDDs will be accumulated post-harvest.

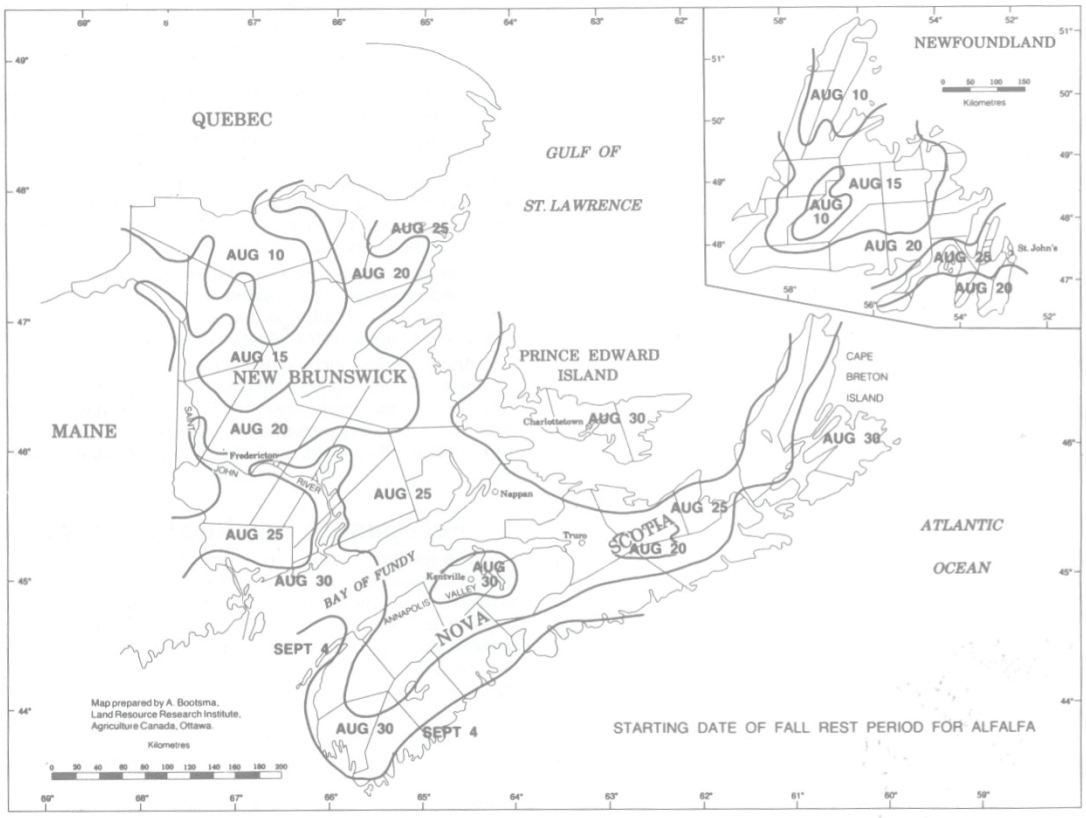

Figure 14. Starting date of critical harvest period of alfalfa.

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Perennial forage cost of production (Establishment and Production years)

OVERALL ASSUMPTIONS

- $1.43/L diesel cost[2] – 15.4 cent/litre fuel tax program discount[3] = $1.28/L diesel discounted.
- Field operations = fuel cost by implement (Table 11) + $10/ac machinery operating cost1
- Number of field operations as outlined by Table 11, unless otherwise stated.
- Labour is not included.
- Assumption is that all equipment is owned, and that adequate storage for forage is available.
- For fertilizer, the nitrogen (N) values are based on recommended rates of nitrogen for alfalfa and grass crops. The P_2O_5 and K_2O values are based on the "Medium" ratings provided by the NSDA soil lab.
- Manure is not applied to the fields in these scenarios. Fertilizer requirements may be reduced if manure is applied.
- Yields are based on an average yield from local small plot research trials within Nova Scotia for pure alfalfa and different pure grass species.
- For baleage, round bales of 54 inches are made and weigh 567kg (1250lbs) at 50% dry matter (DM). Bales are wrapped using netwrap and plastic (30-inch roll).
- For silage, it is assumed that horizontal bunker silos already exist, which are 2.44m tall x 33.53m long x 6.10m wide (8ft tall x 110 ft long x 20 ft wide). The silage is chopped at 40% DM and packed to 845.77 kg/cubic meter (52.8 lbs/cu ft).
- The bunker is covered with bunker plastic (8 mil) and an oxygen barrier.
- Packing and silage consumable costs are as calculated by "Guidelines for Estimating COP on NS Dykelands[1]".

ESTABLISHMENT YEAR COST TABLES

Establishment year assumptions

- The identified seed cost is $13.22/kg ($6/lb), which is the average price for perennial forages with current prices ranging from $6.61/kg ($3/lb) to $19.84+/kg ($9+/lb).
- The seeding rate chosen is 15.69 kg/ha (14 lb/acre) based on the Guidelines for Estimating COP on NS Dykelands[1].
- Pre-tillage herbicide (glyphosate) is applied in both alfalfa (legume) and grass scenarios. An application of 2,4-D is applied in the grass scenario post crop emergence.
- For fertilizer in alfalfa, 22N - 80 P_2O_5 - 107 K_2O-22S is applied prior to seeding and 0N - 10 P_2O_5 - 54 K_2O - 0S is applied post-harvest to replace some nutrient removal.
- For fertilizer in grass, 45N - 80 P_2O_5 - 107 54 K_2O - 22S is applied prior to seeding and 30N - 10 P_2O_5 - 30 K_2O - 0S is applied post-harvest to replace some nutrient removal.

Table 1. Alfalfa field establishment costs, per acre.

ESTABLISHMENT COSTS PER ACRE - ALFALFA	
Pre-Tillage Herbicide	$45.78
Lime	$142.54
Conventional tillage	$24.35
Fertilizer at seeding	$197.36
Fertilizer spreader	$10.54
Seed Costs	$84.00
Seeding Costs	$13.33
Clipping	$11.89
Total establishment costs per acre	**$529.79**

Table 2. Establishment year – Alfalfa balege costs, per acre. Does not include establishment costs.

ESTABLISHMENT YEAR HARVEST - ALFALFA BALEAGE	Assuming a yield of 2.8, 54-inch bales at 567 kgs (1250 lbs) each per acre
Mowing - mower/conditioner	$11.89
Raking	$10.33
Round Baler	$11.69
Hauling: Round Bale 12-18 bale for 6 acres	$2.95
Fertilizer (post-harvest)	$53.83
Fertilizer spreader	$10.54
Total equipment & post-harvest fertilizer costs per acre	**$101.23**
STORAGE CONSUMABLES	
Net wrap costs per acre	$2.33
Plastic wrap costs per acre	$15.75
Total storage consumable costs per acre	**$18.08**
Total costs (fertilizer, equipment & storage) per acre	**$119.31**
Total costs per bale (2.8 bales per acre)	**$42.61**

Table 3. Establishment year – Alfalfa silage costs, per acre. Does not include establishment costs.

ESTABLISHMENT YEAR HARVEST - ALFALFA SILAGE	Assuming a yield of 2.17 Metric Tonnes (MT)/acre and packed at 52.8 lbs/cu ft into an 8 ft tall x 110 ft long x 20 ft wide horizontal bunker
Mowing - mower/conditioner	$11.89
Raking	$10.33
Chopping and blowing into cart	$17.68
Hauling and Packing	$3.49
Fertilizer (post-harvest)	$53.83
Fertilizer spreader	$10.54
Total equipment & fertilizer (post-harvest) costs per acre	$107.76
STORAGE CONSUMABLES PER ACRE OF SILAGE	
Bunker plastic wrap costs per acre	$0.93
Oxygen barrier costs per acre	$0.26
Total storage consumable costs per acre	**$1.19**
Total costs (fertilizer, equipment & storage) per acre of silage	**$108.95**
Total costs per metric tonne	**$50.21**

Table 4. Grass field establishment costs, per acre.

ESTABLISHMENT COSTS PER ACRE - GRASS	
Pre-Tillage Herbicide	$45.78
Lime	$142.54
Conventional tillage	$24.35
Fertilizer at seeding	$205.27
Fertilizer spreader	$10.54
Seed Costs	$84.00
Seeding Costs	$13.33
Clipping	$11.89
Herbicide	$20.18
Total establishment costs per acre	**$557.88**

Table 5. Establishment year – Grass balege costs, per acre. Does not include establishment costs.

ESTABLISHMENT YEAR HARVEST - GRASS BALEAGE	Assuming a yield of 2.7, 54-inch bales at 567 kgs (1250 lbs) each per acre
Mowing - mower/conditioner	$11.89
Raking	$10.33
Round Baler	$11.69
Hauling: Round Bale 12-18 bale for 6 acres	$2.95
Fertilizer (post-harvest)	$58.21
Fertilizer spreader	$10.54
Total equipment & post-harvest fertilizer costs per acre	**$105.61**
STORAGE CONSUMABLES	
Net wrap costs per acre	$2.25
Plastic wrap costs per acre	$15.19
Total storage consumable costs per acre	**$17.44**
Total costs (fertilizer, equipment & storage) per acre	**$123.05**
Total costs per bale (2.7 bales per acre)	**$45.57**

Table 6. Establishment year – Grass silage costs, per acre. Does not include establishment costs.

ESTABLISHMENT YEAR HARVEST - GRASS SILAGE	Assuming a yield of 2.12 Metric Tonnes (MT)/acre and packed at 52.8 lbs/cu ft into an 8 ft tall x 110 ft long x 20 ft wide horizontal bunker
Mowing - mower/conditioner	$11.89
Raking	$10.33
Chopping and blowing into cart	$17.68
Hauling and Packing	$3.41
Fertilizer (post-harvest)	$58.21
Fertilizer spreader	$10.54
Total equipment & fertilizer (post-harvest) costs per acre	**$112.06**
STORAGE CONSUMABLES PER ACRE OF SILAGE	
Bunker plastic wrap costs per acre	$0.91
Oxygen barrier costs per acre	$0.25
Total storage consumable costs per acre	**$1.16**
Total costs (fertilizer, equipment & storage) per acre of silage	**$113.22**
Total costs per metric tonne	**$53.41**

Production year cost tables

PRODUCTION YEAR ASSUMPTIONS

- For fertilizer in alfalfa, 9N - 33 P_2O_5 - 55 K_2O-11S is applied in the spring at green up and after first cut.
- For fertilizer in grass, 68N - 67 P_2O_5 - 114 54 K_2O - 9S is applied in the spring at green up and 46N - 0 P_2O_5 - 0 K_2O - 7S is applied after first and second cut.
- For baleage, round bales of 54 inches are made and weigh 567kg (1250lbs) at 50% dry matter (DM). Bales are wrapped using netwrap and plastic (30-inch roll).
- For silage, it is assumed that horizontal bunker silos already exist, which are 2.44m tall x 33.53m long x 6.10m wide (8ft tall x 110 ft long x 20 ft wide). The silage is chopped at 40% DM and packed to 845.77 kg/cubic meter (52.8 lbs/cu ft).

Table 7. Production year - Alfalfa baleage costs, per acre.

ALFAFA PRODUCTION YEAR COSTS PER ACRE - BALEAGE	Assuming a yield of 8.4, 54-inch bales at 567 kg (1250 lbs) each per acre
Spring fertilizer application	
Fertilizer application	$10.54
Fertilizer	$92.73
HARVEST 1	
Mowing - mower/conditioner	$11.89
Raking	$10.33
Round Baler	$11.69
Hauling: Round Bale 12-18 bale	$8.84
Fertilizer application	$10.54
Fertilizer	$92.73
Total equipment & fertilizer (post-harvest) costs per acre	**$249.29**
HARVEST 2	
Mowing - mower/conditioner	$11.89
Raking	$10.33
Round Baler	$11.69
Hauling: Round Bale 12-18 bale	$8.84
Total equipment costs per acre	**$42.75**

HARVEST 3	
Mowing - mower/conditioner	$11.89
Raking	$10.33
Round Baler	$11.69
Hauling: Round Bale 12-18 bale	$8.84
Total equipment costs per acre	**$42.75**
Total costs (fertilizer & equipment) per acre	**$334.79**
STORAGE CONSUMABLES	
Net wrap costs per acre for season	$7.00
Plastic wrap costs per acre for season	$47.25
Total storage consumable costs per acre	**$54.25**
Total costs (fertilizer, equipment & storage) per acre	**$389.04**
Total costs per bale (8.4 bales per acre)	**$46.31**
Seeding Year Costs	Residual seeding year costs, spread over four production years

Table 8. Production year - Grass baleage costs, per acre.

GRASS PRODUCTION YEAR COSTS PER ACRE - BALEAGE	Assuming a yield of 8.2, 54-inch bales at 567 kg (1250 lbs) each per acre
Spring fertilizer application	
Fertilizer application	$10.54
Fertilizer	$211.82

HARVEST 1	
Mowing - mower/conditioner	$11.89
Raking	$10.33
Round Baler	$11.69
Hauling: Round Bale 12-18 bale	$8.84
Fertilizer application	$10.54
Fertilizer	$43.36
Total equipment & fertilizer (post-harvest) costs per acre	**$319.01**

HARVEST 2	
Mowing - mower/conditioner	$11.89
Raking	$10.33
Round Baler	$11.69
Hauling: Round Bale 12-18 bale	$8.84
Fertilizer application	$10.54
Fertilizer	$43.36
Total equipment & fertilizer (post-harvest) costs per acre	**$96.65**

HARVEST 3	
Mowing - mower/conditioner	$11.89
Raking	$10.33
Round Baler	$11.69
Hauling: Round Bale 12-18 bale	$8.84
Total equipment costs per acre	**$42.75**
Total costs (fertilizer & equipment) per acre	**$458.41**
STORAGE CONSUMABLES	
Net wrap costs per acre for season	$6.83
Plastic wrap costs per acre for season	$46.13
Total storage consumable costs per acre	**$52.96**
Total costs (fertilizer, equipment & storage) per acre	**$511.37**
Total costs per bale (8.2 bales per acre)	**$62.36**
Seeding Year Costs	Residual seeding year costs, spread over four production years

Table 9. Production year - Alfalfa silage costs, per acre.

ALFALFA PRODUCTION YEAR COSTS PER ACRE - SILAGE IN BUNKER	Assuming a yield of 5.25 Metric Tonnes (MT)/acre and packed at 52.8 lbs/cu ft into an 8 ft tall x 110 ft long x 20 ft wide horizontal bunker
Spring fertilizer application	
Fertilizer application	$10.54
Fertilizer	$92.73

Harvest 1	
Mowing - mower/conditioner	$11.89
Raking	$10.33
Chopping and blowing into cart	$17.68
Hauling and Packing	$4.23
Fertilizer application	$10.54
Fertilizer	$92.73
Total equipment & fertilizer (post-harvest) costs per acre	**$250.67**

Harvest 2	
Mowing - mower/conditioner	$11.89
Raking	$10.33
Chopping and blowing into cart	$17.68
Hauling and Packing	$2.11
Total equipment cost per acre	**$42.01**

Harvest 3	
Mowing - mower/conditioner	$11.89
Raking	$10.33
Chopping and blowing into cart	$17.68
Hauling and Packing	$2.11
Total equipment cost per acre	**$42.01**
Total costs (fertilizer & equipment) per acre	**$345.23**
Storage consumables per acre of silage	
Bunker plastic wrap costs per acre for season	$2.26
Oxygen barrier costs per acre for season	$0.63
Total storage consumable costs per acre	**$2.89**
Total costs (fertilizer, equipment & storage) per acre of silage	**$348.12**
Total costs per metric tonne	**$66.31**
Seeding Year Costs	Residual seeding year costs, spread over four production years

Table 10. Production year - Grass silage costs, per acre.

Grass production year costs per acre - Baleage	Assuming a yield of 5.13 Metric Tonnes (MT)/acre and packed at 52.8 lbs/cu ft into an 8 ft tall x 110 ft long x 20 ft wide horizontal bunker
Spring fertilizer application	
Fertilizer application	$10.54
Fertilizer	$211.82
Harvest 1	
Mowing - mower/conditioner	$11.89
Raking	$10.33
Chopping and blowing into cart	$17.68
Hauling and Packing	$4.13
Fertilizer application	$10.54
Fertilizer	$43.36
Total equipment & fertilizer (post-harvest) costs per acre	**$320.29**
Harvest 2	
Mowing - mower/conditioner	$11.89
Raking	$10.33
Chopping and blowing into cart	$17.68
Hauling and Packing	$2.07
Fertilizer application	$10.54
Fertilizer	$43.36
Total equipment & fertilizer (post-harvest) costs per acre	**$95.87**
Harvest 3	
Mowing - mower/conditioner	$11.89
Raking	$10.33
Chopping and blowing into cart	$17.68
Hauling and Packing	$2.07
Total equipment cost per acre	**$41.97**
Total equipment cost per acre per season	**$468.67**
Storage consumables per acre of silage	
Bunker plastic wrap costs per acre for season	$2.21
Oxygen barrier costs per acre for season	$0.62
Total storage consumable costs per acre	**$2.83**
Total costs (fertilizer, equipment & storage) per acre of silage	**$471.50**
Total costs per metric tonne	**$91.91**
Seeding Year Costs	Residual seeding year costs, spread over four production years

Table 11. Number of Field Operations & Litres of Fuel per Acre per Operation. Guidelines for Estimating Crop Production Costs on NS Dykelands, 2023.

CROP	NUMBER OF FIELD OPERATIONS & LITRES FUEL PER ACRE PER OPERATION											
	cultivator or tandem disk	high speed disk	harrow or land roller	air drill	row planter	SP sprayer	Hay rake	hay tedder	mower conditioner	round baler	broadcast spreader (fertilizer/lime)	chopper & dump trailer
	2.3	3.5	1.1	2.6	1.7	0.5	0.3	0.26	1.48	1.32	0.42	6.0
Alfalfa Baleage - establishment year	1	0	1	1	0	1	1	1	1	1	2	0
Alfalfa Silage - establishment year	1	0	1	1	0	1	1	0	1	0	2	1
Grass Baleage - establishment year	1	0	1	1	0	1	1	1	1	1	2	0
Grass Silage - establishment year	1	0	1	1	0	1	1	0	1	0	2	1
Alfalfa Baleage - production year	0	0	0	0	0	0	1	3	3	3	3	0
Grass Baleage - production year	0	0	0	0	0	0	1	3	3	3	3	0
Alfalfa Silage - production year	0	0	0	0	0	0	1	0	3	0	3	1
Grass Silage - production year	0	0	0	0	0	0	1	0	3	0	3	1

References

1. Bilodeau, M. “Guidelines for Estimating Crop Production Costs on Nova Scotia Dykelands”. Dalhousie University Faculty of Agriculture. 2023.

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3. “Fuel Tax Program – What You Need to Know”. Nova Scotia Federation of Agriculture. 2022. https://nsfa-fane.ca/fuel-tax-program/. Accessed 11 April 2025.

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