Forage FACTSHEET

BRITISH COLUMBIA
Ministry of Agriculture
Food & Fisheries

February 2002

FORAGE PREPLANT SOIL MANAGEMENT

Introduction

Forage crops are quite versatile in being able to produce feed for livestock on land ranging in agricultural capability from class 1 to class 6. The level of production and range of suitable crops are usually lower with poorer soil quality; however, good management can compensate for some soil limitations. It is important for the forage producer to recognize both the problems and assets associated with the land resource and to manage it in such a way as to maximize the positive aspects while minimizing the liabilities.

Each farm offers a variable land resource, both between and within fields. The producer should be able to assess differences in characteristics such as drainage, soil texture, and topography and to select forage varieties or mixes to optimize production on the various soil types. In most areas of the province it is possible to consult a soil survey report and/or an agrologist specializing in soil science for assistance.

This paper discusses the management of physical and chemical soil factors prior to seeding a perennial forage crop. Soil management decisions made before forage establishment may significantly influence establishment and yield because they result in modification of the soil's physical, chemical and biological properties.

Tillage Requirement for Forage Establishment

Primary tillage may be accomplished using a variety of implements. The type of equipment and intensity of tillage depend on the previous crop and soil characteristics such as texture and structure. If the previous crop was a cereal grain or silage corn, for example, minimum (or zero) tillage may be adequate to meet all the objectives of good tillage. Only those operations necessary to mix and distribute the residue of the crop are required. If the previous crop was perennial forage, the transition to a new seeding may include a major tillage operation. Extensive root development, sod formation and soil compaction in perennial stands require extensive tillage operations. Initial sod-breaking must be followed by additional tillage to incorporate the residue uniformly in the soil profile before a suitable seedbed can be established. Before reviewing individual methods, the overall objectives of tillage in perennial forage establishment should be clearly stated. They are:

- weed control
- modification of soil structure
- incorporation of organic soil amendments, lime and fertilizer
- seedbed preparation

Weed Control

An old, non-productive forage stand will likely include serious weeds such as dandelions, thistles and undesirable grasses. In most cases these weeds can be controlled chemically, although the costs may be prohibitive. Research in BC and elsewhere has indicated that complete inversion of the soil as in moldboard plowing generally gives the best control of perennial weeds, especially dandelions, until the new seeding is established. The use of a sod-breaking moldboard plow rather than a stubble plow is necessary for best results.

Modification of Soil Structure

All crops require a minimum volume of soil pore space and an optimum balance of air and water in the pores. Soil compaction may occur with manure spreading, harvesting or grazing during the productive life of the sward. Plow layer (0-20 cm) compaction can generally be improved by normal primary tillage.

Research on a clay soil near Prince George has shown that the air-filled pore space in the soil (aeration porosity) was maximized with moldboard plowing. Other practices, such as rotovating prior to plowing and chisel plowing, gave less favourable results (Table 1). Compaction below the plow layer may be reduced by using a subsoiler or a paraplow.

Table 1
Aeration porosity and bulk density of soil (0-10 cm) sampled in the spring following fall tillage. Trials were conducted on a Pineview clay soil near Prince George

	Tillage Treatments			
	Moldboard Plowing	Rotovation and Moldboard Plowing	Chisel Plowing	Rotovation and Chisel Plowing
Aeration Porosity (%)	20.4	15.6	10.0	9.1
Bulk Density (kg/m)	897	903	1027	1090

Aeration porosity: The volume of the soil not occupied by soil particles (i.e. air and water). Expressed as a % of the total soil volume.

Bulk density: The mass of dry soil per unit of bulk volume (including airspace). Expressed as kg per cubic meter of soil. Bulk densities of approximately 1000 kg/m^3 are typical of clay soils.

Incorporation of Manure, Lime and Fertilizers

Organic amendments, lime, and certain fertilizer materials (phosphorus (P) and potassium (K)) do not readily move into the soil with infiltrating water and are only incorporated effectively by mechanical mixing. The greater the depth of incorporation and the more uniformly these materials are mixed in with the soil, the greater the volume of favourable rooting zone produced. The time to pay attention to building soil P and K fertility and modifying soil pH is prior to crop establishment.

Seedbed Preparation

Tillage should also provide a good environment for seed germination and seedling development. Particularly important in providing a good seed environment is the preparation of a firm surface layer to provide good soil:seed contact and a continuous transfer of water from the soil to the seed and young seedling. These stringent requirements make it necessary to conduct secondary tillage with lighter implements to produce a fine seedbed.

Producers in northern regions with grey luvisols (grey wooded soils), and those with erodible soils, should leave the soil somewhat cloddy and increase the seeding rate. The grey wooded soils are particularly subject to severe crusting if over-cultivated.

In areas such as northern British Columbia, low spring soil temperatures may limit germination and early growth. When cold soils persist, tillage practices such as moldboard plowing reduce the insulating surface trash and facilitate more rapid soil warming in the spring. Other tillage practices such as chisel plowing are less effective in increasing soil temperature, yet do provide some increase over that observed for undisturbed sod. Tillage can provide soil temperature increases in early-mid June of 2–5^{o}C over those found in undisturbed sod.

In addition to choosing the method, decisions as to timing and depth of tillage have to be made. A poor choice for either of these factors can substantially reduce the benefit of any tillage.

The timing of tillage will vary depending on location and site characteristics. For example, sod tillage on fine textured soils in the interior and northern BC has been most successful in the fall. In most years, soil moisture conditions outside the coastal regions are closer to optimal in the fall than in the spring. Soil moisture is especially crucial for clay soils which have a narrow range of moisture content within which they are workable; too much moisture results in compaction and stuck tractors! Too little moisture and the soil structure is unnecessarily damaged by the tillage operation, contributing to increased erosion and/or crusting.

Fall plowing may be necessary to break up an existing sod or to incorporate heavy residues. The winter freeze-thaw action tends to reduce the size of surface clods and thus the requirements for secondary tillage to form a seedbed. In coastal areas, where winter rainfall is high and temperatures moderate, or in areas with highly erodible soils, it is usually undesirable to leave bare soil over the winter. Where fall tillage must be carried out on such soils, the fields should be left as lumpy as possible to reduce erosion potential during the winter or consider a winter cover crop.

Tillage depth depends on the nature of the soil, including the presence of compacted layers, and the amount of crop residue to be incorporated. Although forage crops can establish themselves in a fairly shallow cultivated zone it can be beneficial to increase slightly (by 2-3 cm) the depth of the plow layer prior to each forage renovation. This depth adjustment is especially useful in clay soils in which rooting is restricted to the plow layer.

Care should be taken not to plow too deeply as this will bring up subsoil clods and create additional problems in seedbed preparation. Deeper cultivation will, however, increase the depth of incorporation of manure, crop residues, lime and fertilizers, increasing the soil volume favourable to root exploitation for water and nutrients. Naturally, rates of lime or fertilizer P or K application should be adjusted upwards if the plowing depth is increased.

A great deal has been written on minimum tillage for a wide variety of crop production systems (Direct Seeding for Perennial Forage Crops). While there appears to be a definite tillage requirement in BC forage production systems, it is appropriate for the producer to question each tillage operation. Is it needed? Is there a better method?

The data presented in Table 2 illustrate a research example from a Central Interior clay soil. The soil was fall-plowed and seeded to barley silage prior to re-establishment of perennial forage. Shallow rotovation before plowing, a common practice, increased costs and decreased profits compared to moldboard plowing. The selection of the most appropriate primary tillage method clearly gave the lowest cost and highest returns. In effect, “minimum” tillage in this case was achieved with moldboard plowing as the chisel plow required several passes to achieve some degree of sod control.

Table 2
Economic analysis of tillage methods for sod breaking on a Pineview clay near Prince George

Tillage Method	Barley Silage yield*	t/ha	Tillage Cost $/ha	Returns $/ha
Moldboard plow	21.9	438	157	281
Rotovation and Moldboard plow	15.6	312	253	59
Chisel plow	11.6	232	183	49
Rotovation and Chisel plow	13.1	262	279	(17)

* Crop produced in the year following fall tillage. Yield at 65% moisture with returns based upon $20.00/t silage. All treatments received 112 kg/ha of fertilizer N as 46-0-0

The subsequent timothy-alsike clover forage yields in the third year continued to show the effects of selecting the appropriate tillage method. Moldboard plowing, with and without rotovation, and chisel plowing, with and without rotovation, produced forage dry matter yields of 9.0, 6.3, 6.0 and 6.1 t/ha respectively. The legacy of inappropriate tillage (chisel plowing in this example) prior to forage seeding may continue well into the life of the stand; even heavy fertilization may not compensate for a management mistake at establishment.

Soil Fertility Management at Establishment

The mineral nutrition of forage crops is essentially similar to that of other crop plants. There is a specific requirement for 17 essential elements, although only nitrogen (N), phosphorus (P), potassium (K), sulphur (S) and some micronutrients such as boron (B) are frequently deficient in BC. There are, however, three factors unique to forage cropping systems:

1. Legumes, frequently used in pure stand or mixed with grasses, can provide their own N through nitrogen fixation.

2. Unlike most arable crop monocultures, forages are frequently grown in mixed stands (e.g. legumes and grasses) in which the two or more species have different nutritional requirements.

3. Forage crops are usually long-lived perennials and certain types of soil modification can only be accomplished effectively prior to establishment.

Nutrient Mobility Concept

Several years ago Roger Bray, a soil scientist at the University of Illinois, indicated that the behaviour and management of plant nutrients is conditioned by their ability to move in the soil profile. The mobility of nutrients in the soil is reduced either by reaction to form insoluble compounds or by adsorption of particles to clay and organic matter. Boron and N (in the nitrate form) are quite mobile, while P, K, Calcium (Ca), Magnesium (Mg) and most micronutrients are relatively immobile.

Because of its mobility, N is added annually or even in split applications during the production year. It does not pay to attempt to build soil N levels with commercial fertilizer since the available pool in the soil is not stable and substantial losses may occur prior to crop demand. In contrast, it is frequently appropriate to build the levels of P and K and other immobile nutrients well in advance of crop uptake.

Building P and K Levels

Soils with low to medium available P (less than 65 kg/ha) or K (less than 230 kg/ha) levels may benefit from a surface broadcast application of fertilizer (P + K) incorporated with tillage prior to seeding. Broadcast application after establishment of fertilizers containing low mobility nutrients will only increase the available concentrations of P and K to approximately 5cm depth. During some growing seasons, the soil in the layer is dry and any fertilizer placed on the surface will be positionally unavailable to the roots for uptake.

Research in Alberta has indicated little difference in the total production of an alfalfa seeding between a single large application and the same amount of P applied in annual increments. Producers must determine whether the possibility of dry surface soil conditions and reduced effectiveness of broadcast P merit the larger initial investment in incorporating P during the establishment year. In the wet coastal areas, satisfactory results have been observed with broadcast fertilizer P on established perennial forages. Obviously, in addition to agronomic judgments, farm cash flow will influence the choice between a large single cash outlay in one year versus smaller amounts annually.

Band Application vs Broadcast Fertilization

Phosphorus (and K, in low K soils) may be placed in a band 2-4 cm below or offset below the seed with banding attachments on the seeder. This approach may be particularly effective in cold soils or in soils in which P and K availability is rapidly reduced by fixation. Fixation involves the binding of soluble nutrient ions to soil particles in such a way that the nutrients become unavailable (at least temporarily) to the plants. Indeed, significant improvements have frequently been reported in forage establishment and yields following P/K fertilization in the first year. However some reduction in emergence and yield may be experienced at low seeding rates and high fertilization. This response is often a consequence of salt toxicity and is most acute with banded N and K, each of which occurs in a soluble salt form. Banding of these soluble nutrients is not desirable where limited moisture may result in a highly concentrated salt solution. Care should also be taken in adjusting the banding attachment so that the fertilizer is not placed too close to the seed furrow.

Banding fertilizers with row seeding may have other advantages in addition to enhanced early P and/or K availability. These are:

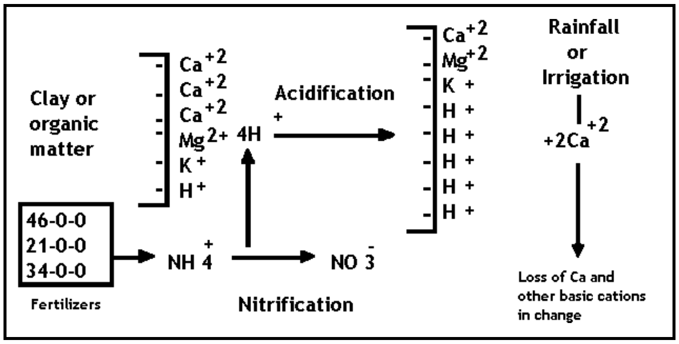
- reduced weed competition
- immobile nutrients (P and K) are placed deeper and are more likely to be in moist soil.
- early root growth is stimulated.
- winter survival of alfalfa is enhanced.
- the efficiency of fertilizer use at low rates of application is likely to be higher than with the broadcast application of the same rates.

Liming

Soil water is an essential component of the nutrient uptake system. Nutrients must be dissolved in water before they are accessible to the plant. An important property of this soil solution is the soil reaction or pH; that is whether it is acid, neutral or alkaline. The pH scale (0-14) provides a relative measure of acidity which is important for plant growth and nutrient uptake.

Many soils in coastal and northern British Columbia are naturally acidic with pH values less than 6. In other cases, the soil pH has declined as a result of management practices such as heavy N fertilization, especially in conjunction with irrigation. The latter process may be illustrated as follows:

Figure 1



Positively-charges cation (e.g. calcium and magnesium) may be bound to the negatively charged soil clay and/or organic matter. When high N fertilizers are used, ammonium is converted to nitrate and positively charged hydrogen ions (H+) are released into the soil solution. These ions can displace some of the basic ions such as calcium from the soil cation exchange complex. The displaced calcium may be lost from the soil via leaching. As a result, the soil particles now have a greater number of hydrogen ions bound and the soil is acidified.

An increase in soil acidity (decrease in pH) below the slightly acidic, optimum range of 6 to 7 can have a number of negative impacts on crop growth. Firstly, the availability of several nutrients declines. Notable among these changes is a reduction of available soil P, which reacts with iron (Fe) and aluminum (Al) at low pH (5.5) to form insoluble precipitates. Another important effect of low pH is the reduction in soil microbial activity, particularly by bacteria and actinomycetes. Suppressed microbial activity reduces the decomposition of organic matter and the mineralization of N and S which are predominantly supplied to plants via soil organic matter. Thatch build-up may also occur under acidic conditions as a consequence of reduced organic matter breakdown. In addition to generally lower nutrient availability, some soils may develop toxic concentrations of Al and possibly manganese (Mn), further reducing plant vigour.

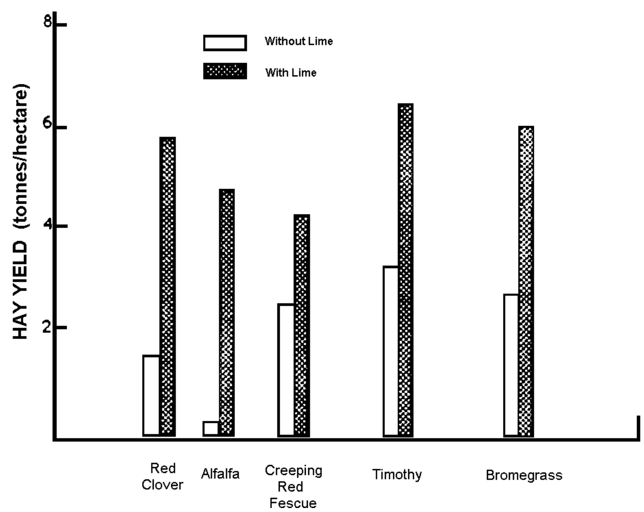
Chemical & Biological Activity in Soils of Different pH

Perennial legumes such as alfalfa or white clover are grown, in part, for their ability to utilize atmospheric nitrogen gas (N_2) as a source of nitrogen for growth in a special relationship with soil bacterium *Rhizobium*. Legumes are particularly sensitive to low pH. While the deleterious effect of soil acidity on legumes may result from a direct toxicity to the plant, the numbers of symbiotic *Rhizobium* bacteria in the soil and their ability to fix N_2 are also reduced. In some cases the reduction of molybdenum (Mo) availability at low pH may further inhibit the activity of *Rhizobium* in fixing atmospheric N. Although some legumes (red and alsike clover) and grasses (reed canarygrass, fescue, timothy) tolerate low pH and should be used if liming is not practical, liming will likely increase the vigour, yield, and longevity of highly productive forage stands. The response to lime by some forage species grown on a strongly acidic soil in the Peace River region is shown in Figure 2.

Figure 2

Liming Response of Grasses and Legumes in the Peace River Region*

*Yield response measured on a strongly acid soil (less than pH 5.5) in the absence and presence and lime (soil pH adjusted to approximately 6.2). Adapted from information in Hoyt et al. (1974)



Because of its low solubility in water, lime is similar to the immobile plant nutrients in that it must be incorporated and mixed with the soil mechanically. Obviously the most effective time to do this is prior to establishing a new seeding. Several months should be allowed to give the lime a chance to react with the soil.

Refer to the factsheet "Liming Acid Soils in Central BC" for more detailed information on lime and liming soils.

Organic Soil Amendments

Livestock wastes are frequently used on established forage stands and good responses can be achieved as long as application rates are not too high. Manure management is concerned primarily with the management of nitrogen; losses of N through storage, handling and spreading can be extensive. Other plant nutrients (P, K, Ca and Mg) are not as readily lost and are less influenced by improper management.

Since broadcast application of manure will influence primarily the soil surface (0-5 cm), there may be some benefit in incorporating manure to the full depth of the plow layer in low organic matter soils. Some studies have also indicated that the effectiveness of broadcast P is higher when P is incorporated in combination with an organic amendment. The final advantage of manure incorporation is that there will likely be better conservation of the ammonium-nitrogen component of the manure as compared to surface application.

Diagnosis of Soil Fertility Status

One of the most profitable investments a forage producer can make is the time and cost associated with soil sampling and analysis. A knowledge of the actual soil fertility status may prevent yield loss due to inadequate nutrient concentrations or prevent the unnecessary use of fertilizer in high testing soils. In order for the soil test to be meaningful, however, the sample must be properly collected.

Soil Sampling

Although soils can be samples at any time for most nutrients, the fall and spring are generally regarded as most appropriate.

The lead time required to obtain sample results (1-2 weeks), means that careful planning is required in order to coordinate application and incorporation of soil amendments such as lime and fertilizer with the appropriate tillage operation. Soils can be sampled with an auger, corer (e.g Oakfield probe) or a spade. Particular care is required when sampling with a spade to ensure a uniform 2-3 cm slice is removed from the full depth of the plow layer. During the sampling procedure it is often possible to detect compacted layers, which may suggest the need for subsoiling or paraplowing to improve root penetration.

A composite sample may be taken from a field of 8 ha or less if it is uniform in slope, colour, soil type, drainage and cropping practice. Small atypical areas such as dead furrows, low wet areas or areas close to trees or fence rows should be avoided. An example of field sampling is illustrated in Figure 3a in which the X's represent individual cores in a uniform field. Since uniform fields are a rarity in BC, some variation of the situation shown in Figure 3b is quite common. In the latter case, topography and previous crop history suggest that the field be sampled in four sub-units and four individual composite samples sent for analysis.

The division of a field into sub-units for separate sampling and analysis is a process called stratified random sampling. Stratified random sampling for the example shown in figure 3b would increase soil analysis charges. However, the additional information provided could easily save that added cost by more accurately estimating the soil fertility of a non-uniform field. Such information permits a producer to adjust applied fertilizer levels to existing fertility gradients in the field and to avoid excessive applications. This approach is used with digitized aerial soil maps to program a computerized mixer and application vehicle and custom mixes are automatically produced and distributed as a vehicle moves across the soil gradients in the field.

Producers should seek advice regarding where to send their samples for analysis; several private laboratories are available to BC producers. Where possible the same lab should be used over a number of years to standardize the methods of handling samples and to permit comparison among years for trends in available P, organic matter and other soil-related changes.

Figure 3 Soil Sampling Patterns

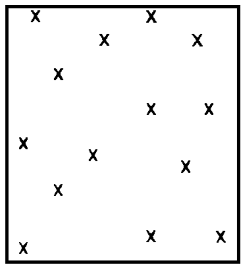


Figure 3a.   Random sampling in uniform field

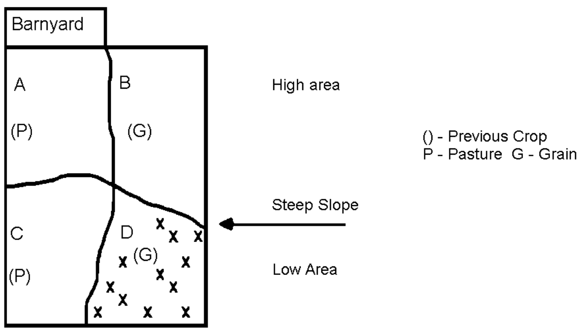


Figure 3b. Stratified random sampling of variable area

Sources of Field Variability

Even apparently uniform fields may vary greatly in their chemical characteristics. The following are examples of some of the sources of variation within fields.

- Crop history, eg. pasture vs grain
- Soil differences in texture, organic matter and other characteristics. These may be directly visible following cultivation or indirectly observed through crop growth patterns.
- Topographical variation, which may be related to nutrient differences caused by soil erosion.
- Different fertilizers contain differing levels of micronutients.
- Old barn lots or fields near feeding areas which have been heavily manured may supply much larger quantities of N, P and K.
- Unknown problems may be revealed by poor crop growth relative to the rest of the field. Often the field surface will appear uniform because it has been leveled. However, leveling of hummocky forest soils may expose very acidic or very basic (high lime) subsoils. In coastal BC, highly acidic ditch cleanings are frequently used to fill in low spots.

Fertilizer management which removes, or is adjusted for, variation of fertility within a field can increase the total productivity of that field and result in more even maturity and uniform stand composition and quality.

Summary

The period prior to establishment of a new forage seeding offers the producer an opportunity to modify the soil environment to improve the uniformity, productivity and longevity of the stand. Pre-plant soil management appropriately included incorporation of immobile fertilizer nutrients, (P and K) as well as lime and organic amendments where required. The effectiveness of incorporation and the creation of suitable physical conditions for crop emergence and development are dependent on the selection of an appropriate tillage method. Generally, forage seeding following a previous forage crop requires moldboard plowing for complete burial of crop residues and weed control. Additional tillage, such as rotovation, does not appear to be justified except where necessary to establish a firm seedbed. Good information on the level and variability of available plant nutrients through proper soil sampling and analysis can increase yields and/or save money by reducing redundant application of fertilizer.

Courtesy of

Dr. A.A. Bomke
Department of Soil Science, U.B.C.

Adapted from Preplant Soil Management, Chap 2
U.B.C. Access in Agricultural Science 1986, with permission.