Management Practices to Optimize Silage Quality and Yield

Jane R. King

Department of Agricultural, Food and Nutritional Science, 4-10 Agriculture Forestry Centre, University of Alberta, Edmonton T6G 2P5
Email: jane.king@ualberta.ca

■ Take Home Message

- Your silage is only as good as the crop you grow.
- Grow what grows well in your area and what fits your rotation.
- Perennial and annual crops each have advantages.
- To maximize crop growth maximize crop health and maximize light interception.
- Intercrops may offer some new opportunities.
- Harvest at the right time to get the quality you need.
- Maximize fermentation and reduce heating by excluding air.
- Reduce feed out losses.

■ Choice of Crop

"You can ensile just about any plant material" is one reason often given for choosing silage over hay and the comment is largely true provided the plant has an appropriate sugar and moisture content. However, some crops ferment more easily than others and some of the crops that are the foundation of silage production in other parts of the world are difficult to grow here in Western Canada.

So the first piece of advice is to **"grow what grows well in your area".** For much of Alberta the crop of choice for top quality dairy silage is alfalfa, an alfalfa grass mix, or a cereal silage, most often barley silage. Sometimes a legume such as pea may be included in a cereal silage to increase the silage quality.

Successful silage crop production is based on a number of key factors that include:

- Species and variety selection
  - Adaptation to the particular growing zone – soil type, soil pH, length of growing season or frost free period, ability to over-winter
  - Appropriate plant form – height, leafiness, ability to stand
- Fit with the planned crop rotation
- Soil fertility or fertilizer regime
- Pest control – weeds, insects and diseases
- Optimal harvest date – optimize quantity and quality, weather restraints
- Minimizing harvest and storage losses

Species and Variety Selection

Perennial vs. Annual

The first choice may be between a perennial or annual crop. Perennials such as alfalfa or an alfalfa grass mix have the advantages of amortizing the establishment costs over a number of years, enhancing soil quality, providing fixed nitrogen, and often providing more than one harvest per growing season. Disadvantages may be a longer establishment time, reduced flexibility in planning crop rotations, more complex pest and fertility management, and the risk of winter kill.

Using an annual crop you have the opportunity to try something new each year, or to fine-tune your system over a number of years. You can reap the pest control benefits from rotating crops or varieties. Fertility and pest management can be adjusted each year and you have continuing access to new cultivars. Recent work in Lacombe has indicated that if you are not rotating crops from year to year, even rotating cultivars within a crop species can be beneficial in reducing disease build-up and rotating between crops with different harvest times may assist in weed control (Turkington et al. 2005).

Locally Bred Varieties

We are lucky in Alberta that we still have considerable plant breeding effort occurring in the province so cereal and alfalfa cultivars are being bred for our particular growing environments.

This is particularly important for the perennial crops where longevity of the stand will be influenced by the winter hardiness of the crop. Selection for winter hardiness is most successfully done by “mother nature” so cultivars bred to be productive in warmer growing areas may not persist under our cold winter conditions. When deciding which cultivars to grow access local production figures wherever possible, and for a perennial crop, production data should be available for several consecutive years.

Annual crops may also perform differently in different areas of the province according to variations in soil type, temperature and moisture availability. While semi-dwarf barley varieties may not yield as much biomass as standard types in the southern part of the province their performance may be very similar under high moisture conditions in central Alberta.

Plant Form

Plant form, time to maturity and quality are all characteristics that can differ between plant varieties.

For a silage crop we are usually looking for a crop that is leafy to provide a high protein content. We also need those leaves to be retained after harvest. Plant growth rate is positively correlated to leaf area – so leafier crops will generally have a faster growth rate. This is particularly true early in the season for an annual or early in the regrowth period for a perennial. The multifoliate alfalfa cultivars may offer some advantages but the multifoliate character generally has to be combined with fine stems and good leaf retention if the potential advantages are to be manifest.

“Standability”, or the ability not to lodge, is an important characteristic for a cereal silage and some semi-dwarf barleys have yields similar to taller standard barley types, particularly when grown in regions with higher rainfall. Breeding for cereal types that have a slower rate of leaf senescence may increase silage protein content and digestibility.

If you are choosing corn as your silage crop you need to be certain that you have a cultivar that will reach a suitable stage of maturity within the available growing season. That means checking the Corn Heat Unit (CHU) rating for your area and ensuring that the cultivar you select is suitable.

If you are growing cereal silage it is possible to extend the harvest window by growing a combination of different cultivars, or different cereal species on different fields. Barley cultivars will generally reach silage stage a week before oats or triticale. Inclusion of a winter triticale crop can also help to spread the harvest window. Another option is spreading out the seeding dates but this can result in lower yields from the later establishment (Kibite, unpublished data 2001). Since plant development is largely driven by the accumulation of heat or Growing Degree Days, crops that are planted later generally mature more quickly so differences between harvest dates will not be as great as differences between seeding dates. Under hot conditions plants will mature more quickly, and this will often produce a higher quality but lower yielding crop. Growing a mixture of two cereal genotypes may confer some advantages; general advice is to harvest the crop when the larger cereal component is at the appropriate silage stage.

Silage Mixtures

Peas as a silage crop can provide high quality material but because of their weak stems and twining habit are prone to lodging. Pulse crops have the advantage of being nitrogen “self sufficient” and supplying nitrogen to a following cereal crop. The N benefit and higher quality silage can help to offset the larger seed costs. Mixing a cereal with the peas can help to improve standability. Recent research in Alberta is looking at other pulse crops that may be suitable for silage production. Work by Strydhorst et al. (2005) tested peas, faba beans and lupins grown alone and in mixtures. In the mixtures the pulses were seeded at their optimum seeding rate and barley was added at 25% of the normal seeding rate. The mixtures always out yielded the monoculture pulse (12.4 t DM ha^{-1}), the faba bean–barley mix equalled the yield from a barley monoculture and the pea–barley mix was higher than the barley monoculture. Further increasing the barley percentage in the mix could further increase yield but would reduce the % pulse in the mixture and thus reduce the pulse crop benefits.

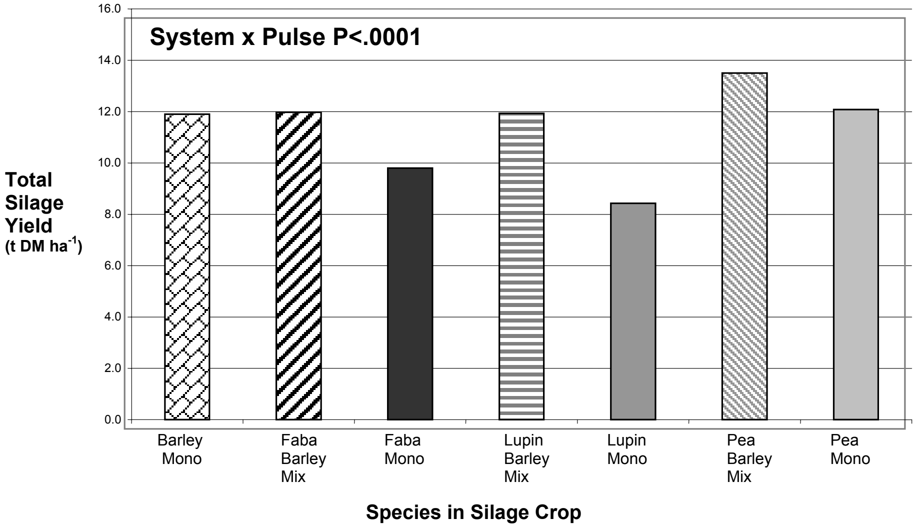

Figure 1. Traditional Pulse Monoculture and Pulse-Barley Silage Yields (data is an average of six site years).

Other work at the U of A has looked at intercrops of berseem clover *Trifolium alexandrium* (a tall growing annual clover with a low bloat capacity) with cereals for silage. Silage yields of intercropped berseem and triticale (9.9 t DM ha^{-1}) were higher than that of berseem-barley (8.8 t DM ha^{-1}) or berseem-oat (9.7 t DM ha^{-1}) in two out of four years (Ross et al. 2004a). The more open canopy of the triticale crop favored an increased berseem percentage in the harvested material. A relatively small clover percentage (~ 20%) caused some improvement in forage quality with NDF being reduced by 25-45 g kg^{-1} compared to cereal alone. Further studies are required to assess how the presence of berseem would affect intake, digestibility and milk yield. A secondary benefit to these intercrops was the regrowth of the berseem clover (1.8 – 3.0 t DM ha^{-1}) following the initial silage harvest. This high quality material (21% protein) could provide late season grazing, green chop, or be incorporated to increase soil carbon and nitrogen. A second study that looked at berseem intercropped with a range of barley and oat cultivars suggested that shorter stature (barley) and earlier maturing (oat) cereal cultivars allowed a higher clover % in the intercrop (Ross et al. 2004b).

Current research at the U of A and AAFC Lacombe is studying if a permanent legume living mulch can provide fixed nitrogen and other benefits to an inter-seeded cereal silage crop. Rotations containing barley, oats and triticale are seeded into a permanent stand of kura clover. Initial results indicate that an early season glyphosate application on the clover may be needed to reduce early season competition from the clover crop. Where barley followed barley in the rotation there is some evidence that the clover living mulch offered a barrier to the development of barley leaf diseases (Kosinski unpublished data).

Red clover is a species that has recently been receiving attention as a silage crop in Europe and parts of the USA. A very productive, though short lived crop in the wetter parts of the prairies, red clover like alfalfa has a relatively low water soluble carbohydrate (WSC) content and high buffering capacity. In Britain adding red clover to a ryegrass sward increased the silage quality and reduced the need for N inputs – a particularly important factor as more farms in Britain move to organic production. Also of interest is the presence in red clover of the enzyme polyphenol oxidase which reduces protein breakdown in the silo giving red clover silage only 60-80% of the non-protein N found in alfalfa silage. Work in Wisconsin has found that the utilization of both energy and crude protein is greater in red clover silage than alfalfa silage so that feeding red clover silage could reduce the loss of N into the environment through manure (Broderick et al. 2001).

■ Fertility

Heavy feeding silage crops such as corn can be good crops on which to spread manure. Whether you are using manure or mineral fertilizer to provide nutrients a soil test is recommended before determining how much to apply. Keep in mind that when you harvest that silage crop you are frequently removing more nutrients from the system than when harvesting a grain crop. If a properly inoculated legume is included in the silage mix (whether it is an annual or a perennial) you can anticipate that the legume will be largely self sufficient in N. That means that the mineral N present in the soil will largely be available for the non-legume companion. The efficiency with which legumes fix N will be influenced by other growing conditions and by the plant's health. A legume that is stressed for lack of P and K, moisture stressed or diseased will provide less energy to support the N fixing rhizobia so fixation rates will be lower. Rhizobia function best in soils that are at a pH above 5. If you are working with acid soils apply an inoculant that has been selected to be effective a lower soil pH.

In a grass legume perennial stand it is generally thought that a stand that has at least 30% legume will be self sufficient in N. Interestingly enough there is little empirical evidence to support this assumption. Although alfalfa does not require much in the way of N fertilization it has a fairly high requirement for phosphorus (P) and thus it can be a good idea to "bank" P by incorporating the equivalent of several years P requirement prior to the alfalfa establishment. Potassium (K) is also an important fertilizer for alfalfa since adequate K is associated with lower levels of winter kill.

■ Crop Establishment

Most cereal silage crops are seeded between mid and late May. Seeding rates generally range between 85 – 140 kg ha^{-1}; the lower rates being more appropriate for the drier areas. Higher seeding rates can help with weed control (O'Donovan et al. 2000).

Corn is a C4 crop and therefore grows best at higher temperatures. Corn requires a soil temperature of at least 10°C to germinate. Planting at cooler soil temperatures may result in poor or patchy germination.

Corn has traditionally been grown at a 76 cm row spacing but narrower row spacings may be beneficial. Recent work in Lethbridge (Beres 2005) has shown that higher seeding rates and narrower row spacing can increase silage yields. Seeding at a narrow row spacing effectively spaces the plants more equidistantly thus allowing each plant to have equal access to light, water and nutrients. At a narrow 38 cm row spacing, yield was maximized at 84-86,000 kernels ha^{-1} while at a traditional 76 cm row spacing seeding rates of 98,000 kernels ha^{-1} were needed. In central Alberta new 2000 CHU corn hybrids had a maximum silage yield at 90,000 kernels per ha at a conventional row spacing and yielded 12-15 tonnes/ha dry matter with 6.8%

CP% and 43% NDF. Higher densities tended to delay maturity and reduced the chance that silage harvest stage would be reached (Stanton, 2006).

Establishing a Perennial Silage Crop

Establishment of a perennial forage mixture for silage production requires some forethought. The old adage "well sown half grown" is particularly appropriate for a perennial forage crop since forage seeds are typically small and the seedlings slow growing and poor competitors. Weed problems as far as possible should be corrected before seeding. This is particularly important for perennial weeds such as Canada Thistle or toad flax – perennial weeds can become a perennial problem. Select cultivars that are suitable for your area and are compatible with each other. Seed at an appropriate seeding rate. Seeding rates for grass legume mixtures should take into account the relative size of the different seed components. Because alfalfa generally has a low WSC level and a high buffering capacity it is harder to ensile than some of the annual crops. The inclusion of a grass with alfalfa helps to overcome some of these problems. Remember when seeding a grass legume mixture that with time the grass may tend to out compete the legume particularly if the grass is rhizomatous. Inoculate the legume with an appropriate rhizobium species. Handle the inoculum and the inoculated seed with appropriate care. High temperatures and UV light will kill the rhizobia and keep freshly inoculated seed out of the direct sunlight and at a cool temperature. If you use a cereal cover crop plant it 50% of the normal seeding rate to reduce the competition with the forage seedlings. Barley is the most competitive of the cereals when used as a cover crop. Plant the forage at a shallow depth and plant as early as you can in the spring to catch the moisture. Because forage seeds are small they need to be planted near to the soil surface but the soil surface can dry out quickly. Packing with a packer wheel or a roller packer can help to remove air spaces in the soil and create capillary channels that will bring moisture to the surface.

▪ Harvest

Silage harvest time is a compromise between forage quantity and quality and the development of an adequate WSC content. Usually we have to sacrifice a little yield in order to obtain optimum quality.

For cereals the optimum harvest time is at the milk to soft dough stage. For corn optimum harvest is at the 1/4 to 2/3 milk line, and for alfalfa silage at the bud to 10% flower stage. The 10% flower stage is when 10% of the plants have one open flower. At the soft dough stage cereal silage will be close to the desired 65% moisture needed for good fermentation in a bunker silo. Legume silage mixtures are generally harvested at the appropriate cereal silage stage.

In some seasons corn may not meet the appropriate developmental stage prior to the first fall frost. Since moisture loss from frosted corn can be very rapid harvest should proceed quickly after a killing frost to avoid the material reaching too high a dry matter content when adequate fermentation will be restricted.

Perennial forages can provide two or more silage cuts in the growing season. In a brome grass–alfalfa mixture the first cut is often dominated by the grass so it will have a lower quality than the second cut which usually has a higher legume content. Cutting intervals need to consider not only the available yield but also the health and persistence of the perennial stand.

Too frequent harvests will weaken the alfalfa by not allowing the plant to replenish its carbohydrate and protein reserves. This can be particularly important in the fall when the alfalfa plants need to accumulate storage compounds and undergo physiological changes that will allow them to harden so that they can withstand the cold winter temperatures.

Winter Damage to Perennial Silage Crops

Managing to avoid winter kill is one of the challenges of managing a long term alfalfa stand or alfalfa grass mix. The thinning out over time of the alfalfa in an alfalfa grass mix can be partly attributed to loss of plants over winter.

Careful cultivar selection can ensure that you are planting a suitably winter hardy alfalfa but even the most hardy cultivars can suffer winter damage when we have a particularly harsh winter, especially if there is minimal snow-cover.

Each perennial crop has a different tolerance to cold temperature. Scientists refer to the LD_{50} which is the temperature at which we can expect 50% of the individual plants to die. Of course the length of time over which the plant experiences the temperature will influence the likelihood of damage occurring as will the “health” of the exposed plant. Diseased plants are thought to be more susceptible to winter kill, as are those plants that go into winter with a low level of stored carbohydrates. Studies carried out in the Peace River district by Stout in the late 70’s showed that plants that had been harvested less frequently during the growing season were less likely to winter kill and the occurrence of a harvest in the period six weeks before the final killing frost made the plants particularly susceptible. Further studies showed that the susceptibility to winter kill was affected by the carbohydrate status of the plant.

The protein or nitrogen status of the plant has also been shown to correlate to winter survival and the vigour of new growth in the spring.

The ability of a dormant plant to over-winter is influenced by a number of factors:

- The ability to "harden" or undergo physiological changes that prepare the plant tissue to withstand the cold temperatures. This is a genetic trait that is dependent on the plant receiving and responding to the environmental signals that winter is approaching. Cooler temperatures and changes in day length tell the plant that winter is approaching.
- The ability of the plant to maintain the integrity of the cell membrane that surrounds each cell wall. This is a genetic characteristic. Those plants that can maintain the fluidity or flexibility of the membrane at low temperatures are able to continue their normal function.
- During the hardening process the plant produces anti-freeze like substances - the K status of the plant appears to help in this process. Insuring adequate K in the soil will help the plants to harden.
- If water freezes within the plant cells the ice crystals that form can physically damage the cell membrane. The less free water there is in the cell the greater the chance that ice crystals will form. Thus, during the hardening period the plant concentrates the cells contents and reduces the amount of free water. The ability to successfully reduce the amount of free water in the cells can, however, be limited under very wet conditions. This is one reason why winter-kill is often seen in low lying areas.
- The hardening process itself is an energy expensive process, as is the ability of the plant to maintain the hardened state. Plants that are stressed in the fall may not harden adequately.
- Just like the bear preparing to go into hibernation the perennial plant has to lay down extra stores of carbohydrates in order to survive the winter. If you take your last silage cut of alfalfa during the "sensitive period", six weeks before the fall frost, the plants will use up their stored carbohydrates initiating new growth rather than building up the necessary stores for winter. Alfalfa has to have a good six inches of growth before it starts to have excess carbohydrates to put into storage.
- The level of certain amino acids or "nitrogen pools" in the dormant tissue has also been shown to correlate to winter survival and spring vigor.

■ Storage and Feed-out

Having taken care to produce a high quality plant product, take care to ensure that all the nutrients are captured by a good fermentation and feed-out plan. Carbohydrates will be preserved and heating damage avoided if the aerobic phase is kept as short as possible. This is aided by a suitable chop length to allow for rapid packing in a bunker silo. A rapid fill rate and applying thin layers of material to the silage stack will increase the effectiveness of packing. The stack should be covered as quickly as possible and should be covered if final fill is delayed due to inclement weather. Uncovered silos may loose the top three feet of material to spoilage before the stack self seals. Silo bags need to be well sealed and checked frequently for any signs of damage. A few small holes that allow O_2 to seep back into the bag can cause a disproportionately large amount of spoilage. Putting up silage too wet can cause a large loss of nutrients through seepage. Feed out needs to be rapid to ensure that material on the silage face does not spoil due to O_2 ingress prior to feeding. It is suggested that feeding 10 inches off the open face per day can control spoilage.

▪ Conclusions

Dairy farmers in Alberta have a large variety of crops and a range of different silage systems available to help them produce the high quality product that is needed to support the lactating cow. Milk production starts with good crop production. Choosing the best species or mixture for your growing conditions, taking care with establishment, fertility, and pest control, and harvesting at the correct stage and moisture content will help to ensure silage quantity and quality is maximized.

▪ References

Beres, B., K. Coles and C. Van Dasselaar (2006) Effect of row spacing and seeding rate on silage yield in southern Alberta. Proceeding Farm Tech 2006 Edmonton http://www.farmtechconference.com/2006.shtml (Accessed January 10, 2007)

Broderick, G. A. R. P. Walgenbach, and S. Maignan. (2001) Production of Lactating Dairy Cows Fed Alfalfa or Red Clover Silage at Equal Dry Matter or Crude Protein Contents in the Diet. J. Dairy Sci. 84:1728–1737

O'Donovan, J.T. K. N. Harker, G.W. Clayton, L.M. Hall (2000) Wild oat *Avena fatua* interference in barley Hordeum vulgare is influenced by barley variety and seeding rate. Weed technology 14(3); 624-629

Kibite S. (2001) Cited in Anon (2004) Silage Manual, Edmonton, AAFRD

Ross, S.M., J.R. King, J.T. O'Donovan and D. Spaner (2004a) Forage potential of intercropping berseem clover with barley, oat or triticale. Agron. J. 96:1013-1020

Ross, S.M., J.R. King, J.T. O'Donovan and D. Spaner (2004b) Intercropping berseem clover with barley and oat cultivars for forage. Agron. J. 96:1719-1729
Stanton D.J. Agronomic evaluation of early maturing silage maize hybrids in central Alberta. MSc Thesis, University of Alberta 102p.
Strydhorst, S. M., J.R. King K.J. Lopetinsky, G. Clayton and K.N. Harker (2005) Sustainable silage production with pulse power. Farm Tech Edmonton.
Turkington T.K., K. Xi, J.P. Tewari, H.K. Lee, G.W. Clayton and K.N. Harker (2005) Cultivar rotating as a strategy to reduce leaf diseases under barley monoculture. Can. J. of Plant Path. 27(2):283-290