# Impact of fertilization on forage production and animal performance

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### Forage Fertility – Agronomy Standpoint

Large portions of the land area in the temperate humid zone are best suited to growing forage crops than grain crops (Cherney and Kallenbach, 2007). Forage crops remove large amounts of nutrients, affecting both the future productivity of the field and the mineral balance in the animals that consume the forage. Best management practices for forage fertilization will optimize yield and quality, and minimize impacts on the environment. The International Plant Nutrition Institute (IPNI) effectively summarizes forage fertilization into four steps: Apply the right source, at the right rate, at the right time, in the right place. Primary fertilization options are lime, manure, and N, P, and K fertilizer, with occasional micronutrient issues.

### Lime

Liming materials vary greatly in quality. Regardless of the liming material, effective neutralizing value (ENV) is a function of total neutralizing value (calculated as calcium carbonate equivalents) times the fineness of the material. All lime passing through a 100-mesh screen will react in the first year, while only 60% of lime passing a 20-mesh screen will react within a year of application. Ground limestone is the most common lime sold in New York State. Limestone with less than 6% Mg is termed ‘calcitic limestone’, while limestone with more than 6% Mg is called ‘dolomitic limestone’. The choice of limestone is typically based on availability and price. In New York State, we recommend testing fields for soil pH at least once every three years (Ketterings et al., 2006). Lime recommendations are not simply based on current and desired pH, but also include the capacity of the soil to buffer changes in pH, and tillage depth. Most soils in New York State have adequate pH for perennial grasses, but many soils are below the desired pH of 6.5 for alfalfa production.

### Manure

On farms with livestock, manure can supply much of the required P and K, as well as micronutrients. Nitrogen in manure is in an inorganic (ammonium) form and an organic form. Ammonium N may account for up to 50% of the total N in manure, but some or all of the ammonium N can be lost to the air from exposed manure on the barn floor or feedlot, in storage, or after spreading. Of the remaining ammonia N at application, 100% can be conserved by injection, or a portion of the ammonia can be conserved by incorporation, depending on the delay in incorporation. Organic N is assumed to be released at rates of 35, 12 and 5% for the first three years, assuming manure dry matter is less than 18% (Ketterings et al., 2005). Release rates of organic N from manure vary with the source of the manure (e.g. cows vs. poultry), as well as with the dry matter content of the manure.

Perennial grasses harvested for conserved forage can utilize large amounts of nutrients, increasing nutrient management options and reducing the risk of negative environmental impacts (Mikhailova et al., 2003). We studied impact of semi-solid dairy manure application rate and timing on yield and nutritive value of orchardgrass (Cherney et al., 2010a) in northern New York. Manure was applied at spring green-up, and after all three harvests in seven treatment combinations, not exceeding 44.8 Mg ha$^{-1}$ per application during the growing season. Average dry matter (DM) yields for total seasonal manure applications of 44.8, 67.2 and 89.6 Mg ha$^{-1}$ were 7.02, 7.89, and 9.10 Mg ha$^{-1}$, respectively. There was no significant effect of timing of manure applications on total DM yield, although there was a tendency for lower yields when manure was autumn-applied only. Manure applied at the seasonal rate of 179.2 Mg ha$^{-1}$ resulted in greater DM yields than inorganic N fertilization by the second year of the study. Neither application rate nor timing of manure application had an impact on forage nutritive value.

Another study was conducted in northern New York to determine the effects of nutrient application source and timing on yield and quality of orchardgrass, reed canarygrass, and tall fescue (Cherney et al. 2010b).

Six nutrient treatments were applied for four consecutive years. Three of the treatments received 224 kg N $ha^{-1}$ $yr^{-1}$ applied as ammonium nitrate: 1) in a single application at spring green-up; 2) split-applied at green-up (112 kg) and after 1st cut (112 kg); or 3) split-applied at green-up (112 kg), and after 1st (56 kg) and 2nd (56 kg) cuts. Two treatments received semi-solid dairy manure (with sawdust bedding) applied at 90 Mg $ha^{-1}$ $yr^{-1}$: 4) manure split between spring green-up (45 Mg $ha^{-1}$) and after first cut (45 Mg $ha^{-1}$), and 5) manure split-applied, plus 56 kg N fertilizer $ha^{-1}$ per cutting. The 6th treatment received no manure or N fertilizer.

With annual manure applications, soil P, organic matter (OM), pH, and nitrate all increased; in contrast, they decreased with annual N fertilizer applications as ammonium nitrate (P, OM, and pH) or increased more slowly (nitrate). Grass species had no effect on soil pH, OM, or P levels. While manure increased soil P and K to high levels, manure combined with N fertilizer removed more P and K due to higher yields. Manure plus N fertilizer produced the greatest DM and milk yields. By year 4, manure without N fertilizer produced similar DM yields to N fertilizer. Split-applied (112 + 112 kg N $ha^{-1}$) N fertilizer increased DM yield over a single spring application of 224 kg $ha^{-1}$ $yr^{-1}$, but did not affect N recovery or forage quality. Splitting the 2nd 112 kg N $ha^{-1}$ application over 2nd and 3rd cuts (56 + 56 kg N $ha^{-1}$) did not affect yield or N recovery. Grass species had similar N recovery. Tall fescue produced greater milk yields and more uniform yield distribution than reed canary grass and orchardgrass.

From a nutrient use-efficiency standpoint, corn and forage grass fields are preferred for manure applications, but manure application to alfalfa or alfalfa-grass fields is sometimes useful (Ketterings et al., 2007). When manure is applied to established alfalfa stands, a combination of high soil moisture levels and heavy application equipment can result in severe compaction with up to 100% plant mortality in the compacted areas. Wheel traffic damage can be minimized by planting traffic tolerant varieties, using small tractors for cutting, raking and harvest, avoiding unnecessary trips across the field, using larger harvesting equipment, avoiding tractors with dual wheels, and driving on fields as soon after cutting as possible. Nitrogen addition from manure will suppress alfalfa N fixation and will favor any grass in the stand. Alfalfa-grass mixtures with a higher proportion of grass are better candidates for manure applications.

## Nitrogen

Best management practices for managing environmental impacts generally involve diagnostics, application, and minimizing nutrient losses (Bruulsema, 2006). The previous crop, and previous applications of manure, can have a major impact on N availability. In times of high production costs and fluctuating milk and fertilizer prices, methods are being developed to maximize the efficiency of applied N.

### Enhanced-Efficiency N Sources

Controlled-release fertilizers are typically urea-based (Bundick et al., 2009). Nitrogen release can be limited by temperature or moisture. With a slow-release product such as *Nitroform*, about 2/3 of the N requires microbial activity to be released. Release of N can also be controlled by coating fertilizer granules with a polymer or sulfur. Polymers allow more N to diffuse through the coating during warmer weather. Sulfur coatings must first breakdown, followed by soil microorganism breakdown to release N. While these products can reduce N losses and salt damage to seedlings, they can be considerably more expensive.

Urease inhibitors such as *Agrotain* inhibit the conversion of urea to ammonia, and they can be effective up to 14 days. This allows time for rain to incorporate the N fertilizer, minimizing ammonia volatilization losses. Nitrification inhibitors such as *N-Serve* and *Guardian*, inhibit conversion of ammonium to nitrate, so they only work with fertilizers such as urea, anhydrous ammonia or ammonium sulfate. Conversion is influenced by soil pH and temperature, and may take 4 to 10 weeks. These work best in sandy soils (leaching potential) or poorly drained soils (denitrification losses). Economic benefits of controlled-release fertilizers are weather and management specific, requiring a higher level of management to receive the benefits.

Pasture N Fertilization

Grass pastures for dairy cattle require N fertilization to maximize yield and quality. Dairy cattle excrete about 80% of the N they consume, but distribute it very unevenly across pastures. The urine patch area of a pasture over a season is estimated to be as low as 20% of the total area. New Zealand and Australian researchers have adapted optical sensors to detect N rich pasture zones (Hills et al., 2015). Liquid urea-ammonium nitrate fertilizer was applied to commercial dairy farms in Tasmania, using Smart-N optical sensor technology to avoid N application to N rich zones. Results indicate that Smart-N technology has the potential to reduce N fertilizer application rate by 30%, while maintaining the same pasture yields.

Pasture Yield Assessment for Optimum Fertilization

Current biomass yield of pastures can now be rapidly determined, providing information for animal rotation and fertilization needs. New Zealand researchers have developed the C-Dax pasture meter, a sensor array mounted on a skid that is pulled over the pasture (McLaren and Pembleton, 2015). Both pasture height and density are evaluated many times per second. Variation in pasture biomass can be mapped immediately prior to grazing, using the C-Dax meter along with a GPS console. The study showed that diverse pasture mixtures have less variability in biomass compared to monoculture pastures.

## Potassium

Forages remove large amounts of nutrients, requiring regular soil testing for P and K, and possibly some micronutrients. While many forage plants have a high requirement for K, animals have significant problems with excess K. Most soils have an abundant supply of K, but only a small portion of the total K is available for plant uptake at any given time (Cherney et al., 1998). Potassium in commercial fertilizer and in organic sources such as manure is highly soluble, resulting in rapid plant uptake. Approximately 95% of the K fertilizer used in North America is potassium chloride. Grass forages exhibit luxury consumption of K, dependent on soil available K, and plant concentration of K varies through the canopy (Cherney et al., 2004). Grasses also outcompete alfalfa for K, due to their fibrous root system, increasing the chances of K deficiency in alfalfa when grown in mixtures.

## Sulfur

Sulfur is an essential nutrient for crop production. Previous studies in the Northeast USA determined that crop S requirements were sufficiently met from the S in soil organic matter and atmospheric S deposition. However, atmospheric deposition of S from power plants has declined greatly, and many fertilizers and pesticides are now S-free. This has resulted in a potential deficiency of S in the Northeast, particularly for alfalfa. On the other hand, application of sewage sludge to agricultural lands can result in excess S and other trace elements (McBride and Cherney, 2004). On average in New York State, alfalfa annually removes approximately 300, 25, 200, 100, 25, and 20 kg $ha^{-1}$ of N, P, K, Ca Mg, and S. Both tissue and soil testing for S were effective for predicting an alfalfa yield increase from S fertilization (Ketterings et al., 2011). New York data support a critical S level of 0.25% S for alfalfa samples taken at the 3$^{rd}$ cutting. Soil test data suggest a critical level of 8 ppm S (0-20 cm depth), with samples taken at 1$^{st}$ cutting. Non-manured alfalfa fields should be monitored for S over time, as soil S can be quickly depleted under alfalfa.

## Forage Fertility – Animal Standpoint

You are what you eat. This is as true for a cow as it is for us. We have illustrated how important it is to properly fertilize plants from an agronomic standpoint. Now we will discuss effects of fertilization on the animal. Cows get their nutrients from four sources: homegrown forages, imported feeds, bedding, and their water. Bedding and water contribute minimally to nutrient requirements. As more producers try to minimize environmental impact and be sustainable, fertilization of homegrown feeds is increasingly important.

## Nitrogen

A key management tool for dairy cow production systems has been the use of N fertilizer. The response of grasses to N fertilizer is dramatic, assuming other nutrients and water supply are relatively non-limiting. Average efficiency of feed N utilization for milk production by lactating dairy cows (N in milk/N in feed × 100) was 28.4% (SD = 3.9) for 454 farmers in the Chesapeke Bay Drainage Basin (Jonker et al., 2002). Balancing rations for proper protein in the diet can have a dramatic impact as well. Cows do not need to be eating forage with above 200 g N $kg^{-1}$ DM (20%). Any more than that is stored in forage plants as soluble protein. Unless your protein and energy are well matched, you will lose that extra N as ammonia, increasing environmental problems and decreasing average efficiency.

## Phosphorus

Phosphorus is essential for both plants and animals for energy storage and transformation, but there are many other functions in the cow including maintaining bone strength (80% of P is found in bones), maintaining rumen pH, maintaining rumen microbes and as a part of cell walls (Ferris and Harrison, 2014). Lactating dairy cows require a large amount of P in their diets as they secrete large amounts of P in milk. The growing fetus in the last third of pregnancy will require P as well. Phosphorus is especially important in fertility and reproduction in dairy cattle. As such, P has often been fed in excess of requirements. Excess P above requirements can result in severe environmental issues. However, feeding less P to dairy cows will be unacceptable if cow performance, health, fertility and welfare are compromised (Ferris and Harrison, 2014). We suggest that P be added to forage for maximum agronomic effect (including environment) and then managing P in animal diets according to best available knowledge on requirements using exported feeds and feed additives.

## Potassium

Potassium deficiency is usually not a problem on dairy farms. You add potash to legumes according to soil test. For grasses, the issue is finding grasses low enough in K to use with up close cows (cows transitioning from 2-3 weeks pre-parturition to shortly after parturition). Many farms have used their non-legume land to place manure on. Doing this often results in soil tests with high soil K, values especially near the barn. To compound the problem, plants are luxury consumers of K, meaning that they take up much more than they need due to luxury consumption (Cherney and Cherney, 2005).

Both K and N fertilization can greatly impact concentrations of Ca and Mg in grass herbage, impacting the dietary cation-anion difference (DCAD). The DCAD, calculated as DCAD = meq (Na + K) - (Cl + S), impacts blood acid-base status directly and predictably. Besides feeding low K forage, feeding a negative DCAD is one of the best tools we have for preventing hypocalcemia or milk fever (Tremblay et al., 2008). Milk cows in the United States have a milk fever incidence of about 5% of animals. Cow produces much less milk during the subsequent lactation and their productive life is reduced about 3.4 years compared to cows not getting milk fever (Block, 2011).

## Sulfur

Sulfur amino acids are an essential but small component of some proteins. Ratio of S:N in animal products varies from 0.055 to 0.068, so requirements of N and S are closely correlated. In addition, S has long been recognized as essential to ruminal microbes. Ruminant microbes provide ruminants with the amino acids cysteine, cystine, and methionine, and the vitamins thiamin and biotin (Kazemi-Bonchenari et al., 2014). Sulfur or the amino acids or vitamins must be provided in the diet. As noted above, improving environmental conditions may actually raise a need for more close monitoring of sulfur and other trace minerals in forages (Ketterings et al., 2011). This is particularly important for animals receiving most of their nutrition from grazing.

Ruminant diets should contain 1.0 to 3.0 g S $kg^{-1}$ DM (Buxton et al., 1996). Critical level of S required in diets of ruminants to avoid depressing effects on forage intake and digestibility is 1.8 g S $kg^{-1}$ DM (Minsen, 1990). Concentrations above 3.5 g S $kg^{-1}$ DM in diet have been associated with decreased intake and consequently milk production (Tisdale, 1977). Like K above, S plays an important role in the in the DCAD of up-close dairy cows and has been used extensively to control DCAD (Goff and Horst, 1998).

**Summary**

Common Fertility Mistakes:

1. Incorrect soil sampling depth. Plow depth for cultivated fields; depth of 3-4 inches for permanent pastures; and two depths from no-till fields: samples at 1-2 and 1-6 inches.
2. Not applying lime at least six months in advance of an alfalfa seeding.
3. Applying unprotected urea at the wrong time.
4. Not calculating N credits from perennial forages for following crops.
5. Overfeeding N to dairy cattle.
6. Not controlling DCAD in late lactation.

With protected N fertilizer sources, and the potential to use optical sensor technology for N applications on forage crops, best management practices will be able to minimize impacts to the environment. The future of forage crop research, however, is in jeopardy due to the rapidly dwindling number of forage researchers, primarily due to the fact that forages lack commodity status and political support (Cherney, 2015).

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