Manure Use for Alfalfa–Grass Production

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Executive Summary[1]

- Nutrient management plans require manure application to corn and forage grasses to be limited to crop N needs possibly resulting in manure having to be applied to other cropland such as alfalfa fields.

- The deeper rooting system of established alfalfa as compared to grasses and/or corn, its relatively high P and K demands, and its ability to reduce N fixation upon availability of a readily available N form, make alfalfa a more appropriate alternative (assuming odor is controlled) for manure application than corn or grass fields for which N needs have already been met.

- Established stands with non-fixing alfalfa varieties or mixed alfalfa-grass stands with more than 50% grass are better alternatives for manure application than newly established monocultures of N-fixing alfalfa cultivars or fields that still need to be seeded to alfalfa or alfalfa-grass mixes.

- It is recommended to test soils for P and K (and other nutrients) at least once in three years to determine P and K needs. Phosphorus needs in the seeding year (for soils with a Cornell Morgan P test <80 lb/acre P) can be met with spring-applied manure but rates should be limited to 3,000-4,000 gallon/acre and manure should be incorporated to reduce N loss in the seeding year as very little N uptake occurs in the first 4-6 weeks after germination. If soil test P levels are ≥80 lb/acre, manure applications in either fall or spring prior to seeding of a new alfalfa-grass stand should be avoided to reduce N loss and enable P drawdown.

- When soil nitrate levels are above 15 ppm, soil pH is 6.8 or higher, soil temperature is 60^{o}F or higher within 3-4 weeks after germination, soil P and S fertility is optimal, and healthy populations of N-fixing bacteria are present, applying pre-plant N (either with manure or fertilizer) to a new alfalfa or alfalfa-grass seeding will not increase yield and may negatively impact N-fixation. Thus, N application to a new alfalfa or alfalfa-grass seeding is typically discouraged.

[1] In this bulletin, average crop and manure analyses were used to derive estimates of crop removal and manure N, P, and K application rates. More accurate estimates will be obtained from farm-specific manure and forage quality analyses.

- Seedings with companion crops harvested for silage or grain (e.g. oats, spring barley, triticale) will require N for optimal establishment and growth of the companion crop. Fertilizer N applications should be limited to 60-80 lb fertilizer N/acre for agronomic returns. Manure can be applied to meet the N needs of the companion crop. However, spring manure application rates in excess of 6,000-8,000 gallon/acre can lead to lodging of the companion crop and increase N loss to the environment.

- For established stands (topdressing), smothering and/or salt injury to the stand increases with manure application rates in excess of 4,000 gallon/cut, especially when applications are delayed beyond 3-4 days after cutting.

- Alfalfa-grass harvest typically removes about 13 lb of P_2O_5 and 56 lb of K_2O per ton dry matter (DM) and, assuming an average crude protein (CP) content of 15% of DM (grass dominated grass-alfalfa mixture), a 2 ton DM alfalfa-grass crop contains about 80 lb of N whereas a 20% CP crop (pure alfalfa) contains 110 lb N.

- Recognizing that crop nutrient removal is a management concept rather than a goal or requirement, given a typical P and K content of manure, it would on average require less than 2,000 gallon of liquid manure to apply the equivalent of P removal and slightly more than 4,000 gallon to equate to K removal of a 2 ton DM/acre yield. For N, established stands could receive 6,000-8,000 gallon/acre for each 2 ton of forage removal assuming N fixation is reduced to 20% of the total N uptake and taking into account soil N uptake as for corn (see Appendix A in Ketterings et al., 2003).

- In cases where maintaining (not increasing) P levels is part of the management strategy, manure application rates should be limited to 4,000 gallon/acre for the year (across all years of the stand). Manure application in the seeding and early production years is not recommended a practical approach to maintaining P levels could be to apply manure at 4,000 gallon/acre after cuttings (where field conditions allow) in the final years in the stand, rebuilding P (and K) levels after drawdown in years 1-3. Manured fields should be checked for forage K content when the forage is being considered for feeding to non-lactating cows.

- If manure is being applied in the last production year to address P and K levels that have been reduced over the life of the alfalfa-grass stand, it is recommended to apply the manure while the crop is still actively growing to enhance N uptake (during summer or early fall) and to kill the alfalfa-grass in the following spring (rather than the previous fall) to prevent large N fluxes prior to establishment of the following corn crop.

- Wheel traffic damage can be minimized by planting traffic tolerant varieties, using small tractors if possible, avoiding unnecessary trips across the field, using larger harvesting equipment, and driving on fields as soon after cutting as possible.

- Application of manure from animals infected with pathogens, particularly Johne's disease is a potential method of spreading these infections. In the case of Johne's disease, exposure of young animals (<1 year old) to contaminated pastures or to feed coming from these fields should be prevented.

- Plant breeding and/or genetic engineering for selection/development of germplasms should focus on ways to effectively reduce N fixation in high N situations without compromising yield and/or quality.

- The management guidelines in this bulletin are based on our current knowledge of N use and N dynamics in alfalfa-grass systems, derived from the studies referred to in section 2 of this bulletin. Additional (local) research is ongoing and these guidelines will be updated once additional research findings with relevance to New York State become available.

Disclaimer

This extension bulletin reflects the current (and past) authors' best effort to interpret a complex body of scientific research, and to translate this into practical management options. Following the guidance provided in this fact sheet does not assure compliance with any applicable law, rule, regulation or standard, or the achievement of particular discharge levels from agricultural land.

1. Introduction

From a nutrient use efficiency standpoint, corn (*Zea mays* L.) and forage grass fields tend to be the preferred fields for manure application on dairy farms. Alfalfa (*Medicago sativa* L.) typically meets its nitrogen (N) requirement through biological N fixation so N from other sources is unnecessary if conditions for N fixation are satisfactory. However, nutrient management plans require that manure application to corn and forage grasses be limited to crop N needs, increasing the likelihood that manure will need to be applied to alfalfa fields. In addition, alfalfa fields may at some times be the only fields accessible for manure application.

In this bulletin we summarize scientific literature on the impacts of manure application to alfalfa and mixed alfalfa-grass stands in the establishment year and beyond (Section 2), describe current Cornell University fertility guidelines for alfalfa and alfalfa-grass mixtures (Section 3), and give guidelines for manure management of such stands in situations where manure application to alfalfa is necessary (Section 4).

2. Summary of Scientific Literature

2.1 New Alfalfa and Alfalfa-Grass Seedings

A 1977 search through state fertility guides by Hojjati et al. (1978) showed that although land grant university N guidelines were consistent for established alfalfa stands (no N recommended), recommendations for N to establish legume stands varied widely. The authors sent surveys to all 50 states' land grant university agronomy departments and found a wide range of N recommendations (from 0 to 300 lb N/acre), with nearly half of the 45 responding states calling for no N fertilization to establish pure alfalfa, and minimal fertilization (less than 30 lb N/acre) to establish mixed alfalfa-grass stands. Several states had indefinite or non-existent recommendations, and the remaining states covered the range of responses. This disparity in the recommendations most likely reflected (1) differences in climate, soils, and soil fertility, and (2) limited scientific data on the impact of N addition on yield, quality, stand and environmental loss.

In the past two decades, additional studies on N use for alfalfa were conducted. Most recently, the focus has been on assessment of benefits and disadvantages of manure use to (1) meet fertility needs of alfalfa and mixed alfalfa-grass stands at establishment and beyond; and (2) as an alternative use for manure not needed by corn and/or grass fields. At first glance, the literature seems inconclusive yet the apparent contradictions among studies become more understandable when the effects of N addition are investigated separate from the benefits of other nutrients in the manure. In Section 2.1.1 we evaluate studies that address the question “Will a new alfalfa or mixed alfalfa-grass seeding benefit from nitrogen?”. In Section 2.1.2, the focus is on the question: “Will the new seeding benefit from manure addition?”.

2.1.1 Nitrogen Needs

Focusing on pure alfalfa seedings, Giddens (1959) pointed out that “adequate nitrogen should be present in the soil to allow young plants to become established until nitrogen fixation begins”. More recently, Shuler and Hannaway (1993) described this pre-fixation period as a “transient period of N-starvation in seedling growth”. The existence of such an N-limited period prior to the onset of N fixation could explain the advantage of initial application of N for seedling development found in studies where yields in the establishment year (pure alfalfa stands) were boosted by pre-plant N fertilizer (Giddens, 1959; Gerwig and Ahlgren, 1958; Kunelius, 1974; Peters and Kelling, 1989; Fishbeck and Phillips, 1981; Trimble et al., 1987). However, as the N needs of young alfalfa seedlings are relatively small, N levels low enough to impact early seedling growth are only expected in soils that are very low in organic matter (less than 1.5%) and/or in situations where N mineralization and nitrification are severely compromised (e.g. due to low temperatures, drought, or N immobilization).

A response to N addition could also occur if N fixation is compromised beyond the initial pre-fixation period in alfalfa seedling growth. One factor that could play a role in determining likeliness of a response to N addition is the abundance of N fixing bacteria, either as native population or through inoculated seeds. Two field experiments conducted over 3 years on pure alfalfa stands in Oregon showed that where inoculation of plants was unsuccessful and native populations of *Rhizobium meliloti* were unable to fix sufficient N to satisfy plant needs (typically under acidic soil conditions), N fertilizer at establishment was effective in stimulating seedling growth (Eardly et al., 1985). Where inoculation was successful, N application decreased nodulation without impacting dry matter (DM) yields. Ineffectively nodulated seedling alfalfa plants (non-fixing alfalfa cultivars) in the same study showed substantial increases in yield after application of N fertilizer (Eardly et al., 1985). A shortage of N fixing bacteria could also explain the response to 60 or 90 lb N/acre addition at planting in a study by Giddens (1959) and the positive effect of the addition of

25 lb N/acre in the seeding year in a New Jersey study by Gerwig and Ahlgren (1958). The data from these studies suggest that N fertilization is not needed for alfalfa establishment if inoculated seed is used and conditions for N fixation are satisfactory.

As mentioned above, low temperatures can limit N mineralization and nitrification. Soil temperature during root development can also directly impact legume infection, nodule formation, and N fixation (Lie, 1974). Shuler and Hannaway (1993) showed a yield response to N in their growth chamber study with river sand (low N) when temperatures were low (64^{o}F in day and 54^{o}F during the night). At higher day/night temperatures (75-81^{o}F and 61-70^{o}F) the shoot dry matter yield of the controls were equal to the yields at the highest N rate (71 lb N/acre) suggesting that at the lower temperatures N fixation was insufficient to meet N demands. They concluded that the optimum temperature for N fixation was 68-77^{o}F. Duke and Doehlert (1981) showed that nodulation was delayed at temperatures below 59^{o}F also suggesting that soil temperatures of 60^{o}F or higher are needed for optimum N fixation.

The N-fixation process may be further compromised by: (1) mechanical plant damage (Barta, 1978; Vance et al., 1979; Joern and Volenec, 1996); (2) pH lower than 6.7 (Lie, 1974; Undersander et al., 2004); (3) compaction and poor drainage (Schmitt, 1993; Lamb et al., 2005; Undersander, 2006; Schmitt et al., 1994); (4) low phosphorus (P), sulfur (S), and molybdenum (Mo), all nutrients essential for N fixation (e.g. Undersander et al., 2004); and/or (5) high N availability (e.g. Peterson and Russelle, 1991; Heichel et al., 1984; Russelle and Buzicky, 1988; Schertz and Miller, 1972; Schmitt et al., 1994; Trimble et al., 1987; Shuler and Hannaway, 1993; Cherney and Duxbury, 1994). These same conditions apply for N fixation in established stands and will be discussed in more detail in section 2.2.

While evaluating studies that show a yield response to fertilizer N, it is important to keep in mind not only the likeliness of a response to N addition but also the extent of the response in relation to fertilizer costs and application expenses. Yields in the study by Giddins (1959) were low (highest yield was 1.25 ton DM/acre). A closer assessment of the yield data showed that the increase in DM yield with 60 and 90 lb N/acre was less than 10 lb DM per lb of N. A similar minimal response was found by Kunelius (1974). With current N fertilizer prices, yield increases need to be substantially above 10 lb DM per lb of purchased N to be of economic interest. Obviously, since manure is not purchased, the economics are very different from those of fertilizer applications.

The 1977 search through state fertility guides by Hojjati et al. (1978) showed that many of the responding states called for a small N application rate (about 30 lb N/acre) to establish mixed alfalfa-grass stands, reflecting that grass in the stand will require some N for optimum establishment. Larger amounts can make grasses more competitive over alfalfa over time and although a shift toward more grass in the mixed alfalfa-grass stand might not impact yield or quality of the stand (Cherney et al., 2006; Min et al., 1999) producers should realize that N addition will lead to greater N needs for the stand over time (e.g. Berdahl et al., 2001; Griffeth, 1966; Kunelius, 1974).

Addition of N can increase weed pressure (Kunelius, 1974; Eardly et al., 1984; Kelling and Schmitt, 2003). While weeds are not often a problem after first cutting (Schmitt et al., 1991), growers should be prepared to address the potential initial weed pressure with appropriate weed management tools (Kelling and Schmitt, 2003; Schmitt et al., 1991).

We summarize the literature on N use for alfalfa establishment by stating that response to N is unlikely unless mineralizable N at planting is very low and/or nodulation is compromised due to any of the following factors: (1) pH less than 6.7; (2) overall low initial fertility status; (3) soil temperatures below $60^{o}C$; or (4) no prior history of legumes combined with lack of inoculation or poor inoculant viability. Disadvantages of N use beyond a small amount applied to mixed alfalfa-grass seedings include greater weed pressure and more competitive grasses in mixed alfalfa-grass stands over time.

2.1.2 Benefits and Disadvantage of Manure Application

Even in situations where a response to fertilizer N is not likely, application of manure in advance of a new alfalfa seeding could result in a yield response in the seeding year if nutrients other than N are limiting growth. For example, Schmitt et al. (1994) concluded that the observed yield response upon manure addition in the establishment year, and lack of a response in the 2nd year, were at least partly due to P and K addition with manure. Their results suggested that the manure contained enough P and K to overcome the P and K deficiency for at least two years. Similarly, Russelle and Buzicky (1988) found in a study in Minnesota that when plots were established with adequate amounts of K, S, and boron (B) following University of Minnesota fertility guidelines, manure application did not affect the establishment year yield of pure alfalfa stands.

If manure is applied to meet crop N needs for the corn in the alfalfa-grass and corn rotation, P and K deficiencies are not likely, especially if manure is surface applied and not incorporated (Lory et al., 2000). However, given average manure N, P, and K contents and manure rates and timing of application adjusted to make maximum use of the urea-N in the manure (i.e. spring incorporation), P and K will likely be applied at rates that exceed average annual corn P and K removal, resulting in P and K buildup over time. If soil tests classify fields as very high in P, a crop response to additional P is very unlikely (Ketterings et al., 2003b) and manure application beyond crop removal will increase soil test P levels and P runoff risk (Czymmek et al., 2003). Buildup of K levels is not an environmental concern, but may result in forage quality concerns. The 2005 Dairy One Forage Laboratory database (www.dairyone.com/Forage/FeedComp/default.asp) showed an average hay crop forage P concentration of 0.29% and K concentration of 2.17% suggesting that an alfalfa-grass stand removes 13 lb of P_2O_5 and 56 lb of K_2O per ton DM. Given an average P and K content of manure, it would require less than 2000 gallon of manure to apply the equivalent of P removal and slightly more than 4000 gallon to equate K removal of a 2 ton DM alfalfa-grass crop in its establishment year. Given average N, P and K content of manure and alfalfa-grass N, P, and K removal rates, a P-removal based manure application would result in mining of soil K whereas a K-removal based application would result in an increase in soil test P over time. As alfalfa-grass typically follows corn in the crop rotation, and P and K levels typically increase under the corn years of the rotation (with N-based manure application rates), soil testing prior to alfalfa-grass seeding is recommended to determine acceptable manure application rates.

An alfalfa-grass stand with an average yield of 2 ton DM per acre in the establishment year and average annual yields of 4.5 ton of DM in the three years following, is estimated to remove about 200 lb of P_2O_5 over the four years of the seeding, the equivalent, on average, of a 15,000 gallon/acre manure application. Application of this amount prior to establishment of new seedings will lead to considerable N losses in the establishment year as N needs for a new seeding are small, the peak in N release from manure does not coincide with the period of greatest N uptake by the new seeding (either spring or summer seedings), and, in a new seeding, roots are not yet capable of reducing nitrate leaching over our humid fall, winter and early spring. Nitrogen loss concerns exist for application of manure to corn too but (1) N uptake is larger for the corn crop than for the establishment year alfalfa-grass stand, and (2) the most rapid uptake of N by corn is usually 4-6 weeks after manure application, earlier than the peak time for N uptake by a new alfalfa seeding. Schmitt et al. (1994) measured soil nitrate with varying levels of pre-plant manure application (3,000, 6,000, and 12,000 gallon/acre) to pure alfalfa stands in Minnesota. For one of the three sites, total N applications were estimated at 231, 462, and 924 lb N (50% being inorganic N). Manure was broadcast and incorporated within 4 hours. Their results showed soil nitrate-N peaked at 96, 248, and 352 lb nitrate-N/acre, respectively, 41 days after application. At a second site, soil nitrate-N measured 44 days after application reached 104, 144, and 248 lb nitrate-N/acre with the addition of 159, 318, and 636 lb total N/acre with the manure. This manure source was 74% inorganic N and manure was incorporated within 4 hours. At the third location, peaks were 32, 72, and 144 lb N/acre with the application of 108, 216, and 432 lb N/acre (29% inorganic N) in the form of manure. Here too, manure was incorporated within 4 hours. The authors could not account for all applied N in the crop or in the soil, leading them to conclude that significant amounts of N were lost following application (Schmitt et al., 1994).

If the goal is to pre-apply K needs for the entire rotation, an alfalfa-grass stand with an average yield of 2 ton DM per acre in the establishment year and average annual yields of 4.5 ton of DM in the three years following is estimated to remove about 875 lb of K_2O, which would equate to a manure application rate of more than 34,000 gallon for the four alfalfa years in the rotation. This should not be applied as one pre-plant application either as it results in a P application that is twice the amount likely to be removed by alfalfa-grass harvest during the four years in the rotation and would lead to exceptionally large N losses in the alfalfa-grass establishment year, as stated earlier. It might be better to build K levels during the corn years or, where needed, apply manure to older alfalfa-grass stands.

If manure application prior to seeding targets P removal/buildup for the rotation, seeding alfalfa with a companion crop (e.g. oats, spring barley, or triticale) can minimize N losses from pre-plant applied manure as the N demand of the spring grains coincides better with the N release from manure than N uptake by alfalfa. Seeding with a companion crop may also slow growth of broadleaf weeds, and, if the companion crop is harvested for silage, increase DM yields in the establishment year (Hoy et al., 2002). To reduce the risk of lodging of the companion crop and alfalfa establishment failure, manure applications should still be modest and spring grains should be harvested at the boot stage (e.g. Lory et al., 2000).

One additional concern with manure use in the establishment year is weed control; in addition to supplying N that could stimulate weed growth during the establishment phase (Kunelius, 1974; Eardly et al., 1984; Kelling and Schmitt, 2003), manure can also be a potential source of weed seeds (Takabayashi et al., 1979; Daliparthy et al., 1995). Work by Schmitt (1991) on the effects of manure on weedy first cut stands suggested that manure application may show a negative effect only in the establishment year. This was illustrated by heavy weed pressure where weed control failed in the alfalfa establishment year following five years of manure application to corn in the rotation in central New York (Figure 1). In pure stands of Roundup-Ready alfalfa, increased weed density due to manure application can easily be addressed.

We conclude that manure use for establishment of a new seeding could boost yields *if* additional P, K, S and/or B are needed, or if the N-fixation process is compromised. However, if manure is applied in the spring to meet rotation P or K needs before a new seeding, the addition of a companion crop at stand establishment is recommended to minimize N loss to the environment while the perennial crop is getting established. If manure was applied in each of the corn years preceding the new seeding, P and K application with manure should not exceed P and K uptake of the alfalfa-grass years in the rotation.

Figure 1: Manure application can lead to severe weed pressure in the establishment year. In this situation, weed control in the alfalfa-grass establishment year following five years of annual manure addition to corn failed due to an excessively wet spring season.

2.2 Established Grass/Legume Stands

2.2.1 Nitrogen Fixation

The 2005 forage analysis database of the Dairy One Forage Laboratory (www.dairyone.com/Forage/FeedComp/default.asp) showed an average of 2.7% N (DM basis) for nearly 9,000 alfalfa-grass samples. As mentioned previously, for established stands in the Northeastern USA, an average yield of 4.5 ton/acre is not uncommon. Such a yield would represent an N removal just shy of 250 lb N/acre while a high yielding stand with a 6 ton/acre crop would remove a little more than 300 lb of N/acre.

The scientific literature shows greatly varying study-to-study estimates (and wide ranges within the same study) for the contribution of N fixation to the total amount of N in the crop. Heichel et al. (1981) reported that, without additional N applied during the seeding year, the two alfalfa populations in their study averaged about 43% of the N needs from N fixation. Additional work (Heichel et al., 1984) showed that N derived from N fixation was 58% of the total crop N in the seeding year (average of the two cultivars) and 77% in the 4th and last year of the study. Cherney et al. (1998a) reported that 55 to 85% of the total crop N (above ground) over the two years of their study was derived from N fixation (no additional N supplied).

It is well-established that N addition suppresses N fixation (i.e. Heichel et al., 1984; Peterson and Russelle, 1991; Russelle and Buzicky, 1988; Schertz and Miller, 1972; Schmitt et al., 1994; Trimble et al., 1987). If manure addition results in a decline in N fixation similar to the amount of N added with the manure, alfalfa fields could be an excellent option for manure addition. However, estimates of the percentage reduction in N fixation upon N addition (either manure or fertilizer) are as variable as the estimates of N fixation for non-fertilized stands. Shuler and Hannaway (1993) cite studies that suggest that the presence of readily available soil nitrate completely inhibits biological N fixation. Work by Cherney and Duxbury (1994), Cherney et al. (1998a), and Lamb et al. (1995) suggested that although biological N fixation decreased with increasing levels of N fertilization, fixation continued even at the highest N application rates. Cherney et al. (1998a) reported N from N fixation reduced from 55-85% to 13-27% at high N fertilization rates. Lamb et al. (1995) reported that even when 750 lb N/acre (split over 4 applications following harvest) was applied, biological N fixation still supplied 20-25% of the total N uptake. If alfalfa continues to fix 15-25% of its N in the presence of high soil nitrate levels, manure application rates should not exceed the equivalent of 75-85% of N removed in harvest to minimize annual manure N leaching losses.

Studies by Lamb et al. (1995), comparing different alfalfa cultivars, showed no difference in DM yield and N content of N fixing alfalfa and non-fixing alfalfa (ineffectively nodulated alfalfa) varieties. These results suggest that non-fixing alfalfa varieties removed roughly the same amount of N as N fixing varieties, but that the non-fixing varieties collect it from the soil rather than fixing it from the air. Work by Blumenthal et al. (1999) supported this, showing that non-fixing cultivars absorbed 30 to 40% more N from the subsoil than normal N fixing cultivars. Cherney and Duxbury (1994) concluded that increased availability of N consistently decreased N fixation but that significant differences among alfalfa germplasms existed when intermediate levels of N were added (versus no differences with either low or high N additions). Also plant-to-plant variability within each alfalfa germplasm was considerable. These studies suggest (1) non-fixing alfalfa varieties or mixed alfalfa-grass stands are better alternatives for manure application than monocultures of N fixing alfalfa cultivars; and (2) opportunities for plant breeding and/or genetic engineering for selection/development of germplasms that are most effective in reducing N fixation in high N situations without compromising on DM yield or forage quality.

2.2.2 Yield

If fertility levels are optimum and N fixation is not compromised, a pure alfalfa stand is not likely to respond to manure application. Manure topdressing of a pure alfalfa stand can lead to a yield response if a response to P, K, and/or secondary macro- and/or micronutrients is expected. Mixed alfalfa-grass stands are likely to respond to N in the manure although actual N needs and crop response might differ depending on sod composition. Bock (1969) found that application of 50 lb of N to alfalfa-timothy (*Phleum pratense* L.) and alfalfa-bromegrass (*Bromus carinatus* Hook. & Arn.) stands on five different soil types in Pennsylvania produced 36% higher yields in 1966 and 25% higher in 1967 than in the control treatment across soil types. More recently, Jacobsen and Surber (1995) studied mixed alfalfa-bromegrass in Montana and reported a response to N with a fall application of 44 lb N/acre broadcast urea. Research conducted in New York from 1994-1998 showed higher alfalfa-orchardgrass (*Dactylis glomerata* L.) yields with N applications of 60 lb/acre or greater (Cherney et al., 1998a). Griffeth (1966) concluded that if more than 60% in the mixed stands is grass, a response to N is likely.

2.2.3 Nitrogen Losses (Nitrogen Use Efficiency)

A disadvantage of topdressing established stands (grasses or alfalfa) with manure is the potential for large N volatilization losses. Staff at the Minnesota Soil and Water Conservation District used an Aerway aerator/tillage tool to incorporate manure on established alfalfa in an attempt to reduce runoff losses (Fuchs, 2002). Their data suggest that this type of tool is effective in reducing nutrient runoff flow as compared to surface-applied manure, and such partial incorporation will likely reduce volatilization losses as well, but additional work is needed to quantify the impacts.

Alfalfa has a much deeper rooting zone that facilitates utilization of nitrates that have already moved lower in the soil profile (Schmitt et al., 1991; Mathers et al., 1975). Yet, nitrate leaching can be an issue at high manure application rates to alfalfa as well. Daliparthy et al. (1994) studied the impact of various manure application rates on stands of pure alfalfa at two sites in Massachusetts. They showed that 2 years of manure application at relatively low N application rates (5,000 gallon/acre, 0.33% total N and 0.15% ammonium-N) had no adverse effects on quality, yield and soil nitrate levels, but that significant leaching occurred if manure was applied at 15,000 gallon/acre (same manure composition) after the first cutting (Daliparthy et al., 1994).

The practice of applying manure shortly before plow-down and rotation to corn is a common and convenient method of manure application, since alfalfa injury is not a concern, and there is a wider window of time during which manure can be spread. However, except at very low rates, this practice should be discouraged because it will likely overload the field with N, both from the manure and from the alfalfa, leading to increased risk of N leaching (Peterson and Russelle, 1991). Alfalfa plow-down alone (without addition of fertilizer) has been shown to supply sufficient N for the following corn crop in 70 of 77 trials conducted by Morris et al. (1993) in Iowa, Bundy and Andraski (1993) in Wisconsin, Schmitt and Randall (1994) in Minnesota, Fox et al. (1988) in Pennsylvania, and most recently by Lawrence et al. (2008) in New York. The optimum N rate for 6 responsive sites (of a total of 29 sites) in the study in Iowa was 25 lb N/acre (Morris et al., 1993). The optimum N rate for the only responsive site in Minnesota was 42 lb N/acre (Schmitt and Randall, 1994). If manure is applied to address P and K levels that have been reduced over the life of the alfalfa-grass stand, it is recommended to apply the manure while the crop is still actively growing to enhance N uptake (during summer or early fall), and to kill the alfalfa-grass in the following spring (rather than the previous fall) to prevent large N fluxes prior to establishment of the corn crop.

2.2.4 Phosphorus Buildup

Assuming an average P_2O_5 equivalent content in manure (500 samples from 2003) of 0.17% (~14 lb P_2O_5 per 1,000 gallon) the annual manure application rate to fields with the highest DM production (6 ton/acre) should not be higher than about 6,000 gallon/year if P replacement (0.29% on a DM basis) is the target. Given average yields for established stands (4.5 ton/acre), application rates greater than 4,000 gallon/acre per year will lead to P buildup over time. As mentioned earlier, if the goal is to apply P for the entire rotation, an alfalfa-grass stand with and average yield of 2 ton DM per acre in the establishment year and average annual yields of 4.5 ton of DM per acre in the three years following is estimated to remove about 200 lb of P_2O_5 per acre which would equate to a manure application of about 15,000 gallon/acre for the four alfalfa years in the rotation. Soil test P levels will increase if higher rates are applied and although this might not impact crop yields, excessively high P levels will increase P runoff potential (see e.g. literature citations and discussion in Czymmek et al., 2003).

2.2.5 Stand Composition/Persistence

Several studies show that fertilization of a mixed alfalfa-grass stand tends to favor the grass component over the N-fixing legume resulting in increasing N needs with age of the stand. One example is a 5-year study of grass versus grass-alfalfa in the semiarid Great Plains conducted by Berdahl et al. (2001). Six varieties of grass were sown in monoculture or in mixtures with 'Rangelander' alfalfa, in control plots receiving no fertilization and in treatments receiving 45 lb N/acre. Supplemental N did not increase the total yield of the mixture, but did favor the grasses; with no N addition, the ratio of grass to alfalfa DM yield was 1:19 and with 45 lb N/acre the ratio was 1:10. Similar shifts towards grass were obtained in an experiment conducted at Cornell University (Griffeth, 1966) and in studies by Nuttall et al. (1991), Wolf and Smith (1964) and Chan and MacKenzie (1971). Longer-term impacts of N fertilization on the percentage grass in the stand vary depending on actual amount of N applied. In the study by Berdahl et al. (2001) grass species dominated the mixtures during the first 3 years after seeding but then shifted to alfalfa by the 5th year after seeding possibly due an inadequate supply of soil N for the grass component in the stand, impacting the grasses more than the alfalfa. The study by Griffeth (1966) did not find the same shift in dominance after the first 3 years, instead observing that the legume population continued to shrink.

Grasses and legumes also differ in their tolerance to low K levels. Joern and Volenec (1996) pointed out that grass can effectively tolerate lower soil test K levels than alfalfa, suggesting that soil test K and relative amounts of K and N in applied manure are critical factors for stand competition. Work by Cherney and Cherney (2005) in New York shows less drastic results; only a very modest reduction in perennial grass yields occurred under very low soil K availability. As manure contains substantial amounts of K, manured fields are generally sufficiently high in K to not favor grasses over legumes from this perspective.

In situations with a recurring manure surplus (i.e. more manure than can be applied to corn and grass at optimum agronomic N rates), a manure-induced shift in stand composition might not impact yield as legume-grass stands can yield forages that can be as good or better than either pure alfalfa or pure grass for lactating dairy cows (Cherney et al., 2006; Min et al., 1999). However, if the goal is to apply manure and maintain a substantial legume component in the stand over time, the choice of a grass species that is not unduly competitive with alfalfa is crucial. Chan and MacKenzie (1971) concluded in their study in Quebec that grass with upright leaves would allow the grass to be more competitive. Sheaffer et al. (1990) stated that for producers who harvest forage frequently with the goal of retaining a high alfalfa component in mixtures, reed canarygrass (*Phalaris arundinacea* L.) sown with alfalfa may present a more desirable option than bromegrass or orchardgrass.

2.2.6 Weed Pressure

As mentioned earlier, it is well-established in the literature that manure application tends to increase weed pressure in the seeding year (Schmitt et al., 1991; Daliparthy et al., 1994 and 1995; Kunelius, 1974; Eardly et al., 1984; Kelling and Schmitt, 2003). However, this is generally a concern in the establishment year only (Schmitt, 1991).

2.2.7 Compaction

When manure is applied to established alfalfa or alfalfa-grass stands, a combination of high soil moisture levels and heavy application equipment can result in severe compaction resulting in up to 100% plant mortality in the compacted areas (Schmitt et al., 1993; Hamza and Anderson, 2005; Lamb et al., 2005). Wheel traffic damage can be minimized by: (1) planting traffic tolerant varieties, (2) using small tractors if possible, (3) avoiding unnecessary trips across the field, (4) using larger harvesting equipment, (5) avoiding tractors with dual wheels, and (6) driving on fields as soon after cutting as possible (Undersander, 2006).

2.2.8 Burn and/or Salt Damage

Direct burn, salt damage and physical smothering of the stand are other concerns when manure is applied. Research at the Northern Research and Demonstration Farm of Iowa State University showed that alfalfa recovered successfully from manure applications up to 4,500 gallon/acre, but suffered from reduced vegetative regrowth at 6,000 and 9,000 gallon/acre (Barnhart, 2000). A recent study by Lamb et al. (2005) showed no detrimental effect of hog manure application if applied within 4 days after cutting and if rates were limited to no more than 2,950 lb/acre organic solids (the equivalent of about 2,900 gallon/acre of manure with 12% solids). To minimize plant damage in established stands, Kelling and Schmitt (2003) recommended no more than 3,000-5,000 gallon/acre liquid manure (or 10 ton of solid manure) applied immediately after cutting. Similarly, Undersander et al. (2004) recommend limiting manure applications to 3,000 gallon/acre. Delaying manure application after cutting beyond 2-3 days will increase burn risk as new leaves are most sensitive to the ammonium and salts in the manure (Kelling and Schmitt, 2003; Lory et al., 2000).

2.2.9 Forage Quality

Manure application could increase forage protein levels in mixed stands, especially when a significant portion of the stand is grass (Min et al., 2002). On the other hand, high N applications could cause nitrate toxicity (Eardly et al., 1985; Crawford et al., 1961) although work by Lee and Smith (1972) suggested that nitrate toxicity is not likely a concern if N applications do not exceed crop N removal.

Another forage quality benefit/concern is manure-induced elevated K levels. Potassium is important for winter survival and maintenance of an alfalfa stand. However, high K forages can cause metabolic health problem including ketosis, metritis, retained placenta and displaced abomasums for non-lactating cows (Beede, 1996; Goff and Horst, 1997; Cherney et al., 1998b). It is recommended to only feed grass forage with less than 2.5% K (DM basis) to non-lactating cows based on research by Goff and Horst (1997). Grasses are luxury consumers of K and if sufficient N is available for growth, herbage K concentration will be directly related to soil available K; uptake will greatly exceed plant requirements if there is excess available soil K (Cherney et al., 1998b). Kelling and Schmitt (2003) reported that the 12,000 gallon application rate used in their studies in Minnesota and Wisconsin added about 360 and 270 lb K_2O/acre, respectively. By comparison, average manure K in 500 manure samples submitted to the Dairy One Forage Testing Laboratory in 2003 was 0.33% K, the equivalent of about 6.6 lb K_2O per ton of manure or 26 lb K_2O per 1000 gallon (Paul Sirois, personal communication). Assuming 2 ton DM in the establishment year and 4.5 ton of DM in years 2, 3 and 4, the average K removal of 875 lb K_2O/acre for a 4-year rotation would be met with a total manure application of about 34,000 gallon. Such an application, even when split over the years following establishment of the stand, will lead to elevated forage K levels if soils tested high or very high in K at the onset of the rotation (in addition to leading to P buildup and N losses). Thus, it is more desirable to built K levels during the corn portion of the rotation.

Schmitt et al. (1993) found that herbage K levels increased in direct proportion to the rate of manure or commercial fertilizer applied at all sites in Rosemount and Waseca, Minnesota. Similarly, Lory et al. (2002) illustrated that if manure is applied at a N removal rate, K will be over-applied. Thus, repeated application of high rates of manure to forages may increase forage K to levels that are undesirable for non-lactating cows.

Manure contamination of forage at the moment of harvest will likely result in poor silage fermentation and special precautions should be taken if alfalfa is ensiled rather than baled as hay (Rammer and Lingvall, 1997). Wiederholt et al. (2002) recommend the use of silage inoculants to ensure the presence of sufficient lactic acid bacteria in alfalfa forage (Wiederholt et al., 2002) but work by Kung et al. (2003) showed that with significant manure contamination, silage additives are not likely to improve the quality of the silage (Rammer and Lingvall, 1997).

Manure application following harvest does not necessarily result in manure contamination of the next harvest. Research conducted at the Miner Institute over a 2-year period evaluated the effect of applying 4,200 gallon/acre of dairy manure slurry after first cutting to alfalfa-grass stands (Thomas, 1997; Thomas et al., 1998). In these studies there were no differences between the control and manure treatments for forage analysis, vomitoxoin or microbiological levels (minisilo study).

2.2.10 Human and Animal Pathogens

Aside from forage nutritional quality, the decision to apply manure to alfalfa should be considered from the perspective of disease and sanitation as well. Pathogens that are of potential concern include *E.coli O:157:H7*, *Listeria monocytogenes*, *Salmonella spp.* and *Mycobacterium paratuberculosis*. Among these, *M. paratuberculosis* is the most likely to be persistent over longer periods of time. Also, concern about the spread of Johne's disease caused by *M. paratuberculosis* is growing due to its increasing prevalence, resulting economic losses, and controversy over possible spread to humans as Crohn's disease. In 2007, the U.S. Department of Agriculture's National Animal Health Monitoring System (USDA-NAHMS) conducted the Dairy 2007 study. This study estimated a 68% prevalence of Johne's infected herds with a clear impact of herd size; the prevalence for herds with 500 or more cows was 95% versus 75% for farms with 100 to 499 cows and 63% for farms with fewer than 100 cows (USDA-NAHMS, 2008). Calves are most susceptible, only requiring ingestion of a small amount of manure or milk to become infected. Infected animals may show no sign of disease for 2-10 years, and may infect other animals in that time (Jansen and Godkin, 2005) so it is critical to monitor and continually test herds for the presence of Johne's shedders. In the early stages of the disease, all animals will test negative, so Collins and Manning (2005) suggest continuous testing utilizing two or more of the available methods. However, testing in the absence of changes to calving hygiene management will not be economical or effective in controlling the prevalence of Johne's disease (Groenendaal, 2005).

Application of manure from infected animals to pastures or forages is a potential method of spreading Johne's disease to other animals because *M. paratuberculosis* can live in the soil for up to a year (Stabel, 1998). It is advised to prevent exposure of young animals (< 1 year old) to either grazing on these pastures or feed coming from these fields. Small-scale fermentation studies by Katayama et al. (2000, 2001) in Japan suggest that, with ensiling at 60-75% moisture, low pH and high formic acid or with the addition of 3% ammonia to high moisture forage, *M. paratuberculosis* counts can be decreased drastically. In the USA, formic acid and ammonia are not generally used as alfalfa silage additives and it is unknown if the *M. paratuberculosis* counts would be lowered without these treatments.

Hygienic farm management practices can reduce new infections in a herd. Prevention of Johne's disease is much more economical than containment of the disease, with the added benefit that such measures tend to improve overall herd health. Although prevention programs are farm-specific, based on herd risk assessments, there are some general recommendations related to manure management, such as decreasing calf exposure to manure and preventing manure contamination of feed and water for the entire herd (Jansen and Godkin, 2005; Stabel, 1998). In addition to testing the herd on the farm, new livestock should be purchased from herds certified to be at low risk from Johne's disease in order to ensure that the bacterium is not present in the manure (NAHMS, 1997; Groenendaal, 2005). Additionally, manure storage and composting techniques may aid in the reduction of pathogens to be spread on alfalfa (Grewal et al., 2006).

Several Northeastern states have Dairy Quality Management programs that focus on management improvement to prevent Johne's disease. For New York, we refer to the New York State Cattle Health Assurance Program (NYSCHAP, www.nyschap.vet.cornell.edu).

2.2.11 Odor

Although from a water quality point of view, summer application of manure has great advantages, many odor related complaints initiate from situations where manure is being spread in the summer months on recently harvested alfalfa or grass fields (Rankin, 2006). This could in part be addressed by using partial incorporation or injection techniques and applying manure in cool weather.

3. Cornell Fertility Guidelines for Alfalfa and Alfalfa-Grass Stands

3.1 pH and Lime

Alfalfa grows best on deep, well-drained soils with a soil pH of 6.8 to 7.0 or higher. Seeding alfalfa into soils with a pH of 6.5 or lower can result in establishment failure and shorten the stand life. Lime can be applied shortly before seeding if the soil pH is 5.8 to 6.6. If the pH is below 5.8, lime should be applied at least 6-12 months in advance of seeding using a split application with half the amount of lime needed for optimum pH applied and plowed down and the remainder applied to the surface (Cornell Cooperative Extension, 2008; Bergstrom, 1987). For current equations used to derive a lime recommendation for a legume rotation in New York, see "Lime Guidelines for Field Crops in New York" (Ketterings et al., 2006).

3.2 Nitrogen

3.2.1 Establishment

No N is needed for establishment of pure or mixed alfalfa-grass stands if proper inoculation and nodulation occurred, soil fertility levels are adequate, and soil temperatures are 60^{o}F or higher 3-4 weeks after germination.

Spring seeding with a companion crop such as wheat, barley, oats or triticale has the advantages of: (1) decreased soil erosion; (2) additional forage in the seeding year; (3) potentially reduced weed competition; and (4) reduced risk of N leaching. Seeding with companion crops harvested for silage (oats, spring barley, triticale) will require N for optimal establishment and growth of the companion crop. However, N fertilizer applications should be limited to 60-80 lb fertilizer N/acre for an agronomic response.

Mineralization of organic N in the manure increases with warming of the soils and mineralization tends to coincide with N uptake by the crop resulting in relatively low N losses from organic N in the manure. However, N losses from the urea-N fraction of the manure can be large and if manure is applied in the fall after corn harvest and prior to seeding, the urea N fraction of the manure (usually about 50% of the manure N) will be lost over the fall, winter and early spring in northeastern climates. If manure is applied and incorporated shortly after application, volatilization losses can be reduced but conversion to nitrate will occur and if there is nitrate-N in excess of what the new seeding can take up in the first 6-8 weeks, the urea-N fraction becomes subject to early season leaching losses. It is therefore recommended that, if spring manure applications are done prior to establishment of the new seeding to address P needs, application rates be limited to 3,000-4,000 gallon/acre.

A seeding with companion crops harvested for silage (e.g. oats, spring barley, triticale) will likely require N for optimal establishment and growth of the companion crop. As mentioned above, N fertilizer applications should be limited to 60-80 lb fertilizer N/acre. This N need could be met with manure but spring manure application rates to mixed seedings should not exceed 6,000-8,000 gallon/acre to reduce the risk of lodging of the companion crop and/or N loss to the environment. It is recommended to seed the small grains with half the recommended seeding rate for grain and harvested before heading to provide adequate forage quality for dairy cows (Cornell Cooperative Extension, 2008; Bergstrom et al., 1987).

3.2.2 Topdressing

Nitrogen is not required for pure alfalfa stands or stands with more than 50% legume, given that conditions for N fixation are satisfactory. However, N is recommended when the legume content of a legume-grass stand is less than 50% (Cornell Cooperative Extension, 2008).

If the stand is more than 50% legume:	NetRequiredN = 0 lb/acre	[1]
If the stand is 25-50% legume:	NetRequiredN = 30-50 lb/acre	
If the stand is less than 25% legume:	NetRequiredN = 75-225 lb/acre	

Manure application rates for established stands (topdressing) are generally controlled by stand-survivability and P buildup over time. Established stands could receive

6,000-8,000 gallon/acre for each 2 ton of forage removal assuming N fixation reduction to 20% of the total N uptake and soil N supply as for corn (see Appendix in Ketterings et al., 2003a for documentation of Cornell University soil N supply estimates). However, risk of burn, smothering, and/or salt injury to the stand increase with manure application rates exceeding 4,000 gallon/cutting. Also, if P buildup is to be avoided manure application rates should be limited to 4,000 gallon/acre for the year (across all years of the stand). A practical approach could be to apply manure at 4,000 gallon/cutting for 2-3 cuts in the final years in the stand, rebuilding P levels after drawdown in years 1-3. Manured fields should be checked for forage K content when the forage is being considered for feeding to non-lactating cows.

3.3 Phosphorus

Legumes produce a single tap root that grows almost straight down from the seed. Small seedlings need relatively large quantities of P for growth as their root system is small and cannot obtain P from a large volume of soil. Phosphorus fertility guidelines for establishment of a new seeding depend on Cornell Morgan soil test P (STP) results and can be derived with the following set of equations:

If STP ≥80 lb/acre P, P recommendations = 0 lb P_2O_5/acre
If STP ≥40 but <80 lb/acre P, P recommendations = 10 lb P_2O_5/acre
If STP ≥20 but <40 lb/acre P, P recommendations = 20 lb P_2O_5/acre
If STP ≥10 but <20 lb/acre P, P recommendations = 40 lb P_2O_5/acre
If STP <10 lb/acre P, P recommendations (lb P_2O_5/acre) = 85 - (5 * STP) [2]

Note that the guidelines suggest the application of P even when the soil test P is in the Very High category (>40 lb/acre). This is because legumes are highly responsive to P, especially when the P is placed in a band directly below the seed when planting (Bergstrom et al., 1987). It will require at least four times as much broadcast P to give the same response as when P is banded. It is acknowledged that very few new seedings are established with the use of banded fertilizer due to efficiency and/or equipment issues, but it is also believed that many forage seedings could be improved by the use of a small amount of banded P fertilizer, especially when the Cornell Morgan P is less than 10 lb/acre.

Once an alfalfa or alfalfa-grass stand is established, the P requirements can be reduced by about 30 lb of P_2O_5 per acre for a given STP level (compared to a new seeding):

If STP $\geq$20 lb/acre P, P recommendation = 0 lb P_2O_5/acre
If STP $\geq$9 but <20 lb/acre P, P recommendation = 10 lb P_2O_5/acre
If STP <9 lb/acre P, P recommendation (lb P_2O_5/acre) = 55 – (5 * STP) [3]

For topdressing established stands, the P in broadcasted manure is considered to be as efficient as P in fertilizer. See Ketterings et al. (2003b) for more detailed documentation of current Cornell University P guidelines for field crops. These agronomic P fertilizer guidelines for field crops are based on decades of field research conducted in New York by D.R. Bouldin, S.D. Klausner, D.J. Lathwell, W.S. Reid, retired faculty members at the Department of Crop and Soil Sciences, Cornell University, and more recent studies by Ketterings et al. (2005).

3.4 Potassium

Potassium requirements increase with plant growth. The new seedling does not require large amounts and there is greater flexibility in the methods and rates of application than with P. However, more than 60-80 lb K_2O/acre in the fertilizer band can cause salt injury to the seedlings. Potassium guidelines for stand establishment and established stands are calculated according to the equations listed in Tables 1 and 2. In these equations, YPA is the soil-specific alfalfa yield potential in ton/acre (88% DM) and STK is the Cornell Morgan extractable K in lb/acre. Soil type (management group) specific yield potentials for alfalfa can be found in Ketterings et al. (2003c) and are reprinted in Appendix A. See Ketterings et al. (2003c) for more detailed documentation of current Cornell University K guidelines for field crops. The guidelines for field crops are based on decades of field research conducted in New York by D.R. Bouldin, S.D. Klausner, D.J. Lathwell, W.S. Reid, retired faculty members at the Department of Crop and Soil Sciences, Cornell University.

Table 1: Potassium guidelines for alfalfa and alfalfa-grass establishment. Soil test K (STK) is the Cornell Morgan extractable K in lb/acre.

Soil Management Group	K Recommendation (lb K_2O/acre)
1	(100 - STK) * 0.70
2	(110 - STK) * 0.70
3	(130 - STK) * 0.80
4	(160 - STK) * 0.90
5	(200 - STK) * 0.70
6	(200 - STK) * 0.70

Table 2: Potassium guidelines for topdressing alfalfa and alfalfa-grass stands. The soil test K (STK) is the Cornell Morgan extractable K in lb/acre. Annual yield potentials (YPAs) are in ton/acre (88% DM).

Soil Management Group	K Recommendation (lb K_2O/acre)
1	[{(YPA * 40) – STK} / 0.6] – 120
2	[{(YPA * 40) – STK} / 0.6] – 100
3	[{(YPA * 40) – STK} / 0.6] – 80
4	[{(YPA * 40) – STK} / 0.6] – 60
5	[{(YPA * 40) – STK} / 0.6] – 40
6	[{(YPA * 40) – STK} / 0.6] – 40

3.5 Other Nutrients

Magnesium (Mg) is not commonly limiting yield in soil of New York State. However, if soil test results indicate the potential of a Mg deficiency (Table 3), Mg is most economically added as a component of the liming program (Cornell Cooperative Extension, 2008; Bergstrom et al., 1987). Broadcast rates of 20-40 lb/acre of Mg should be sufficient for alfalfa. Magnesium deficiency is recognized as interveinal chlorosis (leaf tissue between veins turns yellow while the veins remain green, resulting in striping) of the older leaves. Manure is a significant supplier of Mg and manured fields are not likely to be Mg-deficient.

Boron is known to potentially be deficient for legumes in New York soil, especially coarser textured loams, sandy loams, loamy sands and sands (Hudson Valley and Northern New York soils and soil along Lake Ontario) (Cornell Cooperative Extension, 2008; Bergstrom et al., 1987). A boron deficiency shows as younger leaves that become yellow then white near the growing point and internodes that become shortened giving the plant a rosette appearance (bushy appearance at the top of the stunted plant). Boron deficiencies show before significant yield reduction occurs. Soil testing is the best way to identify a B deficiency. Soils with less than 0.35 lb/acre hot-water extractable B (Cornell hot water test) are classified as low in B (Table 3). Soils with 0.36-0.75 lb/acre B are considered medium in B availability. If a boron deficiency is determined (usually in spots of a field and not in entire fields), a B application of 2-5 lb of B/acre, topdressed on well-established alfalfa-grass stands, should be sufficient for several years. Boron application in the establishment year of a mixed alfalfa-grass stand should be avoided as grass seedlings are sensitive to B toxicity (Cornell Cooperative Extension, 2008; Bergstrom et al., 1987).

Zinc is not usually deficient but if soil test zinc is low and deficiency symptoms are observed (recognized as interveinal chlorosis or striping of the youngest leaves), 8-10 lb/acre of Zn in soluble sources (e.g. zinc sulfate) before seeding should be enough for 5 or more years (Cornell Cooperative Extension, 2008). Manure is a significant supplier of Zn and manured fields are not likely to be Zn-deficient.

Table 3: Classification of soil test results for magnesium, boron and zinc (Cornell Cooperative Extension, 2008).

Nutrient	Low lb/acre	Medium lb/acre	High lb/acre	Very High lb/acre
Magnesium[a]	≤65	66-100	101-199	≥200
Boron[b]	≤0.35	0.36-0.75	≥0.76	
Zinc[a]	<0.5	0.5-1.0	>1.0	

[a] Cornell Morgan extraction. [b] Cornell hot water extraction.

Sulfur is a component of numerous enzymes that regulate photosynthesis and N fixation. Because of the role of S in N fixation, it is needed at higher levels for alfalfa than for grass or corn (Table 4). Sulfur deficiency looks similar to N deficiency (leave yellowing and interveinal chlorosis), but because S is not very mobile in the plant, the younger leaves will show the deficiency first. The risk for sulfur deficiency varies with soil type, the crops grown on the soil, the manure history, and the level of organic matter in the soil. A deficiency is more likely to occur on acidic, sandy soils, soils with low organic matter levels, and soils that are cold and dry in the spring which decreases mineralization of soil organic matter and hence S release into the soil solution. If S is deficient, it can be applied as ammonium sulfate or other S-containing fertilizers. Manure is a significant supplier of S and manured fields are not likely to be S-deficient.

Table 4: Sulfur removal estimates for New York field crops (derived from composition data (main library) reported by Dairy One (www.dairyone.com/Forage/FeedComp/default.asp).

Crop	Sulfur Removal (lb S/ton)
Alfalfa hay	4.88 lb S/ton of hay (90% DM)
Alfalfa silage	1.72 lb S/ton of silage (35%DM)
Grass hay	3.11 lb S/ton of hay (90% DM)
Grass haylage	1.44 lb S/ton of silage (35% DM)

4. Manure Nutrient Credits

Manure contains macro- and micronutrients. For N, there are primarily two forms in manure: inorganic (ammonium) N and organic N (Figure 2). The ammonium N is initially present in urine as urea and usually accounts for about 50% of the total N in liquid dairy manure. Urea in manure is no different from urea in commercial fertilizer; it is rapidly converted to ammonium and can be lost through conversion to ammonia.

In principle, all of the ammonium from urea in manure is expected to be available for plant uptake in the year it is applied, but timing and method of application have a huge impact on how much ammonium is actually captured by the crop. For example, part or all of the ammonium may be lost because it is rapidly converted to ammonia as surface applied manure begins to dry (Klausner, 1997; Lauer et al., 1976; Bouldin et al., 1984).

Atmospheric exposure of manure on the barn floor, in the feedlot, in storage, or after spreading increases N loss. Thus, an analysis of the manure is useful to determine how much inorganic N may be conserved before spreading. Table 5 shows the expected fraction of ammonium N remaining for plant use from various livestock manures given alternative application methods and timing of application (from Klausner, 1997; Lauer et al., 1976).

Organic N is more stable, present in the feces and is only slowly released. The decomposition of organic N to a less-stable, plant-available inorganic form occurs at different rates usually described as an organic decay or mineralization series. Such a decay series reflects that less resistant organic N will decompose during the year of application, while the more resistant organic N compounds decompose slowly in future years.

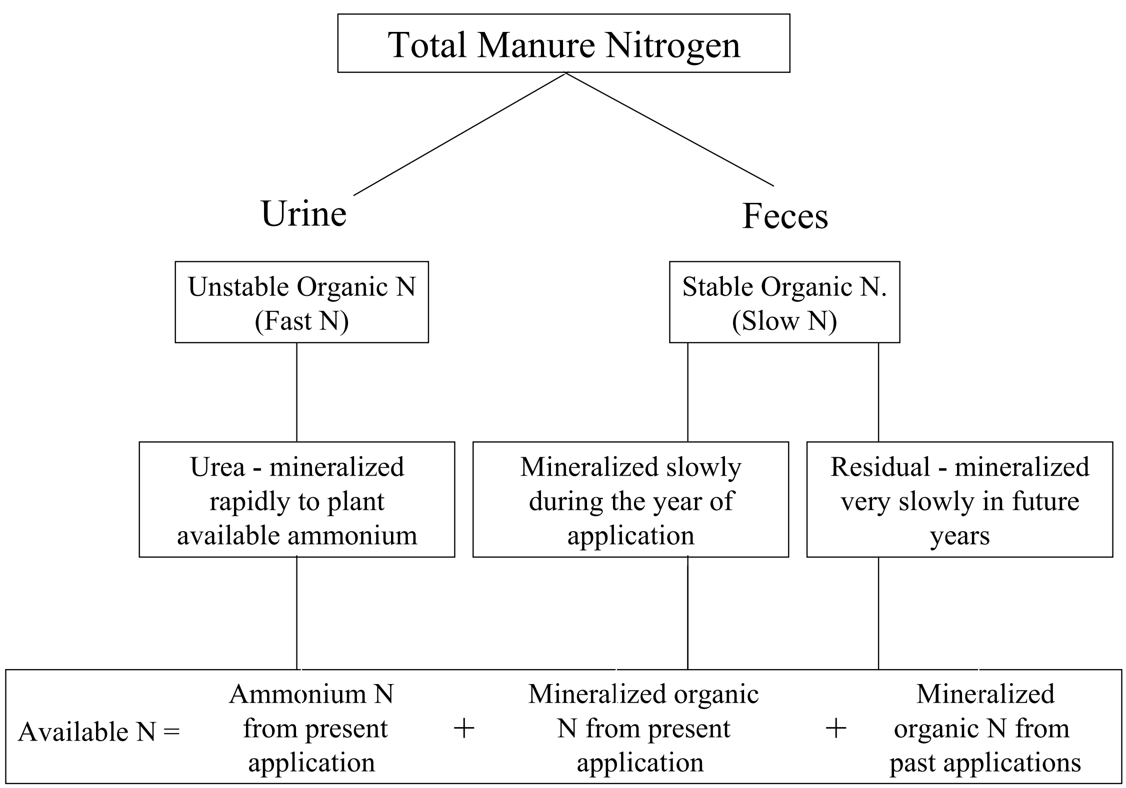

Figure 2: Manure N consists of ammonium and organic N (Klausner, 1997).

Table 5: Cornell guidance for estimated ammonia-N losses as affected by manure application method (Klausner, 1997, derived from work by Lauer et al., 1976).

Manure Application Method	Ammonium-N Utilized by the Crop % of Ammonium-N
Injected during growing season	100
Incorporated within 1 day	65
Incorporated within 2 days	53
Incorporated within 3 days	41
Incorporated within 4 days	29
Incorporated within 5 days	17
No conservation/injected in fall	0

A decay series of 35, 12, and 5% is used to estimate the rate of decomposition of organic N in liquid (<18% dry matter) dairy manures in New York (Table 6). This sequence of numbers means that 35% of the organic N is mineralized and potentially taken up by the growing crop during the year the manure was applied, 12% of the initial organic N application is mineralized and taken up during the second year, and 5% is mineralized and taken up in the third year. There is evidence that manure containing large amounts of bedding may mineralize at a slower rate than fresh manure. Therefore, the estimated availability of N during the year applied is reduced from 35 to 25% when the dry matter content of bedded manure exceeds 18% (Table 6).

Table 6: Cornell guidance for manure organic N release by animal type (Klausner, 1997, derived from work by Klausner et al., 1994).

		Release Rate for Organic N in Manure		
Source	Dry Matter Content %	Present Year “Decay_current” %	Last Year “Decay_lastyr” %	Two Years Ago “Decay_2yrs” %
Cows	<18	35	12	5
Cows	≥18	25	12	5
Poultry	<18	55	12	5
Poultry	≥18	55	12	5
Swine	<18	35	12	5
Swine	≥18	25	12	5
Horses	<18	30	12	5
Horses	≥18	25	12	5
Sheep	<18	35	12	5
Sheep	≥18	25	12	5

The following calculations are used to determine the residual manure N contribution (ResidualN_manure):

ResidualN_manure = ResidN1 + ResidN2

ResidN1 = 12/100 * (Organic N/100) * ManureRate_lastyr

ResidN2 = 5/100 * (Organic N/100) * ManureRate_2yrs [3]

Where:

ResidualN_manure is the total residual N from manure (lb N/acre).

ResidN1 is the residual N from manure applied last year (lb N/acre).

ResidN2 is the residual N from manure applied two years ago (lb N/acre).

ManureRate_lastyr is the amount of manure applied last year (lb/acre).

ManureRate_2yrs is the amount of manure applied 2 years ago (lb/acre).

Organic N is the organic N content of the applied manure on an as sampled basis.

A manure N credit calculator is downloadable from the Nutrient Management Spear Program website: nmsp.css.cornell.edu/software/manure_Nutrient_credits.xls. For a complete description of current Cornell N guidelines for field crops, including manure N credits, see "Cornell nitrogen guidelines for field crops" (Ketterings et al., 2003a). As mentioned before, these agronomic N fertilizer guidelines for field crops are based on decades of field research conducted in New York by D.R. Bouldin, S.D. Klausner, D.J. Lathwell, and W.S. Reid, retired faculty members at the Department of Crop and Soil Sciences, Cornell University.

4. Considerations for Manure Use on Alfalfa

- Manure application for stand establishment:
  - If spring manure applications are done in the establishment year, the application should be limited to stands seeded with a companion crop and to rates not exceeding 6,000-8,000 gallon/acre. Higher applications will increase the chance of lodging of the companion crop in addition to increasing N loss. Phosphorus needs in the seeding year (for soils with a Cornell Morgan P test below 80 lb/acre P) can be met with spring-applied manure but rates should be limited to 3,000-4,000 gallon/acre and manure should be incorporated to avoid large N losses in the seeding year.
- Manure application for established stands:
  - Although established stands could receive 6,000-8,000 gallon/acre for each 2 ton of forage removal assuming N fixation reduction to 20% of the total N uptake

and soil N supply as for corn, application rates in excess of 4,000 gallon/acre could lead to burn, smothering, and/or salt injury to the stand. If P buildup is to be avoided, manure application rates should be limited to 4,000 gallon/acre for the year (across all years of the stand). A practical approach could be to apply manure at 4,000 gallon/cutting for 2-3 cuts in the final years in the stand, rebuilding P levels to optimal after drawdown in years 1-3.

- Manured fields should be checked for forage K content when the forage is being considered for feeding to non-lactating cows.
- Wheel traffic damage due to manure spreaders can be minimized by planting traffic tolerant varieties, using small tractors if possible, avoiding unnecessary trips across the field, using larger harvesting equipment, and driving on fields as soon after cutting as possible.
- Application of manure from animals infected with pathogens, particularly Johne's disease is a potential method of spreading these infections. In the case of Johne's disease, exposure of young animals (<1 year old) to contaminated pastures or to feed coming from these fields should be prevented.

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Appendix A: Soil Management Groups and Alfalfa Yields

Soil management group (SMG) and alfalfa yield potential (YP in ton/acre 12% moisture) for undrained (UD) and artificially drained (DR) NY soils.

Soil Name	SMG	Yield Potential	
		UD	DR
		ton/acre	
Acton	4	4.0	5.5
Adams	5	4.5	4.5
Adirondack	4	4.0	4.0
Adjidaumo	1	2.5	3.5
Adrian	6	2.5	4.0
Agawam	4	6.0	6.0
Albia	3	3.5	4.5
Albrights	2	4.5	5.0
Alden	3	2.0	3.5
Allagash	5	5.0	5.0
Allard	3	6.0	6.0
Allendale	3	2.5	3.5
Allis	3	2.5	4.5
Alluvial Land	3	3.0	4.0
Almond	3	2.5	3.0
Alps	3	4.5	5.0
Altmar	5	4.5	5.0
Alton	5	5.5	5.5
Amboy	4	5.5	5.5
Amenia	4	5.0	5.5
Angola	2	3.0	4.5
Appleton	2	4.0	4.5
Arkport	4	5.5	5.5
Armagh	2	2.5	4.0
Arnot	3	4.0	4.0
Ashville	3	3.0	3.5
Atherton	3	2.5	4.0
Atkins	3	2.0	3.5
Atsion	5	3.0	4.5
Au Gres	5	3.0	4.5
Aurelie	3	2.0	2.5
Aurora	2	4.5	4.5

Soil Name	SMG	Yield Potential	
		UD	DR
		ton/acre	
Barbour	3	6.0	6.0
Barcelona	3	3.5	4.5
Barre	1	2.5	4.0
Bash	3	5.0	5.5
Basher	3	5.5	6.0
Bath	3	5.0	5.0
Becket	4	4.5	4.5
Becraft	3	5.5	6.0
Belgrade	3	5.5	6.0
Benson	4	4.0	4.0
Berkshire	5	5.5	5.5
Bernardston	4	5.5	5.5
Berrien	5	4.5	5.0
Berryland	5	2.0	3.5
Beseman	6	2.5	3.5
Bice	5	5.0	5.0
Biddeford	2	2.0	3.5
Birdsall	3	2.5	3.5
Blasdell	3	5.5	5.5
Bombay	4	5.0	5.5
Bonaparte	4	4.5	4.5
Bono	1	3.0	4.0
Boots	6	2.5	3.5
Borosaprists	6	2.0	3.5
Boynton	3	2.5	4.0
Braceville	4	4.0	5.0
Brayton	4	3.0	4.5
Bridgehampton	3	6.0	6.0
Bridport	2	3.5	4.5
Briggs	4	5.0	5.0
Brinkerton	2	2.5	4.0
Broadalbin	4	5.5	5.5

Soil Name	SMG	Yield Potential	
		UD	DR
		ton/acre	
Brockport	1	4.0	4.5
Brookfield	3	5.0	5.0
Buckland	3	0.0	4.0
Bucksport	6	2.0	3.5
Budd	4	5.5	5.5
Burdett	2	4.0	4.5
Burnham	3	2.0	3.5
Busti	3	3.5	4.0
Buxton	2	5.0	5.5
Cambria	2	2.5	3.5
Cambridge	3	5.0	5.5
Camillus	3	5.0	5.0
Camroden	3	4.0	4.5
Canaan	4	4.5	4.5
Canaan-rock outcrop	4	4.5	4.5
Canadice	2	3.0	4.0
Canandaigua	3	2.5	4.0
Canaseraga	3	5.0	5.5
Canastota	2	4.5	5.0
Caneadea	2	4.0	4.5
Canfield	3	4.5	5.0
Canton	4	5.5	5.5
Carbondale	6	2.0	3.5
Carlisle	6	2.0	3.5
Carrollton	3	3.5	3.5
Carver	5	4.0	4.0
Carver-Plymouth	5	4.0	4.0
Castile	4	5.5	5.5
Cathro	6	2.5	3.5
Cathro-Greenwood	6	2.5	3.5
Cattaraugus	3	5.5	5.5
Cavode	2	3.5	4.5
Cayuga	2	5.5	5.5
Cazenovia	2	5.5	5.5
Ceresco	3	6.0	6.0
Chadakoin	3	5.5	5.5
Chagrin	3	6.0	6.0
Champlain	5	3.5	3.5
Charles	3	2.0	3.0

Soil Name	SMG	Yield Potential	
		UD	DR
		ton/acre	
Charlton	4	5.5	5.5
Chatfield	4	4.5	4.5
Chaumont	1	3.0	4.0
Chautauqua	3	5.0	5.0
Cheektowaga	5	3.0	4.0
Chenango	3	5.5	5.5
Cheshire	4	5.0	5.0
Chippeny	6	2.0	3.5
Chippewa	3	2.5	4.0
Churchville	2	3.0	4.5
Cicero	2	3.5	4.5
Clarkson	2	5.5	6.0
Claverack	4	5.5	5.5
Clymer	4	5.0	5.0
Cohoctah	4	2.5	3.5
Collamer	3	5.5	6.0
Colonie	5	4.5	4.5
Colosse	4	4.5	4.5
Colrain	4	5.5	5.5
Colton	5	4.5	4.5
Colwood	3	2.5	4.0
Conesus	2	5.0	5.5
Conotton	3	5.5	5.5
Constable	5	4.5	4.5
Cook	5	2.5	3.5
Copake	4	6.0	6.0
Cornish	3	3.5	4.5
Cosad	4	4.0	5.0
Cossayuna	4	5.5	5.5
Covert	4	5.0	5.5
Coveytown	4	3.0	4.5
Covington	1	2.5	3.5
Crary	4	4.0	4.5
Croghan	5	4.5	4.5
Culvers	3	4.5	5.0
Dalbo	3	4.5	4.5
Dalton	3	3.0	4.0
Danley	2	4.5	5.0
Dannemora	4	2.5	3.5

Soil Name	SMG	Yield Potential	
		UD	DR
		ton/acre	
Darien	2	3.5	4.5
Dawson	6	2.5	3.5
Deerfield	5	4.5	4.5
Deford	4	4.0	4.0
Dekalb	4	5.0	5.0
Depeyster	3	5.5	6.0
Deposit	3	5.0	5.5
Derb	3	3.5	4.0
Dixmont	5	4.5	5.0
Dorval	6	2.0	3.5
Dover	4	5.5	5.5
Duane	4	4.0	4.5
Dunkirk	3	5.5	5.5
Dutchess	4	5.5	5.5
Duxbury	4	5.0	5.0
Edwards	6	2.5	3.5
Eel	2	4.5	5.5
Eelweir	4	5.0	5.5
Elka	4	4.5	4.5
Ellery	3	2.5	4.0
Elmridge	5	4.5	5.5
Elmwood	4	4.5	5.0
Elnora	5	4.5	5.0
Empeyville	4	3.5	4.5
Enfield	3	5.5	5.5
Ensley	3	3.0	3.5
Erie	3	3.0	4.0
Ernest	3	4.0	4.0
Essex	5	4.5	4.5
Fahey	5	4.0	4.5
Farmington	3	4.0	4.0
Farnham	4	5.0	5.5
Fernlake	4	3.0	3.0
Fonda	2	2.0	3.5
Fredon	4	3.0	4.0
Freetown	6	2.5	3.5
Fremont	2	3.0	4.5
Frenchtown	3	2.5	4.0
Frewsburg	3	3.0	4.0

Soil Name	SMG	Yield Potential	
		UD	DR
		ton/acre	
Fryeburg	3	4.0	4.0
Fulton	1	2.5	2.5
Gage	3	3.0	4.0
Galen	4	5.0	5.5
Galestown	5	4.0	4.0
Galoo	4	3.5	3.5
Galoo-rock outcrop	4	3.5	3.5
Galway	4	5.0	5.0
Genesee	2	6.5	6.5
Georgia	4	5.0	5.5
Getzville	3	3.0	3.5
Gilpen	3	4.0	4.0
Gilpin	3	4.0	4.0
Glebe	4	3.0	3.0
Glebe-Saddleback	4	3.0	3.0
Glendora	4	3.0	3.0
Glenfield	3	2.5	3.5
Gloucester	4	4.5	4.5
Glover	4	3.5	3.5
Gougeville	5	2.0	4.0
Granby	5	2.0	3.5
Grattan	5	4.5	4.5
Greene	3	3.0	4.0
Greenwood	6	2.0	3.0
Grenville	4	5.5	5.5
Gretor	3	2.5	3.0
Groton	4	4.5	5.0
Groveton	4	4.0	5.0
Guff	1	2.5	3.0
Guffin	1	2.5	3.5
Gulf	4	2.5	3.5
Hadley	3	5.0	5.0
Haights	3	3.0	3.5
Haights-Gulf	3	3.0	3.5
Hailesboro	3	4.0	5.0
Halcott	2	3.0	3.5
Halsey	4	2.5	3.5
Hamlin	2	6.5	6.5
Hamplain	2	5.5	5.5

Soil Name	SMG	Yield Potential	
		UD	DR
		ton/acre	
Hannawa	4	3.0	4.0
Hartland	4	6.0	6.0
Haven	4	6.0	6.0
Hawksnest	3	2.5	3.0
Hempstead	4	6.0	6.0
Henrietta	6	2.0	3.5
Herkimer	3	5.5	6.0
Hermon	4	5.0	5.0
Hero	4	5.5	6.0
Heuvelton	2	4.5	5.5
Hilton	2	5.5	6.0
Hinckley	5	4.5	4.5
Hinesburg	4	5.5	5.5
Hogansburg	4	5.0	5.5
Hogback	5	4.0	4.0
Hogback-Ricker	5	4.0	4.0
Holderton	3	4.0	4.5
Hollis	4	3.5	4.5
Holly	2	2.5	3.5
Holyoke	3	4.0	4.0
Holyoke-rock outcrop	3	4.0	4.0
Homer	2	4.0	5.0
Honeoye	2	5.5	5.5
Hoosic	4	5.0	5.0
Hornell	2	3.0	4.0
Hornellsville	3	2.5	3.0
Houghtonville	5	4.5	4.5
Houghtonville-Rawson	5	4.5	4.5
Housatonic	3	3.0	4.5
Houseville	2	4.0	5.0
Howard	3	5.5	5.5
Hudson	2	5.0	5.5
Hulberton	2	4.0	4.5
Ilion	2	2.5	4.0
Insula	4	3.0	3.0
Ipswich	6	2.5	3.5
Ira	4	4.5	5.0
Ischua	3	4.0	4.5
Ivory	2	2.5	3.0

Soil Name	SMG	Yield Potential	
		UD	DR
		ton/acre	
Jebavy	5	3.0	4.0
Joliet	4	2.5	4.0
Junius	5	3.0	4.0
Kalurah	4	5.0	5.5
Kanona	2	2.5	3.5
Kars	4	5.5	5.5
Kearsarge	3	3.0	3.0
Kendaia	2	4.0	4.5
Kibbie	3	4.0	5.0
Kingsbury	1	3.5	4.5
Kinzua	3	4.5	4.5
Knickerbocker	5	4.5	4.5
Lackawanna	3	5.5	5.5
Lagross	3	5.0	5.0
Lagross-Haights	3	5.0	5.0
Lairdsville	2	4.5	4.5
Lakemont	1	2.5	3.5
Lakewood	5	4.0	4.0
Lamson	4	2.5	4.0
Lanesboro	3	4.0	4.0
Langford	3	4.5	5.0
Lansing	2	5.5	5.5
Leck Kill	3	4.0	4.0
Leicester	4	2.5	3.5
Leon	5	3.0	4.5
Lewbath	3	4.5	4.5
Lewbeach	3	5.5	5.5
Leyden	2	4.5	5.0
Lima	2	5.0	5.5
Limerick	3	3.0	4.5
Linden	4	6.0	6.0
Linlithgo	3	3.5	4.5
Livingston	1	2.0	3.0
Lobdell	3	4.5	5.5
Lockport	2	4.0	4.5
Lordstown	3	4.5	4.5
Lovewell	2	4.5	5.5
Lowville	4	5.0	5.0
Loxley	6	2.5	3.5

Soil Name	SMG	Yield Potential		Soil Name	SMG	Yield Potential	
		UD	DR			UD	DR
		ton/acre				ton/acre	
Lucas	2	5.0	5.5	Millis	4	5.0	5.0
Ludlow	4	5.0	5.5	Millsite	4	4.5	4.5
Lupton	6	2.5	3.5	Mineola	4	5.0	5.5
Lyman	4	4.0	4.0	Miner	1	2.5	3.5
Lyman-Becket-Berkshi	4	4.0	4.0	Mino	4	3.0	5.0
Lyme	5	2.5	4.0	Minoa	4	3.0	5.0
Lyons	2	2.5	3.5	Mohawk	2	5.5	5.5
Machias	4	4.5	5.0	Moira	4	4.0	5.0
Macomber	4	3.5	3.5	Monadnock	4	3.5	3.5
Macomber-Taconic	4	3.5	3.5	Monarda	4	3.5	4.5
Madalin	1	2.5	3.5	Mongaup	3	4.5	4.5
Madawaska	5	4.5	5.0	Montauk	4	5.0	5.0
Madrid	4	5.5	5.5	Mooers	5	3.0	3.5
Malone	4	3.5	4.5	Morocco	4	3.0	4.0
Manahawkin	6	2.5	3.5	Morris	3	3.5	4.5
Mandy	3	4.0	4.0	Mosherville	4	3.5	4.5
Manheim	2	3.5	4.5	Muck	6	2.0	3.5
Manhoning	2	3.0	4.5	Muck-Peat	6	2.0	3.5
Manlius	3	4.5	4.5	Mundal	4	3.5	3.5
Mansfield	3	2.0	3.5	Mundalite	3	4.5	4.5
Maplecrest	2	5.5	5.5	Mundalite-Rawsonville	3	4.5	4.5
Marcy	3	3.0	4.0	Munson	2	3.5	4.5
Mardin	3	4.5	5.0	Munuscong	4	2.0	3.5
Marilla	3	4.0	4.5	Muskego	6	2.0	3.5
Markey	6	2.0	3.5	Muskellunge	3	3.5	4.5
Marlow	4	5.0	5.0	Napoleon	6	2.0	3.5
Martisco	6	2.5	3.5	Napoli	3	2.5	3.5
Massena	4	3.5	4.5	Nassau	4	4.0	4.0
Matoon	1	3.0	4.0	Naumburg	5	3.0	4.5
Matunuck	6	2.5	3.0	Nehasne	4	5.0	5.0
Medihemists	6	2.0	3.5	Nellis	4	5.5	5.5
Medomak	3	2.0	2.5	Neversink	4	2.0	3.5
Melrose	4	5.0	5.0	Newfane	4	5.5	5.5
Menlo	4	2.5	3.5	Newstead	4	3.5	4.5
Mentor	4	5.5	5.5	Newton	5	2.0	3.5
Merrimac	4	5.0	5.0	Niagara	3	4.0	5.0
Middlebrook	3	4.0	4.5	Nicholville	4	4.0	4.5
Middlebrook-Mongaup	3	4.0	4.5	Ninigret	4	5.5	6.0
Middlebury	3	4.5	5.5	Norchip	3	2.5	3.5

Soil Name	SMG	Yield Potential	
		UD	DR
		ton/acre	
Norwell	5	3.5	4.5
Norwich	3	2.5	3.5
Nunda	2	5.0	5.5
Oakville	5	4.5	4.5
Occum	4	5.5	5.5
Odessa	2	4.0	4.5
Ogdensburg	4	3.5	4.5
Olean	2	5.5	6.0
Ondawa	4	6.0	6.0
Oneida	4	3.5	4.5
Onoville	3	4.0	4.5
Ontario	2	6.0	6.0
Onteora	3	3.5	4.5
Ontusia	3	3.5	4.5
Oquaga	3	4.5	4.5
Oramel	2	5.5	5.5
Organic	6	2.5	3.5
Orpark	2	3.5	4.5
Orwell	2	3.0	4.5
Ossipee	6	2.0	3.5
Otego	2	5.0	5.5
Otisville	4	4.5	4.5
Otsego	3	4.5	5.0
Ottawa	5	5.0	5.0
Ovid	2	4.0	4.5
Palatine	2	4.5	4.5
Palms	6	2.5	3.5
Palmyra	3	5.5	5.5
Panton	1	3.5	4.5
Papakating	2	2.5	3.5
Parishville	4	4.0	5.0
Parsippany	1	2.5	3.5
Patchin	3	2.5	3.5
Pawcatuck	6	2.5	3.5
Pawling	4	5.5	5.5
Paxton	4	5.0	5.0
Peacham	3	2.0	3.0
Peat	6	2.5	3.5
Peat-Muck	6	2.0	3.5

Soil Name	SMG	Yield Potential	
		UD	DR
		ton/acre	
Peru	4	4.5	5.0
Petoskey	4	5.5	5.5
Phelps	3	5.0	5.5
Philo	3	5.5	6.0
Pillsbury	4	2.5	4.0
Pinckney	3	4.5	4.5
Pipestone	5	2.5	4.0
Pittsfield	4	5.5	5.5
Pittstown	4	5.0	5.5
Plainbo	5	3.0	3.0
Plainfield	5	4.5	4.5
Plessis	3	3.5	4.0
Plymouth	4	4.0	4.0
Podunk	4	5.5	6.0
Poland	2	5.5	5.5
Pompton	4	4.5	5.0
Pootatuck	4	5.0	5.5
Pope	4	5.5	5.5
Potsdam	4	5.0	5.0
Poygan	1	2.0	3.0
Punsit	3	3.0	4.5
Pyrities	4	5.5	5.5
Quetico	4	3.0	3.0
Quetico-rock outcrop	4	3.0	3.0
Raquette	4	4.0	5.0
Rawsonville	5	4.0	4.0
Rawsonville-Beseman	5	4.0	4.0
Rayne	3	5.0	5.0
Raynham	3	3.5	4.5
Raypol	3	2.5	3.5
Red Hook	4	3.5	4.5
Redwater	3	4.5	5.5
Remsen	2	3.0	4.5
Retsof	2	3.5	4.5
Rexford	4	3.0	4.5
Rhinebeck	2	4.0	4.5
Ricker	4	4.0	4.0
Ricker-Lyman	4	4.0	4.0
Ridgebury	4	3.0	4.0

Soil Name	SMG	Yield Potential	
		UD	DR
		ton/acre	
Rifle	6	2.5	3.5
Riga	2	4.5	4.5
Rippowam	4	2.5	3.5
Riverhead	4	4.5	5.5
Rockaway	2	5.5	5.5
Romulus	2	3.0	4.0
Ross	2	6.0	6.0
Roundabout	3	3.5	4.0
Rumney	2	2.0	4.0
Runeberg	4	2.0	3.0
Ruse	4	2.5	3.5
Rushford	3	4.5	5.0
Saco	3	2.0	3.0
Salamanca	3	4.0	4.5
Salmon	4	5.0	5.0
Saprists	6	2.0	3.5
Saugatuck	5	3.0	4.5
Scantic	2	3.0	4.5
Scarboro	4	2.5	4.0
Schoharie	1	5.0	5.0
Schroon	5	5.0	5.0
Schuyler	3	4.5	5.0
Scio	3	5.0	5.5
Scituate	4	4.5	4.5
Scriba	4	3.5	4.5
Searsport	4	2.5	4.0
Shaker	2	3.5	4.5
Shoreham	2	2.0	3.5
Sisk	4	2.0	3.5
Skerry	5	4.0	4.5
Sloan	3	2.0	3.5
Sodus	4	5.0	5.0
Somerset	5	3.0	4.5
St Johns	4	2.5	4.0
Staatsburg	3	4.0	4.0
Stafford	4	3.5	4.5
Steamburg	3	4.0	4.5
Stetson	5	5.0	5.0
Stissing	4	2.5	4.0

Soil Name	SMG	Yield Potential	
		UD	DR
		ton/acre	
Stockbridge	3	5.5	5.5
Stockholm	5	3.0	4.0
Stowe	4	4.5	4.5
Sudbury	4	4.0	5.0
Suffield	2	5.0	5.5
Summerville	4	4.0	4.0
Sun	4	2.5	3.5
Sunapee	4	3.5	4.5
Suncook	5	3.0	3.0
Suny	4	2.0	3.4
Surplus	4	2.0	3.5
Surplus-Sisk	4	2.0	3.5
Sutton	4	5.0	5.0
Swanton	4	3.0	4.5
Swartswood	4	5.0	5.0
Swormville	1	3.0	4.5
Sutton	4	5.0	5.0
Swanton	4	3.0	4.5
Swartswood	4	5.0	5.0
Swormville	1	3.0	4.5
Taconic	3	3.5	3.5
Taconic-Macomber	3	3.5	3.5
Tawas	6	2.5	3.5
Teel	2	4.5	5.5
Tioga	3	4.5	4.5
Toledo	2	2.0	3.5
Tonawanda	2	3.0	4.5
Tor	4	2.0	3.5
Torull	3	3.0	4.0
Towerville	3	4.5	5.0
Trestle	3	5.5	5.5
Trout River	5	4.0	4.0
Troy	3	5.0	5.5
Trumbull	1	2.5	3.5
Tughill	4	2.5	3.5
Tuller	3	3.5	4.0
Tunbridge	4	4.5	4.5
Tunbridge-Adirondack	4	4.5	4.5
Tunkhannock	3	5.5	5.5

Soil Name	SMG	Yield Potential	
		UD	DR
		ton/acre	
Turin	2	3.0	4.5
Tuscarora	4	5.5	5.5
Unadilla	3	6.0	6.0
Valois	3	5.5	5.5
Varick	2	2.5	3.5
Varysburg	2	5.5	5.5
Venango	3	3.5	4.5
Vergennes	1	4.5	5.0
Vly	3	4.0	4.0
Volusia	3	3.5	4.5
Waddington	4	5.0	5.0
Wainola	5	3.0	4.5
Wakeland	3	3.5	4.5
Wakeville	3	4.0	5.0
Wallace	5	4.0	4.0
Wallington	3	3.5	4.5
Wallkill	3	2.0	4.0
Walpole	4	3.0	4.5
Walton	3	5.5	5.5
Wampsville	3	5.5	5.5
Wappinger	3	6.0	6.0
Wareham	5	3.0	4.5
Warners	3	2.0	3.5
Wassaic	4	4.5	4.5
Watchaug	4	3.0	4.0
Waumbeck	4	3.0	4.5
Wayland	2	2.5	3.5
Weaver	3	3.5	4.5
Wegatchie	3	2.5	4.0
Wellsboro	3	4.5	5.0
Wenonah	4	5.0	5.0
Westbury	4	3.0	4.5
Westland	2	2.5	3.5
Wethersfield	4	5.5	5.5
Wharton	2	4.5	5.0
Whately	4	2.0	3.5
Whippany	2	3.5	4.5
Whitelaw	4	5.5	5.5
Whitman	4	2.0	3.5
Wilbraham	4	3.0	4.5
Willdin	3	4.5	5.0
Willette	6	2.5	3.5
Williamson	4	4.5	5.0
Willowemock	3	4.5	5.0
Wilmington	4	2.5	4.0
Wilpoint	1	4.0	5.0
Windsor	5	4.5	4.5
Winooski	4	5.0	5.0
Wolcottsburg	1	2.5	3.5
Wonsqueak	6	2.0	3.5
Woodbridge	4	4.5	5.0
Woodlawn	4	4.5	4.5
Woodstock	4	4.0	4.0
Woodstock-rock outcrop	4	4.0	4.0
Wooster	3	5.0	5.0
Woostern	3	5.5	5.5
Woostern-Bath-Valois	3	5.5	5.5
Worden	4	2.0	3.5
Worth	4	4.5	4.5
Wurtsboro	4	4.0	4.5
Wyalusing	3	3.0	4.0
Yalesville	4	5.0	5.0
Yorkshire	3	3.5	4.0