CHAPTER 29

Can Slurry Manure Replace Commercial Fertilizer?

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Figure 1. The 'drag shoe' or 'sliding shoe' applicator for spreading manure in narrow bands directly on the soil surface, beneath the crop canopy.

Manure is a valuable source of nutrients and organic matter for crops but manure nutrients are difficult to use effectively. Nutrients in slurry manure are very dilute so large volumes are required and this takes a lot of hauling, heavy equipment, and often leads to soil compaction and yield loss. When applied to established forages, manure spreading may lead to crop injury, the manure may coat and smother the crop, and much of the available N may be lost as ammonia. It is difficult to analyze manure nutrients in practice since this requires that the stored manure is mixed several days prior to application to allow time for the laboratory analysis (see chapter by K. Smith). Also, the proportion of nutrients in manures are not well matched

Slurry manure research—deconstructed Agassiz, BC

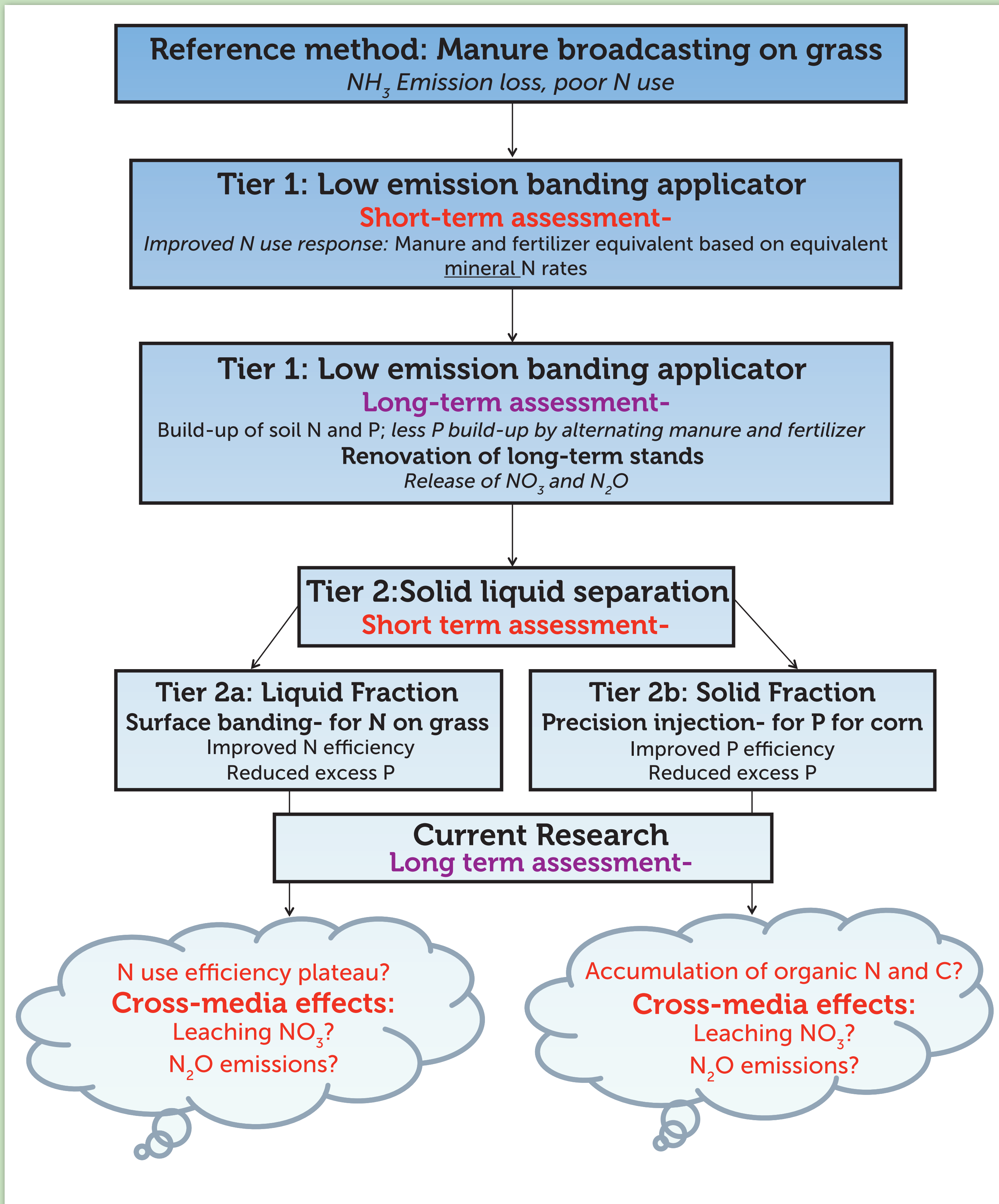

Figure 2. Dairy slurry manure applied on tall fescue by surface banding about one week after grass harvest.

to crop needs, which leads invariably to the loss of nutrients to the environment or accumulation in soil (typically N as nitrate, ammonia and nitrous oxide; and organic and soluble P). Finally, manure poses risks to human well-being through its pathogen content and odour emissions. There is little wonder that some farmers are resigned to handling manure as a nuisance waste product while many others are looking for manure processing solutions to help avoid the challenge of direct use as a fertilizer.

We began our investigations on manure nutrients by comparing efficacy of dairy slurry N with N from commercial fertilizer for enhancing grass production (Bittman et al. 1999). We conducted the trials over three years in coastal British Columbia (BC), a region with high fall and winter rainfall and warm dry summers. The nutrients were applied on stands of tall fescue (*Festuca arundinacea*) in April-May and after forage harvests in June-July and September. We also tested applications that were delayed by about one week because it is logistically more difficult for farmers to fertilize their crops in a timely manner with manure than with commercial fertilizer. In our study, slurry was applied either in the conventional manner with a splashplate applicator or with the more advanced sliding shoe (also called drag shoe) (Fig. 1) which places manure directly onto the soil surface, under the crop canopy, in narrow bands (Fig. 2).

The grass yield responded to increasing doses with commercial N fertilizer in the expected curvilinear response curve (Fig. 3). The delayed application of fertilizer produced somewhat lower yields, especially at high N rates, due to slower initial growth. However, the total uptake of N was not affected by delayed applications of N fertilizer (not shown) because delayed application of N increased concentrations of N in the herbage. This may be a useful approach to increase concentrations of crude protein in grass crops.

Response of grass yield to slurry manure applied with the conventional splash plate was lower than to commercial fertilizer when the two products were compared at equivalent rates of inorganic N (Fig. 3). Yield was lower for manure-treated grass in 5 of 9 trials and there was no difference in 4 trials. The poorest yield response to broadcast manure was generally observed in the trials that were conducted in summer. In contrast to broadcast slurry, slurry applied in narrow bands with the drag shoe gave yields which were consistently similar to the yields with commercial N fertilizer in all seasons when the products were compared at equivalent rates of mineral N with no allowance provided for the organic N in the manure. It should be noted that the grass was harvested about 5-6 weeks after manure application so there was little time for N mineralization from the organic fraction. These results show that farmers

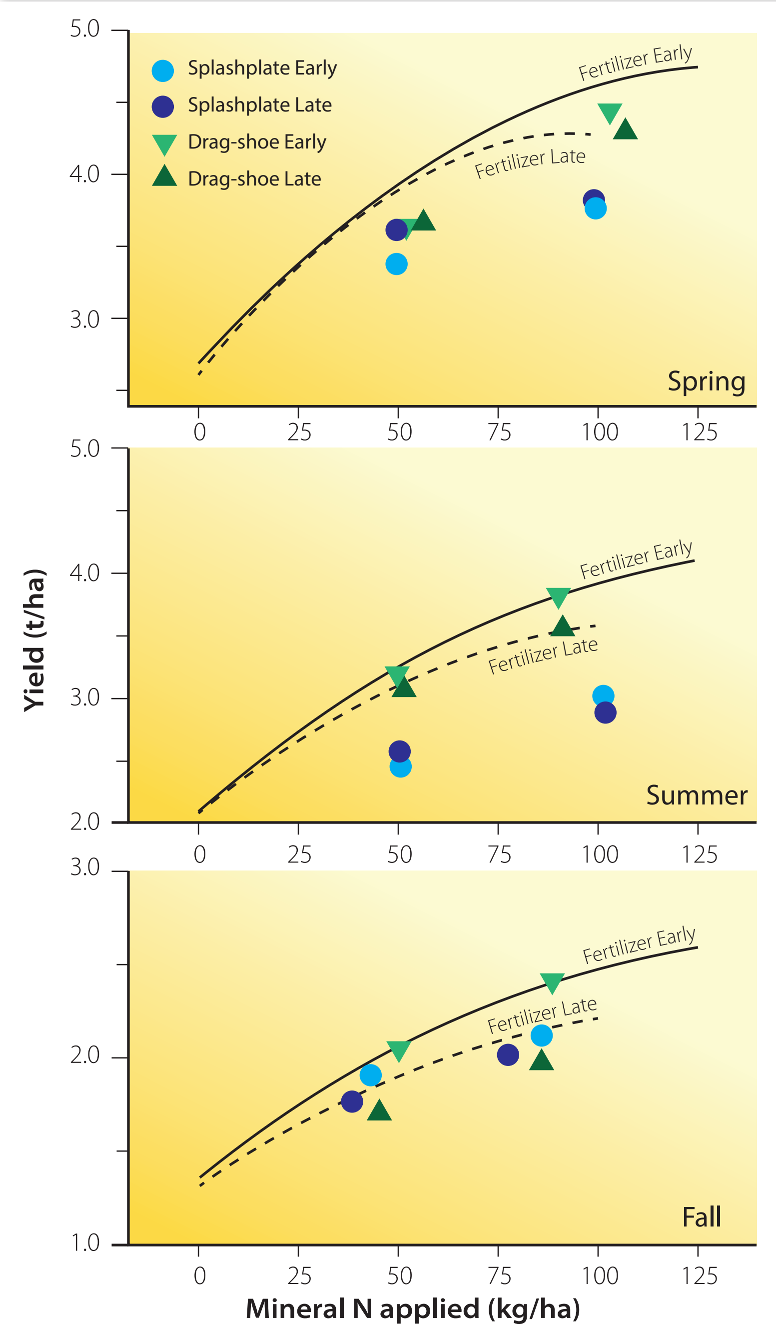

Figure 3. Yield of tall fescue as affected by NH_4NO_3 fertilizer and dairy slurry spread with splash plate and drag shoe applicators in spring, summer, and fall (1994-96) (for T/ac multiply by 0.45).

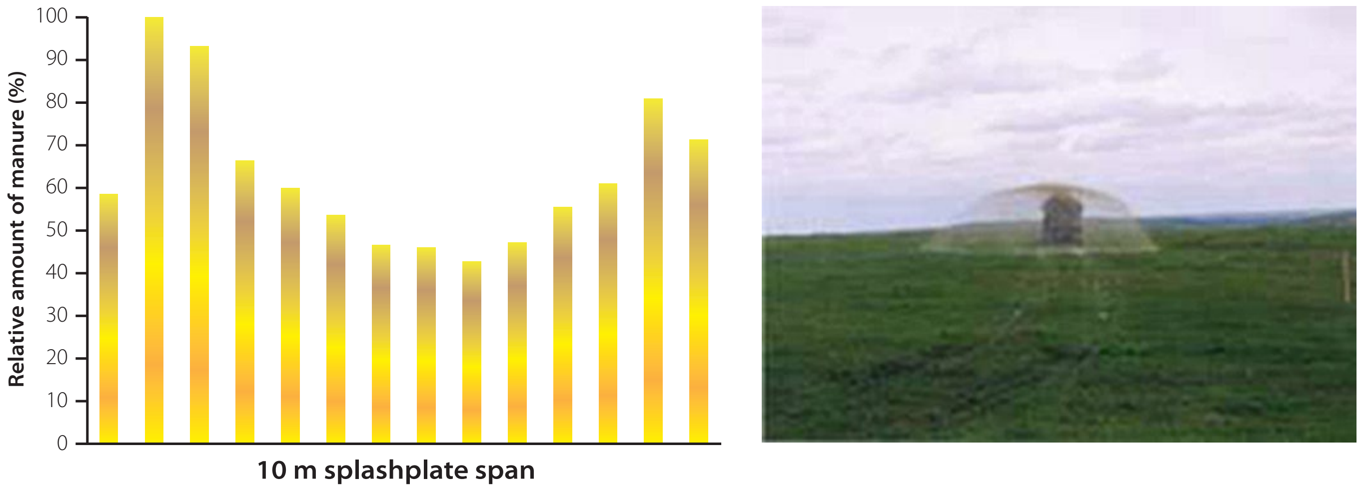

Figure 4. Data and photo showing typical uneveness of broadcast manure applications using a splashplate mechanism.

cannot depend on consistent crop yields from manure applied with conventional applicators. Hence, with access only to conventional application equipment, many farmers will be inclined to supplement with commercial fertilizer to improve yield consistency. However, no supplemental fertilizer would be needed when manure is applied with the drag shoe since yields will consistently match those with mineral fertilizer at equivalent doses of mineral N.

There are other important benefits to slurry application with the sliding shoe, besides consistent yield response. The sliding shoe applies manure evenly across the width of the applicator and spreading uniformity is not affected by wind. Splashplate applicators often distribute the manure unevenly (Fig. 4). The precision placement of slurry on the soil surface in bands with the drag show also means lower emissions of ammonia. In Canada, about 110,000 t of N per year is lost to the atmosphere as ammonia gas after applications of manure to crop and forage land (Sheppard and Bittman, in press (Agriculture, Ecosystem and Environment)). Moreover, with the sliding shoe, the manure can be applied several days after harvest when the grass has grown back without fear of contaminating the herbage (Fig. 2). In fact, there is even evidence that placement of slurry under a 20-cm (8 in.) tall canopy is effective in reducing emissions of ammonia to the atmosphere (see Chapter 26). Finally, there is less risk of drift into sensitive areas such as streams, and reduced odour with drag shoe application.

These trials were short term, with just 4-8 weeks between spreading and harvest, and manure applications were not repeated on the same plot. The trials did not answer the questions: What is the contribution of repeated applications of organic manure N, and can manure applied with low-emission surface-banding applicators be used sustainably as the sole N source in the long term?

Improving Recovery of Manure Nutrients — An Integrated Approach

Most farmers spread their cattle manure on their land, and because cattle are invariably fed forages, much of the manure is inevitably spread on forage land. Forage grasses have a high requirement for nutrients, especially N, and respond well to applications of manure. It is convenient for farmers who take multiple harvests per year, that forage stands can receive manure several times in a year. And because they have well developed root systems, a long growing period and year-round soil cover, forages are less prone than arable crops to loss of nutrients by leaching and runoff. Indeed it is often observed that there tends to be much less residual nitrate after the growing season in grassland soils than in arable soils (Kowalenko 2007). The main disadvantage of manure application on perennial grasses is that manure is usually left on the soil or plant surfaces where it is prone to loss of N by ammonia volatilization. Techniques that improve manure infiltration rate into the soil help to reduce the time that manure is exposed to the air and hence limit ammonia-N loss.

The surest way to minimize air contact is to bury manure in the soil by cultivation or deep (closed slot) injection. Neither approach is well suited to perennial forage stands because of crop damage and soil factors like stones. Instead, there are methods to apply manure in narrow bands at the soil surface using simple devices such as drag hoses or drag (sliding) shoes; these minimize contact with air by reducing surface area and by minimizing contact with plants or crop residues (see Chapters 26 and 27). The sliding shoe is now widely used and even mandated in some European countries and shallow 'open-slot' injection has also gained acceptance in some regions.

While it has often been shown that various low emission application methods protect against ammonia loss to the air

(Bittman et al. 2005), it is not always clear that the conserved N benefits the crop (Webb et al. 2010). The reasons given for not always finding positive crop response is variability of measurements and, if injection is used, crop injury. It is evident and important that if the crop does not take up the conserved N, then it is likely that the additional N will accumulate in the soil or be lost through several possible pathways to the environment, often by leaching. Substituting one form of pollution with another, often called pollution swapping, is a constant concern with proposed manure application BMPs (Best Management Plans) or BATs (Best Available Technologies).

We tested the long-term effects of two methods that reduce exposure of manure to the atmosphere on crop response and N recovery. Both methods involve increasing the rate of infiltration into the soil. The first method involves a low disturbance rolling-tine tool in combination with surface banding to mechanically assist infiltration and limit exposure to air (Bittman et al. 2005). The second method involves removing solids to make the manure less viscous so that it will soak more rapidly into the soil (Bittman et al. 2011). Both methods were tested over multiple applications per year and over multiple years to assess long term effects as they would occur on farms, and to be sure to account for the contribution of organic N in the manure.

Figure 5. Application of dairy slurry by surface banding over aeration slots created by a rolling tine tool.

Figure 6. Left: implement for assisted infiltration comprising of the rolling tines and sliding shoe with application hoses attached. This is an adaptation of SSD® implement manufactured by SAPHolland. Inset: Aeration slots formed by rolling tine.

Method 1. Mechanical assistance of infiltration with a rolling tine

The rolling tine creates intermittent vertical slots in front of manure banded with a trailing hose or sliding shoe (Fig. 5 and 6). The slots help manure infiltrate into the soil and increases soil contact area with the manure. Additional fractures formed in the soil under moderate soil moisture conditions may further serve as infiltration pathways. The manure is placed in narrow bands over the slots so that all banded manure is placed in close proximity to the openings. The sliding shoe also minimizes manure contact with the grass stubble by pushing it aside and directing the manure to contact the ground under the plant canopy. Thus, this method reduces manure exposure to air in both time and space.

In our trial, dairy slurry manure (5-6% DM content) was applied to tall fescue (*Festuca arundinacea*) in spring and after harvests in four doses of 150 kg N/ha (135 lb/ac)per year (March, May, July and September). Banding was performed in all applications but aeration was done just twice per year (March and July) (Fig. 5 and 6). In separate un-manured plots we determined that two aeration passes per year did not damage the grass or affect yield but 4 aeration passes per year damaged the grass and lowered yield. For comparison, the same amount of manure was applied by low trajectory broadcasting through hoses set at a height of 60 cm (24 in). The low trajectory method would be expected to be somewhat more efficient than conventional broadcasting with a splashplate.

In every year of the trial, the rolling tine/banding method increased grass yield, and averaged over 8 years (no harvest in 2006 as the stand was renovated), the yield was 1.0 t/ha (0.45 T/ac) or just over 10% greater than the low trajectory broadcasting used as the control (Fig. 8). Similarly, the assisted infiltration system increased uptake of N from the manure relative to broadcasting by 41 kg/ha (37 lb/ac) per year or 19% (Fig. 8B). It was evident that N uptake increased more than yield, reflecting that assisted infiltration raised the concentrations of plant N and hence crude protein. The greater effect on N uptake than yield could be due to approaching a yield plateau or perhaps to some loss in yield potential due to crop damage.

Figure 7. Manure bands in tall fescue after application with the the tine/sliding shoe implement shown in Figures 1 and 2. Application in early July was at a rate of 45 m^3/ha (~4800 gal/ac). The metal frame is used to measure emissions of nitrous oxide (See figure 8 below).

There are other benefits to the assisted infiltration method including potentially less runoff (van Vliet et al. 2006; See Chapter 31), more uniform manure application across the spreading pass, and less odour (Lau et al. 2003). Lower emissions of ammonia are especially important in areas where atmospheric emissions can lead to human health or environmental contamination issues.

Method 2A. Manure separation: liquid fraction

One of the rather intractable problems with making more efficient use of manure nutrients is that the ratio of N:P in manure is too low for plant needs; most dairy manure in storage has an N:P ratio of 5:1 compared to plant requirements which are closer to 10:1. A contributing factor to this imbalance is that farmers fortify cattle feeds with P, but the more important reason is that N is lost from manure, mostly as ammonia gas, starting almost immediately after excretion, from the floors of houses, then during storage and finally after manure application, whereas throughout these manure handling stages P is not lost and its concentration remains constant. Thus to improve the balance of nutrients, P must be removed from manure; fortunately this can be done relatively easily by removing some of the solid fraction which contains much of the P. The remaining thin liquid fraction, with a higher N:P ratio, may infiltrate more rapidly into the soil reducing the time of contact with air (Fig. 9). In this way, loss of N as ammonia is reduced, further favouring the balance of N:P available to the plants.

Separation of solids can be performed actively with presses and centrifuges or passively by settling. Aggressive methods such as the centrifuge that remove fine particles are most effective.

In our trials we used manure from commercial dairy farms with high-producing cows housed in free stall barns and provided with sawdust bedding. Whole manure was extracted from an agitated tank while the separated liquid fraction was taken from the second of a two stage lagoon system where the first stage was used to settle the solids and the second stage collected the separated liquid fraction. The separated liquid fraction contained about 2% solids compared to 5-6% solids for the whole manure. The manures were applied to tall fescue at different N rates, four times per year, using surface banding to reduce loss of N by volatilization. The experiment was conducted between 2003 and 2011, to allow time for the organic N in the manure (especially in the whole manure) to be released into the soil.

Separation of solids improved annual N uptake from the

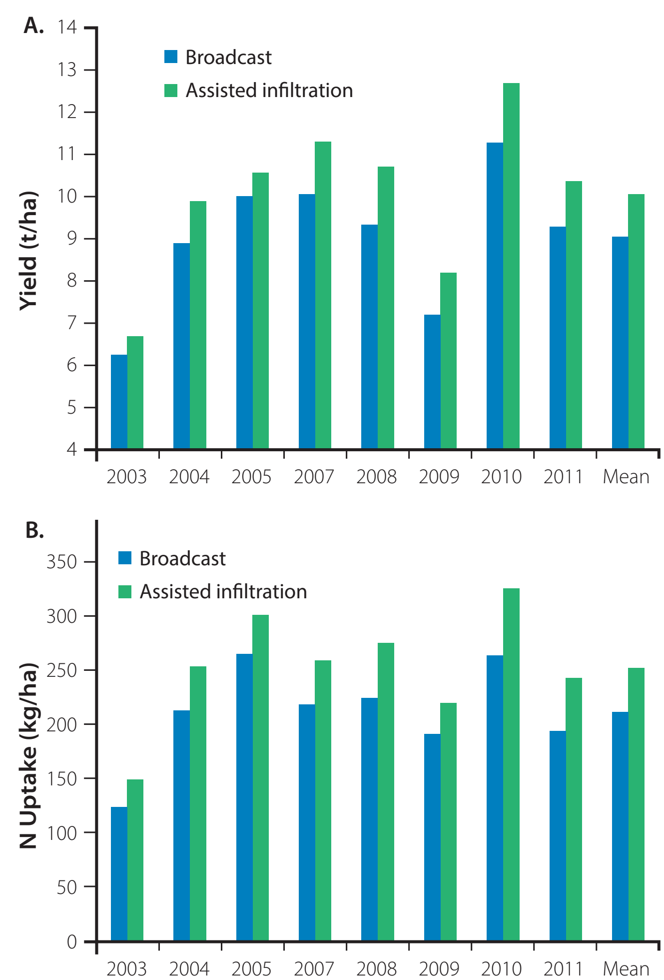

Figure 8 . Effect of assisted infiltration by aeration tines and banding on yield (A) and N uptake (B) by tall fescue over 8 years in Agassiz, BC. (For T/ac, multiply t/ha x 0.45; for lb/ac, multiply kg/ha by 0.9) (Bittman and Hunt, Unpublished).

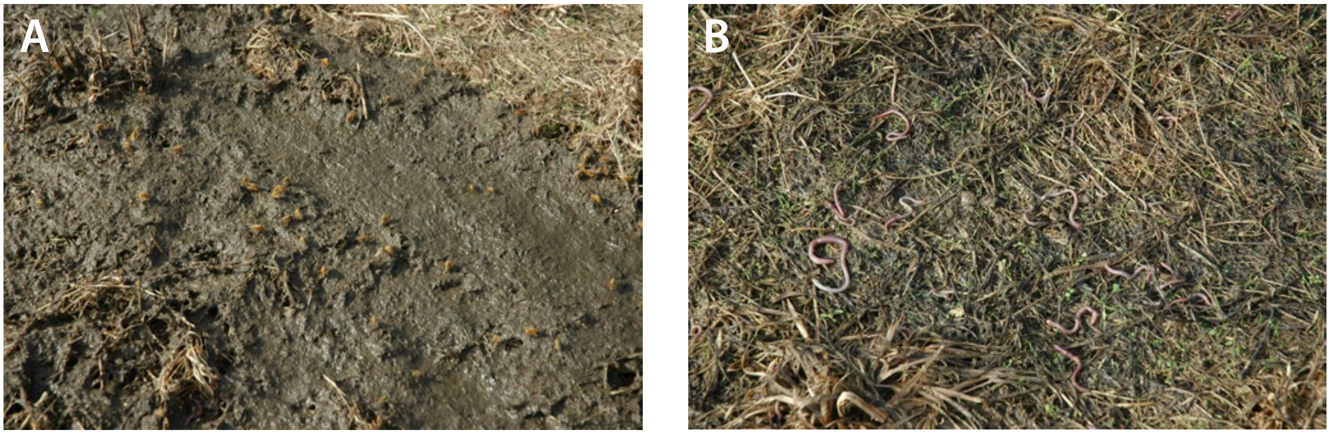

Figure 9. Whole (A) and separated liquid fraction (B) dairy slurry manure about 30 minutes after broadcast application, showing that the whole manure remained longer on the soil surface. Note that the whole manure attracted flies while the separated liquid fraction brought up earthworms.

applied manure by about 50 to 75 kg/ha (45 to 63 lb/ac); almost as much N was taken up from separated manure applied at 440 kg N/ha (396 lb/ac)as from whole slurry applied at about 800 kg N/ha (720 lb/ac)(Fig. 10). Manure separation improved the N use efficiency (defined as increase in yield divided by N application rate) of the manure, especially at the lower (400–450 kg/ha or 360–405 lb/ac) N application rate (Fig. 7A). At the high (600 kg/ha or 540 lb/ac) N rate there was a loss in N use efficiency as the yield response to N levelled off. It is evident that 'apparent N recovery' (or recovery of applied N) was also greatest for the moderate rate of separated manure (Fig. 11B). These results show the effectiveness of applying separated manure at a moderate rate, although the apparent recovery rate is still quite low, especially taking into account the multiple years of manure application. Some of the low recovery can be attributed to the accumulation of organic N in the soil. Nevertheless, we did not observe a narrowing of differences in response to the two manure types over the years so the benefit of organic N from previous applications appears to be fairly limited. The trial will be continued for additional years to determine if apparent N recovery will improve from further accumulation of organic N in the soil.

We found that the advantage of applying separated manure was greater in summer than in early spring or fall for two reasons: first, there is a greater tendency for ammonia volatilization from manure that is left on the soil surface when the weather is warm and sunny, with little chance of rainfall (Bittman et al. 2011; Bhandral et al. 2009); second, the thin separated manure can soak more rapidly into dry summer soils whereas it may take longer for the thin manure to infiltrate especially into wet spring soils due to higher application volume of this fraction needed for a given dosage of N (i.e. N is more dilute).

What happens to the unrecovered N from the manure? Some accumulates as organic N in the soil and some may be gradually lost to the environment. Losses may occur even in winter and early spring when the soil is cold with apparent low biochemical and biological activity (see Chapter by Chantigny et al.). Loss of N from soil as nitrous

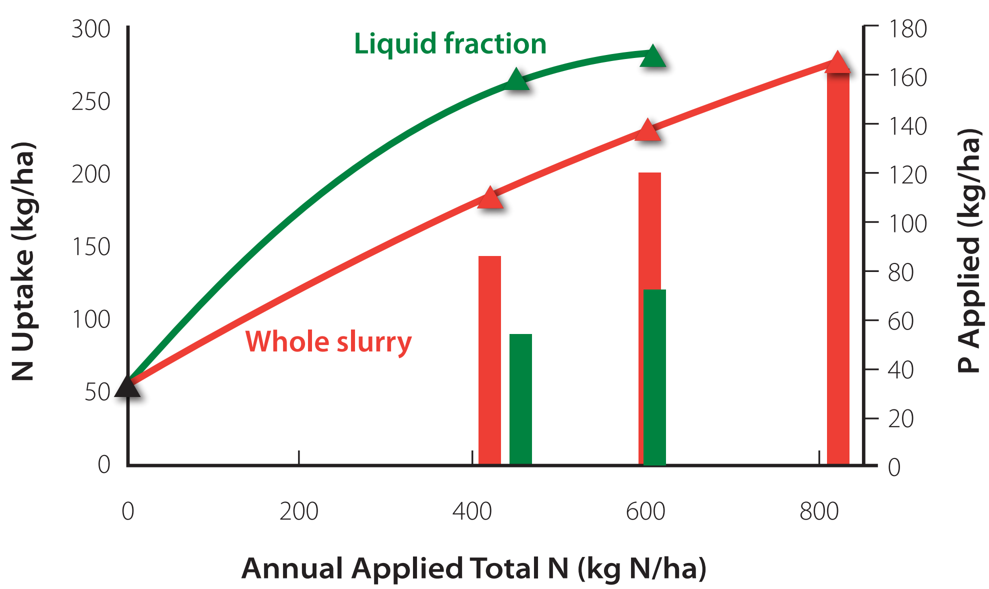

Figure 10. Annual N uptake by tall fescue receiving different N rates as whole (red) and separated liquid (green) dairy slurry (curves) for 8 years. The bars show annual P application rates (loadings) at the respective N application rates of the whole (red) and separated (green) manures. (for lb/ac multiply by 0.9).

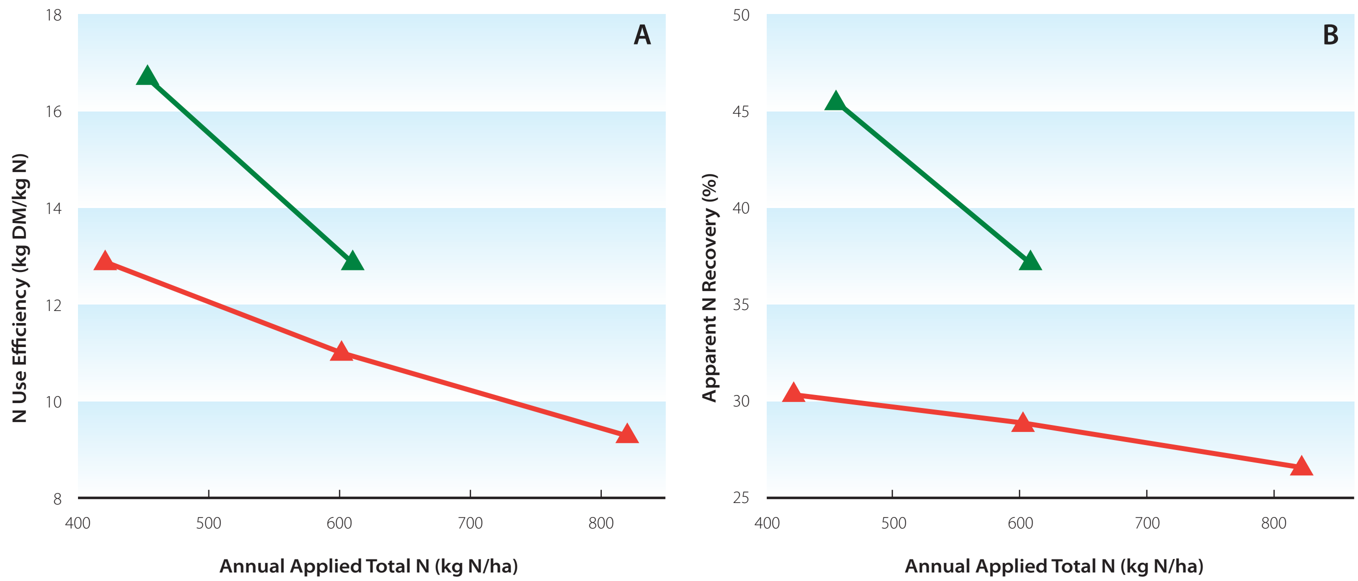

Figure 11. N use efficiency (A) and apparent N recovery (B) of tall fescue at different rates of N applied as whole (red lines) and separated (green lines) liquid dairy slurry (for lb/ac multiply by 0.9).

oxide, thought to be the result mainly of microbial processes of nitrification and denitrification, occurs even in cool weather, sometimes in response to freezing and thawing cycles (Fig. 12).

The separated liquid fraction has a higher N: P ratio and contributes less than whole manure to P loading of the soil. The vertical bars in Figure 6 show that annual loading of P is almost double with whole as with separated manure at equivalent N application rates, and the P loading with whole manure is even greater when compared at equivalent rates of N uptake. To look at it another way, at given application rates of P, there is greater yield and N uptake with separated than with whole manure. At the low application rate of separated manure, there is very little surplus P (P applied—P uptake). Thus crops can produce reasonable yield with good protein concentration using only separated liquid manure, with much reduced environmental risk of P contamination.

Method 2B. Manure separation: solid fraction

Producing the separated liquid fraction can only be justified if there is a use for the thick (solid) fraction. The thick fraction inherently contains much of the P, C and organic N in the manure. The solid fraction contains less water compared to whole manure, so it is more easily transported off the farm or composted, but both options are not always possible or economic.

Corn is usually supplied with substantial quantities of commercial P fertilizer (up to 40 kg P/ha) (36 kg P/ha) by placing it near the seed at planting. This 'starter' P is used even in fields that test high in available P because on-farm experience and research often shows a benefit to corn when

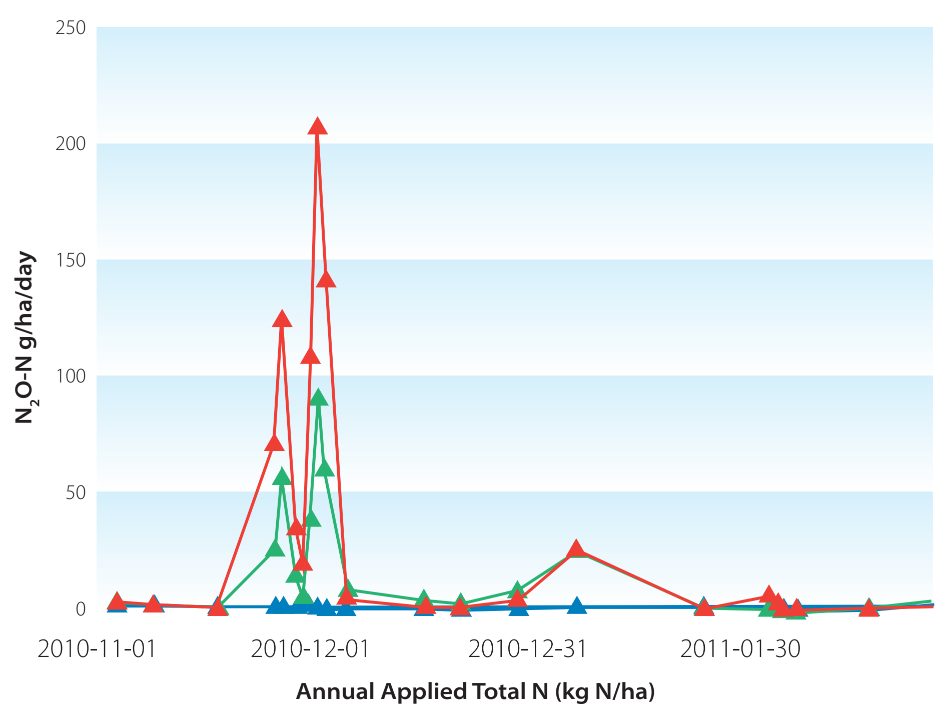

Figure 12. Winter-time emissions of nitrous oxide (N2O) from a grass field treated with whole (red) and separated liquid (green) dairy slurry, or left untreated (blue) in coastal British Columbia; the peaks coincide with freeze-thaw cycles.

Table 1. Response of of corn to separated dairy sludge placed at various distances from corn rows just prior to planting compared to equivalent rates of commercial P fertlizer applied as a sideband during planting.

Treatment	Total yield	Grain yield	Dry matter	Plant P concentration
	t/ha	*t/ha*	*%*	*ppm*
Control	8.15 d*	2.2 c	20.8 b	1.17 b
P fertilizer	15.6 bc	5.5 a	23.5 a	1.44 a
Sludge 0-cm	16.8 ab	5.8 a	23.2 a	1.48 a
Sludge 5-cm	17.0 a	5.9 a	22.9 a	1.44 a
Sludge 10-cm	15.0 c	4.9 b	21.6 b	1.49 a

* Means followed by the same letter were not significantly different ($P > 0.05$)
(for T/ac multiply t/ha by 0.45)

Figure 13. Using separated dairy sludge as a P source for corn in coastal BC. The sludge is injected at corn row spacing (A) and a few days later the corn is planted near the sludge furrows. The position of the sludge furrows in a growing corn crop is shown by the yellow lines (B).

the plants are small. Poor uptake of P by juvenile corn plants is probably due to the limited root system and in some cases to poor colonization of roots by fungi called arbuscular mycorrhizae (AM) that help corn take up P (see *Advanced Silage Corn Management* book on www.farmwest.com). Colonization by these fungi is hard to predict or assess in a timely manner, but poor colonization often results from intense tillage, certain preceding crops, flooding, and other factors. Farmers frequently report more vigorous early growth and advanced maturity at harvest when they use starter P, and this is probably true even with well colonized corn plants.

We tested the possibility of using the separated sludge fraction from settled dairy slurry manure to replace fertilizer P (Bittman et al. 2012). The method involved injecting the sludge at corn row spacing (Fig. 13A) and a few days later, precision-planting the corn near the injection furrows. The corn responds well to the starter sludge with little evidence of reduced plant emergence or injury (Fig. 13B).

Our results indicate that separated sludge can be used to fully replace commercial P fertilizer for corn provided that it is applied close to the corn rows (less than 10 cm or 4 in) (Table 1). There was no loss of whole plant yield, grain yield, dry matter content at harvest or P concentration at harvest from the injected sludge compared to the same rate of commercial fertilizer P side-banded with the planter at 5 cm (2 in) to the side and 3 cm (1.2 in) below the seed. This advantageous end use for the solid fraction provides further justification for applying separated liquid fraction to grassland.

References available online at www.farmwest.com

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