



CHAPTER 32

Long Term Effects of Manure

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Long-term effects of low-emission applications of dairy slurry on perennial forages

Manure is an important source of N fertilizer. Applying dairy slurry in narrow bands on the soil surface beneath grass canopies is known to reduce emissions of ammonia and to improve the yield and N use efficiency of grass stands (Webb et al. 2010). With the banding application method, slurry manure can be used to replace commercial N fertilizer at equivalent application rates of mineral N, without sacrificing crop yield or protein concentration (see chapter above). But what is the long-term fate of N from repeated doses of slurry manure spread using a low emission applicator? Can application rates be eventually lowered due to the mineralization of cumulative organic N from previous manure applications? And is the practice of repeated applications of manure sustainable?

We carried out a multi-year study in south coastal British Columbia (BC) to assess the long-term implications of

applying dairy slurry on a tall fescue (*Festuca arundinacea*) stand with a low emission sliding shoe applicator (Bittman et al. 2007). The climate in the region is mild and wet with a dry summer period. The slurry was obtained from a local high-producing dairy farm which uses wood-chip bedding. Nutrients were applied in equal doses, four times each year at (nominal) annual total-N rates of 200 and 400 kg/ha (180 and 360 lb/ ac) for fertilizer (ammonium nitrate) and 400 and 800 kg/ha (360 and 720 lb/ac) for manure. There was also a treatment called 'Alternate' (ALT) in which the high rates of manure and fertilizer were alternated each application for a total annual N application rate of 600 kg/ha (540 lb/ ac). The manure contained about equal amounts of readily-available inorganic N (mostly ammonium) and less readily-available organic N so that the amount of available N was similar for manure and fertilizer at both the low and high rates of each. Recovery of N by the crop was calculated from the yield and N concentration of the herbage which was harvested four times each year.

Table 1. Fate of N from applications of commercial fertilizer and dairy slurry spread with a low emission applicator on tall fescue over seven years in coastal BC. The blue shaded rows have the same application rate of total N (400 kg/ha) (360 lb/ac). 'Alternate' refers to alternating applications of manure and commercial fertilizer (from Bittman et al. 2007) (for lb/ac multiply by 0.9).

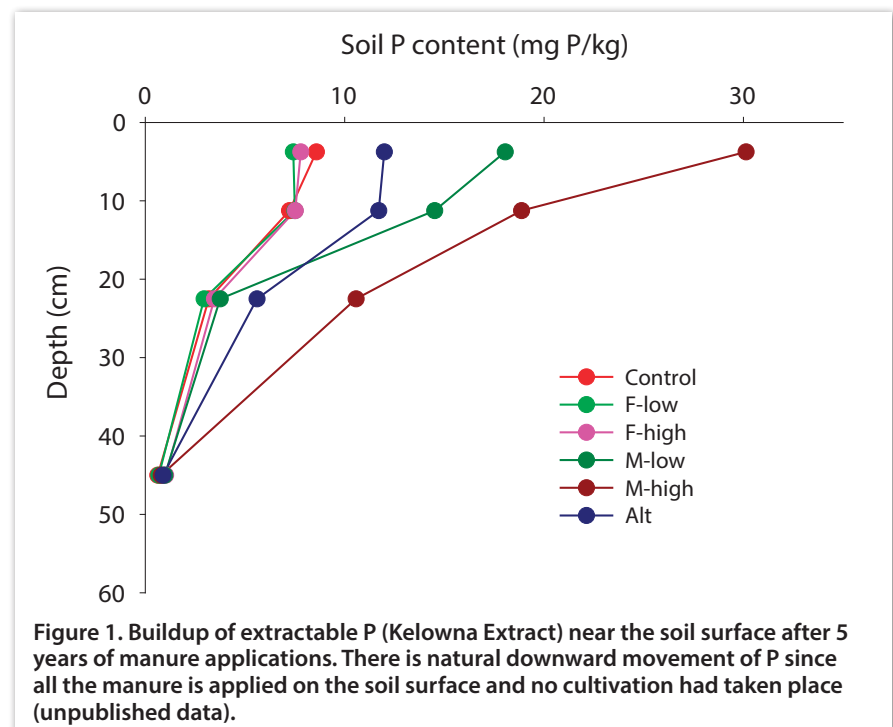
TREATMENT	Mineral N applied	Total N applied	N Recovered by crop	N Remaining in soil	Unaccounted N
	kg/ha		% of total N applied		
Fertilizer-low	200	200	67.1	22.4	10.5
Fertilizer-high	400	400	58.7	14.3	27.0
Manure-low	200	400	42.0	32.0	26.0
Manure-high	400	800	37.4	30.2	32.4
Alternate	400	600	53.3	23.1	23.6

We found that the proportion of applied N recovered by the tall fescue crop was much higher for applications of fertilizer (59-67%) than for applications of manure (37-42%) (Table 1). As expected, the higher rates of recovery were associated with the lower application rates for both fertilizer and manure, and this reflects the fact that the higher application rates were approaching the asymptotic portion of the response curves. Recovery of N by herbage treated with alternate doses of manure and commercial fertilizer was almost as high as for herbage treated with commercial fertilizer. There was ample time in this study for much of the organic N in the manure to mineralize and become available to the crop. However, we found that 30-32% of the entire N applied in manure, or more than half of the applied organic N, remained in the soil in the organic form. In contrast, a much smaller proportion of the applied fertilizer N remained as organic N in the soil; this additional organic N in the soil was probably derived from roots and residue from crops whose growth was enhanced by the commercial fertilizer. The results show that under the mild and moist conditions, despite the potential for high rates of mineralization, much of the organic manure N was sequestered in the soil. The experiment will continue in order to determine if and when an equilibrium point will be reached when soil N no longer increases and more organic N will become available to the crop.

About 11-27% of applied fertilizer N and 26-32% of applied manure N was not accounted for in the crop or soil and must be assumed to be lost to the environment. For manure applied with the sliding shoe, about 20% of mineral N or about 10% of

total applied N might be expected to be lost as volatilized ammonia after application, compared to only about 5% of the ammonium nitrate fertilizer. On the other hand, from lysimeter measurements we have taken on this trial (not shown), more N was lost by nitrate leaching from applications of commercial fertilizer than from manure. The remaining unaccounted N was probably lost as nitrous oxide and N₂ via denitrification and perhaps also nitrification, and by leaching of organic N. Some of the losses probably occurred in winter when the crops were relatively dormant (see Chapter 21).

In contrast to the rapid decline in pH with repeated applications of ammonium nitrate fertilizer, soil pH remained stable with applications of manure thanks to additions of Ca and Mg. However, there is concern about buildup of





Ploughing of long-term manure trial.

other nutrients from repeated applications of manure at rates designed to meet crop N needs. In particular there is the probability that P (Fig. 1) and Zn will accumulate in soils. It will take years of manure application on this particular soil for its capacity to fix P to be exceeded, so no loss of P to water is expected in the foreseeable future. Nevertheless, the buildup of P in soils is not always stable and, by definition, is not sustainable as this P must be replaced in the food production chain with P extracted from mines. The buildup of nutrients can be reduced by applying a mix of fertilizer and manure (e.g. ALT treatment in Fig. 1) and this treatment also had better crop N use efficiency than manure alone. Another strategy for improving use of all nutrients in manure is solid-liquid separation which is described in the chapter above.

Release of mineral nitrogen and nitrous oxide when grass stands are terminated

Nitrogen losses tend to be lower from grassland soils than from arable soils because grassland soils generally contain less nitrate which is prone to leaching and denitrification. Grasses can efficiently capture soil nitrate as it becomes available from nitrification of soil ammonium or from application of fertilizers. The efficiency of N scavenging by grasses can be attributed to their extensive root systems,

year-round ground cover and long growing season. While the concentration of mineral N is low, organic nitrogen and carbon often accumulate in grassland soils due to continual turnover of roots and plant residue, and to the low level of soil disturbance which is limited to the activity of invertebrates and small vertebrate animals. There is a greater buildup of soil organic N when grass stands are fertilized with N, especially as manure (see above). What happens to the N locked up in soil organic matter and crop biomass when a grass stand is terminated in preparation for replanting?

We conducted a study to examine release of mineral N from the soil and emission of nitrous oxide after termination of a multi-year stand of tall fescue that had received annual doses (400 kg N/ha or 360 lb N/ac) of fertilizer and dairy slurry manure as described in the chapter above. The dairy slurry was applied by surface banding with a drag shoe applicator to minimize ammonia-N loss and to ensure that applications were uniform. The grass was harvested four times each year. Grass was terminated in two ways: by conventional tillage (mouldboard plough) or by application of glyphosate (Roundup®) herbicide. We examined the effect of stand termination on soil nitrate in two ways: with conventional soil testing and with anion resin strips. The anion strips act like roots and soak up any released nitrate before it can be transformed, absorbed by crops and

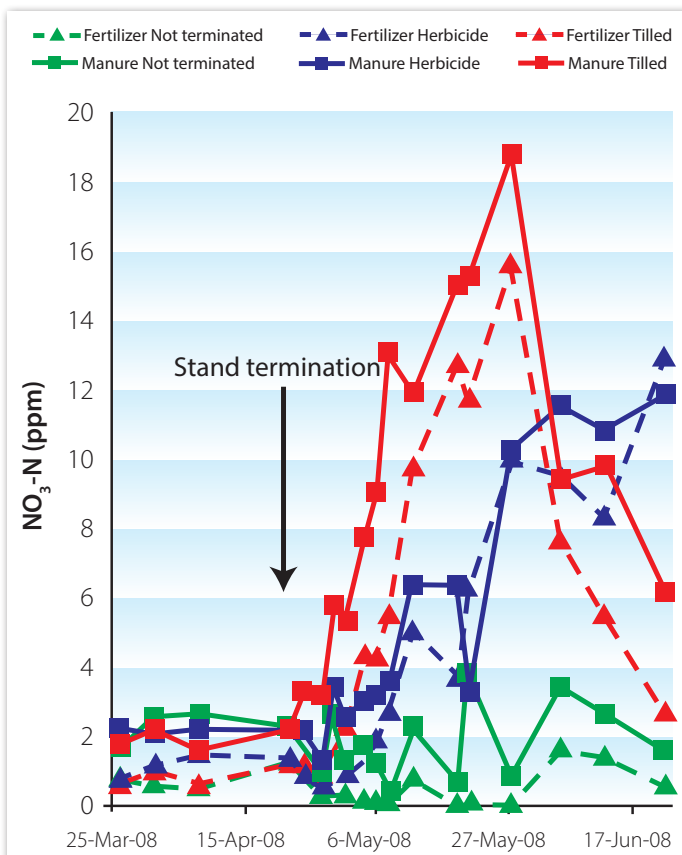


Figure 2. Soil nitrate concentration in the top 15 cm (6 in) of soil (in ppm) before and after termination of a stand of tall fescue with herbicide (blue lines) and tillage (red lines) or not terminated (green lines). Nutrients were previously supplied for many years as fertilizer (dashed lines) or dairy manure (solid lines) (unpublished data).

microbes, or lost by leaching and denitrification.

Conventional soil testing showed that the soil nitrate concentrations were low before stand termination, and for the un-terminated stands, remained low over the 89-day test period irrespective of previous nutrient applications although values for manured plots were slightly higher than fertilizer plots (Fig. 2). The cumulative soil nitrate values of un-terminated plots using resin strips were also higher for the manured than the fertilized plots, but the overall low values for the undisturbed soil indicate that relatively little nitrate was released from the organic N pool despite many years (>15) of manure and fertilizer applications and the mild and moist conditions typical of this region (Fig. 3). This inference cannot be made from the soil concentration values as released nitrate is continually taken up by the living crop and soil microbes, so the amount of released nitrate cannot be determined by soil analysis. Note that Figures 2 and 3 have qualitatively different y-axis scales.

Stand termination with both tillage and herbicide application caused a release of significant amounts of nitrate into the soil in plots receiving both manure and commercial fertilizer (Fig. 2 and 3). Elevated soil nitrate concentrations

relative to un-terminated stands were detected starting just three days after tillage and about ten days after herbicide application. The rapid increase suggests that, initially, some soil ammonium that would have been absorbed in that form by the grass plants was instead nitrified; there was insufficient time for organic N to decompose to ammonium and then nitrify. The rate of increase and eventual peak level in soil nitrate concentration was greater with tillage than with the herbicide treatment, indicating greater soil microbial activity to break down organic N, which is expected with mechanical disturbance of organic matter and soil aggregates, and with aeration of the soil. There was more cumulative nitrate (Fig. 3) in manured than fertilized soils after tillage but more cumulative nitrate in fertilized soils after herbicide. There did not appear to be a difference in soil nitrate concentration due to nutrient source after herbicide treatment (Fig. 2). This effect is still being explored but may suggest that there was a more active soil biota competing with the resin strips in the manured than in fertilized plots after treatment with herbicide and that this soil biota community was disrupted by tillage. There is

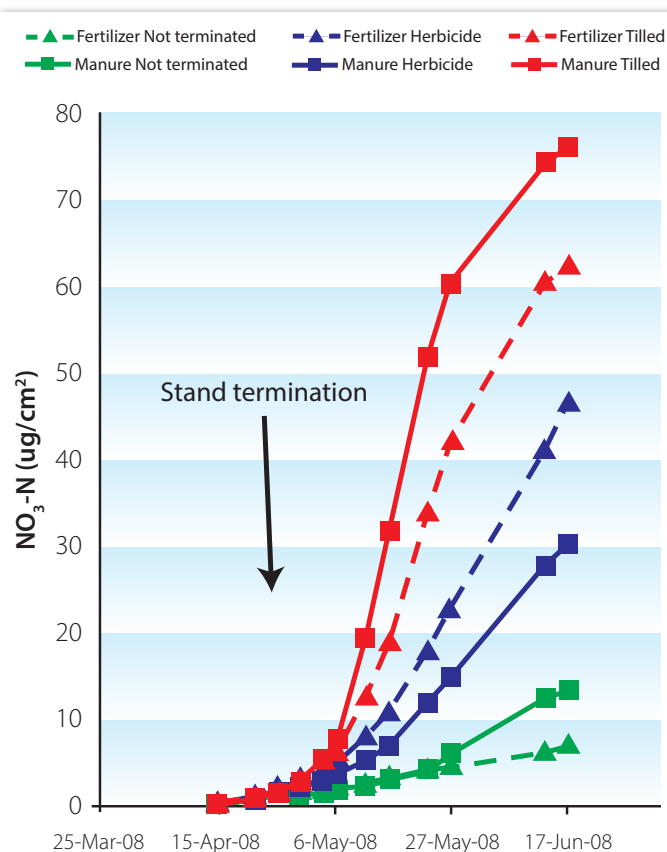


Figure 3. Cumulative values of soil nitrate (micro-grams per square cm of resin strip) before and after termination of a stand of tall fescue with herbicide (blue lines) and tillage (red lines) or not terminated (green lines). Nitrate accumulation was measured with soil resin strips inserted in the top 6 cm (2.5 in) of soil over two week intervals. Nutrients were previously supplied as fertilizer (dashed lines) or dairy manure (solid lines).

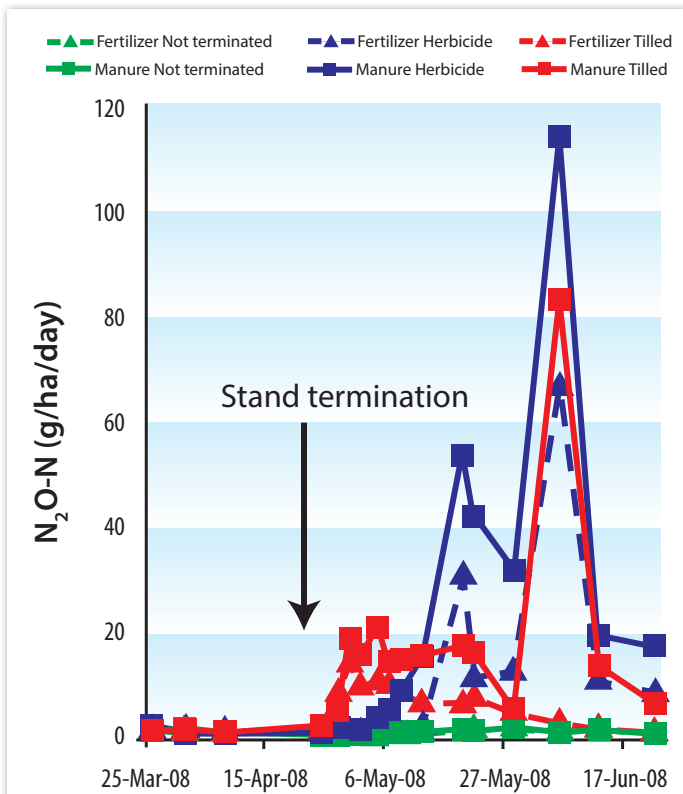


Figure 4. Daily emissions of nitrous oxide (grams N_2O-N / ha) after termination with herbicide (blue lines) and tillage (red lines) herbicide treatment of a multi-year tall fescue stand treated with fertilizer (dashed lines) and manure (solid lines). The control treatment (green lines) was not terminated (unpublished data).

obviously a greater risk of nitrate leaching after mechanical treatment, especially from manured soils, so where there is concern about nitrate leaching, termination of stands with herbicides followed by no-till seeding might be a better choice than tillage. Rapid replanting with a vigorous crop would also be helpful.

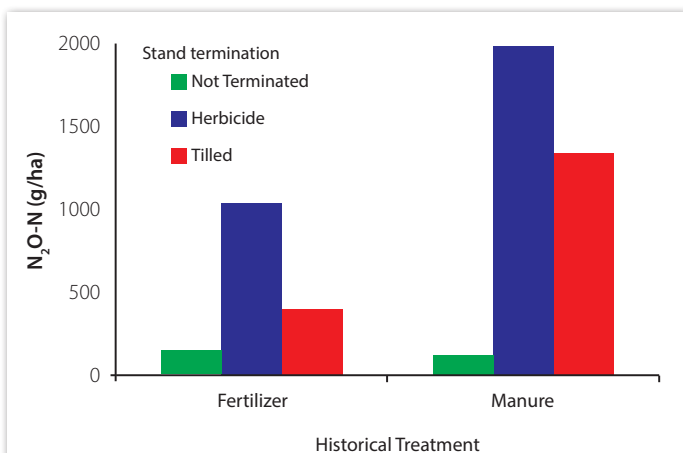


Figure 5. Total emissions of nitrous oxide (grams N_2O-N / ha) in the 62 day period after termination with herbicide (blue bars) and tillage (red bars) of a tall fescue stand treated with fertilizer and manure. The control treatment (green bars) was not terminated (unpublished data).

There was little emission of nitrous oxide prior to stand termination from any of the treatments and this is expected as concentrations of soil nitrate were low (Fig. 4). Low emissions continued for the control (un-terminated) grass throughout the experimental period, regardless of previous nutrient applications. Again, this is expected with the low levels of soil nitrate concentrations that were observed. However, emissions increased sharply within six days after tillage and about 14 days after the herbicide treatment. This pattern mirrors the release of nitrate, which was faster and greater for tillage than for spraying. However, starting about one month after stand termination, emissions were much greater from the sprayed areas than from the tilled areas, even though soil nitrate was lower for the sprayed areas at this time. These results suggest that the less aerobic conditions on the undisturbed, sprayed grass favoured emissions of nitrous oxide and provide evidence that much of the nitrous oxide originated from denitrification rather than nitrification. There were generally greater emissions from stands that had been treated with manure than with fertilizer, but emissions were insignificant regardless of nutrient history when the stand was not terminated (Fig. 5).

The results suggest that it is probably poor practice to leave sprayed areas untilled for more than two weeks after seeding and if seeding will be done after spraying, without tillage, then this should be done very soon after spraying. The emission associated with stand renovation should be allocated to the annual emissions attributed to application of manure or commercial fertilizer according to frequency of renovation.

An unexpected benefit from manure applications: reduced cadmium concentrations

Cadmium (Cd) is a toxic trace element and movement of Cd into the food chain is a significant concern for human health (Meeus et al. 2002). The total Cd intake by humans is a function of Cd concentration and quantity of food consumed, and the Cd consumption should not exceed 70 ug/day. The tendency to accumulate Cd in edible parts of plants varies among plant species (Grant et al. 1998). Food crops such as sunflower, durum wheat and rice are considered Cd accumulators and their Cd concentrations may exceed safe levels even when grown on uncontaminated soils. While sunflower seed is not a major component of human diets in most regions, it serves as a good indicator crop for Cd uptake.

Uptake of Cd is influenced by soil conditions including available Cd, pH, cation exchange capacity, abundance of arbuscular mycorrhizal fungi, organic matter content and availability of competing ions (Grant et al. 1998). The Cd concentration in agricultural products may be reduced by reducing Cd inputs to soil and by reducing Cd uptake by crops through improvements of soil conditions and changes

in agricultural management practices. For example, since commercial P fertilizer can be a significant source of Cd to agricultural soils, minimizing application of P fertilizer can reduce Cd inputs to soil. Livestock manures are typically high in P concentration and may substitute for mineral fertilizers, but the long term effects of manure application on Cd concentration in crops is not

well known. Manure may increase Cd concentrations in plants through addition of N (Mitchell et al. 2000), effects on soil pH, and effects on concentration of other ions such as Zn. Although manure contains some Cd and other heavy metals, at equivalent application rates of N or P the amount of Cd input into soil with manure is usually less than with chemical fertilizer (Del-Castilho et al. 1993). We conducted a study to test the hypothesis that long-term use of dairy manure slurry rather than mineral fertilizers will lower Cd concentrations in a Cd-accumulator crop, namely sunflower (Bittman et al. 2010). The soil for this greenhouse experiment was taken from the long-term experiment, described above, in which manure and fertilizer were applied to tall fescue for several years (Bittman et al. 2007).

We found significantly lower Cd concentration in grains

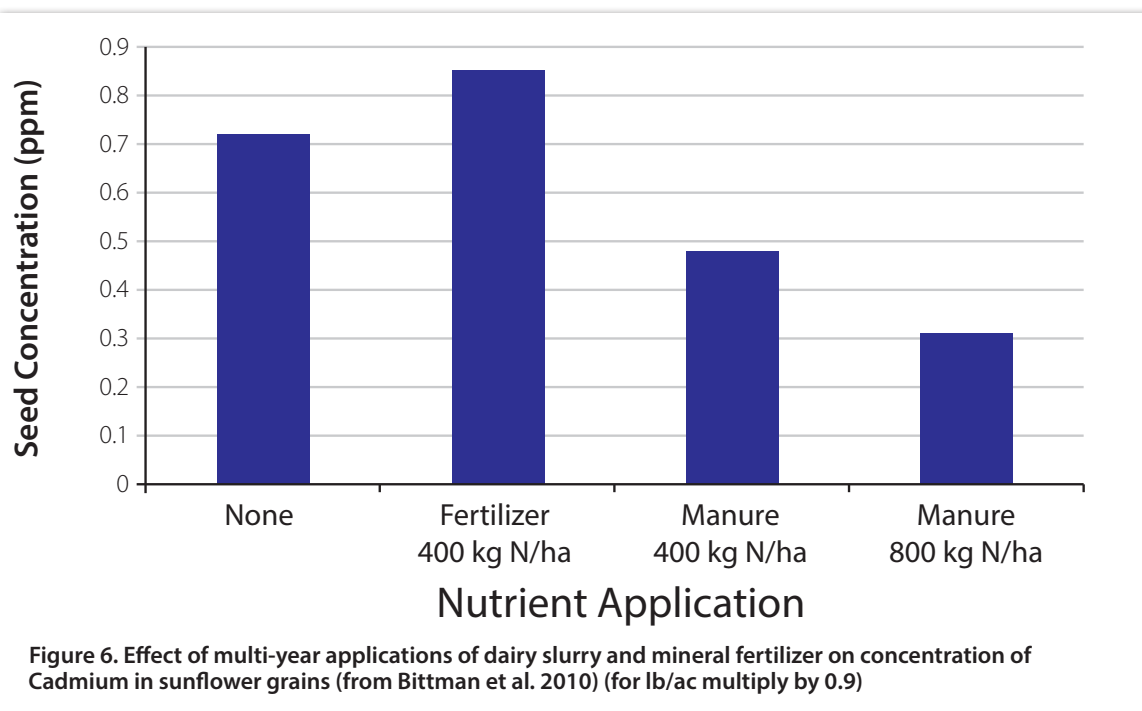


Figure 6. Effect of multi-year applications of dairy slurry and mineral fertilizer on concentration of Cadmium in sunflower grains (from Bittman et al. 2010) (for lb/ac multiply by 0.9)

of sunflowers grown in soils with a long history of dairy slurry application compared to soils that had received either fertilizer or no nutrients (Fig. 6). The most likely explanation is that elevated Zn in manure plots interfered with Cd uptake by plants, although other factors like pH and N availability may have played a role. This study supports the hypothesis that dairy manure may be a safer long-term source of P than mineral fertilizers where Cd accumulation is a concern. The study also suggests that soils with a long term history of manure application may be useful for growing Cd-accumulating crops that include staples such as durum wheat, potatoes and rice. Concentrations of Cd in soils that receive significant amounts of fertilizer P is likely to increase, especially as cleaner phosphate sources are preferentially depleted. On dairy farms, Cd is the toxic trace element at greatest risk of accumulation (Li et al. 2005); therefore, efficient recycling of manure P and limiting usage of commercial P fertilizer will help lower Cd loadings in soils. 🌱

References available online at www.farmwest.com

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