



## CHAPTER 33

# Manure on Alfalfa

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### Why in the world would anyone spread manure on alfalfa?

Good question, and although manure has higher value on non-legume crops, application to alfalfa can be beneficial and even necessary. In this article, we highlight research that demonstrates the benefits and risks associated with applying manure on alfalfa, and offer considerations for minimizing negative economic and environmental outcomes.

Many livestock farmers need more land on which to apply manure. A population density of dairy cows and heifers of only 1.8 animal units<sup>1</sup> (AU) per ha (0.7 AU/ac) will meet crop requirements for phosphorus (P) using manure (Saam et al. 2005). However, dairy farms in California, for example, have a median population density of 8 lactating cows per ha, equivalent to 11.4 AU/ha (4.6 AU/ac) (Powell et al. 2010). Even in Wisconsin, where dairy enterprises are relatively small, 75% of the farms lack sufficient annually tilled (arable) land to avoid excessive accumulation of P in the soil (Saam et al. 2005). Moreover, land on some farms is too far from livestock facilities to allow economic manure applications. While exporting manure to nearby farms can be a solution, suitable farms are not always available (Russelle et al. 2007a). In regions with high livestock populations, a least-cost and sometimes necessary option is to apply manure to alfalfa and other forages (Brewin et al. 2008).

1 An animal unit is defined as 1000 lb, or 454 kg, live weight.

But land area is not the only constraint on manure application. Livestock farmers also face the problem of timing, which arises from the combination of inadequate manure storage, insufficient time or suitable conditions to empty the storage between harvest and planting of annual crops, and restrictions to spreading on frozen soils and near water bodies due to the dangers of water contamination with nitrates and other pollutants in manure (DEFRA 2009). Perennial grass and legume crops provide mid-season windows of opportunity to apply manure during the growing season.

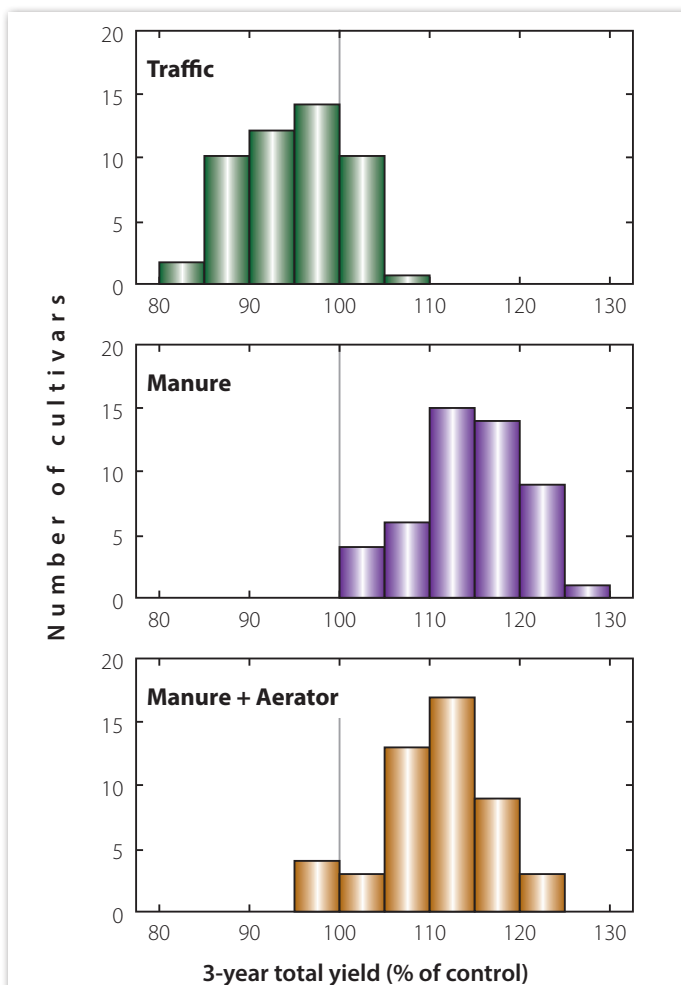
### Benefits

Obviously manure provides the highest returns when applied to crops that need the most additional nutrients. Since alfalfa typically removes more K, P and S than grain crops, ample nutrient additions are needed to support economically-efficient yields. Nutrient needs on pasture are generally lower than on ungrazed land (Wilson et al. 2011) and soil tests or plant tissue tests can indicate whether nutrient applications are necessary (Anonymous 2006).

Although originating from plants, manure is not a balanced source of N, P and K for plants; meeting N or K needs will result in rising soil test P levels and this is a common problem on livestock farms (Bittman 2009). Whereas grass in pure stands or in alfalfa mixes responds to N, alfalfa

generally will not (Ketterings et al. 2008). Like other plants, legumes efficiently absorb inorganic soil N (ammonium and nitrate), but absorbed soil N in legumes results in an equivalent reduction in symbiotic N fixation. Variability in manure N supply does not affect alfalfa as much as non-legume crops; in effect legumes help buffer N availability on farms by reducing or increasing symbiotic N fixation with no change in forage production (Russelle et al. 2007b).

The deep alfalfa roots also help reduce environmental degradation by capturing nitrate that leaches beneath the root zone of other forage and annual grain crops. However, the capacity to absorb inorganic N is limited to the total crop need, or perhaps about 80% of that requirement because of internal recycling of N in the plant (Lamb et al. 1995). Alfalfa has a high N requirement as evidenced in an experiment where high rates of hog manure were applied to alfalfa and timothy over 5 years. Residual nitrate in the 1.5-m (5-ft)-deep soil profile was 60 to 75% less under alfalfa than under timothy (calculated from Olson and Papworth 2006). So without reducing farm nutrient imports, applying manure to alfalfa may reduce N losses from the farm.



**Figure 1.** Distribution of 3-year total yield of 49 alfalfa cultivars treated with tractor traffic, broadcast manure slurry (50 m<sup>3</sup>/ha or 4500 gal/ac twice per year), or broadcast slurry plus tine aeration (based on Bowley et al. 2009).

### Timing of manure application

The best time to apply manure to alfalfa is before planting on medium- to fine-textured soils. Generally 2 to 3 years' worth of P and/or K can be applied provided that the manure is not too dilute or high in N, such as the liquids from non-agitated swine lagoons, since this presents a risk of leaching (Lory et al. 2000). Also, sandy soils, especially under irrigation, present a high risk of nitrate leaching loss so it is inadvisable to apply manure with high ammonium-N concentration before planting on these soils. In such cases, a companion crop may help limit nitrate losses, provide mid-summer feed, and still leave sufficient P, K and other nutrients to benefit the alfalfa. Note that manure applied before planting alfalfa must be mixed thoroughly in the soil to avoid seedling damage.

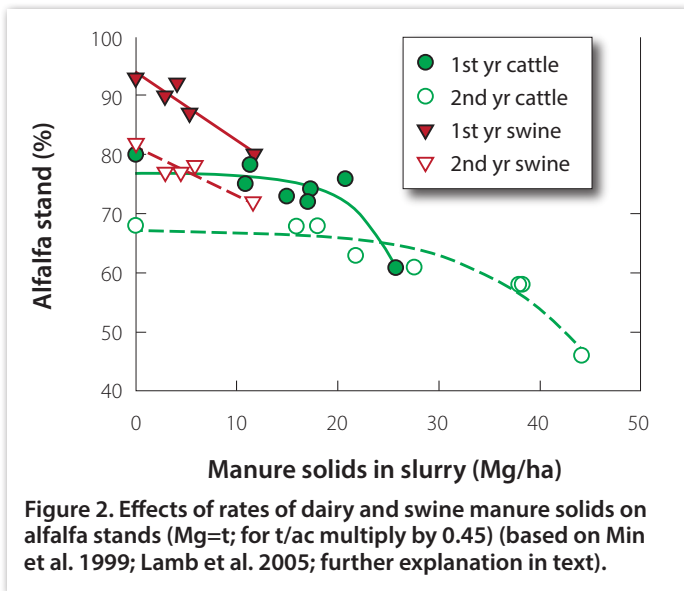
Manure is sometimes applied to old alfalfa stands to minimize yield loss due to stand thinning and to promote the growth of non-legume species. But soil N mineralization increases in older stands due to the accumulated soil organic matter with low C:N ratio, and these stands, unless consisting of significant amounts of grass, are prone to high soil nitrate which may be lost through leaching (Entz et al. 2001).

Although manure application shortly before alfalfa termination is common (Russelle 1997), this practice can result in very high levels of soil N that will exceed the need of the following crop (Lawrence et al. 2008). The risk of leaching is less with broadcast manure due to ammonia losses (Russelle et al. 2008), or with manure containing a high C:N ratio, which immobilizes N (Russelle et al. 2009). Manure is better utilized when applied to growing alfalfa.

Manure application, especially with tankers, involves heavy traffic on fields which can compact the soil and decrease plant vigor and population by direct damage to plants or by facilitating entry of pathogenic organisms into plants. Traffic three days after harvest decreased average alfalfa yields by 5% (Fig. 1; Bowley et al. 2009), and when manure was applied to alfalfa regrowth 9–11 days after harvest, yield in tire tracks declined 32–41% (Brown 2007). Flotation wheels decrease the amount of direct plant damage and soil compaction, but may not lessen stem breakage, especially if traffic is delayed (McBride et al. 2000).

### Broadcast application after harvest

Surface broadcast is the dominant method of manure application for alfalfa and other perennial forages in North America. Slurry that is broadcast-applied to alfalfa can improve yield, but excessive application rates may cause scalding, smothering, leaf coating and traffic damage. Coating leaves with manure causes scorching by increasing leaf temperature (Barrington et al. 1987; Wightman et al. 1997), and leaf burn is caused by high concentrations of dissolved salts like Na, K, or ammonium ions, so the crop is at greater risk when the leaf area begins to increase after



harvest. Manure solids can also seal soil pores, reducing oxygen and carbon dioxide exchange and increasing leaf temperature, resulting in scorch. An upper limit of 28 m<sup>3</sup>/ha (3000 gal/ac) has been suggested to avoid stand damage, based on typical manure characteristics (Ketterings et al. 2008). However, the application volume is less important than the rate of applied solids, the concentration of salts and ammonium, the source of manure and the weather conditions after the slurry application.

There are too few reports to draw firm conclusions about safe manure rates to avoid smothering due to coating alfalfa leaves with manure solids, and the answer may depend on the type of manure. For example, a recent study showed that rates of pig slurry exceeding 27 m<sup>3</sup>/ha (2900 gal/ac) with 12% solids (solids at 3300 kg/ha or 2950 lb/ac) were detrimental to alfalfa (Lamb et al. 2005). In the first study year there was no rain for more than a week after slurry application and the stand was damaged, but no damage occurred in the second year, when 63 mm (2.5 in) of rain fell the week after application suggesting the importance of the rain (Fig. 2). No loss of alfalfa yield occurred when irrigation immediately followed swine manure slurry applied at 4400 kg solids/ha (3930 lb/ac) (Salmerón et al. 2010).

In contrast to swine manure, dairy manure slurry applied at a low rate immediately after harvest to alfalfa growing on a fine sandy loam soil had no adverse effect on yield in a humid climate. Yields declined 15% after applying slurry at an estimated rate of 11,000 kg/ha (9800 lb/ac) solids, very high application rates chosen to challenge the crop (Daliparthi et al. 1995). The yield decline occurred in only one site in a particularly dry year, and yield loss occurred in a nearby site under similar conditions. Crusting of manure solids was observed in another study where 12,500 kg/ha (11,200 lb/ac) were applied following the third forage harvest (Min et al. 1999). Stand losses increased with a second year of high rates of broadcast manure (Fig. 2) but yields did not decline,

perhaps because of compensatory growth. Rain or irrigation soon after application will help rinse solids from the foliage, but increases the risk of surface runoff and/or leaching. Risk of nutrient runoff during snowmelt is exacerbated if manure has been applied to alfalfa during winter (Young and Mutchler 1976). Runoff losses appear to be higher during snowmelt for manure applied to the soil before snowfall, but if rain causes the runoff, manure applied on top of snow could cause higher losses (Williams et al. 2010). There is always a risk of losses from wintertime broadcast manure application onto perennial forages.

The issues of ammonia losses and odors after broadcast manure application are not dealt with here.

### Alternatives to broadcast application

Concerns about odor, gaseous emissions, feed contamination and runoff of nutrients and pathogens from broadcast manure have led to exploration of alternative application methods. Because forage stands are easily damaged by soil disturbance and wheel traffic, improved application methods are limited to shallow injection and surface banding with drag-shoe or trailing-foot with or without tine aeration. These methods reduce the potential for pathogen contamination and plant damage from smothering or leaf burn because manure is applied in narrow bands directly into the soil or on the soil surface, underneath crop canopy, thereby limiting direct contact of foliage with manure. Other possible benefits are reduced odor, nutrient runoff and gaseous emissions. These benefits need to be balanced against the potential for stand or yield loss from soil disturbance and mechanical damage to plants. Damage of application tools has been examined on grass forages, mostly in Europe (e.g. reviews Maguire et al. 2011; Webb et al. 2010), but research on alfalfa is limited.

A Greentrac<sup>2</sup> shallow injector performed well on grass and a bromegrass-alfalfa mix at a swine manure application rate of 37 m<sup>3</sup>/ha (3960 gal/ac), but not at rates of 74 m<sup>3</sup>/ha (7900 gal/acre) or higher (Hultgreen and Stock 1999). Swine manure applied with either the Greentrac injector at 5-cm (2-in) depth or a modified PAMI (Prairie Agricultural Machinery Institute) low-disturbance injector at 12.5-cm (5-in) depth increased yields and protein content of alfalfa on a nutrient-deficient site, but these treatments produced no effect or a slight decrease in yield when soil nutrient levels were adequate (PAMI 2001). Some root damage was noted after manure injection.

A rolling tine aerator implement is designed to ‘aerate’ the surface soil by creating narrow slots that cause minimal soil disturbance and damage to the plant crowns or roots (Bittman et al. 2005). Aerators have been combined with

<sup>2</sup> Mention of trade names or commercial products in this report is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

liquid manure application in a variety of configurations — before or after manure application, with manure broadcast or applied in narrow bands directly over aerator slots, and with varying aerator tine angle (0–10 degrees) to adjust the amount of soil disturbance and size of slots created.

In an Ontario study, liquid dairy manure was applied twice annually to 49 alfalfa cultivars at 50 m<sup>3</sup>/ha (5350 gal/ac) for 3 years; applications were after first and second harvest in a 3-harvest system (Bowley et al. 2009). Manure was applied in 8-cm (3-in) wide bands spaced 19 cm (7.5 in) apart, either directly behind aerator tines or without an aerator. Alfalfa yields over 3 years were increased 10% by aerator-manure application and 14% with manure alone compared to the no-manure control (Fig. 1), implying that the aerator slightly reduced the yield response to manure. The authors suggested that this may be the result of increased manure-root contact by infiltration of manure into the aerator slots. If so, manure composition may be important in affecting alfalfa yield response with an aerator. These investigators made the important observation that some alfalfa cultivars had much larger yield responses to manure than others. They also reported, based on earlier work, that negative yield effects from aeration were reduced if the manure-aeration was done closer to harvest (2, 7, and 9% yield decline for 2, 4, and 6 days after harvest, respectively).

Similar results were observed in other Ontario experiments in which aerator-manure application increased alfalfa yields less (9%) than manure alone (16%), averaged across three sites (two with manure following the aerator and one with manure before; Brown 2007). No yield decrease was noted from aerator alone, even though damage to crowns and less vigorous regrowth were observed.


Another trial conducted for only one growing season in Minnesota compared liquid dairy manure broadcast on third-year alfalfa with or without incorporation by an aerator or with the aerator alone (Hansen and Fuchs 2003). Manure application had no effect on yields at either of two sites, whereas aerator alone decreased yield at one site. Runoff from rain simulation was evaluated at one site. Treatment did not affect runoff volume, but manure application increased losses of dissolved N, dissolved P and total P, and increased biological oxygen demand in the runoff, both with or without aeration.

We found no other research evaluating environmental effects of manure plus aerator application on alfalfa. Extensive work in British Columbia with banded dairy manure-tine aeration, termed Sub-Surface Deposition, on tall fescue/orchardgrass has shown close to 50% reductions in ammonia emissions, 50 - 90% lower surface runoff losses of sediment, N, and dissolved P, and significant reductions of odor (Bittman et al. 2005; van Vliet et al. 2006). Others have found ammonia emissions were not reduced by aeration before or after broadcasting dairy manure on mixed grass and red

clover but in these studies the manure was broadcast rather than banded (Gordon et al. 2000). Effects on runoff and P losses from aeration of broadcast manure on grass forages have been inconsistent or have varied with soil drainage class (summarized by Maguire et al. 2011). Although the principles should be applicable to alfalfa, the extent of these effects might vary because of differences in plant growth pattern and stand density between alfalfa and grass forages.

Surface banding of manure on alfalfa with a drag-shoe or trailing-foot applicator is another option that could potentially provide environmental benefits and reduce forage contamination, and also cause less soil and plant disturbance than occurs with injection or tine aeration. We found no reports of research on alfalfa using drag-shoe/trailing-foot applicators. However, the results from Bowley et al. (2009), discussed earlier, showed alfalfa yield increases from manure band-applied using drop-hoses with fan nozzles. Extensive research with these techniques on grass forages in Europe and more limited work in North America has shown significant reductions in ammonia emissions and runoff N and P losses compared to surface broadcast application (Bittman et al. 2005; van Vliet et al. 2006; Pfluke et al. 2011; and reviews by Webb et al. 2010 and Maguire et al. 2011). It remains to be determined whether and how such application methods affect alfalfa yield, quality, and persistence, and the environmental outcomes.

## Conclusion

Many crop-livestock operations that produce a lot of alfalfa need to utilize alfalfa fields in their manure management plans. The advantages to manure application on alfalfa (ample uptake of P, K, S and other nutrients and nutrient uptake from depth) need to be considered in the context of some potential concerns — plant damage from manure or wheel traffic, pathogen transmission in the feed, nutrient runoff, and excessive N at stand termination. Some of these risks can be minimized by careful management, for example by spreading soon after harvest, avoiding traffic on wet soils, and avoiding application at stand termination if the N credit from the forage is adequate for the next crop. Several innovative liquid manure application methods offer promise to improve N utilization, minimize forage contamination, decrease nutrient runoff, and provide more uniform manure application. To a very large extent, however, the success of manure application on alfalfa depends on the specific conditions at the site and good decision-making by the manager. 

## References available online at [www.farmwest.com](http://www.farmwest.com)

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