Applications of Manure to Alfalfa: Crop Production and Environmental Implications

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ABSTRACT

Manure is increasingly being applied to alfalfa because of its ability to recycle nutrients including nitrogen, its potential to extract nutrients from significant depth, its capacity to withstand multiple applications, and environmentally may it be the best alternative available. Research studies show that preplant manure applications even at rates up to 30,000 gal/a did not adversely affect the alfalfa and in some cases significantly improved alfalfa growth more than equivalent rates of P and K fertilizer. Adequate weed control is the key to success in applying manure at this time. Applying manure as a topdress to established alfalfa increases risk of stand loss, but may be done successfully by restricting rates to 3000-5000 gal/a or 10 T/a per application, applying before regrowth starts, applying to the grassiest stands, and avoiding soil compaction during the spreading operation. Environmentally alfalfa has the potential to be a major manure-N sink, but may increase risks of runoff nutrient losses when topdressed especially on frozen soils.

Key Words: **manure, nutrient recycling, crop response, manure management**

INTRODUCTION

Applications of manure on alfalfa have historically been avoided due the perceived associated risks (palatability, weed invasion, compaction, and stand loss) and the knowledge that alfalfa typically does not respond to nitrogen additions from any source. Increased pressures to do systematic nutrient management planning, and related concerns over ground and surface water pollution are causing livestock producers to reevaluate their manure management strategies. There are several reasons why farmers and regulators are becoming increasingly interested in applying manure to alfalfa; these include:

Dairy farmers typically have a significant proportion of their land in alfalfa.

2. Alfalfa can recycle substantial amounts of nutrients including more than 300 lb N/a/yr.

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3. Alfalfa will preferentially use fixed N from the soil or applied nutrient sources before it expends energy to fix atmospheric N.

4. Alfalfa is deeply rooted so it may recycle some nutrients that otherwise could leach beyond the root zone of other crops.

5. Alfalfa may benefit from the nutrients other than nitrogen contained in the manure.

6. Forage cropland may be available for spreading during times of the year when other cropland is unavailable.

7. Manure applied to first-year corn following forage legumes often results in significant over application of N.

As noted in a recent Wisconsin publication on assigning priorities to fields to receive manure (Wolkowski et al., 1995), alfalfa fields may not be the best possible location for the manure, but they may be the best of what is available. A simplistic example is the choice between a preseeding application to alfalfa versus an application to first-year corn following alfalfa. In most situations, the former is the better choice since the legume credit by itself can usually meet the corn N needs. From both an agronomic and environmental perspective, manure use on alfalfa is an alternative that must be considered.

AGRONOMIC CONSIDERATIONS

Manure may be applied prior to seeding alfalfa or topdressed after harvest or at both times. Either choice results in some unique potential benefits and associated risks.

Preseeding Manure Applications

Yields

Several studies have been completed recently which examined the efficacy of forage legume pre-establishment manure applications. Table 1 shows results from a Minnesota study where hog manure (Rosemount) or dairy manure (Waseca) was broadcast and incorporated at three rates prior to the establishment of alfalfa. Three commercial fertilizer treatments were also applied at rates equivalent to the P and K contained in the manure. In both site-years at Rosemount the addition of manure resulted in significant increases in harvested forage yields, and these increases tended to be larger than the increases associated with the comparable fertilizer applications. This difference is possibly due to the "extra" nutrients such as N, S, and micronutrients applied with the manure or that actual manure nutrient quantities added were slightly higher than the amount added as fertilizer.

Table 1. Forage yields and estimated weed composition from first cuttings in the establishment year of alfalfa as affected by preplant incorporated manure or fertilizer.*

Treatments	Rosemount - 1989		Rosemount - 1990		Waseca - 1989	
	DM Yield	Weeds	DM Yield	Weeds	DM Yield	Weeds
	T/A	--%--	T/A	--%--	T/A	--%--
Control	1.62	5	1.01	11	1.36	3
Manure						
3000 GPA	1.79	6	1.58	11	1.45	5
6000 GPA	1.96	8	1.89	9	1.24	9
12000 GPA	1.62	9	2.05	9	1.30	12
Fertilizer						
Low+	1.60	2	1.22	8	1.48	7
Medium+	1.70	2	1.36	8	1.51	5
High+	1.76	9	1.59	6	1.58	6
Pr >F	0.01	0.37	0.00	0.22	0.00	0.04

*Adapted from Schmitt et al., 1993.
+The inorganic fertilizer rates were based on applying similar quantities of available phosphate and potash as the manure rates.

At Waseca, although increasing fertilizer rates increased yields on this low testing site (P = 8.5 ppm; K = 94 ppm), the manure did not increase yields. The combination of manure additions and large-scale application equipment created a severe compaction problem and increased weediness resulting in almost no alfalfa stand in the wheel tracks.

Wisconsin experiments have also shown improved seeding-year alfalfa growth associated with preplant manure applications (Table 2). The responses to manure or fertilizer applications at Marshfield were seen in all three years of the study, however, in two of the three years, the manure outperformed the fertilizer even where N was included. This provides some support to the suggestion that secondary or micronutrients contained within the manure may be providing benefit beyond that from the macronutrients alone. Previous work at this location observed seeding-year responses to S (Erickson et al., 1981). Somewhat surprisingly, this site also showed apparent responses to N from either fertilizer or the manure, whereas other experiments on this soil have not shown seeding-year N responses (Simson et al., 1981). It seems apparent that at least some of the benefit associated with preseeding manure applications is due to the N contained in the manure. A yield response by alfalfa to applied N is more common in the establishment year (Baldock and Musgrave, 1980; Peters and Kelling, 1989).

Table 2. Effect of manure or fertilizer treatments on seeding-year alfalfa yields at Marshfield, WI.*

Approx. manure or fertilizer rate	1988	1989	1990
	T/a		
Control	0.88	1.61	2.68
Manure			
12000 GPA	1.16	2.07	3.26
18000 GPA	1.07	1.91	3.31
24000 GPA	1.20	2.30	3.45
P & K Fertilizer+	0.98	1.79	2.46
N & P & K Fertilizer	1.25	2.10	2.86
Pr > F	0.05	0.00	0.02

*Adapted from Peters, 1991.

+Fertilizer treatments were equivalent to the low rate of manure without or with N, respectively.

Table 3 shows the residual effects of the manure or fertilizer treatments on the first full hay year of each of the previously cited studies and a Manitowoc Co., Wisconsin experiment where treatments of about 0, 7000, 14000 or 21000 gal/a of liquid dairy manure was injected after winter wheat harvest. At all three locations there is a clear tendency for higher yields where the manure was applied. Even more dramatic was the doubling of yields for the manure treatments at Manitowoc over the three-year-term of the experiment compared to the control. It also appears that while the fertilizer treatments may have been of some benefit, especially at the low soil-testing Waseca site, the manure treatments provided a greater response.

Weed Competition

In the Minnesota experiments at Waseca weediness was increased by the addition of both manure and fertilizer but was most severe at the high rates of manure (Table 1). Other researchers have similarly reported increased weed competitiveness resulting from nitrogen applications (Doll, 1962; Eardley et al., 1985). In some cases, the enhanced weed growth was partly offset by additional alfalfa growth (Kunelius, 1964). The Marshfield, Wisconsin experiments also showed that weed growth was enhanced by addition of manure or N-containing fertilizer, however, this effect did not persist as stand counts during the following years showed no treatment influences (data not shown).

Table 3. Residual yields (first full production hay-year) from manure or fertilizer treatments seeded during years shown.

Treatment	Minnesota*			Marshfield+		Manitowoc√
	Rosemt 89	Rosemt 90	Waseca 89	1988	1989	
	T/a					
Control	3.81	4.67	2.84	2.84	2.83	3.09
Manure						
3000 GPA	4.31	4.72	3.40			
6000 GPA	4.60	5.09	4.12	--	--	
12000 GPA	4.55	5.22	4.49	2.87	2.90	3.49
18000 GPA	--	--	--	3.06	2.94	3.24
24000 GPA				3.15	2.94	3.60
Fertilizer						
low	3.87	4.89	3.28	2.85	2.91	
medium	3.97	4.83	3.71	2.91	2.91	
high	4.17	4.80	4.57	--	--	
Pr > F	0.00	0.18	0.00	0.08	0.09	

*Adapted from Schmitt et al. 1993.

+Adapted from Peters 1991. Fertilizer treatments at Marshfield were equivalent to the low rate of manure without and with N, respectively.

√Adapted from Hendrickson and Miller, 1991. Yields measured for cuts 1, 2 and 4.

Several other studies have also noted this short-term flush of weeds when evaluating the influence of N treatments made prior to alfalfa seedings (Peters and Kelling, 1989; Peters and Strizke, 1970). In these cases, as with the Marshfield manure trials, the stimulation of weeds was restricted to the seeding-year.

Tissue Nutrient Accumulations

Table 4 shows the first cutting harvested tissue concentrations for N, P and K for the establishment year averaged across the 2 site-years in Minnesota and 3 site years at Marshfield. These data show that N concentrations were not increased significantly in the Minnesota study, but did increase about 25% with manure or fertilizer N application at Marshfield. This difference may be due to the greater proportion of annual weeds present in the Marshfield studies in this harvested material. In all cases, the P levels application of nutrients regardless of source. This is likely due to the relatively high

Table 4. Effect of manure or fertilizer applications on first cutting establishment-year alfalfa N, P, and K concentrations averaged across site years.

	Minnesota*			Marshfield+		
Treatment	N	P	K	N	P	K
	%					
Control	3.2	0.30	2.00	1.99	0.29	2.72
Manure						
3000 GPA	3.0	0.30	2.21			
6000 GPA	3.2	0.29	2.43	--	--	
12000 GPA	3.2	0.30	2.60	2.42	0.32	3.53
18000 GPA	--	--	--	2.39	0.32	3.84
24000 GPA	--			2.58	0.32	3.76
Fertilizer						
low	3.3	0.30	2.05	2.03	0.30	3.02
medium	3.1	0.30	2.27	2.55	0.31	3.69
high	3.1	0.29	2.54	--	--	--

*Average of 2 site years; adapted from Schmitt et al., 1993.

+Average of 3-site-years; adapted from Peters, 1991. Fertilizer treatments at Marshfield were equivalent to the low manure rate without and with N, respectively.

initial soil test P levels at these sites (Bray P_1 = 30-35 ppm at Minnesota and 38-42 ppm at Marshfield.

It is clear, however, that in both studies the addition of manure or fertilizer substantially increased tissue K levels even where yield responses were not observed. It is interesting to note that equivalent rates of manure or fertilizer resulted in about equivalent increases in tissue K. This supports previous work which showed very high availability (85-95%) of manurial K (Motavalli et al., 1989).

The accumulation of K from repeated manure applications and subsequent luxury consumption of K may be a factor which limits manure loading to alfalfa fields. As noted in the Marshfield study, tissue levels at times exceeded 4.5% K for the first cutting in the establishment year at the high manure rate where about 540 lb K_2O/a was applied. In the production years, concentrations generally remained above 3.5% K, especially for the first cutting. As has been discussed by Howard (1995) and Oetzel (1993), forages containing more than about 2.75% K may cause ration balance problems especially in dry cows and springing heifers. The high forage K levels makes ration balancing with respect to divalent cations such as magnesium and, to a lesser extent, calcium particularly difficult. Since manure applications at typical rates may supply several hundred pounds of K_2O, this nutrient will likely be over supplied. For example, the 12,000 gal/a rate used in both the Minnesota and Marshfield studies added about 360 and 270 K_2O/a, respectively. The problem may be exacerbated when manure is repeatedly applied to meet the N needs of the crop to be grown since the available N to available K ratio in dairy manure is typically about 1:2, and the ratio in crop tissue is about 1:0.8.

Topdressed Manure Applications

Several studies have shown that topdressed manure may be successfully applied to established alfalfa, but that care must be exercised to maintain the stand. At the University of Wisconsin Experiment Station at Marshfield, liquid manure somewhat diluted with parlor wastes was irrigated onto an alfalfa-grass field before green-up in the spring (Hensler et al., 1971). Manure was also irrigated on another field after first cut. Table 5 shows that manure either had no effect on yields or tended to decrease alfalfa-grass hay yields. Heavier rates of manure applied in the summer increased the percentage of grass or weed species at the expense of legumes. This did not occur with the spring applications because rains soon after the treatment reduced the manure's salt effect.

Table 5. Effect of liquid manure on alfalfa-grass yield and composition.*

	Yield		Composition (3rd cutting)		
Manure application rate	Dry matter	Protein	Alfalfa	Grass	Other
gal/a	T/a	lb/a	%		
		Spring			
0	6.0	2000	50	35	15
1200	5.7	1890	50	30	20
4800	5.4	1740	50	35	15
14600	5.4	1760	60	20	20
		Summer			
0	5.6	1800	45	45	10
1200	5.5	2760	35	50	15
4800	5.6	1730	30	55	15
14600	5.5	1660	5	75	20

*Adapted from Hensler et al., 1971.

Another Wisconsin study, with dairy manure (Table 6) shows that although preplant manure application may improve initial yields, subsequent topdressed manure applications decreased yields. The apparent recovery of yields for the topdressed plots in 1983 was probably due to increased weed growth. The wheel track areas from repeated applications were particularly affected. Crown counts confirmed that there was less alfalfa in the topdressed plots.

Table 6. Effect of preplant or top-dressed liquid dairy manure on alfalfa yields.*

Preplant Manure Rate	Alfalfa Yield			
	without topdress		with topdress+	
	1982	1983	1982	1983
gal/a	----- T /a -----			
0	3.32	5.19	--	--
5000	3.84	5.07	3.01	5.30
10000	3.86	5.40	3.09	5.35
20000	3.96	5.65	3.15	4.96

*Manitowoc County; data from S.R. Hendrickson (personal communication)

+Topdressed after each cutting at 1200 gal/a.

In other situations topdressing manure has provided some yield benefits. For example, data from the Minnesota studies show yields increased up to 30% over the control from topdress applications or that the applications effects were neutral (Table 7). The authors also noted more apparent bare spots within the high topdressed rate plots, but subsequent stand counts did not show significant differences. Timing of the topdress applications may influence the subsequent crop performances. In two separate studies where manure was topdressed in the winter on frozen soil, there was a tendency for yield improvements (Converse et al., 1976; Young and Mutchler, 1976) where manure was added.

Because of the potential production risks associated with topdressed manure application the following suggestions are offered.

1. Apply to fields that contain the most grass, usually the oldest stands, as these will derive the most benefit from nitrogen in manure.

2. Apply no more than 3,000-5000 gallons of liquid manure or no more than about 10 tons of solid manure per acre in a single application. Applying more may cause salt burn, and damage or suffocate plants.

Table 7. Effect of topdressed manure treatments on alfalfa forage yields at 2 Minnesota locations.

Topdressed Treatment[+]		Alfalfa Yields Rosemount	Waseca
		(T/a)	
Control		3.81	2.84
Manure	3000 gal/a/yr	4.47	2.93
	6000 gal/a/yr	4.98	2.82
P & K Fertilizer		4.21	2.97

[*]Adapted from Schmitt et al. 1991.

[+]Manure and fertilizer treatments applied after first cutting in seeding and full production year.

3. Apply the manure immediately after removing a cutting so manure contacts the soil instead of the foliage. This reduces the risk of salt burn and avoids palatability problems.

4. Adjust the spreader to break up large chunks or pieces of manure that can smother regrowth.

5. Limit soil compaction and avoid damaging crowns by spreading only when soils are firm, however, due to increased risk of nutrient runoff, applications to frozen soil should also be avoided.

ENVIRONMENTAL IMPLICATIONS

Nitrogen Sink

Alfalfa has the ability to extract and remove significant amounts of N from the soil. For example, Mathers et al. (1975) showed that where manure had been previously applied at very high rates, alfalfa could remove accumulated nitrate to a depth of 12 ft by its second year of growth. The amount of N taken up was directly proportional to yield. The magnitude of these removals is seen in the Minnesota work (Schmitt et al., 1994) where seeding year N removals ranged from 109 to 269 lb N/a and from 254 to 357 lb N/a during the production years.

Others (Schertz and Miller, 1972; Muir et al., 1976) have also shown that alfalfa can effectively scrub the soil profile of available inorganic N. This ability is related to the plant's preferential use of available, fixed N when it is present. The Rhizobium bacteria in alfalfa roots fix atmospheric N_2 in amounts inversely correlated to available soil N and only go to this energy expensive process when fixed N is not available (Phillips and DeJong 1984). Russelle and Buzicky (1988) directly measured a decrease in alfalfa N fixation following topdressing with manure. As concluded by Schertz and Miller (1972), alfalfa has significant value as a nitrate sink for rotations in which excess soil nitrate has accumulated.

Although the Minnesota studies were not able to account for all of the manure-applied N (i.e. at Rosemount-South 924 lb/a N was applied with the 12000 gal/a treatment, or a 344 lb/a increase in nitrate was measured in the soil, and 109 lb/a was removed in the herbage) the authors did not believe significant leaching occurred in this system (Schmitt et al., 1994). Soil samples taken periodically throughout the term of the experiment showed no differences between the control or the manure treatments at the 3 ft depth. They suggest that appreciable amounts of manurial N may be immobilized, denitrified or volatilized after application. This implies that significant amounts of manure N may be applied to alfalfa without risk to the environment.

Nutrient Runoff

The effect of vegetative cover such as alfalfa on runoff losses from fields that receive manure can be significant. As shown by Young and Mutchler (1976), topdressing manure on alfalfa fields may constitute more of a pollution hazard than spreading manure on plowed corn areas (Table 8). Some variation existed between years, but

Table 8. Effect of manure on soil, and water and nutrient loss from spring snowmelt (3 yr avg.)

Test	Soil loss	Runoff	Total N loss	Soluble P loss
	lb/a	in	lb/a	lb/a
		corn		
Check	38	2.6	1.0	0.09
Fall manure, plowed under	36	0.6	0.6	0.12
Fall manure on frozen soil	0	0.5	1.5	0.30
Spring manure on snow	0	0.5	1.8	0.09
		alfalfa		
Check	0	3.4	2.4	0.09
Fall manure on frozen soil	0	2.8	18.5	3.32
Spring manure on snow	0	1.4	16.1	0.95

Adapted from Young and Mutchler, 1976.

it is clear that total N, total P and soluble P losses averaged about 10 times higher from the manured alfalfa than from the manured corn. A preliminary simulated rainfall study reported by Young (1974) showed that where manure was applied about 30 days after planting, corn, oats, or alfalfa, the manured alfalfa plots lost substantially more N and P than did the others. This was attributed to the smoother, more finely worked soil surface created for this small-seeded crop.

Hensler et al. (1970), using small runoff plots studied the N and P losses from winter-applied fertilizer and manure in runoff water from fallow and sod or vegetated soils. The concentration of nutrients in the runoff water was lower for fallow areas compared to vegetated areas. They suggested that although runoff is usually much less for vegetated soil compared to bare soil, vegetation prevents waste components from coming in contact with the soil, thereby increasing the likelidhood of waste constitutents being removed in the runoff. Ross et al. (1978) also found that after a 1-day period between application of liquid manure and the simulated rainfall event, runoff from the bare soil generally contained a much lower percentage of COD and N compared to the runoff from sod.

Using simulated rainfall studies Wendt and Corey (1980) concluded that surface applied manure does not appear to greatly increase the pollution potential of rainfall-induced runoff of unfrozen soil. However, they are quick to caution that surface-applied manure to frozen soils may constitute a significant hazard. Converse et al. (1976) also observed large differences in runoff nutrient loads where winter versus fall manure was applied to established alfalfa.

These several experiments emphasize that under some conditions, especially where manure is topdressed on frozen soil, runoff losses of manure nutrients may be unacceptably large. The magnitude of this environmental risk must, however, be determined on a site-specific basis.

SUMMARY

Preplant manure applications generally can have a positive effect on seeding-year alfalfa dry matter production where weeds are adequately controlled. This response may also be carried over into the full production years. The response to manure is probably due to more than just P and K since yield responses occurred even when soil tests for P and K were such that yield responses would not be expected, and manure responses were generally larger than thoe obtained with equivalent amounts of P and K fertilizer. The causative factor for these responses is not completely clear, but may include seeding-year N responses, secondary or micronutrient benefits and/or improvements in soil physical condition. Although manure may increase certain seeding-year weed problems these usually do not persist past the first cutting.

Topdressing manure to established alfalfa is somewhat more risky in that while benefits can be obtained, especially on low-testing soils or on legume-grass mixtures, problems from compaction and stand suffocation can occur. Where alfalfa is to be topdressed with from compaction and stand suffocation can occur. Where alfalfa is to be topdressed with manure certain precautions are suggested.

Applications of manure to alfalfa can have either a positive or negative environmental impact depending on rate, timing and application site characteristics. Alfalfa can be a major sink for recycling N and other nutrients, however, topdress applications, especially to frozen soils may result in unacceptably large nutrient runoff losses.

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