

Effects of Surface-Applied Dairy Slurry on Herbage Yield and Stand Persistence: II. Alfalfa, Orchardgrass, Tall Fescue and Alfalfa-Orchardgrass

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ABSTRACT : The first paper of this series compared the effects of rates and frequencies of application of dairy slurry on herbage yields and stand persistence of orchardgrass (*Dactylis glomerata* L.), reed canarygrass (*Phalaris arundinacea* L.), and alfalfa (*Medicago sativa* L.)-grass mixtures managed as a 4-cutting system. This paper compares the effects of rates and frequencies of application of dairy slurry on herbage yield and stand persistence of alfalfa, orchardgrass, tall fescue (*Festuca arundinacea* Schreb.), and alfalfa-orchardgrass mixture managed as a 5-cutting system. The results presented here are part of a larger study having a primary objective of comparing alfalfa, various grasses, and alfalfa-grass mixtures for utilizing nutrients from dairy slurry applied to established stands. A randomized complete block design with treatments in a split plot arrangement with four replicates was used. The main plots consisted of 9 fertility treatments: 7 slurry rate and frequency of application treatments, one inorganic fertilizer treatment, and an unfertilized control. The sub-plots were the forage species. Manure used for the study was composed from stored solids scraped from the alleyways of a free-stall dairy barn. Water was added to form a slurry having about 8 % solids. Slurry was pumped from the liquid spreader tank into 10.4 L garden watering cans for manual application to the plots. Herbage yields of alfalfa, tall fescue, and alfalfa-orchardgrass were generally not affected by slurry application rates and were not significantly different from the inorganic fertilizer treatment. Tall fescue significantly outyielded all other forage species at all manure and the inorganic fertilizer treatments in the second year when rainfall during the growing season was unusually high. Grasses generally had a greater response to manure applications than alfalfa and alfalfa-orchardgrass. Increasing rates of manure did not increase herbage yields of alfalfa and alfalfa-orchardgrass. Herbage yields within each species were not affected by frequency of application of the same total rate. Stand ratings of alfalfa, orchardgrass and alfalfa-orchardgrass were significantly lower for the very high manure application rate compared to the control treatment. Based upon the results of this study, multiple annual applications of slurry manure can be made onto these species at rates up to 1,700 kg total N ha⁻¹ yr⁻¹ without detrimental effects on herbage yield and stand persistence. (*Asian-Aus. J. Anim. Sci.* 1999. Vol. 12, No. 5 : 766-771)

Key Words : Dairy Slurry, Herbage Yield, Stand Persistence, Alfalfa, Grasses, Alfalfa-Orchardgrass, 5-Cutting System

INTRODUCTION

As livestock and poultry farms increase in size and intensity, manure utilization/disposal becomes a considerable challenge. Large numbers of animals and birds are being concentrated on small land areas, creating the need for efficient cropping systems to utilize the nutrients in the manure. Further restricting the land area available for manure application on ruminant livestock farms is the large portion of the cropland devoted to alfalfa and other forage legumes, crops on which manure applications have been discouraged in the past. The manure generated often exceeds the nutrient requirements of the crops to which manure has traditionally been applied - maize (*Zea mays* L.) and cereal grains. Thus, manure applications have at times been made to these crops at rates that exceeded crop requirements, especially in the

case of maize, simply to dispose of the excess manure.

Considerable variation exists in recommendations for the use of manure on forage legumes. The effects of N on yields of established alfalfa are still a matter of controversy. There have been concerns about manure possibly suppressing or destroying the ability of legume plants to fix N, resulting in yield losses. It is still not clearly understood if N fixation ability following manure or N fertilizer application can be fully resumed. In Minnesota, when dairy manure was broadcast and incorporated at rates of 28,050, 56,100, and 112,200 L ha⁻¹ (224, 372, and 740 kg total N ha⁻¹, respectively) before the direct-seeding of alfalfa, establishment-year alfalfa yields from manure and commercial fertilizer treatment were equal to or greater than the control yield. After the establishment year, yields were also similar for the manure and fertilizer treatments, indicating that the manure was not harmful to alfalfa production (Schmitt et al., 1993). Daliparthi and Herbert (1994) observed that application of liquid dairy manure at low rates (37 Mg ha⁻¹ year⁻¹) to alfalfa had no significant effect on forage yield and weed population. They concluded that dairy manure

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can be applied to alfalfa at 112 kg N ha⁻¹ yr⁻¹ without detrimental effects.

Lee and Smith (1972) reported no increase in alfalfa yield from as much as 896 kg N ha⁻¹ as ammonium nitrate. In contrast, Nuttall (1985) and Eardly et al. (1988) found alfalfa yields were increased with N fertilizer. In northeastern Saskatchewan, Nuttall (1985) reported that the highest herbage yield of alfalfa on a yearly basis was obtained with the 45 kg N and 45 kg S ha⁻¹ treatment when rates of 10, 45, and 67 kg N ha⁻¹ were applied in combination with 0, 22, and 45 kg S ha⁻¹ in the spring of each year.

Since little is known about the comparative utilization of manure nutrients for forage production with alfalfa, cool-season grasses, and alfalfa-grass mixtures grown under the same conditions, this study was initiated to investigate the effects of multiple annual applications of slurry to established stands. The overall objective of this research was to determine the upper limits of slurry applications without detrimental effects on yield, quality, and stand persistence and without creating environmental risk from excessive nutrient application. The specific objectives of this project and the rationale for selecting the manure and inorganic fertilizer rates are presented in the previous paper.

MATERIALS AND METHODS

Details of the cultural practices, manure application and harvesting procedures, weather conditions, and statistical analysis are given in previous paper. A randomized complete block design with treatments in a split plot arrangement with four replicates was used. The main plots consisted of 9 fertility treatments: 7 slurry rate and frequency of application treatments, one inorganic fertilizer treatment, and an unfertilized control (no manure or fertilizer). Main plots were 3.66

× 6.10 m with 0.91 m borders between treatments and 1.20 m between replications. The sub-plots were alfalfa, orchardgrass, tall fescue and alfalfa-orchardgrass, hereafter referred to simply as species. All species were harvested in a 5-cutting management system. Each 0.91 × 6.10 m sub-plot contained 5 plant rows with 15 cm spacing. A 30 cm border separated sub-plots. All plots were seeded on May 24, 1994 with 'WL 320' alfalfa, 'Dawn' orchardgrass, and 'Forager' tall fescue. The seeding rates were: alfalfa, 8.17 kg ha⁻¹; orchardgrass, 4.54 kg ha⁻¹; tall fescue, 6.81 kg ha⁻¹; and alfalfa-orchardgrass, 6.36 and 1.36 kg ha⁻¹. Manure applications and data collection were initiated after the first harvest in late May 1995. Dates and rates of manure and inorganic fertilizer applications are given in tables 1 and 2.

The cutting dates in 1995 were July 6 (2nd cut), August 8 (3rd cut), September 11 (4th cut) and November 28 (5th cut). Cutting dates in 1996 were May 20 (1st cut), July 9 (2nd cut), August 7 (3rd cut), September 20 (4th cut) and November 20 (5th cut).

RESULTS AND DISCUSSION

Herbage yield

Cumulative herbage yields of 2nd, 3rd, 4th, and 5th cuts in 1995 ranged from 6.9 to 11.9 Mg ha⁻¹ for the slurry and inorganic fertilizer treatments (table 3). There was a significant ($p < 0.001$) fertility rates × species interaction in 1995. Herbage yields of tall fescue were generally significantly higher than orchardgrass from the application of slurry and inorganic fertilizer except for treatments 1 and 3. There were no significant yield differences between alfalfa and alfalfa-orchardgrass across any of the fertility treatments including the control. There were no significant differences in yield of orchardgrass at the medium, high and very high rates of slurry and

Table 1. Dairy slurry application times and N (organic + ammonium), P, and K rates, 1995

Fertility rates	N rates and application time			Total application		
	After 1st cut (06-15-95)	After 3rd cut (08-09-95)	After 4th cut (09-12-95)	N	P	K
	kg ha ⁻¹					
1. Low manure	111	65	264	440	58	398
2. Low manure	222	65	132	419	55	364
3. Medium manure	222	195	264	681	86	583
4. Medium manure	333	65	264	662	83	548
5. High manure	222	97	528	847	109	745
6. High manure	444	97	264	805	103	603
7. Very high manure	333	130	528	991	128	872
8. Inorganic fertilizer	224	0	0	224	37	279
9. Control	0	0	0	0	0	0

Table 2. Dairy slurry application times and N (organic+ammonium), P, and K rates, 1996

Fertility rates	N rates and application time					Total application		
	Early spring	After 1st cut	After 2nd cut	After 3rd cut	After 4th cut	N	P	K
	(04-20-96)	(05-31-96)	(07-25-96)	(08-26-96)	(10-05-96)			
	kg ha ⁻¹							
1. Low manure	227	194	192	0	224	837	83	388
2. Low manure	454	0	384	0	0	838	74	419
3. Medium manure	454	194	192	242	224	1306	128	674
4. Medium manure	681	0	384	0	224	1289	114	676
5. High manure	454	388	384	242	224	1692	172	872
6. High manure	908	0	576	0	224	1708	149	870
7. Very high manure	454	388	384	484	224	1934	217	1017
8. Inorganic fertilizer	168	112	112	112	56	560	37	279
9. Control	0	0	0	0	0	0	0	0

inorganic fertilizer treatments. When averaged over manure treatments, herbage yield of orchardgrass increased by 68 % over the control treatment. There were no differences in herbage yields between all manure and the inorganic fertilizer treatments for alfalfa, alfalfa-orchardgrass and tall fescue except for tall fescue in treatment 6.

Table 3. Total herbage yields of cuttings 2, 3, 4, and 5 of alfalfa (AL), orchardgrass (OR), tall fescue (TF), and alfalfa-orchardgrass (AL-OR) as affected by fertility rates, 1995

Fertility rates	AL	OR	TF	AL-OR
	Mg ha ⁻¹			
1. Low manure	11.3yb ¹	6.9xb	8.3xb	11.3ya
2. Low manure	11.4yb	7.2xbc	10.1ycd	11.3ya
3. Medium manure	10.3yzab	8.1xbcd	9.5xybc	11.0yza
4. Medium manure	10.8yab	8.6xcd	11.0ycde	11.8ya
5. High manure	10.0xyab	9.0xd	11.0ycde	11.2ya
6. High manure	11.2yb	8.6xcd	11.7ye	10.6ya
7. Very high manure	11.0yab	9.1xd	11.2yde	11.9ya
8. Inorganic fertilizer	10.6yzab	7.7xbcd	9.8ybcd	11.7za
9. Control	9.5ya	5.0xa	6.0xa	10.6ya
Mean ²	10.7	7.8	9.8	11.3

¹ x,y,z=LSD (0.05) for species comparisons within the same fertility rate.

a,b,c,d,e=LSD (0.05) for fertility rate comparisons within the same species.

² LSD (0.05)=0.4 for mean comparisons of species over the fertility rates.

Herbage yields of tall fescue were comparable to alfalfa and alfalfa-orchardgrass across all manure treatments except treatment 1. There was no significant increase in herbage yield of tall fescue for treatments

4 through 7 but yield at the very high rate was significantly higher than treatment 1. Herbage yield for tall fescue averaged across manure treatments increased by 70 % over the control treatment. As in the preceding paper, grasses were generally more responsive to manure nutrients than alfalfa and alfalfa-orchardgrass in 1995. As expected, herbage yields of alfalfa and alfalfa-orchardgrass were significantly higher than orchardgrass and tall fescue in the control treatment. This is most likely due to symbiotic dinitrogen fixation by alfalfa. Herbage yields within each species were not affected by time of application for the same total rates (treatments 1 vs. 2, 3 vs. 4, and 5 vs. 6) except tall fescue at the low rate (treatments 1 and 2).

In 1996, herbage yields from slurry application ranged from 14.5 to 22.0 Mg ha⁻¹. Unlike 1995, tall fescue outyielded all other forage species at all manure rates and the inorganic fertilizer treatment (table 4). There were no significant differences in herbage yields within orchardgrass, alfalfa, and alfalfa-orchardgrass due to fertility rates from manure or inorganic fertilizer application. In the case of tall fescue, herbage yield of treatments 1 and 3 were significantly different from each other, treatment 3 having the highest yield of all species in both cutting management systems in 1996. Treatment 1 had the lowest early spring manure application rate of all the manure treatments, 227 vs. 454, 681, and 908 kg total N ha⁻¹ (table 2). Plant available nitrogen (PAN) as reported by the University of Maryland Soil Testing Laboratory. Manure Analysis Program was estimated to be about 50 kg ha⁻¹ for treatment 1, while the other treatments received an estimated 110, 169, and 225 kg PAN ha⁻¹.

Yield differences between treatments 3 and 1 were +0.5, +0.7, -0.2, +0.7, and +0.4 Mg ha⁻¹ for cuttings

1, 2, 3, 4, and 5, respectively. Treatment 3 received higher rates of manure than treatment 1 in early spring and after 3rd cutting. The higher rate of manure for treatment 3 in early spring appears to have increased the yields of the 1st and 2nd cuttings. Treatment 3 received manure after 3rd cutting and treatment 1 did not. This appears to have increased the yields of the 4th and 5th cuttings for treatment 3.

Unlike 1995, orchardgrass had herbage yields in 1996 comparable to or greater than alfalfa and alfalfa-orchardgrass across the fertility rate treatments, except for treatment 2 where alfalfa-orchardgrass had significantly higher yield than orchardgrass. This was most likely the result of very favorable growing conditions for grasses due to ample rainfall during the growing season of 1996. Herbage yields of alfalfa-orchardgrass for treatments 1, 4, 5, and 7 were significantly higher than alfalfa. In 1996, herbage yields for orchardgrass and tall fescue averaged over manure treatments increased by 38 and 50 %, respectively, when compared to the control treatment. Within species treatments, herbage yields of the manure treatments were not different from the inorganic fertilizer treatment. Alfalfa-orchardgrass had significantly higher herbage yields than alfalfa alone across the manure and inorganic fertilizer treatments. Mixed stands are usually expected to have higher yields than pure stands.

As in 1995, herbage yields of alfalfa and alfalfa-orchardgrass in 1996 did not significantly change with increasing manure application rates. This finding is in agreement with other research reports showing increasing manure application rates to alfalfa did not increase herbage yields (Daliparthi et al., 1995; Schmitt et al., 1994). Determining whether nitrogen fixation is still occurring in alfalfa after dairy slurry application is a question that needs to be answered in the future. Recent research showed that alfalfa still fixed 20 to 25 % of its N content after application of 840 kg N ha⁻¹ yr⁻¹ as ammonium nitrate (Lamb et al., 1995). Even with high concentrations (20 mM) of nitrate in the subsoil, substantial N₂ fixation took place in alfalfa (Blumenthal and Russelle, 1996). In Vermont, Daliparthi et al. (1995) reported that dairy slurry could be surface applied to alfalfa at low rates, equivalent to 112 kg N ha⁻¹, immediately after 1st cutting without any adverse effect on herbage productivity or stand quality.

As shown in the table 4, herbage yields within each species were not affected by frequency of application in 1996. Herbage yields within each species for the more frequent application treatments (treatments 1, 3, and 5) were not different from the less frequent application treatments (treatments 2, 4, and 6). The grasses used in this study demonstrated a good potential to increase herbage yields with dairy

slurry application.

Table 4. Total herbage yields of alfalfa (AL), orchardgrass (OR), tall fescue (TF), and alfalfa-orchardgrass (AL-OR) as affected by fertility rates, 1996

Fertility rates	Mg ha ⁻¹			
	AL	OR	TF	AL-OR
1. Low manure	15.3xa	15.5xyb	19.8zb	17.1ya
2. Low manure	15.8xya	15.2xb	21.0zb	17.4ya
3. Medium manure	15.6xa	16.9xb	22.0yb	17.2xa
4. Medium manure	14.6xa	16.4yb	21.4zb	17.8ya
5. High manure	15.2xa	16.6xyb	20.9zb	17.7ya
6. High manure	15.4xa	15.7xb	21.3yb	16.5ya
7. Very high manure	14.5xa	16.2xyb	20.1zb	16.5ya
8. Inorganic fertilizer	14.6ya	16.4xyb	20.4zb	16.5ya
9. Control	14.1ya	11.6xa	13.9ya	16.0za
Mean ²	15.0	15.6	20.1	17.0

¹ x,y,z=LSD (0.05) for species comparisons within the same fertility rate.

a,b=LSD (0.05) for fertility rate comparisons within the same species.

² LSD (0.05)=0.6 for mean comparisons of species over the fertility rates.

Stand ratings

There were no significant differences in 1996 stand ratings for tall fescue and alfalfa-orchardgrass mixture due to manure treatments when compared to the control treatment (table 5). However, alfalfa and orchardgrass were affected. The very high rate of manure (treatment 7) significantly reduced stands of alfalfa compared to all other treatments. Although stand ratings were reduced, recall that there were no differences in herbage yields among manure treatments. The high rate, less frequent application treatment (treatment 6) resulted in significantly lower stand ratings of orchardgrass compared to the control and inorganic fertilizer treatments. This difference probably has no practical significance since there was no significant difference in ratings the following year. Stand ratings within each species were not affected by frequency of application for the same total rates (treatments 1 vs. 2, 3 vs. 4, and 5 vs. 6) applied in 1995. Stand ratings of orchardgrass and tall fescue for the very high slurry treatment from slurry were not different from the inorganic fertilizer treatment, whereas stand ratings of alfalfa and alfalfa-orchardgrass at the very high treatment from the slurry were significantly lower than the inorganic fertilizer treatment.

Alfalfa stand ratings were significantly lower for treatments 5 through 7 than treatments 1, 3, and the control in the spring of 1997. Stand rating of alfalfa for the very high slurry treatment was significantly

Table 5. Stand ratings of alfalfa (AL), orchardgrass (OR), tall fescue (TF) and alfalfa-orchardgrass (AL-OR) in the spring of 1996 and 1997

Fertility rates	AL		OR		TF		AL-OR	
	96	97	96	97	96	97	96	97
	%							
1. Low manure	78	68	63	70	74	80	76	76
2. Low manure	75	63	61	63	76	74	76	68
3. Medium manure	74	68	65	68	78	75	72	66
4. Medium manure	72	61	62	65	75	74	78	69
5. High manure	73	58	65	69	76	70	70	67
6. High manure	76	58	56	61	71	68	70	66
7. Very high manure	61	46	63	56	69	69	68	50
8. Inorganic fertilizer	82	60	66	63	75	72	81	66
9. Control	80	68	67	69	76	78	77	73
Spring of 1996					Spring of 1997			
¹ LSD1 (0.05)=8.0					LSD1 (0.05)=7.0			
LSD2 (0.05)=9.0					LSD2 (0.05)=9.0		LSD3 (0.05)=8.0	

¹ LSD1; species comparisons within the same fertility year. LSD2; fertility comparisons within the same species and year. LSD3; mean comparison of years within the same fertility and species.

² Rating scale : A perfect stand is defined as one in which 100% of the plants are the designated species and in which 100% ground cover exists.

lower than all other manure treatments. However, as in 1995, there was no significant difference in alfalfa herbage yields in 1996. Although stand ratings for treatment 7 were significantly lower than the other manure and inorganic fertilizer treatments both years, there were no significant differences in yield either year. This was probably due to the yield compensation ability of alfalfa that has been reported (Min, 1994). Some smothering of crown buds and coating of leaves of alfalfa was observed after the 3rd cutting when 484 kg total N ha⁻¹ of dairy slurry was applied to the very high rate treatment. Several days of hot, dry weather following this application caused crusting of the manure solids.

Orchardgrass at the very high manure application rate (treatment 7) had significantly lower stand ratings in 1997 than the manure treatments 1, 3, and 5 and the control treatment. The high and very high manure applications (treatments 5, 6, and 7) on tall fescue resulted in significantly lower stand ratings than the low rate, more frequent applications (treatment 1). Like alfalfa, stand ratings of alfalfa-orchardgrass at the very high manure rate (treatment 7) were significantly lower than the other manure rates, inorganic fertilizer and the control treatment in the spring of 1997. Stand ratings of tall fescue were significantly higher than alfalfa across all fertility treatments except for the treatment 3 and higher than orchardgrass for treatments 1, 2, 4, 7, 8, and 9. The very high manure rate (treatment 7) had a significant detrimental effect on stand ratings of all species except tall fescue when compared to the control treatments based on 1997 stand evaluations.

Comparison of the 2 yr shows alfalfa stand ratings for most of the fertility treatments significantly decreased from 1996 to 1997, whereas orchardgrass and tall fescue maintained similar ratings from one year to the next. For alfalfa-orchardgrass, ratings for the very high manure rate, inorganic fertilizer and treatment 4 significantly declined over this period. Thus, it appears that grasses are more tolerant of dairy slurry applications, especially higher rates, than alfalfa. Since the stand ratings of alfalfa significantly decreased from the spring of 1996 to 1997 across the manure, inorganic fertilizer and control treatments, the decline in stand condition appears to be loss unrelated to manure applications. The above normal rainfall in 1996 probably contributed to the stand loss. Phytophthora root rot (*Phytophthora megaspera* (Drechs.) f. sp. *medicaginis*) is a common disease of alfalfa in Maryland that can frequently result in loss of stands on wet soils. However, the dramatic loss of alfalfa and alfalfa-orchardgrass at the very high manure application rate is at least partially a result of smothering of plant crowns. Depth of solids for some applications was as much as 5-6 cm, entirely covering the plant crowns, and crusting of solids did occur following the August 1996 application as previously mentioned. Champman and Heath (1987) reported that when dairy slurry was applied at a rate of 57.6 Mg ha⁻¹ to supply 60 kg plant available N ha⁻¹ to clover/grass swards in summer, there was a significant reduction in clover dry matter yield and clover percentage compared to the 28.8 Mg ha⁻¹ rate. They suggested that this was likely caused by secondary effects of slurry, such as coating of clover leaves and

stolons.

Stand ratings within each species were not affected by frequency of application. Treatments having less frequent applications but higher rates each time (treatments 2, 4, and 6) were not different from treatments having more frequent applications with lower rates each time (treatments 1, 3, and 5). Thus, there appears to be flexibility in the timing of slurry applications.

CONCLUSIONS

Herbage dry matter yields of alfalfa, alfalfa-orchardgrass and tall fescue managed in a 5-cutting system were generally not affected by slurry application rates and were not significantly different from the inorganic fertilizer treatment. Total cumulative yields of the 2nd and later cuttings of tall fescue were comparable to alfalfa and alfalfa-orchardgrass in 1995 when growing season rainfall was below normal and significantly higher than alfalfa, orchardgrass and alfalfa-orchardgrass in 1996 when rainfall was substantially above normal. Total cumulative yields of the 2nd and later cuttings of orchardgrass were generally lower than the other species in 1995, particularly for the high and very high manure application rates and the inorganic fertilizer treatment. Herbage yields within each species were not affected by frequency of application of the same total rate.

The very high manure application rate had a significant detrimental effect on stand ratings of alfalfa, orchardgrass and alfalfa-orchardgrass after 2 yr of application when compared to the control treatment. Tall fescue appeared to be less affected. Stand ratings of orchardgrass and tall fescue did not significantly differ between 1996 and 1997 at the very high manure application rate whereas alfalfa and alfalfa-orchardgrass showed significant stand losses. Heavy applications of dairy slurry should be avoided during hot, dry summer weather conditions, especially onto alfalfa and alfalfa-orchardgrass.

Based upon the results of the first 2 yr of this study, multiple annual applications of dairy slurry to alfalfa, orchardgrass, tall fescue, and alfalfa-orchardgrass at rates up to 1,700 kg total N ha⁻¹ yr⁻¹ appears to be feasible without detrimental effects on herbage yield and stand persistence. However, the effects of rates of application on soil N and P levels and environmental risks need to be evaluated before establishing upper limits for manure applications. Additional information over a longer time period and looking at aspects of forage quality and N and P

uptake is needed before an integrated system for forage production and nutrient utilization can be designed. Some of the results presented in this paper contradict results presented in the preceding paper. Since orchardgrass and alfalfa-orchardgrass were common species in both cutting management systems, some of the differences in results will be addressed in the next paper which compares the effects of cutting frequency on herbage yield and stand persistence.

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