Effects of Surface-Applied Dairy Slurry on Herbage Yield and Stand Persistence : I. Orchardgrass, Reed Canarygrass and Alfalfa-Grass Mixtures

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ABSTRACT : Comparative studies of the effects of rates and frequency of application of dairy slurry on herbage yield and stand persistence of alfalfa and various forage grasses have not previously been conducted. The results being reported here are part of a larger study having a primary objective of comparing the effectiveness of alfalfa (*Medicago sativa* L.), various grasses and alfalfa-grass mixtures for utilizing nutrients from applied dairy slurry. The objectives of this part of the study were to evaluate the effects of various rates and frequencies of application of slurry on herbage yield and stand persistence of orchardgrass (*Dactylis glomerata* L.), reed canarygrass (*Phalaris arundinacea* L.), and alfalfa-orchardgrass and alfalfa-reed canarygrass mixtures managed as a 4-cutting management system. 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 time of application treatments, one inorganic fertilizer treatment, and an unfertilized control. The sub-plots consisted of the two grasses and two alfalfa-grass mixtures mentioned above. Slurry was composed from stored solids scraped from the alleyways of a free-stall housing barn and water added to form a slurry having about 8% solids. Manure was pumped from a liquid spreader tank into 10.4 L garden water cans for manual application to the plots. Herbage yields within species were generally unaffected by various rates of application in the first production year. Herbage yields of grasses and alfalfa-grass mixtures the second year were generally not affected by frequency of application for the same rate of slurry applied. Slurry application resulted in greater herbage yield increases in grasses than alfalfa-grass mixtures in the 4-cutting management system. In general, herbage dry matter yields of grasses from the dairy slurry treatments equaled or exceeded yields from the inorganic fertilizer treatment. Stand ratings of grasses and alfalfa-grass mixtures were not changed by manure application rates. In this study, the highest rate of slurry (967 kg total N ha^{-1} in 1995 plus 2,014 kg N ha^{-1} in 1996) was not detrimental to herbage yields or stand persistence of any of the species. It was concluded that applying dairy slurry to these cool-season grasses and alfalfa-grass mixtures managed in a 4-cutting system is an acceptable practice from the standpoint of herbage yield and stand persistence and by doing so the utilization of inorganic fertilizers can be reduced. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 5 : 758-765*)

Key Words : Dairy Slurry, Herbage Yield, Stand Persistence, Alfalfa, Grass, Alfalfa-Grass Mixtures, 4-Cutting System

INTRODUCTION

Environmental issues are among the highest priority concerns of individuals, governments, and organizations. Animal production is being targeted as one of the serious non-point sources of nutrient pollution, and in some cases, confinement operations, are now being considered as point sources of pollution.

Increased yield from applying cattle manure to forage legumes, grasses and legume-grass mixtures have been reported. Kelling (1985) found that application of 34 Mg solid manure ha^{-1} on pure and mixed alfalfa stands for 4 yr of a 5 yr study in Wisconsin showed yields increased slightly compared to control and composition of the stand did not change appreciably. Bosworth and Jokela (1994) reported a grass farmer could optimize returns over costs by combining manure applications and supplemental N from ammonium nitrate fertilizer. They found that a total of 101 to 134 kg N ha^{-1} yr^{-1} split into 3 applications gave the greatest return over treatment costs. Johnson et al. (1992) reported average annual forage dry matter yields of corn (*Zea mays* L.), rye (*Secale cereale* L.) and bermudagrass [*Cynodon dactylon* (L.) Pers.] ranging from 26.3 to 28.2 Mg ha^{-1} from dairy manure applications ranging from 381 to 986 kg N ha^{-1} in Georgia. Magdoff and Amadon (1980) reported that applications of both dairy manure and inorganic N were necessary to obtain maximum continuous corn silage yields on a typically low yielding clay soil in Vermont. In United Kingdom, Beckwith and Hemingway (1987) reported that applying 50 m^3 slurry liquor ha^{-1} (total nitrogen 1.9%) to Italian ryegrass (*Lolium multiflorum* Lam.) five times per year produced a yield response equivalent to 60 kg N ha^{-1} applied in each of three applications as ammonium nitrate fertilizer.

Long and Gracey (1990) reported the injection of 59 m^3 ha^{-1} of beef cattle slurry (equivalent to 126 kg total N ha^{-1}) increased dry matter yield of an

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established grassland sward by 65% over the control while 112 m^3 ha^{-1} rate (equivalent to 252 kg total N ha^{-1}) resulted in a further 21% yield improvement. They concluded that injection of slurry can be a more effective means of utilizing slurry N since injection reduces the loss of ammonia gas compared with surface application. Anderson et al. (1993) reported that higher rates (186 kg N ha^{-1} in the spring and 267 kg N ha^{-1} in the summer) of dairy cattle slurry on timothy (*Phleum pratense* L.) did not increase total yearly yield compared to lighter rates (132 kg N ha^{-1} in the spring and 134 kg N ha^{-1} in the summer).

Comparative studies evaluating the influence of rates and frequencies of manure application on herbage yield, forage quality and stand persistence of alfalfa, orchardgrass, tall fescue (*Festuca arundinacea* Schreb.), reed canarygrass and alfalfa-grass mixtures and the effectiveness of these crops for utilizing nitrogen (N) and phosphorus (P) from manure have not previously been reported. The overall goal of this research was to determine the upper limits of slurry applications without detrimental effects on yield, quality and persistence and without creating environmental risk from excess nutrient application.

The specific objectives of the research project were:

1. Evaluate the influence of various rates and frequencies of manure application on herbage yield of alfalfa, three cool-season grasses and two alfalfa-grass mixtures and determine the suitability of the herbage for dairy feed as well as the influence of manure treatments on quality and mineral parameters;
2. Assess any changes in stand composition and persistence related to the various rates and frequencies of manure application and identify rate and/or time periods of application that are likely to result in loss of stands;
3. Evaluate the effectiveness of these crops to utilize N and P from manure and assess the potential of the various rate and frequency treatments to contribute to excess soil N and P; and
4. Develop dairy manure nutrient management strategies to maximize nutrient utilization, minimize environmental risk and provide high forage yields and quality through integrated cropping systems.

Manure and inorganic fertilizer rates were established based upon perceived attainable dry matter yields, particularly for alfalfa and alfalfa-grass mixtures, and the nitrogen removal rate associated with those yields. Herbage dry matter yields in the range of 12 to 16 Mg ha^{-1} for alfalfa and some alfalfa-grass mixtures have been common in University of Maryland research trials. While these yields are higher than the average on-farm yields in Maryland, they are representative of the yields obtained by alfalfa growers using the latest improved management practices.

Assuming a concentration of 25 g N kg^{-1} herbage dry matter, 25 kg N is contained in each megagram of herbage harvested. Dry matter yields in the range of 12 to 16 Mg ha^{-1} thus contain 300 to 400 kg N ha^{-1}. These values were the basis for establishing the manure application rates.

This paper presents herbage yield and stand persistence results for species managed in a 4-cutting system. Part II presents yield and persistence results for species managed in a 5-cutting system. While Maryland dairy farmers typically harvest alfalfa and alfalfa-orchardgrass mixture 5 times per year, reed canarygrass will not withstand harvesting more than 4 times per year. Thus, two different cutting management systems were imposed. Orchardgrass and alfalfa-orchardgrass were common to both systems. Utilization of N and P will be presented later in other papers.

MATERIALS AND METHODS

Field studies were established in 1994 at the Central Maryland Research and Education Center Clarksville Facility (USA) (39°15'N, 76°56'W, elevation IIIm). The experiment was conducted on a moderately well-drained Delanco silt loam soil (fine-loamy, mixed, mesic Aquic Hapludults). The slope of experimental site was 2.5%. Soil test results prior to initiation of the experiment showed high levels of both P (32 mg kg^{-1}) and K (82 mg kg^{-1}), soil pH 7.1 (1:1 by volume water:soil) and organic matter 26.5 g kg^{-1}.

Dairy cattle bedded pack manure from an uncovered stockpile was broadcast on the soil surface at the rate of 67 Mg ha^{-1} and immediately incorporated by disking on April 27, 1994. The manure contained 10.5, 2.3, and 10.2 kg Mg^{-1} total N, P, and K, respectively.

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 forage grasses and alfalfa-grass combinations, hereafter referred to simply as species. All species were harvested in a 4-cutting management system. Each 0.91×6.10 m sub-plot contained 5 plant rows with 15 cm spacing. Sub-plots were separated by

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

Fertility rates	N rates and application time		Total application		
	After 1st cut (06-20-95)	After 3rd cut (08-25-95)	N	P	K
	kg ha^{-1}				
1. Low manure	137	278	415	90	336
2. Low manure	274	139	413	93	339
3. Medium manure	274	417	691	151	561
4. Medium manure	411	278	689	157	567
5. High manure	274	556	830	180	672
6. High manure	548	278	826	186	678
7. Very high manure	411	556	967	212	786
8. Inorganic fertilizer	224	0	224	37	279
9. Control	0	0	0	0	0

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

Fertility rates	N rates and application time				Total application		
	Early spring (04-24-96)	After 1st cut (05-31-96)	After 2nd cut (07-25-96)	After 3rd cut (08-26-96)	N	P	K
	kg ha^{-1}						
1. Low manure	217	161	203	209	790	179	511
2. Low manure	434	0	406	0	840	181	609
3. Medium manure	434	322	203	209	1168	278	822
4. Medium manure	868	0	406	0	1274	246	877
5. High manure	434	322	406	418	1580	346	1118
6. High manure	868	322	203	209	1602	343	1090
7. Very high manure	868	322	406	418	2014	442	1385
8. Inorganic fertilizer	224	112	112	112	560	37	279
9. Control	0	0	0	0	0	0	0

a 30 cm border. Plots were seeded May 23, 1994 with 'WL 320' alfalfa, 'Dawn' orchardgrass, and 'Palaton' reed canarygrass. The seeding rates were: orchardgrass 4.54 kg ha^{-1}, reed canarygrass 4.54 kg ha^{-1}, alfalfa-orchardgrass 6.36 and 1.36 kg ha^{-1} and alfalfa-reed canarygrass 6.36 and 3.63 kg ha^{-1}.

Manure applications and data collection were initiated after the first harvest in May 1995. Dates and N, P, and K rates of manure applications are given in tables 1 and 2. Manure application rates were targeted to supply 200, 300, 400 and 500 kg plant available nitrogen (PAN) ha^{-1} yr^{-1}. Since manure applications were not initiated until after the first cutting in 1995, application rates were reduced accordingly the first year. Manure nutrient analysis was performed by the University of Maryland Soil Testing Laboratory. The PAN values reported by the laboratory for surface applied manure (without soil incorporation) are based on organic nitrogen having 35% mineralization rate during the year of application and 100% ammonium nitrogen loss. However, since PAN can vary with climatic conditions following application and thus are not absolute values, N application rates are presented as total N (organic N+ammonium N). Manure used for the study was taken from a pit that stored solids scraped from the alleyways of a free-stall housing barn. The solids were loaded into a water-tight box manure spreader. To liquefy the solids, water was sprayed into the box spreader and liquid then pumped into a liquid spreader tank. Average solids content of the slurry was 8%. To minimize settling of solids in the tank during the application process, a manure pit agitator was placed in the tank and continuously operated. In addition, a 319 cc gasoline engine powered trash pump outside of the liquid spreader tank continuously withdrew slurry from the tank to fill 10.4 L garden watering cans for manual application to the plots. Excess slurry was recirculated to the tank.

Manure samples were taken periodically as the tank was unloaded to monitor consistency of the slurry as it was being applied. Samples were analyzed through the manure testing program of the University of Maryland Soil Testing Laboratory. For the inorganic fertilizer treatment, 224 kg N ha^{-1} as NH_4NO_3, 37 kg

Table 3. Monthly average rainfall and air temperature in 1995-96 and 30-yr mean values

Month	Rainfall			Air temperature		
	1995	1996	30-yr	1995	1996	30-yr
	mm			℃		
January	104	211	91	2.8	-1.7	-0.6
February	239	234	71	-2.2	0.0	1.1
March	53	104	97	7.2	3.9	6.1
April	48	99	91	10.6	11.7	11.1
May	135	147	124	16.7	17.2	16.7
June	86	150	104	22.2	22.8	21.7
July	46	208	107	25.6	23.3	23.9
August	104	119	102	24.4	22.2	23.3
September	97	157	99	18.9	19.4	19.4
October	168	117	91	11.1	12.8	12.8
November	147	127	94	3.9	4.4	7.2
December	122	-	94	0.0	-	2.2

P ha^{-1} and 279 kg K ha^{-1} were applied in 1995. In 1996, 560 kg N ha^{-1} as NH_4NO_3, 37 kg P ha^{-1} and 279 kg K ha^{-1} were applied.

The cutting dates in 1995 were July 13 (2nd cut), August 23 (3rd cut), and November 21 (4th cut). Forage yields were determined by cutting 0.91×6.10 m areas of the plots to a 7-cm stubble height using a Carter Harvester (flail-type). The harvested herbage was captured in a canvas bag and weighed to measure the fresh weight yield from each plot. Sub-samples (800 to 1000 g wet weight) were taken from the harvested herbage of plots for moisture determination and samples were dried at 60℃ for 72 hrs. Forage stands (percentage of ground cover) were independently estimated by three scientists in the spring of 1996 and 1997 after plants had initiated growth. Values were expressed as the mean of the three estimates. A perfect stand was defined as one in which 100% of the plants were the designated species and in which 100% ground cover existed.

Total annual precipitation (rain+snow) was 1,340 mm in 1995 and 1,673 mm in 1996 (table 3). These precipitation amounts were above the 30-yr mean total precipitation of 1,164 mm. Total precipitation during the March through October growing season was 737 and 1,101 mm for 1995 and 1996, respectively. The 30-yr mean average precipitation for this period is 815 mm. June, July, and September 1995 were considerably drier than normal. Considerably above average normal precipitation was received in January, February, June, July, and September 1996. The average monthly temperatures in 1995 and 1996 were close to the normal.

Data were subjected to analysis of variance to test the effects of fertility rates, species, and fertility rates $\times$ species interaction using PROC MIXED (SAS/STAT, 1996). Fertility rates, species and fertility rates $\times$ species were considered as fixed effects. Means were separated using Fisher's protected least significant difference (LSD) test with an alpha level of 0.05.

Table 4. Total herbage dry matter yields of cuttings 2, 3, and 4 of orchardgrass (OR), reed canarygrass (RC), alfalfa-orchardgrass (AL-OR), and alfalfa-reed canarygrass (AL-RC) as affected by fertility rates, 1995

Fertility rates	Species			
	OR	RC	AL-OR	AL-RC
	Mg ha^{-1}			
1. Low manure	7.0xbc[1]	6.4xb	10.4yb	9.8yab
2. Low manure	6.6xb	6.7xb	11.2yb	11.7yc
3. Medium manure	8.2xc	7.5xb	11.2yb	10.6yabc
4. Medium manure	7.7xbc	7.3xb	10.6yb	11.3ybc
5. High manure	8.2xc	6.9xb	10.9yb	10.6yabc
6. High manure	7.9xbc	7.8xb	10.4yb	10.1yab
7. Very high manure	7.5xbc	7.3xb	11.0yb	10.5yabc
8. Inorganic fertilizer	7.3xbc	7.2xb	10.2yb	10.6yabc
9. Control	4.8xa	4.5xa	8.6ya	9.7ya
Mean[2]	7.2	6.9	10.4	10.5

[1] x,y=LSD (0.05) for forage species comparisons within the same fertility rate.
a,b,c=LSD (0.05) for fertility rates comparisons within the same species.
[2] LSD (0.05)=0.4 for mean comparisons of species over the fertility rates.

RESULTS AND DISCUSSION

Herbage yield

There was a significant ($p<0.0001$) difference in herbage yield due to both fertility rates and forage species in 1995 when dairy slurry was applied after the 1st and 3rd cuttings. Total herbage yields (cuttings 2, 3, and 4) of alfalfa-orchardgrass and alfalfa-reed canarygrass mixtures were significantly higher than orchardgrass and reed canarygrass for all fertility rates (table 4). Dry weather during the growing season in 1995, particularly in June and July, undoubtedly reduced the herbage yields for the grasses. There was no significant increase in herbage yield within each species with increasing rates of dairy slurry application. Similar results were observed by Anderson et al. (1993) where they applied dairy cow slurry to timothy. They found no differences in herbage yield between light (132 and 134 kg N ha^{-1} in the spring and summer, respectively) and high (186 and 267 kg ha^{-1} in spring and summer, respectively) slurry rates. In contrast, Champman and Heath (1987) reported when slurry was applied to grass-clover swards, clover dry matter and clover proportion in swards were reduced. There was no significant difference in yield between orchardgrass and reed canarygrass or between alfalfa-orchardgrass and alfalfa-reed canarygrass averaged over fertility rates.

Herbage yields for the manure and inorganic fertilizer treatments were significantly higher than the control treatment except for alfalfa-reed canarygrass that showed no yield differences due to fertility rates. This may have been due to this mixture being predominantly alfalfa that did not show a yield response to manure and inorganic fertilizer applications as will be pointed out in the next paper. Herbage yields of grasses in manure treatments increased more than alfalfa-grass mixtures when compared with the control treatment. This is probably due to N_2 fixation by alfalfa in the control treatment. Averaged over manure treatments, dairy slurry increased herbage dry matter yields over the control treatment by 61, 60, and 26% for orchardgrass, reed canarygrass and alfalfa-orchardgrass, respectively, in 1995. None of the dairy slurry application treatments had an adverse effect on herbage yields within grasses and alfalfa-grass mixtures in 1995 in the 4-cutting management system.

Total herbage yields for the dairy slurry application treatments ranged from 14.8 to 20.1 Mg ha^{-1} and from 15.1 to 18.0 Mg ha^{-1} for the inorganic fertilizer treatment in 1996. Unlike 1995, the yield differences between grasses and alfalfa-grass mixtures were very small in 1996 (table 5). This was most likely due to higher than normal rainfall during the 1996 growing season (table 3). This is in agreement with Kaffka and Kanneganti's work in Connecticut (1996). They reported that orchardgrass response to liquid manure application was greater in year one with abundant rainfall than in year two with dry conditions during most of the growing season.

There was a significant ($p<0.0001$) fertility rate × forage species interaction in 1996 when slurry was applied in early spring and after each cut except the last. Alfalfa-orchardgrass yields were significantly higher than orchardgrass and reed canarygrass at the low rate, more frequent application treatment (treatment 1). Reed canarygrass was the lowest yielding species in the control treatment and the highest yielding in the very high manure treatment. The highest slurry rate (treatment 7) significantly increased orchardgrass yield compared to the inorganic fertilizer treatment, both theoretically providing the same amount of PAN. The high and very high slurry rate treatments (5, 6, and 7) significantly increased reed canarygrass compared to the inorganic fertilizer treatment. There were generally no significant yield differences between the slurry and inorganic fertilizer treatments for the alfalfa-grass mixtures. Herbage yield of orchardgrass at the very high slurry rate was significantly higher (by 2.0 Mg ha^{-1}) than at the low rate, however, there were no significant yield differences between the medium, high and very high rates. Kanneganti and Klausner (1996) in New York reported that herbage yields of orchardgrass increased linearly with up to 300 kg N ha^{-1} yr^{-1} as ammonium nitrate in addition to 150 kg total N ha^{-1} yr^{-1} from dairy manure applied before the onset of active crop growth in early spring (second week of April).

Reed canarygrass at the high and very high slurry rates had significantly higher yields than at the low rate. Herbage yields of alfalfa-grass mixtures were not affected by slurry rates in 1996. When averaged over fertility rates, alfalfa-grass mixtures had significantly

Table 5. Total herbage dry matter yields of orchardgrass (OR), reed canarygrass (RC), alfalfa-orchardgrass (AL-OR), and alfalfa-reed canarygrass (AL-RC) as affected by fertility rates, 1996

	Species			
Fertility rates	OR	RC	AL-OR	AL-RC
	Mg ha^{-1}			
1. Low manure	16.2xb[1]	15.7xbc	19.0ycde	17.5xyab
2. Low manure	16.4xybc	14.8xb	17.5ybc	17.0ya
3. Medium manure	18.0xybcd	18.0xyde	19.5yd	16.4xa
4. Medium manure	19.0yd	17.0xcd	17.5xybc	19.2yb
5. High manure	17.3xbcd	18.0xyde	19.9yd	17.3xab
6. High manure	17.8xybcd	19.1yef	16.7xab	17.5xyab
7. Very high manure	18.2xycd	20.1yf	19.5xyd	17.6xab
8. Inorganic fertilizer	16.2xyb	15.1xbc	18.0ybcd	17.2ya
9. Control	10.3ya	7.6xa	15.3za	16.9za
Mean[2]	16.6	16.1	18.1	17.4

[1] x,y,z=LSD (0.05) for forage species comparisons within the same fertility rate.
a,b,c,d,e,f=LSD (0.05) for fertility rates comparisons within the same species.
[2] LSD (0.05)=0.6 for mean comparisons of species over the fertility rates.

Table 6. Stand ratings of orchardgrass (OR), reed canarygrass (RC) alfalfa-orchardgrass (AL-OR), and alfalfa-reed canarygrass (AL-RC) in the spring of 1996 and 1997

Fertility rates	Species							
	OR		RC		AL-OR		AL-RC	
	Year							
	96	97	96	97	96	97	96	97
	%							
1. Low manure	69	67	80	78	80	77	85	78
2. Low manure	65	68	80	78	80	78	80	81
3. Medium manure	65	65	81	78	75	75	76	73
4. Medium manure	59	61	82	77	76	77	78	80
5. High manure	61	69	80	78	72	80	78	78
6. High manure	62	63	79	74	73	76	78	77
7. Very high manure	61	62	75	77	73	77	75	76
8. Inorganic fertilizer	57	56	80	78	76	73	80	77
9. Control	70	72	82	76	71	79	89	84

Spring of 1996: [1]LSD1 (0.05)=7.0; LSD2 (0.05)=7.0
Spring of 1997: LSD1 (0.05)=7.0; LSD2 (0.05)=9.0
LSD3 (0.05)=7.0

[1] LSD1 for forage species comparisons within the same fertility rate and year. LSD2 for fertility rates comparisons within the same species and year. LSD3 for mean comparison of years within the same fertility rates 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.

higher yields than grasses and there was no difference between orchardgrass and reed canarygrass. Alfalfa-orchardgrass had significantly higher yield than alfalfa-reed canarygrass. When averaged over manure treatments, herbage yields increased by 70, 130, and 21% over the control for orchardgrass, reed canarygrass, and alfalfa-orchardgrass, respectively, in 1996. Manure and fertilizer treatments did not affect alfalfa-reed canarygrass yields.

As shown in the table 5, herbage yields of grasses in 1996 were not affected by time of application for the same total rates (treatments 1 vs. 2, 3 vs. 4, and 5 vs. 6). This is in agreement with Kaffka and Kanneganti's work (1996) where herbage yield of orchardgrass was not affected by number of applications of dairy manure i.e., a single application at the onset of crop growth in spring vs. applications in early spring and after the second cutting vs. applications in early spring and after the first, second and third harvests. In contrast, treatments 3 vs. 4 and 5 vs. 6 in alfalfa-orchardgrass and 3 vs. 4 in alfalfa-reed canarygrass were affected by time of manure application. In these cases less frequent, larger individual applications reduced yield.

In this study, applying split applications of dairy slurry to established stands of orchardgrass and reed canarygrass alone and in combination with alfalfa at rates up to 967 kg total N ha^{-1} in 1995 and 2,014 kg total N ha^{-1} in 1996 plus a preplant manure application of 704 kg total N ha^{-1} in 1994 were not detrimental to herbage yields.

In both years, herbage yields of the alfalfa-grass mixtures were not increased by increasing manure application rates. Reed canarygrass showed a significant yield response to increasing rates of manure in 1996, a year when ample rainfall occurred during the growing season, but not in 1995. The highest herbage yield measured was for reed canarygrass at the very high manure application treatment in 1996. Herbage yields of grasses were more responsive to manure application when there was ample rainfall in 1996. Herbage yields of alfalfa-grass mixtures were less affected by lack of rainfall than the grasses in 1995 and were not affected by manure application rates. Gajda and Sawicki (1987) in Poland reported that herbage yield of hay fertilized with the dairy slurry was dependent on the level of precipitation during the growth period. They concluded that a more favorable yield response to slurry was noticed in years with higher precipitation.

Stand ratings

There was a significant ($p<0.001$) fertility rates $\times$ species interaction for stand ratings in the spring of 1996. As shown in the table 6, orchardgrass consistently had significantly lower stand ratings than the other species across all fertility treatments, including the control, in the spring of both 1996 and 1997. Orchardgrass had poorer initial establishment than the other species in 1994. There were no meaningful differences in stand ratings for reed canarygrass and alfalfa-grass mixtures due to application of manure. Comparisons of the stand ratings of the highest manure application rate (treatment 7), the inorganic fertilizer (treatment 8) and the control (treatment 9) for these species show no significant differences in the spring of 1997 after two years of manure applications. While there was no detrimental effect of manure on reed canarygrass and the alfalfa-grass mixtures, stand ratings for orchardgrass were significantly reduced not only by the higher rates of manure application (treatments 4 through 7 in 1996 and treatments 4 and 7 in 1997), but also by the inorganic fertilizer treatment. Thus it appears that the stand loss was not a direct result of the manure, such as from smothering of the plant crowns, but rather some effect of the higher rate of fertilization since the lowest stand ratings were associated with the inorganic fertilizer treatment. There were no changes in stand ratings of orchardgrass when the two years were compared.

Though stand ratings of orchardgrass were significantly lower than reed canarygrass in both production years, there was no significant yield difference between orchardgrass and reed canarygrass for most manure treatments. Thus, stand ratings were not necessarily proportional to herbage yields. Min (1994) reported that there was no yield difference between the lowest (16 plants m^{-2}) and highest (494 plants m^{-2}) densities of alfalfa in Alberta, Canada. He also found that plant size (yield per shoot, shoots per plant and stem diameter) was larger at the lowest density.

As shown in table 6, stand ratings were not affected by time of application for the same total amounts of slurry applied (treatments 1 vs. 2, 3 vs. 4, and 5 vs. 6). Thus there appears to be flexibility in scheduling when manure is applied without adversely affecting stand persistence. A comparison of stand ratings between the springs of 1996 and 1997 indicates that stand ratings within each species were not changed by slurry application in the 4-cutting management system.

Anderson et al. (1993) reported that the lighter rate (supplying 132 kg N ha^{-1} in the spring and 134 kg total N ha^{-1} in the summer) of surface-applied dairy slurry had less physical suppression of timothy during the first cut following application than the higher rate (supplying 186 kg N ha^{-1} in the spring and 267 kg total N ha^{-1} in the summer). In contrast to their study, late winter application rates in this study up to 868 kg total N ha^{-1} and summer applications up to 418 kg did not cause smothering or loss of stands.

CONCLUSIONS

Given the high rate of N applied in the inorganic fertilizer treatment and the fact that the very high slurry application rate and the inorganic fertilizer treatment at least theoretically should have supplied similar amounts of PAN, the significant increase in orchardgrass yield between the inorganic fertilizer treatment and very high manure treatment in 1996 was unexpected. Likewise with reed canarygrass, the significant differences between the inorganic fertilizer and the high and very high manure treatments were not expected. We do not know if some of the ammonium nitrate fertilizer N might have been leached below the root zone of the grasses due to the higher than the normal rainfall. Some N was undoubtedly lost through volatilization. Given the high yields obtained, the rate of N from ammonium nitrate might have been insufficient for maximum yield. Although the formula for calculating PAN for surface-applied manure does not include credit for ammonium N, some of the ammonium N was likely captured with the above normal rainfall and increased the N contribution of the manure above the amount expected. Additional studies are needed, particularly since both years of this study had periods of abnormal precipitation.

Alfalfa-grass mixtures would usually be expected to have a yield advantage over grasses, but abundant rainfall in 1996 enabled the grasses to generally produce yields as high or some cases even higher than the alfalfa-grass mixtures. Since the yields of grasses and alfalfa-grass mixtures can be quite similar under some conditions, the choice of which species to use may be largely determined by the forage quality and/or N and P utilization potential of each species. These aspects are being investigated in this project and will be presented later.

The results of this study indicate that dairy slurry can be effectively used to produce yields comparable to those obtained with inorganic fertilizer, even at high yields. No detrimental effects of slurry application were found on stand persistence during the 2 yr of this study. Increased use of manure on forage grasses and alfalfa-grass mixtures could not only reduce fertilizer costs for forage producers but be environmentally beneficial as well by providing additional land areas for application of manures.

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