Crop Response to Liquid Swine Effluent and Solid cattle Manure over Four Years in East-Central Saskatchewan

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Introduction

Due to the advent of relatively cheap chemical N fertilizers, the use of livestock manure as a source of nutrients to crops was downplayed (James, *et al.,* 1996). However, the expansion of the livestock industry, the need to utilize of the manure in an environmentally friendly and economically viable manner, and the desire to minimize the use of chemical N fertilizers have rekindled interest in the use of livestock manure as a fertilizer. Of particular interest is the need to utilize manure from large-scale intensive livestock operations (Chang and Janzen, 1996). This report is part of an on-going study initiated in 1996 to examine the soil and crop response to application of liquid swine manure and solid feedlot cattle manure at different rates and methods of application. Furthermore, the study seeks to evaluate nutrient forms and amounts in the manure and the effect of rate and method of manure application on soil fertility, nutrient utilization and crop yield. This paper puts together and summarises the results of crop response to annual application of the two types of manure compared to that of urea fertilizer observed over the past four years, 1997 to 2000.

Materials and methods

Two sites were selected in the fall of 1996 in the Black soil zone near Humboldt, Saskatchewan. The first site (Burr) was located on a field with soil classified as Black Chernozem (Meota Association) of sandy loam texture underlain by a gravel lens of variable depth with significant sub-surface salinity. The second site (Dixon) was situated on a Black Chernozem (Cudworth Association) of loamy texture. Various treatment combinations were used for both the swine and cattle manure experiments to cover a period of three years initially and later extended to the fourth year (Table 1). Quantities of manure-N application for the 1997 to 2000 growing seasons are given in Table 2. Both manure and urea fertilizer applications were made in the preceding fall of each growing season, respectively. Urea fertilizer application rates were 50, 100 and 200 kg N ha^{-1} for the low, medium and high treatment levels, respectively.

Table 1. Manure and Fertilizer Application Regimes for the 1997, 1998, 1999 and 2000 growing seasons at Burr and Dixon

Swine manure							Cattle manure						
Trt	**'97**	**'98**	**'99**	**'00**			**Trt**	**'97**	**'98**	**'99**	**'00**		
1	0	0	0	0	No injection		**1**	0	0	0	0	Check with incorporation	
2	0	0	0	0	Injection pass @ 12"		**2**	1	0	0	1	Cattle	Broadcast/incorporated
3	1	0	0	1	Swine	Injection @ 12"	**3**	1	1	1	1	Cattle	Broadcast/incorporated
4	1	1	1	1	Swine	Injection @ 12"	**4**	2	0	0	2	Cattle	Broadcast/incorporated
5	2	0	0	2	Swine	Injection @ 12"	**5**	2	0	2	2	Cattle	Broadcast/incorporated
6	2	0	2	2	Swine	Injection @ 12"	**6**	2	2	2	2	Cattle	Broadcast/incorporated
7	2	2	2	2	Swine	Injection @ 12"	**7**	4	0	0	4	Cattle	Broadcast/incorporated
8	4	0	0	4	Swine	Injection @ 12"	**8**	4	4	4	4	Cattle	Broadcast/incorporated
9	4	4	4	4	Swine	Injection @ 12"	**9**	1	1	1	1	Cattle	Broadcast/delayed-incorp.
10	1	1	1	1	Swine	Sweep @ 24"	**10**	1	1	1	1	Urea	Banded
11	1	1	1	1	Swine	Spiked & straight boot	**11**	2	2	2	2	Urea	Banded
12	1	1	1	1	Swine	Broadcast & incorporated	**12**	4	4	4	4	Urea	Banded
13	1	1	1	1	Urea	Banded							
14	2	2	2	2	Urea	Banded							
15	4	4	4	4	Urea	Banded							

Key:	
1	Low
2	Medium
4	High

Table 2. Total N Applied in the Swine and Cattle Manure studies at the Low, Medium and High Application Rates in the 1997, 1998, 1999 and 2000 growing seasons at Burr and Dixon

		Swine manure								Cattle manure							
		1997		1998		1999		2000		1997		1998		1999		2000	
		Burr	Dixon	Burr	Dixon	Burr	Dixon	Burr	Dixon	Burr	Dixon	Burr	Dixon	Burr	Dixon	Burr	Dixon
	Code	(kg N ha^{-1})								(kg N ha^{-1})							
Check	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Low	**1**	204	74	46	51	142	97	97	94	228	121	104	104	74	69	113	113
Medium	**2**	395	147	92	102	285	195	194	188	456	242	208	208	149	138	226	226
High	**4**	790	295	183	204	569	390	388	376	912	484	416	416	298	276	452	452

Results

In all the four growing seasons, pre-seeding available N in the 0 – 60 cm soil profile was significantly elevated by increasing swine manure and urea application rates (Fig. 1). Generally, pre-seeding available N in plots treated with the low, medium and high rates of swine manure was comparable to those receiving corresponding rates of urea. The only exception was in 1998 at Dixon and 1999 at Burr when pre-seeding available N at the high rate of manure remained the same as that at the medium rate. Very little evidence of cumulative effect of swine manure and urea were observed at the low and medium rates on pre-seeding available N at both locations. On the other hand, cumulative effect of high rates of both swine manure and urea on pre-seeding available N were observed in the third and fourth year at Dixon but not at Burr.

At the Dixon site, cattle manure had no significant effect on pre-seeding available N in the 0 – 60 cm soil profile (Fig. 2) in all the four growing seasons. However, although no elevation in pre-seeding available N was observed in 1997 at Dixon, increasing rates of cattle

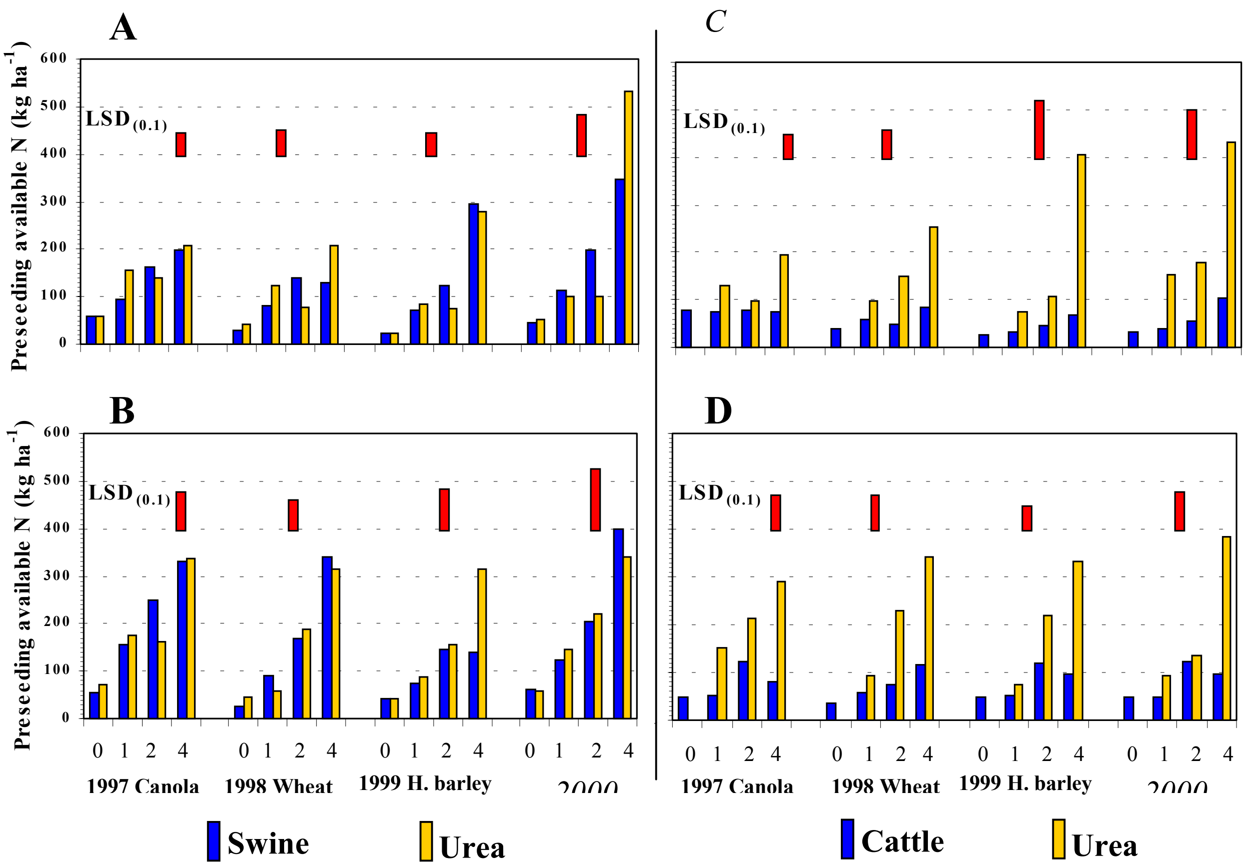

Fig. 1. Pre-seeding available N in 1997, 1998, 1999 and 2000, respectively, in the swine manure study at Dixon (A) and Burr (B), and in the cattle manure study at Dixon (C) and Burr (D).

manure increased pre-seeding available N in subsequent years although these increments were not statistically significant. Similar results were obtained at Burr, except that elevation of pre-seeding available N was evident even in 1997. Compared to cattle manure, urea enhanced presseding available N two to three fold at the corresponding application rates at both locations. As in the swine manure experiment, evidence of cumulative effect of urea on preceding available N was observed at Dixon but not at Burr.

Increasing rates of swine and cattle manure significantly enhanced crop N uptake in all the four crops (Fig. 2). At both Dixon and Burr, crop N uptake in swine manure treated plots tended to be comparable to that in urea treated plots. At Dixon, crop N uptake in urea treated plots was higher than cattle manure treated plots. However, at Burr, no significant difference in crop N uptake was observed in all the four growing seasons between cattle manure and urea treated plots.

No significant differences in grain yield were observed between swine manure and urea treated plots or between cattle manure and urea treated plots in all the crops over the four growing seasons (Fig. 3). However, particularly at Burr, both swine and cattle manure tended to exhibit higher grain yields than urea. In all the four crops, the effect of increasing swine manure on grain protein concentration was the same as that due to increasing rates of urea ferilizer (Table 3). In both cases, grain protein was significantly enhanced by increasing the rate of application. At Dixon, cattle manure did not have a significant effect on grain protein in all the crops except hulless barley in 1999. On the other hand, urea enhanced grain protein in all the crops. At Burr, the effect of increasing cattle manure rate on grain protein was similar to that of urea in all crops except wheat in 1998.

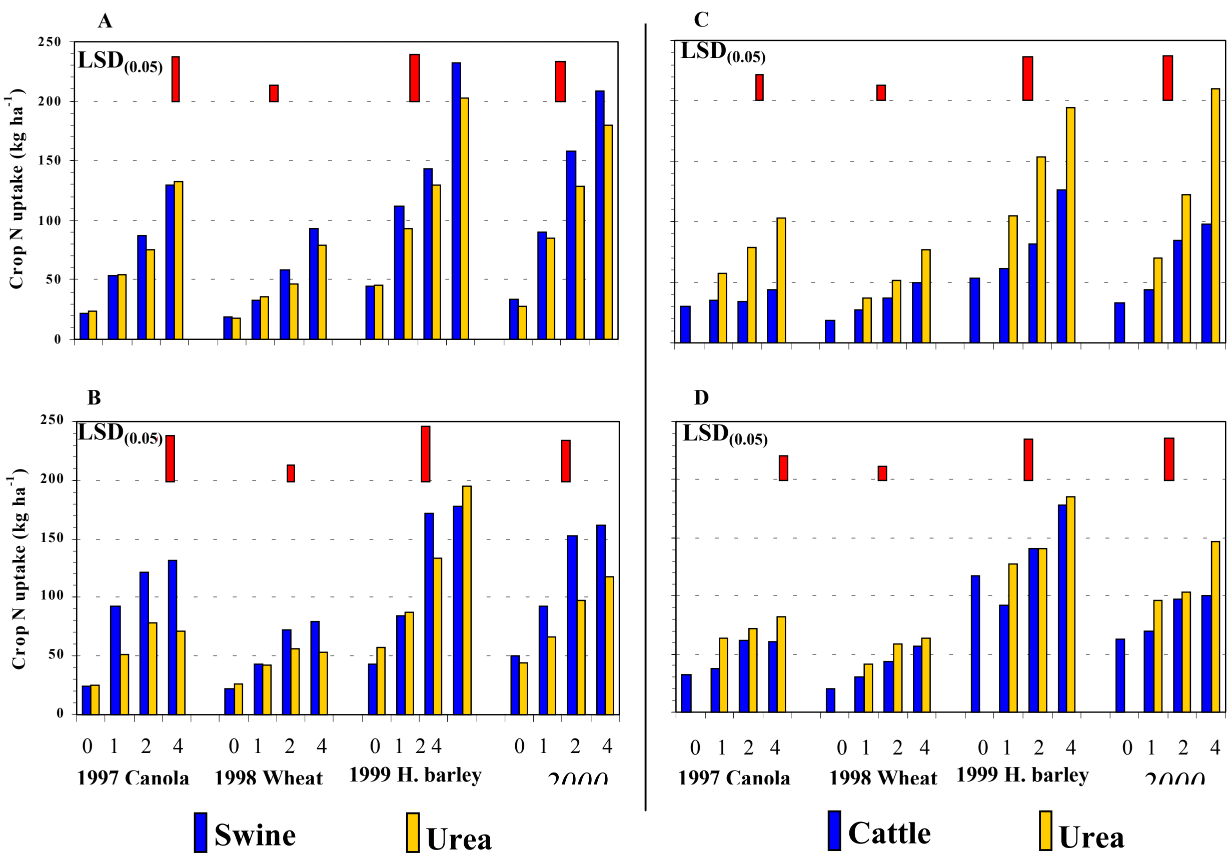

Fig. 2. Nitrogen uptake of canola, wheat, hulless barley and canola in 1997, 1998, 1999 and 2000, respectively, in the swine manure study at Dixon (A) and Burr (B), and in the cattle manure study at Dixon (C) and Burr (D).

Cumulative N use efficiency (NUE) adjusted for straw N of the previous crop in swine manure treated plots was lower but comparable to that of urea at the corresponding rates of application. At Dixon, significantly lower cumulative NUE of swine manure was observed for canola in both 1997 and 2000. At Burr, significantly lower cumulative NUE of swine manure was observed only for canola in 1997. In contrast, NUE of cattle manure was by far

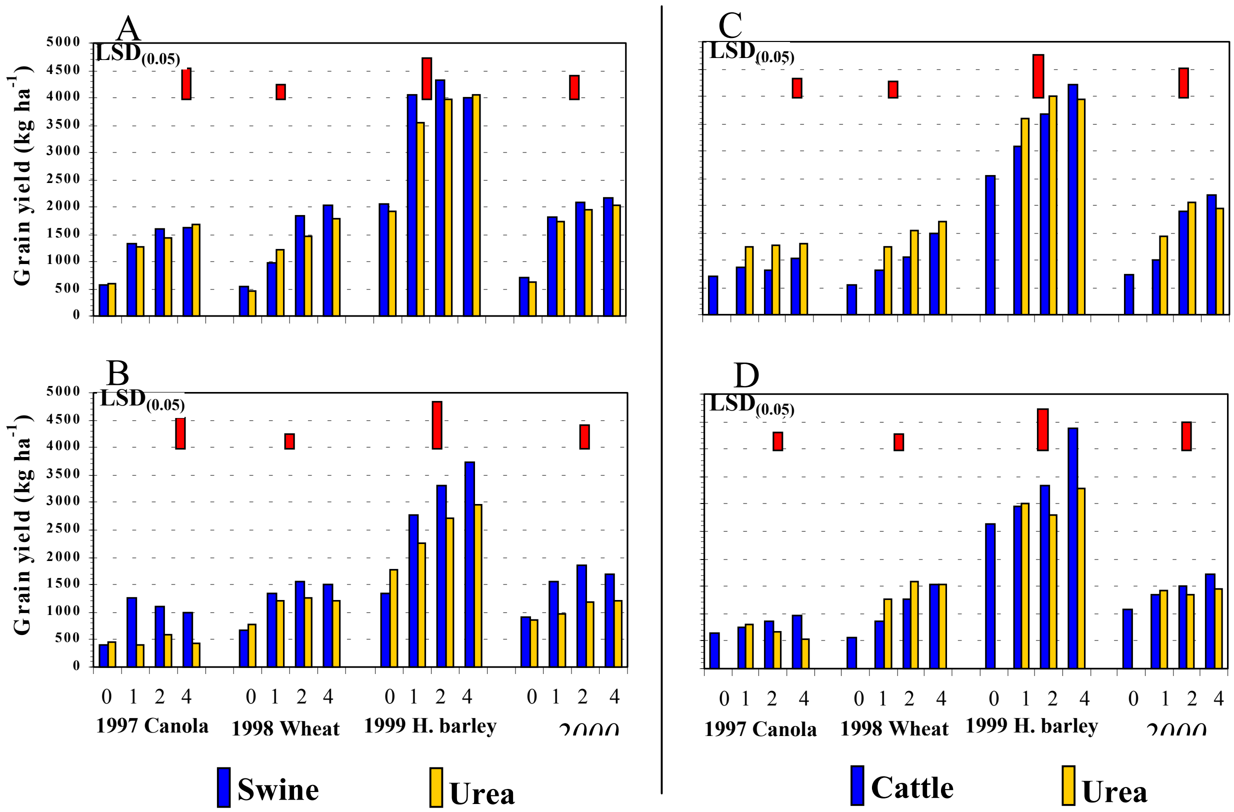

Fig. 3. Grain yield of canola, wheat, hulless barley and canola in 1997, 1998, 1999 and 2000, respectively, in the swine manure study at Dixon (A) and Burr (B), and in the cattle manure study at Dixon (C) and Burr (D).

lower than that of the corresponding rates of urea. However, at Dixon, there was a general trend of improving NUE over the four years.

Discussion

Results of this study show that both swine and cattle manure are viable alternatives to chemical N fertilizers. Most of the N present in swine manure is in inorganic form and therefore, readily available to the subsequent crop (Schoenau *et al,* 2000) as indicated by pre-seeding available N. However, due to a high C:N ratio of cattle manure, pre-seeding available N was not elevated to the same extent as that due to swine manure or urea fertilizer. Notwithstanding, crop N uptake and grain yield in cattle manure treated plots were comparable to those under urea and swine manure treatment. This aspect was more evident at the Burr site, indicating the capacity of cattle manure to enhance soil productivity of marginal soils. These results show that, although pre-seeding available N was not significantly enhanced in treatments receiving cattle manure, sufficient N slowly became available to the crop, through mineralization, resulting in increased grain yield and total N uptake at both locations. The similarity in crop N uptake between swine manure and urea were also

Table 3. Grain protein of canola, wheat, hulless barley and canola in 1997, 1998, 1999 and 2000, respectively, in the swine manure study (A) and in the cattle manure study (B) at Burr and Dixon

A — GRAIN PROTEIN (%)

Trt	Source	Rate '97	'98	'99	'00	1997 Canola Burr	1997 Canola Dixon	1998 Wheat Burr	1998 Wheat Dixon	1999 H.barley Burr	1999 H.barley Dixon	2000 Canola Burr	2000 Canola Dixon
2	Check	0	0	0	0	26.3 bc	19.6 c	14.7 c	16.2 b	10.5 d	8.9 d	24.7 b	22.1 d
4	Swine	1	1	1	1	30.7 a	20.4 c	14.8 c	15.2 bc	11.5 d	10.4 c	25.4 b	21.3 de
7	Swine	2	2	2	2	32.1 a	25.7 b	17.6 b	14.8 bc	14.6 bc	13.1 b	29.5 a	26.9 bc
9	Swine	4	4	4	4	33.0 a	29.5 a	19.6 a	18.3 a	15.1 ab	17.7 a	28.2 a	29.3 a
1	Check	0	0	0	0	24.9 c	18.6 c	15.4 c	16.2 b	11.2 d	8.8 d	23.6 b	19.7 e
13	Urea	1	1	1	1	29.5 ab	21.2 c	16.1 c	14.0 c	13.2 c	10.5 c	28.6 a	21.5 de
14	Urea	2	2	2	2	31.8 a	24.9 b	18.8 ab	15.0 bc	14.4 bc	12.9 b	28.5 a	25.9 c
15	Urea	4	4	4	4	32.3 a	28.3 ab	18.6 ab	18.7 a	16.6 a	16.5 a	28.4 a	28.8 ab

B — GRAIN PROTEIN (%)

Trt	Source	Rate '97	'98	'99	'00	1997 Canola Burr	1997 Canola Dixon	1998 Wheat Burr	1998 Wheat Dixon	1999 H.barley Burr	1999 H.barley Dixon	2000 Canola Burr	2000 Canola Dixon
1	Check	0	0	0	0	23.6 c	19.5 c	17.1 bc	16.0 bc	12.0 cd	9.0 e	23.9 cd	20.0 c
3	Cattle	1	1	1	1	24.2 c	19.7 c	17.0 bc	16.4 bc	11.3 d	9.0 e	22.8 d	20.4 c
6	Cattle	2	2	2	2	28.2 b	19.9 c	17.0 bc	16.8 b	12.4 cd	9.9 de	26.3 b	20.5 c
8	Cattle	4	4	4	4	27.7 b	20.3 c	18.0 ab	16.8 b	13.0 bc	11.1 c	26.5 b	20.7 c
10	Urea	1	1	1	1	29.3 ab	23.5 b	16.1 c	14.6 d	12.6 c	10.2 cd	25.3 bc	20.4 c
11	Urea	2	2	2	2	29.2 ab	27.5 a	17.9 ab	15.3 cd	13.9 b	13.2 b	28.7 a	24.6 b
12	Urea	4	4	4	4	31.4 a	29.5 a	19.0 a	19.0 a	16.2 a	16.7 a	29.6 a	30.1 a

Means followed by the same letter are not different at 0.05 level of significance.

Table 4. Cumulative adjusted NUE of canola, wheat, hulless barley and canola in 1997, 1998, 1999 and 2000, respectively, in the swine manure study (A) and in the cattle manure study (B) at Burr and Dixon

A — Cumulative Adjusted %NUE

Trt	Source	Rate '97	'98	'99	'00	1997 Canola Burr	1997 Canola Dixon	1998 Wheat Burr	1998 Wheat Dixon	1999 H.barley Burr	1999 H.barley Dixon	2000 Canola Burr	2000 Canola Dixon
4	Swine	1	1	1	1	33 b	43 ab	25 a	32 ab	18 ab	46 abc	23 a	43 bc
7	Swine	2	2	2	2	25 b	44 ab	17 ab	35 ab	19 ab	40 bc	21 ab	43 bc
9	Swine	4	4	4	4	14 b	36 b	9 b	27 b	10 b	33 c	11 b	29 d
13	Urea	1	1	1	1	53 a	64 a	20 ab	42 a	21 ab	58 a	22 a	62 a
14	Urea	2	2	2	2	54 a	53 ab	22 ab	33 ab	28 a	48 ab	25 a	53 ab
15	Urea	4	4	4	4	23 b	55 ab	9 b	30 ab	20 ab	43 bc	16 ab	41 c

B — Cumulative Adjusted %NUE

Trt	Source	Rate '97	'98	'99	'00	1997 Canola Burr	1997 Canola Dixon	1998 Wheat Burr	1998 Wheat Dixon	1999 H.barley Burr	1999 H.barley Dixon	2000 Canola Burr	2000 Canola Dixon
3	Cattle	1	1	1	1	2 d	5 c	4 c	6 c	-3 c	7 c	5 c	7 b
6	Cattle	2	2	2	2	6 d	2 c	6 c	5 c	7 bc	8 c	8 c	11 b
8	Cattle	4	4	4	4	3 d	3 c	4 c	5 c	7 bc	9 c	6 c	9 b
10	Urea	1	1	1	1	63 a	55 a	34 a	40 a	26 a	60 a	37 a	49 a
11	Urea	2	2	2	2	39 b	49 ab	23 b	33 a	21 ab	53 a	23 b	49 a
12	Urea	4	4	4	4	24 c	37 b	12 c	24 b	17 ab	36 b	19 b	40 a

Means followed by the same letter are not different at 0.05 level of significance.

demonstrated in a green house study by Qian and Schoenau (2000), who attributed this to the presence of other nutrients in the manure that may enhance root growth and N uptake. Generally, grain yield on swine manure treated plots were higher than that on urea treated plots. These results are in agreement with Stevenson *et al*. (1998) and Cavers (1999), who observed that grain yield and grain protein responses to manure are comparable to responses from commercial fertilizers.

Conclusion

Application of liquid swine manure resulted in an elevation of pre-seeding available N due to its low C:N ratio and high concentration of ammonium similar to that observed in treatments receiving urea fertilizer. Crop response to rate of swine manure was significant and similar to that caused by urea. In contrast, application of cattle manure did not cause an immediate elevation of available N, however, significant response to rates of cattle manure was observed in terms of N uptake and grain yield in all the four growing seasons. The relatively high C:N ratio of cattle manure may initially cause N immobilization of inorganic N in the manure. However, this N is potentially available to the crop during the growing season as N mineralization takes place. Furthermore, the slow release of N reduces the proportion of N that may be available for loss, thus, improving the N use efficiency over the long term.

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