LAND APPLICATION OF ANIMAL WASTE ON IRRIGATED FIELDS

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ABSTRACT

Animal wastes are routinely applied to cropland to recycle nutrients, build soil quality, and increase crop productivity. This study evaluates established best management practices for land application of animal wastes on irrigated corn. Swine (effluent water from a lagoon) and cattle (solid manure from a beef feedlot) wastes have been applied annually since 1999 at rates to meet estimated corn P or N requirements along with a rate double the N requirement (2xN). Other treatments were N fertilizer (60, 120, and 180 lb N/a) and an untreated control. Corn yields were increased by application of animal wastes and N fertilizer. Over-application of cattle manure has not had a negative effect on corn yield. For swine effluent, over-application has not reduced corn yields except for 2004, when the effluent had much greater salt concentration than in previous years, which caused reduced germination and poor early growth. All animal waste and N fertilizer treatments increased soil solution NO_3-N concentration (5-ft depth) compared with the untreated control. Application of animal wastes on a N requirement basis resulted in similar NO_3-N concentrations as fertilizer N applied at 180 lb/a (approximate recommended rate). The 2xN application caused NO_3-N concentrations to about double for both swine and cattle wastes. Application of swine effluent based on P requirement produced similar NO_3-N concentrations as the 2xN rate because of the relatively low P content in the effluent.

INTRODUCTION

This study was initiated in 1999 to determine the effect of land application of animal wastes on crop production and soil properties. The two most common animal wastes in western Kansas were evaluated; solid cattle manure from a commercial beef feedlot and effluent water from a lagoon on a commercial swine facility.

MATERIALS AND METHODS

The rate of waste application was based on the amount needed to meet the estimated crop P requirement, crop N requirement, or twice the N requirement (Table 1). The Kansas Dept. of Agriculture Nutrient Utilization Plan Form was used to calculate animal waste application rates. Expected corn yield was 200 bu/a. The allowable P application rates for the P-based treatments were 105 lb P_2O_5/a since soil test P levels were less than 150 ppm Mehlich-3 P. The N recommendation model uses yield goal less credits for residual soil N and previous manure applications to estimate N requirements. For the N-based swine treatment, the residual soil N levels after harvest in 2001, 2002, and 2004 were great enough to eliminate the need for additional N the following year. So no swine effluent was applied to the 1xN treatment in 2002, 2003, or 2005 or to the 2xN requirement treatment since it is based on 1x treatment (Table 1). The same situation occurred for the N based treatments using cattle manure in 2003. Nutrient values used to calculate initial applications of animal wastes were 17.5 lb available N and 25.6 lb available P_2O_5 per ton of cattle manure and 6.1 lb available N and 1.4 lb available P_2O_5 per 1000 gallon of swine effluent (actual analysis of animal wastes as applied varied somewhat from the estimated values, Table 2). Subsequent applications were based on previous analyses. Other nutrient treatments were three rates of N fertilizer (60, 120, and 180 lb N/a) along with an untreated control. The N fertilizer treatments also received a uniform application of 50 lb/a of P_2O_5. The experimental design was a randomized complete block with four replications. Plot size was 12 rows wide by 45 ft long.

The study was established in border basins to facilitate effluent application and flood irrigation. The swine effluent was flood-applied as part of a pre-plant irrigation each year. Plots not receiving swine effluent were also irrigated at the same time to balance water additions. The cattle manure was hand-broadcast and incorporated. The N fertilizer (granular NH_4NO_3) was applied with a 10 ft fertilizer applicator (Rogers Mfg.). The entire study area was uniformly irrigated during the growing season with flood irrigation in 1999-2000 and sprinkler irrigation in 2001-2006. The soil is a Ulysses silt loam. Corn was planted at about 33,000 seeds/a in late April or early May each year. Grain yields are not reported for 1999 because of severe hail damage. Hail also damaged the 2002 and 2005 crop. The center four rows of each plot were machine harvested after physiological maturity with yields adjusted to 15.5% moisture. Nitrate concentration in the soil solution at the 5 ft depth was determined periodically through the growing season in 2003 and 2004. The 5-ft depth is below the effective rooting depth of corn, so any nitrate movement past this depth is assumed non-recoverable by the corn plant. Suction-cup lysimeters (placed at 5-ft depth) are used to collect the soil water samples. The first samples are collected shortly after corn planting and then every 1-2 week intervals during the growing season as long as sufficient water is present at the 5-ft depth to allow collection. The samples are kept refrigerated after collection until delivered to the KSU Soil Testing laboratory for nitrate-N analysis.

RESULTS

Corn yields were increased by all animal waste and N fertilizer applications in 2006, as has been the case for all years except in 2002 where yields were greatly reduced by hail damage (Table 3). The type of animal waste affected yields in 5 of the 7 years with higher yields from cattle manure than from swine effluent. Averaged across the 7 yr, corn yields were 14 bu/a greater following application of cattle manure than swine effluent on an N application basis. Over application (2xN) of cattle manure has had no negative impact on grain yield in any year. However, over-application of swine effluent reduced yields in 2004 because of considerably greater salt content (2-3 times greater electrical conductivity than any previous year) causing germination damage and poor stands. No adverse residual effect from the over-application was observed in 2005.

The concentrations of NO_3-N in the soil solution at the 5-ft depth for eight sampling periods in 2003 are shown in Table 4. The NO_3-N concentrations were stable between time periods but quite variable among replications. All animal waste and N fertilizer treatments increased solution NO_3-N concentration compared with the untreated control. Application of animal wastes on a N requirement basis resulted in similar NO_3-N concentrations as fertilizer N applied at 180 lb/a (approximate recommended rate). Although for both cattle and swine wastes, no fresh applications were made in 2003 for the N based treatments because of sufficient residual soil N (for swine effluent, there was also no fresh application made in 2002). The 2x N application caused NO_3-N concentrations to more than double for both swine and cattle wastes. Application of swine effluent based on P requirement produced similar NO_3-N concentrations as the 2x N rate because of the relatively low P content in the effluent.

Compared with the 2001 values (data not shown), some treatments showed considerably higher NO_3-N concentrations in 2003. The three treatments (cattle manure applied at 2x N basis and swine effluent applied at 2x N basis or P basis) that had soil solution concentrations >100 mg kg^{-1} of NO_3-N in 2001 showed increases in NO_3-N concentrations in 2003 indicating continual accumulation of NO_3-N at the 5-ft depth. It would be expected that over-application of cattle manure (2x N basis) could result in increased soil solution NO_3-N concentrations. Similarly, since the swine effluent used in this study was relatively low in P, the application rates necessary to meet P requirements over-supplies N as shown by the elevated soil solution NO_3-N concentrations. However, for the 2xN swine effluent treatment there was no effluent applied in 2002 or 2003. With no additional effluent applied since the 2001 water samples were collected, the higher concentration of NO_3-N at the 5-ft depth in 2003 indicates movement of NO_3-N from the upper profile rather than from fresh applications.

Table 5 shows the NO_3-N concentrations in the soil solution at the 5-ft depth for eight sampling periods in 2004. Soil solution NO_3-N concentrations were similar for the untreated control and the low rate of N fertilizer, but increased by all other treatments. In general, soil solution NO_3-N concentrations were greater in 2004 than 2003. It would be expected that the soil solution NO_3-N concentrations for the N based swine effluent treatments would be greater because of the higher N content of the effluent in 2004 (with application rates based on average N content causing greater N loading than targeted). However, soil solution NO_3-N concentrations were also greater following applications of cattle waste based on N requirement and the higher rates of N fertilizer.

CONCLUSIONS

Animal wastes are routinely applied to cropland to recycle nutrients, build soil quality, and increase crop productivity. This study evaluated established best management practices for land application of animal wastes on irrigated corn. Swine (effluent water from a lagoon) and cattle (solid manure from a beef feedlot) wastes were applied annually for eight years at rates to meet estimated corn P or N requirements along with a rate double the N requirement (over-application). Corn yields were increased by application of both animal wastes, compared with no fertilizer. Over-application of cattle manure did not have a negative effect on corn yield. For swine effluent, over-application reduced corn yields only in one year, when the effluent had much greater salt concentration than in previous years, which caused reduced germination and poor early growth. Over-application of animal wastes tended to increase nitrate concentration in the soil solution below the corn root zone. However, applying swine effluent based on crop N requirements or cattle manure based on crop P requirements resulted in solution nitrate concentrations below the root zone similar to those from recommended rates of inorganic N fertilizer.

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Table 1. Application rates of animal wastes, Tribune, KS, 1999 to 2006.

Application basis *	Cattle manure							
	ton/a							
	1999	2000	2001	2002	2003	2004	2005	2006
P req.	15.0	4.1	6.6	5.8	8.8	4.9	3.3	6.3
N req.	15.0	6.6	11.3	11.7	0	9.8	6.8	6.3
2XN req.	30.0	13.2	22.6	22.7	0	19.7	13.5	12.6
	Swine effluent							
	1000 gal/a							
	1999	2000	2001	2002	2003	2004	2005	2006
P req.	28.0	75.0	61.9	63.4	66.9	74.1	73.3	66.0
N req.	28.0	9.4	37.8	0	0	40.8	0	16.8
2XN req.	56.0	18.8	75.5	0	0	81.7	0	33.7

* The animal waste applications are based on the estimated requirement of N and P for a 200 bu/a corn crop.

Table 2. Analysis of animal waste as applied, Tribune, KS, 1999 to 2006.

Nutrient content	Cattle manure							
	lb/ton							
	1999	2000	2001	2002	2003	2004	2005	2006
Total N	27.2	36.0	33.9	25.0	28.2	29.7	31.6	38.0
Total P_2O_5	29.9	19.6	28.6	19.9	14.6	18.1	26.7	20.5
	Swine effluent							
	lb/1000 gal							
	1999	2000	2001	2002	2003	2004	2005	2006
Total N	8.65	7.33	7.83	11.62	7.58	21.42	13.19	19.64
Total P_2O_5	1.55	2.09	2.51	1.60	0.99	2.10	1.88	2.60

Table 3. Effect of animal waste and N fertilizer on irrigated corn, Tribune, KS, 2000-2006.

Nutrient source	Rate basis[†]	Grain yield							
		2000	2001	2002	2003	2004	2005	2006	Mean
		- - - - - - - - - - bu/acre - - - - - - - - - -							
Cattle manure	P	197	192	91	174	241	143	236	182
	N	195	182	90	175	243	147	217	178
	2 X N	195	185	92	181	244	155	213	181
Swine effluent	P	189	162	74	168	173	135	189	155
	N	194	178	72	167	206	136	198	164
	2 X N	181	174	71	171	129	147	196	152
N fertilizer	60 N	178	149	82	161	170	96	178	145
	120 N	186	173	76	170	236	139	198	168
	180 N	184	172	78	175	235	153	200	171
Control	0	158	113	87	97	94	46	122	103
$LSD_{0.05}$		22	20	17	22	36	16	18	12
ANOVA									
Treatment		0.034	0.001	0.072	0.001	0.001	0.001	0.001	0.001
Selected contrasts									
Control vs. treatment		0.001	0.001	0.310	0.001	0.001	0.001	0.001	0.001
Manure vs. fertilizer		0.089	0.006	0.498	0.470	0.377	0.001	0.001	0.013
Cattle vs. swine		0.220	0.009	0.001	0.218	0.001	0.045	0.001	0.001
Cattle 1x vs. 2x		0.900	0.831	0.831	0.608	0.973	0.298	0.646	0.705
Swine 1x vs. 2x		0.237	0.633	0.875	0.730	0.001	0.159	0.821	0.043
N rate linear		0.591	0.024	0.639	0.203	0.001	0.001	0.021	0.001
N rate quadratic		0.602	0.161	0.614	0.806	0.032	0.038	0.234	0.042

[†]Rate of animal waste applications based on amount needed to meet estimated crop P requirement, N requirement, or twice the N requirement.

No yields reported for 1999 because of severe hail damage. Hail reduced corn yields in 2002 and 2005.

Table 4. Nitrate concentration in soil solution at the 5-ft soil depth in 2003 following application of animal wastes and N fertilizer.

Nutrient source	Application Basis*	Time of Sampling May 21	May 29	June 10	June 18	June 23	July 2	July 9	July 16	Mean
		Soil solution NO_3-N, ppm								
Cattle manure	P	45	31	46	38	41	43	45	44	42
	N	75	69	68	62	64	52	61	49	63
	2 X N	322	375	375	348	375	310	371	378	357
Swine effluent	P	264	280	281	280	283	278	296	299	283
	N	106	112	122	103	99	89	94	100	103
	2 X N	272	306	264	288	299	281	290	291	286
N fertilizer	60 N	23	20	22	19	21	18	22	22	21
	120 N	48	41	40	23	31	35	36	24	35
	180 N	102	98	105	84	86	64	71	73	85
Control	0	8	5	7	3	3	4	4	4	5
ANOVA (P>F)										
Treatment		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
Selected contrasts										
Control vs. treatment		0.028	0.034	0.019	0.020	0.012	0.014	0.006	0.005	
Animal waste vs. fert.		0.003	0.003	0.001	0.001	0.001	0.001	0.001	0.001	
Cattle vs. swine		0.139	0.145	0.188	0.090	0.109	0.038	0.070	0.047	
Cattle 1x vs. 2x		0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
Swine 1x vs. 2x		0.038	0.032	0.070	0.018	0.008	0.006	0.004	0.004	
N rate linear		0.306	0.371	0.278	0.380	0.367	0.488	0.432	0.406	
N rate quadratic		0.833	0.805	0.719	0.653	0.709	0.907	0.849	0.647	

* The animal waste applications are based on the estimated requirement of N and P for a 200 bu/a corn crop.

Table 5. Nitrate concentration in soil solution at the 5-ft soil depth in 2004 following application of animal wastes and N fertilizer.

Nutrient source	Application Basis*	May 26	June 4	June 8	June 15	June 23	June 27	July 7	July 14	Mean
		Time of Sampling								
		Soil solution NO_3-N, ppm								
Cattle manure	P	108	109	111	102	111	99	105	111	107
	N	321	335	344	358	306	282	293	294	317
	2 X N	322	418	421	300	454	402	424	405	393
Swine effluent	P	355	366	357	505	476	446	546	531	448
	N	145	127	128	219	146	141	169	170	156
	2 X N	203	303	327	325	247	395	540	307	331
N fertilizer	60 N	14	4	5	7	4	4	4	3	6
	120 N	116	119	109	129	111	120	139	135	122
	180 N	170	183	180	177	201	211	218	234	197
Control	0	8	5	4	4	2	2	1	1	3
ANOVA (P>F)										
Treatment		0.005	0.002	0.003	0.008	0.001	0.001	0.002	0.001	
Selected contrasts										
Control vs. treatment		0.006	0.005	0.007	0.009	0.007	0.003	0.024	0.001	
Animal waste vs. fert.		0.005	0.002	0.002	0.004	0.003	0.001	0.001	0.001	
Cattle vs. swine		0.795	0.753	0.772	0.241	0.993	0.285	0.063	0.258	
Cattle 1x vs. 2x		0.995	0.409	0.465	0.642	0.185	0.248	0.294	0.249	
Swine 1x vs. 2x		0.663	0.248	0.213	0.547	0.535	0.039	0.015	0.217	
N rate linear		0.064	0.060	0.078	0.122	0.059	0.036	0.069	0.013	
N rate quadratic		0.728	0.748	0.834	0.686	0.921	0.883	0.779	0.822	

* The animal waste applications are based on the estimated requirement of N and P for a 200 bu/a corn crop.