RESIDUAL EFFECTS OF MANURE AND N FERTILIZER ON CORN YIELD AND SOIL N AND P UNDER DRIP AND FURROW IRRIGATION

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ABSTRACT

A field experiment was conducted at the Arkansas Valley Research Center in 2007 to test the residual effects of two years (2005 and 2006) of manure application (10, 20, and 30 tons/acre) and N fertilizer (60, 120, and 180 lb N/acre) on corn yield, N and P uptake, and soil $N0_3$-N and P concentrations under subsurface drip irrigation (SDI) and furrow irrigation (FrI). There were no significant differences in corn yield between SDI and FrI in 2005, 2006, and 2007, even though, on average, 43% more water was applied with FrI than with SDI. The highest corn yields were obtained with 180 lb N/acre in 2005 and with as little as 60 lb N/acre or 10 tons of manure/acre in 2006. With no N fertilizer or manure applied in 2007, the residual manure and high N rate treatments produced an average of 224 bu/acre of corn. At the end of 2007, there was enough residual soil N left in the high manure treatment to produce top corn yields for two years. Applying manure in excess of crop nutrient requirements can lead to N and P buildup in the soil and associated water pollution hazards, as demonstrated in this study.

INTRODUCTION

Nitrate-N levels exceeding the Water Drinking Standard of 10 mg/L (ppm) were reported in 14% of domestic wells tested in the Arkansas Valley in 1994 (Yegert et al., 1997). Contamination sources were not determined but could be due in part to excessive N fertilizer application. Research indicates that N fertilizer rate in corn following alfalfa or vegetable crops such as melons can be reduced substantially without a significant drop in corn yield (Halvorson et al., 2005). Excessive N fertilizer application can lead to leaching of NO_3-N below the root zone, which is exacerbated by inefficient irrigation. Over 90% of the cropland in the Arkansas Valley is furrow-irrigated. Manure application in excess of crop requirements can cause a substantial buildup of N, P, and salts in the soil and their potential loss through leaching and runoff, which could adversely impact the environment (Eghball and Power, 1999).

Water quality issues, coupled with diminishing water supplies have led to increased interest in drip irrigation in the Arkansas Valley. The majority of current drip acreage is used for growing high-value crops such as onions, cantaloupes, and watermelons. Research elsewhere has demonstrated the feasibility of SDI for corn and other field crops (Lamm et al., 1995). A well designed and managed SDI system can save water by eliminating runoff losses and minimizing evaporation and deep percolation losses (Berrada, 2005). SDI also has the potential to minimize the leaching of salts and NO_3-N, but little is known about their movement under drip irrigation in the Arkansas Valley.

The main objective of this research in 2007 was to assess the residual effects of two consecutive years of N fertilizer and manure application under SDI and FRI on corn yield, N and P uptake, and soil NO_3-N and P concentrations.

MATERIALS AND METHODS

This research was conducted in 2005, 2006, and 2007 near Rocky Ford, CO. The soil at the study site was Rocky Ford silty clay (fine-silty, mixed, calcareous, mesic Ustic Torriorthents). The plot area was the same each year. Composite soil samples were taken from each replication and from selected treatments prior to fertilizer application in 2005. The soil had a pH of 8.1 and SOM of 1.5%. It averaged 36 ppm of P and 298 ppm of K in the top foot and 153 lb NO_3-N/acre in 0 to 6 ft. The recommended N fertilizer rate was 120 lb N/acre, based on a 250 bu/acre yield goal.

The experiment design was as a randomized complete block split plot with four replications. Irrigation type (SDI vs. FrI) was assigned to the main plots and fertilizer rate to the subplots. Plot size was 20 ft x 60 ft. The SDI system consisted of 0.875-in. diameter drip tapes with 0.45 gpm/100 ft. flow rate and 12-in. emitter spacing, buried 8 in. below ground, and spaced 60 in. apart. Water was pumped from the Rocky Ford Canal and filtered before it reached the drip tapes. Two flow meters were used to monitor irrigation amount. Furrow irrigation consisted of dispensing water from the irrigation ditch, with siphon tubes, to every other furrow. Water flow at the top and bottom of selected furrows was measured with a v-shaped furrow flume. All the plots were furrow-irrigated shortly after the corn was planted to ensure adequate corn germination and emergence. Total FrI irrigation amounts were 47 in. in 2005 and 30 in. in 2006 and 2007. Total SDI irrigation amounts, including the first furrow irrigation, were 26, 19, and 16 inches, respectively. Furrow-irrigation efficiencies were 40 to 50% in 2005 and 50 to 60% in 2006 and 2007. The higher efficiencies in 2006 and 2007 were due to improved management e.g., by switching to lower-diameter siphons after water reached the tail end. SDI efficiency (around 90%) was not as high as it could be (≥95%) because of evaporative water losses due to subbing, which was caused by shallow drip tape placement depth, high flow rate, and long irrigation runs (12 hours on average). Total season rainfall was 6, 11, and 8 inches in 2005, 2006, and 2007 respectively.

Fertilizer rates were: No N added (0N), no N or P added (0NP), 60 lb N/acre (60N), 120 lb N/acre (120N), and 180 lb/acre (180N). Manure rates were 10 tons (10T), 20 tons (20T), and 30 tons (30T) per acre. Phosphorus fertilizer 0-46-0 was added to 0N, 60N, 120N, and 180N at 100 lb/acre in 2005 and 2006. The N source was a polymer-coated urea with a release time of 30 days. Nitrogen and P fertilizers were broadcast by hand on 10 March 2005 and 10 April 2006. Feedlot beef manure was applied with a manure spreader on 18 March 2005 and 14 November 2005. Manure analysis is shown in Table 1. The recommended rate was 11 tons manure/acre for a yield goal of 250 bu/acre. There are several feedlots in the area, which makes manure application economical within a certain radius. An informal survey revealed that manure application rates in the Arkansas Valley varied from 10 t/acre or less to over 40 t/acre, with 20 t/acre being common. The plot area was disked after the first manure application and plowed after the second manure application. *No N or P fertilizer and no manure were applied after corn harvest in 2006.*

Table 1. Selected characteristics of beef feedlot manure applied in the spring and fall of 2005.

Sampling date	Total N lb/ac	Organic N lb/ac	NH_4-N lb/ac	NO_3-N lb/ac	P_2O_5 lb/ac	Water %	Ash %	C:N ratio	EC dS/m	pH
March'05	35.6	28.5	7.1	<0.1	18.3	40.8	18.0	13:1	24.8	7.6
Nov.'05	35.8	28.7	7.1	<0.1	23.6	35.0	28.4	11:1	23.4	8.6

Soil samples were taken in the spring and fall (after corn harvest) of each year to determine NO_3-N and NH_4-N concentrations. Sampling depths were: 0-1 ft, 1-2 ft, 2-3ft, and 3-4 ft in the spring and down to 6 ft in the fall. In addition, available soil P in the top foot was determined with the sodium bicarbonate method in 0NP, 10T, 20T, and 30T in 2005 and 2006 and 0NP, 120N, 10T, 20T, and 30T in 2007.

Corn hybrid Asgrow RX752RR/YG was planted in 30-in rows on 27 April 2005, 21 April 2006, and 3 May 2007 at approximately 33,000 seeds/acre. The preceding crop was soybean. Timely herbicide applications kept the plot area weed-free throughout most of the growing season. Hot and dry conditions in July 2005 led to a substantial infestation of spider mite which was suppressed later by aerial spraying of labeled insecticides. Preventive spraying was done on 27 June 2006 and no treatment was needed in 2007. The two middle rows (5 ft x 50 ft) in each plot were harvested on 18 Oct. 2005, 20 Oct. 2006, and 16 Oct. 2007 to determine grain yield, which was adjusted to 15.5 % water content and 56 lb/bu test weight. Grain samples were dried in the oven at 60 to 65 ^{0}C, ground, and analyzed for total N (all treatments) and P (0NP, 120N, 10T, 20T, and 30T). The soil and plant data were analyzed using the PROC MIXED procedure (SAS 9.1 Software, 2002-2003).

RESULTS

Grain yield

There were no significant differences in corn yield between FrI and SDI in all three years, despite the fact that an average of 43 % less water was applied with SDI than with FrI. In 2005, corn yields in 0N and 0NP were much higher in SDI than in FrI due to higher initial soil NO_3-N levels (Table 2). There was a significant yield reduction in 30T with SDI compared to most of the other treatments. Corn plant population in 2005 was markedly lower in the high manure treatment, particularly with SDI, which may have been caused by high salt concentration in the seedbed early in the season (data not shown). The highest yield in 2005 was achieved with 180N in both FrI and SDI, but was not statistically different than that of 60N and 120N with FrI and 0NP, 60N, 120N, and 10T with SDI (Table 2). There was no significant irrigation type by fertilizer rate effect in 2006 and 2007. The highest yield in 2006 was obtained with 60 to 180 lb N/acre and 10 to 20 t manure/acre (Table 3).

Table 2. Corn yield as affected by irrigation type and fertilizer rate in 2005.

Fertilizer Treatment	FrI (bu/acre)	SDI (bu/acre)	Analysis of variance (PROC MIXED)			
0N	169	202	Effect	DF	F value	Pr > F
0NP	187	214	Irr. Type	1	1.05	0.382
60N	209	212	Fert. Trt.	7	6.40	<0.00
120N	207	227	I x F	7	2.83	0.017
180N	232	231				
10T	200	210				
20T	206	202				
30T	205	183				
Mean	**202**	**210**				
LSD$_{(0.05)}$	25					

Table 3. Corn yield as affected by fertilizer rate in 2006 and 2007.

Fertilizer Treatment	2006 (bu/acre)	2007 (bu/acre)	Analysis of variance (PROC MIXED)			
0N	197	139		DF	F Value	Pr > F
0NP	195	127	Year: 2006			
60N	231	144	Irr. Type	1	0.03	0.869
120N	242	197	Fert. Trt.	7	8.49	<0.00
180N	247	224	I x F	7	1.67	0.144
10T	253	213	Year: 2007			
20T	245	233	Irr. Type	1	2.52	0.210
30T	223	224	Fert. Trt.	7	15.27	<0.00
Mean	229	187	I x F	7	0.77	0.617
LSD$_{(0.05)}$	22	33				

Corn yields averaged187 bu/acre in 2007 compared to 229 bu/acre in 2006 and 206 bu/acre in 2005. There was a large decrease in the yield of 0N, 0NP, and particularly 60N in 2007 compared to 2006. Treatments 180N, 10T, 20T, and 30T averaged 224 bu/acre in 2007 compared to 197 bu/acre with 120N.

Soil N

There was more residual NO$_3$-N in the top three feet of soil in the fall of 2005, in 180N, 20T and 30T compared to the other treatments (Table 4). The fall 2005 and fall 2006 NO$_3$-N levels were similar, except for 30T which increased from 189 to 354 lb N/acre in 0-3 ft. Obviously, N released by the high manure treatment exceeded N uptake by the second corn crop. There was a slight or no increase in NO$_3$-N levels in the spring of 2007 in the 0- to 3-ft depth compared to the fall of 2006. However, twice as much NH$_4$-N (60 vs. 30 lb N/acre) was present in the spring than in the fall (data not shown). Not much NO$_3$-N was left in the top three feet of soil in the fall of 2007 in all the treatments except 20T and 30T (Table 4). Assuming a total N requirement of 1.1 lb N per bushel of corn (Halvorson et al., 2005), there was enough residual N to produce around 100 bu/acre in 20T and over 300 bu/acre in 30T in 2008. Additional N will be released from the manure treatments, but not all the residual N may be available for the next crop. There were generally higher NO_3-N levels in the bottom than in the top three feet of soil in the fall of 2007, which reflects N uptake by corn, and may indicate a downward movement of NO_3-N, particularly in 20T and 30T where NO_3-N levels in the 3- to 6-ft depth increased every year. When averaged over all treatments and depths, there was significantly more NO_3-N (P = 0.086) in SDI than in FrI in the fall of 2007, primarily due to much higher residual N in the manure treatments with SDI. The same trend was observed in 2005, although the effects of irrigation type and irrigation by fertilizer treatment interaction were not significant (data not shown).

Table 4. Soil NO_3-N in the fall of 2005, 2006 and 2007, and the spring of 2007, as affected by fertilizer treatment.

Fertilizer Treatment	Fall 2005	Fall 2006	Spring 2007	Fall 2007	Fall 2005	Fall 2006	Fall 2007
	0- to 3-ft depth				3- to 6-ft depth		
	lb NO_3-N/acre						
0N	26	33	24	10	99	68	67
0NP	30	25	17	12	94	40	45
60N	25	46	41	18	47	43	74
120N	63	88	115	26	145	54	81
180N	155	121	114	24	51	102	105
10T	93	95	71	45	184	74	136
20T	166	176	247	136	87	125	307
30T	189	354	283	372	62	209	409
Mean	**93**	**117**	**114**	**80**	**96**	**89**	**153**
$LSD_{(0.1)}$	102	100	82	186	NS	57	150

Soil P

Soil $NaHCO_3$-P concentration in 0- to 1-ft depth was highly affected by fertilizer treatment as would be expected (Table 5). There was significantly more P in the manure treatments than in the check (0NP) or in 120N in the fall or spring (2007) of each year. Irrigation type did not have a significant impact on soil P. However, the potential for losing P e.g., through runoff is much higher with FrI than with SDI. Available P in 20T and 30T was well above the sufficiency level for irrigated corn production (Mortvedt et al., 2006) in all three years.

Table 5. Soil P concentration in the top foot of soil in selected treatments in the fall 2005, 2006 and 2007, and the spring of 2007.

Fertilizer Treatment	Fall 2005	Fall 2006	Spring 2007	Fall 2007
	ppm (mg/kg)			
0NP	9.3	4.7	6.9	7.3
120N	NA	NA	10.4	6.1
10T	19.0	18.0	26.0	18.1
20T	41.1	25.5	49.5	39.3
30T	37.1	67.0	80.4	44.0
Average	**26.6**	**28.8**	**34.6**	**23.0**
$LSD_{(0.05)}$	13.8	20.8	30.7	20.5

Grain N and P uptake

Nitrogen uptake by corn grain was highest with 180N in 2005 and with the manure and high N rate treatments in 2006 and 2007, in accordance with soil NO_3-N levels (Table 6). There were no significant irrigation type or irrigation type by fertilizer treatment effects in any of the three years. Phosphorus uptake was significantly higher with 120N, 10T, and 20T in 2006, and with 120N and all three manure rates in 2007 compared to the check. The increase (or lack of) in P uptake in 2005 and 2006 in the manure treatments is less than what would be expected based on soil P test levels (Table 5), or indicates the amount of P needed by the corn plants was adequately supplied with no luxury consumption of available soil P by the corn.

Table 6. Corn grain N and P uptake in 2005, 2006, and 2007 as affected by fertilizer treatment.

Fertilizer Treatment	2005	2006	2007	2005	2006	2007
	lb N/acre			lb P/acre		
0N	143	125	92	-	-	-
0NP	152	114	80	30	29	19
60N	158	141	94	-	-	-
120N	168	159	143	31	35	31
180N	181	171	173	-	-	-
10T	169	170	164	32	34	27
20T	159	169	192	33	35	35
30T	157	161	188	30	32	34
Average	**161**	**151**	**141**	**31**	**33**	**30**
$LSD_{(.05)}$	16	25	33	NS	4	4

CONCLUSIONS

There were no significant differences in corn yield between SDI and FrI in all three years, which indicates that SDI may be a feasible alternative to FrI for corn production in the Arkansas Valley. Growing more crops with SDI will save substantial amounts of water in an area where water resources are declining due to the sale and transfer of irrigation water to municipalities along the Front Range of Colorado. Concerns with SDI include high installation cost, salt accumulation, and how to ensure uniform crop germination and emergence in years with low spring precipitation.

Corn yields at or near the maximum were produced with 60 lb N/acre in 2005 and 2006 and with 10 tons of manure/acre in all three years. This confirms the results of Halvorson et al. (2005) and shows that fertilizer rates can be greatly reduced by taking into account residual N. The high manure rates of 20 and 30 t/acre resulted in high NO_3-N concentrations in the spring and fall of 2007. There was enough residual N in 30T after corn harvest in 2007 to produce an additional 300+ bu/acre of corn. Similarly, soil P tests in the manure treatments exceeded P sufficiency levels. Nitrogen and P buildup in the soil can impair water quality through leaching and runoff. The elevated NO_3-N and P levels in the soil led to increased N and P uptake by the corn grain in 2006 and 2007. This study did not show clear differences between SDI and FrI in soil N and P distribution. Part of the reason may be the way SDI was managed (long-duration water applications).

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