THE EFFECT OF MANURE AND N RATES ON CORN YIELD AND SALT AND NITRATE MOVEMENT IN THE SOIL UNDER FURROW AND DRIP IRRIGATION IN THE ARKANSAS RIVER VALLEY

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ABSTRACT

A field experiment was conducted at the Arkansas Valley Research Center (AVRC) in 2005 to test the effects of irrigation type and scheduling and fertilizer rate on corn yield and salts and NO_3-N movement in the soil profile. Four N fertilizer rates (0, 60, 120, and 180 lb N/a) and four manure rates (10, 20, and 30 t/a) under subsurface drip irrigation (SDI) and furrow irrigation (FrI) with two irrigation scheduling regimes (full and deficit irrigation) were compared. The results show no significant difference in corn yield between SDI and FrI, even though nearly twice as much water was applied with FrI than with SDI. Deficit irrigation decreased corn yields since water was withheld during two critical growth stages, silking and milk. Corn did not respond to N fertilizer rates beyond 60 lb N/a under deficit irrigation, while 30 t manure/a depressed the yield due to stand loss. Under full irrigation, the highest yield was obtained with 180 lb N/a which was more than the recommended rate of 120 lb N/a. Manure application increased soil salinity levels, which contributed to the decrease in plant population with increasing manure rate. Salinity issues need to be investigated further. Higher ECe values were observed at the 4- to 6-ft. depth under SDI than under FrI, probably because of greater leaching with the FrI system.

INTRODUCTION

High NO_3-N concentrations have been reported in the Arkansas River Valley of southeastern Colorado (Yergert et al., 1997). Research indicates that corn N fertilizer rate in the Arkansas Valley can be reduced substantially, particularly after vegetable crops, while maintaining optimum yield (Halvorson et al., 2002 and 2005). Leaching of NO_3-N below the root zone is exacerbated by inefficient irrigation. Over 90% of the cropland in the Arkansas Valley is furrow-irrigated. Over-application of manure can also lead to NO_3-N leaching and possibly salt build-up. Extensive monitoring in the Arkansas Valley has shown increasing salt concentration from west to east (Tim Gates, Personal Communication, 2005). Irrigation contributes approximately 14% of the total salt load in the Arkansas River Valley (Miles, 1977). As water moves across the field or through the soil, it dissolves and transports salts and other pollutants.

Water quality issues, coupled with recent droughts and diminishing water supplies have led to renewed interest in drip irrigation in the Arkansas Valley. Most of the current drip acreage is used for growing high-value crops such as onions, cantaloupes, and watermelons. Research elsewhere has shown the feasibility of subsurface drip irrigation (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. It 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 was to assess the comparative effects of SDI and furrow irrigation on corn yield, N uptake, and salt and NO_3-N concentration in the soil profile.

MATERIALS AND METHODS

This research was conducted in 2005 at AVRC in Rocky Ford, CO. The soil at the study site is Rocky Ford silty clay (fine-silty, mixed, calcareous, mesic Ustic Torriorthents). It had a pH of 8.1, 1.5% O.M. and 153 lb NO_3-N/a in 0 to 6 ft. soil depth. The field was planted to soybean in 2004. The recommended N fertilizer rate was 120 lb N/a, based on a 250 bu/a yield goal.

Irrigation treatments consisted of subsurface drip (SDI) and furrow irrigation (FrI) each with full and deficit irrigation (water withheld at10-leaf, silking and tasseling growth stages). Fertilizer rates were Check #1 [no N or P added (0NP)], Check #2 [46 lb P_2O_5/a but no N added (0N)], 60 lb N/a (60N), 120 lb N/a (120N), 180 lb/a (180N). Manure rates were 10 t manure/acre (10T), 20 t manure/a (20T), and 30 t manure/a (30T). One hundred pounds of 0-46-0 per acre was added to treatments 60N, 120N, and 180N (same as 0N). A polycoated urea with a release time of 30 days was used as the N source. Nitrogen and P fertilizers were broadcast on 10 March 2005. Feedlot beef manure was applied on 18 March 2005 with the following contents: 41% moisture, 1.78% total N, 1.43% Organic C, 0.35% NH_4-N, 0.001% NO_3-N, 0.4% P, C/N ratio of 13, and pH of 7.6. The recommended rate was 10 t manure/a. The whole plot area was disked shortly after manure application.

The experiment was designed as a split-split plot randomized complete block, with irrigation type as the main plot, irrigation amount as the first split, and fertilizer treatment as the second split with 4 replications. Plot size was 20 ft. by 60 ft.

The SDI system consisted of 0.875-in. diameter drip tapes with 0.45 gpm/100 ft. flow rate, 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. Furrow irrigation consisted of dispensing water from the irrigation ditch, with siphon tubes, to every other furrow. All the plots were furrow-irrigated on 5 May and on 16 May 2005 (even the SDI plots) to ensure adequate corn germination and emergence. Irrigation dates and depths are shown in Fig. 1. Irrigation was withheld from the deficit-irrigation treatment at the 10-leaf, silking, and milk growth stages.

Corn hybrid Asgrow RX752RR/YG was planted on 27 April 2005 at 33,723 seeds/a in 30-in. rows. Two corn rows were located on 60 inch wide beds. Herbicides provided good weed control. Hot and dry conditions in July led to a substantial infestation of spider mite which was brought under control with aerially spraying. Soil samples were taken in selected treatments in March and November 2005, to determine NO_3-N and P concentrations. The results were not available at this writing. Other soil samples were taken in June and October 2005 in 120N and 20T of the full irrigation (SDI and FrI) treatment to assess soil salinity. The main purpose of the June sampling was to devise an adequate soil sampling scheme and electrical conductivity (EC) measurement method. The November sampling depths were 0-6", 6-12", 1-2', 2-3', 3-4', 4-5', and 5-6' from the furrow, corn row, and middle of the 60" bed. The electrical conductivity (ECe) of 1:1 (soil-to-water ratio, by weight) (all the samples) or saturated-paste (selected samples) extracts was measured with a conductivity meter (Rhoades, 1996).

Data was analyzed using the PROC MIXED procedure (SAS 9.1 Software, 2002-2003). Grain yield was adjusted to 15.5% moisture and 56 lb/bu.

RESULTS AND DISCUSSION

Corn yield averaged 197 bu/a in 2005 across all treatments. The spider mite infestation in July affected the yield, as did irrigation scheduling and fertilizer rates. Full irrigation increased the yield by 20 bu/a, compared with deficit irrigation (P=0.001).

There was no significant difference in grain yield between SDI and FrI. Approximately 40 in. of water was applied with FrI, on average, compared to 22 in. with SDI. However, because of the low efficiency of FrI (41%), the net amount applied was similar, 16 to 17 in., with both irrigation types. In this study, we assumed a SDI irrigation efficiency of 90%, due to evaporation losses caused by subbing, which was the result of shallow drip-tape placement (8 in.) and long irrigation runs. Higher efficiencies were reported with SDI (Camp, 1998).

Fertilizer rate ($P < 0.0001$), and fertilizer by irrigation type ($P = 0.02$) or irrigation scheduling (P=0.11) had a significant effect on corn yield. The highest yield of 233 bu/a was obtained with 180 lb N/a under full irrigation (Fig. 2). Treatments 0NP, 60N, 10T, 20T, and 30T produced similar yields under full irrigation. The significant yield difference between the unfertilized checks, 0N and 0NP, cannot be explained at this time. Under deficit irrigation, the unfertilized checks and 30T had the lowest yields, while the treatments which received fertilizer N or 20 t manure/a had similar yields of 190 to 200 bu/a (Fig. 2).

Figure 3 illustrates the effect of fertilizer by irrigation type on corn yield. Yield ranking under SDI was as follows: 120N = 180N ≥ 60N =10T ≥ 20T = 0N = 0NP > 30T. There were no significant differences among 120N, 180N, and 20T with FrI, while the unfertilized checks had the lowest yields (Fig. 3). It is possible that some of the pre-season soil NO_3-N was not available to corn with FrI, due to leaching (Halvorson et al., 2005). Corn N uptake was significantly higher in 20T and 30T than in the other treatments (Table 1).

Table 1. Corn grain N uptake in 2005 at AVRC as affected by N or manure rate.

Treatment	Checks	N trts	10T	20T & 30T
lb N/bu	0.74c*	0.77b	0.78b	0.82a

*Values followed by a different letter are significantly different at P=0.05

The generally lower corn yields with manure, particularly at the highest rate of 30 t/a, could be attributed in part to low plant population (Fig. 4). Harvest plant population was significantly lower at 20T and 30T than at the other treatments, in both SDI and FrI. This was due to lower corn germination and emergence, in spite of the fact that all the treatments were furrow-irrigated at the start of the season. Visual observations indicate that water in the high manure-rate treatments did not move as much laterally as it did in the other treatments. Most of the manure was located near the soil surface since the field was not moldboard plowed after manure application, hence, more water may have been required to imbibe the seedbed due to high organic matter content, compared to the non-manure treatments.

Table 2. Post-harvest ECe (dS/cm) under SDI and FrI as affected by soil depth and sampling location.

Soil Depth	SDI			FrI		
	Furrow	Row	Bed Center	Furrow	Row	Bed Center
0-6”	2.59	1.53	1.95	1.38	2.01	4.25
6-12”	2.01	1.49	1.28	1.61	1.28	2.62
1-2’	2.06	2.38	1.12	2.02	1.49	1.83
2-3’	2.46	2.94	1.28	2.03	1.91	1.52
3-4’	2.65	2.85	1.95	2.30	2.23	1.65
4-5’	3.32	3.63	3.26	2.76	2.85	2.09
5-6’	3.35	3.72	3.49	2.58	2.94	2.01

Another factor which may have adversely affected corn stand in the manure treatments is salinity. ECe was substantially higher in 20T than in 120N early in the season, particularly under SDI (Fig. 5). ECe values were much lower after corn harvest, which would indicate a downward movement of salts in the soil profile, due to rain and irrigation (Table 2). Fertilizer treatment did not impact post-harvest ECe, while irrigation type by depth by position did. ECe generally increased with depth, with the exception of FrI in the middle of the bed (Table 2). SDI appears to have higher ECe in the furrow and corn row, while FrI appears to have higher ECe in the middle of the bed, although the relative ranking varied with depth. On average, SDI had significantly higher ECe than FrI at the 4- to 6-ft. depth which may have resulted with more leaching potential with the FrI treatment and lower leaching potential with SDI.

These first-year results show that substantial water savings can be achieved by using SDI to grow corn in the Arkansas Valley, without compromising grain yield. It also confirms that water stress imposed at critical growth stages will depress corn yield. Manure at the recommended rate can be as effective as mineral N fertilizer for achieving optimum growth; however issues relating to salinity and stand establishment need to be addressed.

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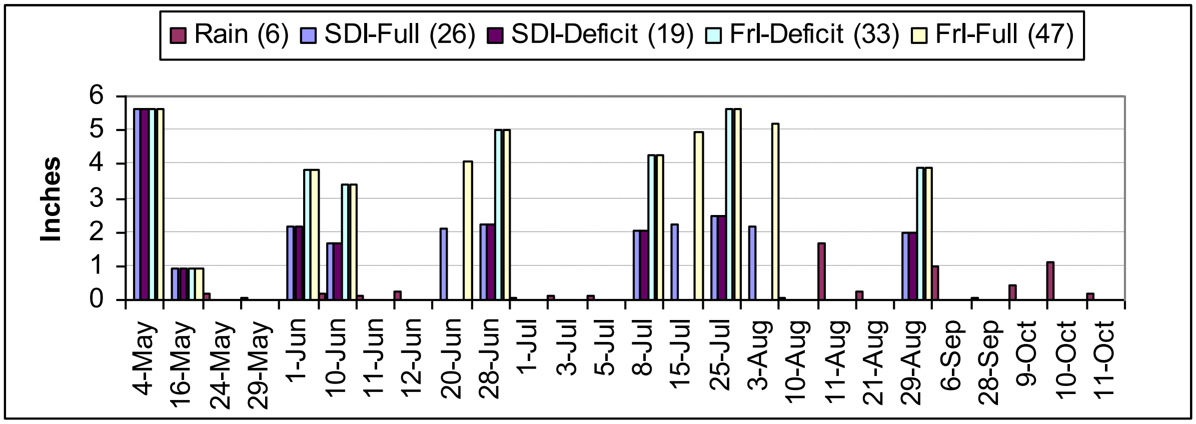

Figure 1. Precipitation amounts at AVRC during the 2005 corn growing season. Numbers in parenthesis are precipitation totals.

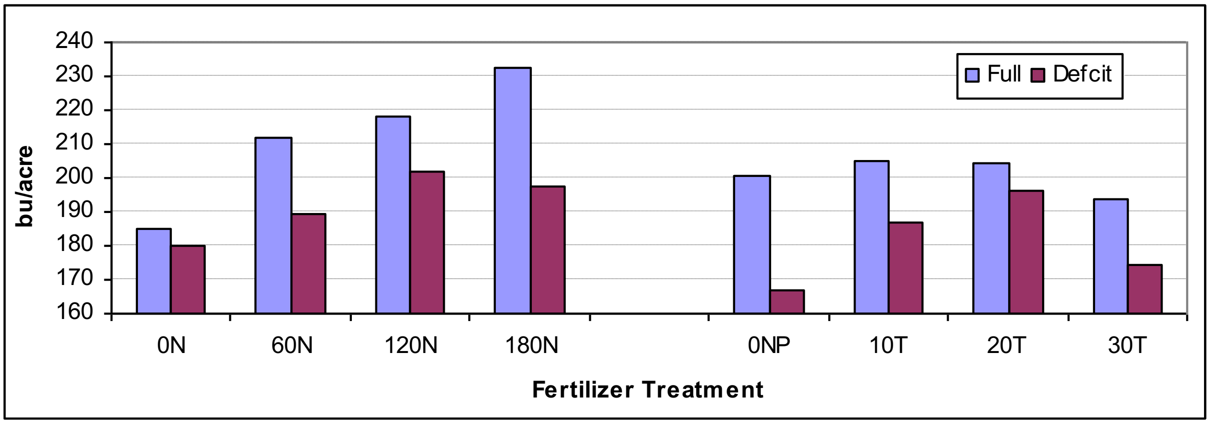

Figure 2. Corn yield in 2005 at AVRC under full and deficit irrigation as affected by N or manure rate.

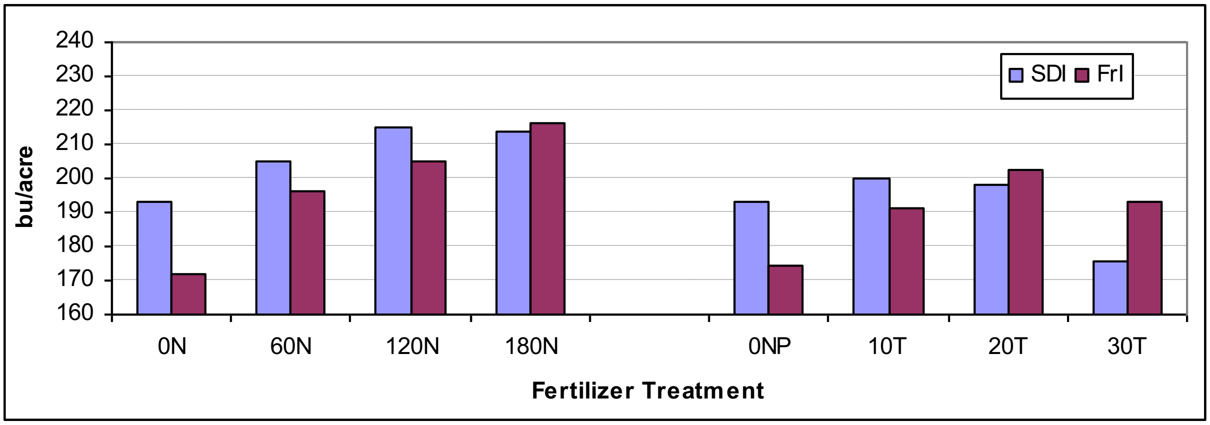

Figure 3. Corn yield in 2005 at AVRC under SDI and FrI as affected by N or manure rate.

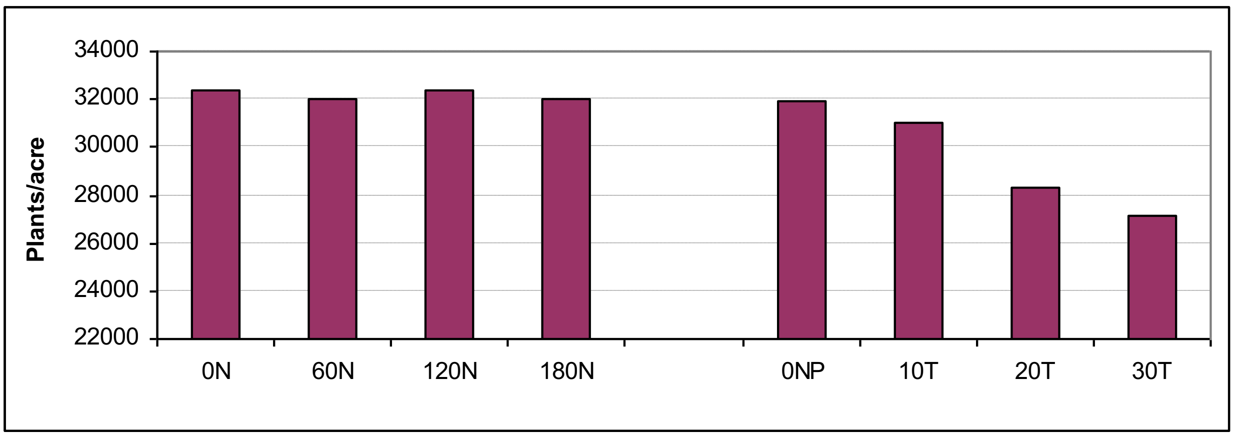

Figure 4. Harvest corn plant population in 2005 at AVRC as affected by N or manure rate.

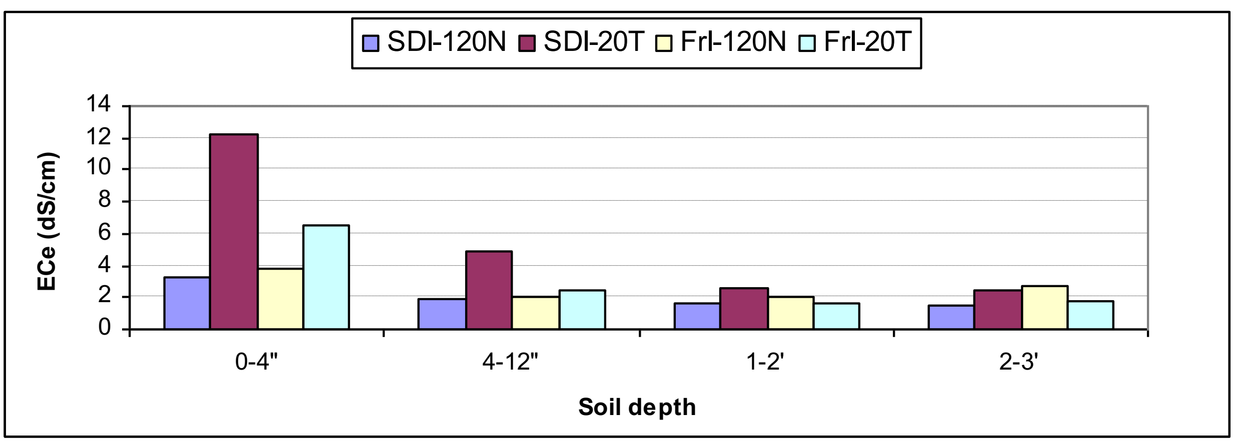

Figure 5. June 2005 ECe under SDI and FrI in 120N and 20T.