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Impact of Management on the Life Expectancy of Drip Systems

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Abstract: A successful maintenance program may increase the longevity of subsurface drip irrigation (SDI) systems. This study evaluated ten subsurface drip irrigation systems in 2008 and eight systems in 2009 that have longevities between six and twenty years. The system performance parameters: Christiansen's Uniformity Coefficient (CUC) and Low Quartile Distribution Uniformity (DUlq) was assessed for eighteen SDI systems and their maintenance practices were documented. The longevity of the system may be related to the water quality of the aquifer. The aquifer does not present any major problem related to chemical compounds that can enhance clogging problems. The uniformity of the ten systems evaluated in 2008 was greater than 79.3%. In 2009, two evaluated systems had low irrigation uniformities (CUC of 57.2 and 61.8%) Maintenance practices among farmers were very similar. Most of the farmers flush their filters daily for at least 1.33 minutes and flush the manifolds once a year. Farmers inject sulfuric acid once a year lowering the pH to less than 3.5. Others use N-pHuric instead of the sulfuric acid. One of the farmers with low CUC has not yet injected sulfuric acid into his system. The sulfuric acid that most farmers use is 95% and they apply it at approximately 0.94 L/ha (1 gal/10 acres). Some farmers inject chlorine every year, but others just every 7 years. The farmer that had the most clogging problems did not use chlorine. The chlorine is Univar's sodium hypochlorite, which is 12% and they apply it at approximately 0.47 L/ha (1 gal/20 acres). One of the systems evaluated in 2009 had very low uniformity which was probably due to the very low operating pressure. A good maintenance program and the use of good quality water should increase the longevity of the SDI system.

Keywords: performance evaluation, microirrigation, chlorination, acidification, chemigation, subsurface drip irrigation.

Introduction

Subsurface drip irrigation (SDI) systems are very uniform when properly designed and installed and distribution uniformities greater than 90% can be obtained with these systems (Enciso et al., 2002 and 2003). Considering the high uniformity of these systems, fertilizers and chemicals can be applied through the water in small and frequent quantities, increasing water application and nutrient utilization efficiencies (Lamm and Camp, 2007). Chemical losses through deep percolation or drifting from sprinklers can be minimized (Bordovsky, 2003). Beginning in the early 1980s, cotton producers in West Texas began to install subsurface drip irrigation (SDI) systems to stretch declining groundwater resources. Henggeler (1995) reported that adoption of SDI greatly improved lint yield and water use efficiency. Several commercial producers noted an average 27% increase in yield over surface (furrow) irrigation, with yield increases 2.5 times greater than dryland. Regular maintenance has prevented clogging, even in systems that were installed more than 15 years ago. It is necessary to determine how these systems are operating after all this time and determine how maintenance has helped to prevent emitter clogging problems. The difficulty in evaluating the systems is that the dripline is typically buried at approximately 33 cm (13 inches) for SDI systems on continuous cotton in Texas. Methodology to assess the SDI system performance and how maintenance programs might affect longevity are needed to assure the sustainability of irrigated agriculture in the region. The main objective of this study was to evaluate the uniformity of ten SDI systems with a life greater than seven years. Another objective was to document maintenance practices that permit the long term sustainability of SDI systems which is the predominant irrigation system in several areas of West Texas. Considering the large investment needed for SDI, it is vital to extend their lifetime with proper maintenance. By assessing the performance of the systems, we can evaluate the effectiveness of the various maintenance programs.

Procedures

Ten farms were selected in 2008 and eight in 2009 to evaluate the SDI system performance and evaluate the maintenance program in the resultant system performance and longevity. The systems were selected according to system age and with the recommendations of collaborating farmers. Farmers suggested which specific systems they wanted evaluated considering the water quality of the aquifer and the producer's system operating and maintenance practices. The farmers were located either in the TransPecos or the St. Lawrence area of Texas. Hydraulic characteristics of the SDI systems, such as the emitter design pressure and flowrate, emitter spacing were obtained from the producer. Emitter flowrate and pressure at the lateral was recorded during the evaluation. Emitter flowrate data was collected from 18 points for each SDI system. The data was collected from 18 random locations within a single SDI zone. The data was used to determine the Christiansen's Uniformity Coefficient (CUC) and the Low Quartile Distribution Uniformity (DUlq).

The Low Quartile Distribution Uniformity is

$$\mathrm{DUlq} = \frac{avg.\,low - quarter\ depth}{avg.\,depth\ of\ water\ accumulated\ in\ all\ the\ containers}$$

Christiansen's uniformity coefficient is defined as

$$CU = \frac{100\ [1 - (\sum \mid (X - x) \mid)}{\sum X}$$

where X is the depth (or volume) of water in each of the equally-spaced catch containers and *x* is the mean depth (or volume) of water in all the catch cans.

Results

Water Analysis

The irrigation water was evaluated for 7 of the 10 sites in 2008 and in 8 sites in 2009. The irrigation water was generally good quality water pumped primarily from the Edwards Trinity Plateau and Ogallala aquifers (Table 1a for 2008 and 1b for 2009) with small amounts of sodium salinity. Site C had the greatest salinity from the 2008 samples with 2352 mg/L of total dissolved solids (TDS). Site K had the greatest salinity of the 2009 samples with 3541 mg/L of total dissolved solids (TDS). Cotton has a relatively high tolerance for salinity and since it is grown continuously in this region, the water has not been a problem. Water hardness is expressed as the combination of calcium and magnesium mg/L. Most values of the combined calcium and magnesium are over 100 mg/L and special precautions are necessary if phosphoric acid is to be injected into the system. The water should be acidified before phosphoric acid is injected to avoid the formation of phosphates that could precipitate in the dripline and clog its emitters. This is often done by mixing the phosphoric acid with N-pHuric[1] (Urea-Sulfuric- Acid). Alternatively, but a less preferable method of avoiding phosphate precipitation is to inject the phosphoric acid at a fast rate to quickly lower the pH below 4 before precipitates can form. The injection of fertilizers containing phosphorus will be a problem if proper precautions are not taken. Iron and Manganese can also represent a clogging potential when the iron concentrations of the water are greater than 0.6 mg/L and when sulfides greater than 2.0 mg/L are present. The water of the study sites had very low concentrations of iron and magnesium; therefore clogging problems caused by these elements did not represent a threat.

Table 1.a. 2008 water quality parameters for the seven of the ten older SDI systems that were evaluated in West Texas.

Parameter analyzed	Site							
	A	B	C	D	E	F	G	Units
Calcium (Ca)	104	129	235	151	101	112	96	mg/L
Magnesium (Mg)	36	41	119	61	39	23	32	mg/L
Sodium (Na)	131	151	334	202	119	79	128	mg/L
Potassium (K)	6	6	16	9	6	6	6	mg/L
Boron (B)	0.80	1.05	1.34	1.26	0.70	0.49	0.79	mg/L
Carbonate (CO_3)	0	0	0	0	0	0	0	mg/L
Bicarbonate (HCO_3)	269	260	238	245	262	279	269	mg/L
Sulfate (SO_4-)	293	350	1128	579	306	143	248	mg/L
Chloride (Cl^-)	95	133	274	190	90	105	102	mg/L
Nitrate-N (NO_3-N)	8.35	9.98	8.70	4.92	5.05	3.67	6.34	mg/L
Phosphorus (P)	0.04	0.04	0.05	0.04	0.03	0.05	0.04	mg/L
pH	7.30	7.30	7.20	7.30	7.40	7.30	7.30	-
Conductivity	1223	1423	2890	1807	1148	960	1146	µmhos/cm
Hardness	24	29	63	37	24	22	22	grains CaCO3/gallon
Hardness	410	491	1074	629	412	373	370	mg/L CaCO3
Alkalinity	221	213	195	201	215	229	221	mg/L CaCO3
Total Dissolved Salts (TDS)	944	1081	2352	1443	929	750	889	mg/L
SAR	2.8	3.0	4.4	3.5	2.5	1.8	2.9	-
Iron (Fe)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	mg/L
Zinc (Zn)	< 0.01	0.02	0.04	0.08	0.06	0.67	0.09	mg/L
Copper (Cu)	0.02	0.01	0.02	0.02	0.14	0.07	0.02	mg/L
Manganese (Mn)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	mg/L
Charge Balance (cation/anion*100)	101	103	102	98	100	102	101	-

Table 1.b. 2009 water quality parameters for eight older SDI systems that were evaluated in West Texas.

Parameter analyzed	Site								
	K	L	M	N	O	P	Q	R	Units
Calcium (Ca)	526	95	91	184	214	116	87	91	mg/L
Magnesium (Mg)	105	27	38	60	59	26	26	27	mg/L
Sodium (Na)	462	95	101	168	125	122	106	75	mg/L
Potassium (K)	11	7	6	10	11	9	8	6	mg/L
Boron (B)	1.39	0.51	0.63	1.01	0.84	0.57	0.49	0.53	mg/L
Carbonate (CO_3)	0	0	0	0	0	0	0	0	mg/L
Bicarbonate (HCO_3)	183	265	258	234	208	258	291	252	mg/L
Sulfate (SO_4-)	1,706	246	273	646	709	270	227	217	mg/L
Chloride (Cl^-)	517	81	96	174	119	99	94	70	mg/L
Nitrate-N (NO_3-N)	29.6	4.2	5.66	7.63	7.4	28.76	1.06	5.04	mg/L
Phosphorus (P)	0.17	0.06	0.04	0.06	0.09	0.39	0.03	0.03	mg/L
pH	7.10	7.51	7.48	7.28	7.32	7.35	7.62	7.5	-
Conductivity	4,100	990	1,077	1,775	1,674	2,120	1,130	890	µmhos/cm
Hardness	102	20	22	41	45	23	19	20	grains CaCO3/gallon
Hardness	1,747	347	384	709	777	395	325	337	mg/L CaCO3
Alkalinity	150	217	211	192	171	211	238	207	mg/L CaCO3
Total Dissolved Salts (TDS)	3,541	820	871	1,485	1,453	929	840	744	mg/L
SAR	4.8	2.2	2.3	2.7	2.0	2.7	2.6	1.8	-
Iron (Fe)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/L
Zinc (Zn)	<0.01	<0.01	0.01	0.03	<0.01	0.06	<0.01	<0.01	mg/L
Copper (Cu)	0.03	0.01	0.04	0.02	0.02	0.02	0.01	0.01	mg/L
Manganese (Mn)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	mg/L
Charge Balance (cation/anion*100)	100	93	94	95	96	91	92	92	-

Evaluations of the SDI Systems

The ten SDI systems evaluated in 2008 had been in place between 8 and 20 years and the eight systems evaluated in 2009 had been in place between 6 and 12 years. Although there were older SDI systems that could have been selected, they were only being used occasionally to irrigate pecan trees. The original designs for none of the evaluated systems could not be located, but the emitter spacing and nominal emitter flow-rate was obtained (Table 2a for 2008 and Table 2b for 2009). The brand of the dripline, diameter of the dripline and fertilizers that were used by the farmers are shown in Table 3a and 3b. During 2008, System I had the least operating pressure [24 kPa (3.5 PSI)] and also had the least DU_{LQ} (79.2%) and least CUC (79.3%) which is probably indicating that this system was being operated below a minimum threshold operating pressure necessary for good performance. The Christiansen's uniformity coefficient and the DU_{LQ} was greater than 85% for 7 of the 10 systems which had a average lifespan to date of 11.7 years. The three other systems with an average CUC of 82.4% and of the DU_{LQ} of 80.7% were approximately 13.7 years old. There was really not any observed relationship between longevity and performance of the system as the oldest system (System J at 20 years) had a CUC of 92.7 and DU_{LQ} of 91.3% during 2008. These results agree well with other published studies that system longevity is a poor indicator of SDI system performance (Hanson et al., 1995; Pitts et al., 1996).

Table 2.a. 2008 results for the performance evaluation of ten older SDI systems in West Texas.

Site	Years since installation	Dripline pressure kPa (PSI)	Measured emitter flowrate $L\ h^{-1}$ (GPH)	Design emitter flowrate $L\ h^{-1}$ (GPH)	Emitter spacing cm (inches)	CUC (%)	DU_{LQ} (%)
A	11	52 (7.5)	0.79 (0.21)	0.91 (0.24)	60 (24)	89.0	87.9
B	8	103 (15.0)	0.79 (0.21)	0.61 (0.16)	60 (24)	92.2	93.0
C	10	124 (18.0)	1.14 (0.30)	0.76 (0.20)	60 (24)	92.1	91.1
D	12	55 (8.0)	1.14 (0.30)	1.51 (0.40)	76 (30)	91.7	91.6
E	11	83 (12.0)	0.91 (0.24)	0.76 (0.20)	60 (24)	84.8	79.4
F	9	38 (5.5)	0.49 (0.13)	0.61 (0.16)	60 (24)	90.3	86.6
G	10	34 (5.0)	0.95 (0.25)	0.76 (0.20)	60 (24)	94.3	92.3
H	15	45 (6.5)	0.79 (0.21)	1.51 (0.40)	76 (30)	83.2	83.4
I	15	24 (3.5)	0.83 (0.22)	1.51 (0.40)	76 (30)	79.3	79.2
J	20	41 (6.0)	0.38 (0.10)	0.56 (0.15)	30 (12)	92.7	91.3

During 2009, System P had the least DU_{LQ} (57.2%) and least CUC (27.2%). System M also presented a low DU_{LQ} (61.8%) and low CUC (27.2%). System P was operated under adequate pressure, but system L was being operated under very low pressure (22 KPa or 3.2 PSI). In both systems phosphoric acid was injected. It is probable that the low uniformity of system "L" could be caused by a low operating pressure. The reasons for the low uniformity of system "P" will be explained by the assessment of the maintenance practices in the following section.

Table 2.b. 2009 results for the performance evaluation of ten older SDI systems in West Texas.

Site	Years since installation	Dripline pressure kPa (PSI)	Measured emitter flowrate L h^{-1} (GPH)	Design emitter flowrate L h^{-1} (GPH)	Emitter spacing cm (inches)	CUC (%)	DU_{LQ} (%)
K	10	68 (9.9)	0.95 (0.25)	0.87 (0.23)	76 (30)	91.9	91.9
L	9	61 (8.8)	0.91 (0.24)	0.87 (0.23)	76 (30)	89.8	87.7
M	10	22 (3.2)	0.58 (0.15)	0.87 (0.23)	60 (24)	61.8	47.8
N	6	118 (17.1)	0.78 (0.21)	0.61 (0.16)	60 (24)	71.0	81.6
O	9	76 (11.0)	0.90 (0.24)	0.87 (0.23)	76 (30)	84.0	81.5
P	9	99 (14.4)	0.86 (0.23)	0.87 (0.23)	76 (30)	57.2	27.2
Q	12	62 (9.0)	0.98 (0.25)	0.87 (0.23)	76 (30)	92.6	90.0
R	10	47 (6.8)	0.88 (0.23)	1.87 (0.23)	76 (30)	95.5	94.3

Table 3.a. 2008 Dripline brand and model names, dripline size (ID), and fertilizers sources for the ten older SDI systems that were evaluated in West Texas.				
Site	Dripline brandname	Dripline Size mm (inches)	Nitrogen fertilizer	Phosphorus fertilizer
A	Netafim Python	22 (0.785)	32-0-0 / N-pHuric	Phosphoric Acid
B	Netafim Python	22 (0.785)	32-0-0	Phosphoric Acid
C	Netafim Python	22 (0.785)	32-0-0	Miller Solugro
D	Netafim Python	22 (0.785)	32-0-0	None
E	Netafim Python	22 (0.785)	32-0-0	None
F	Netafim Python	22 (0.785)	32-0-0	None
G	Netafim Python	22 (0.785)	32-0-0	Phosphoric Acid
H	Netafim Python	20 (0.800)	32-0-0	None
I	Netafim Python	20 (0.800)	32-0-0	None
J	Chapin	16 (0.625)	32-0-0	None

Table 3.b. 2009 dripline brand and model names, dripline size (ID), and fertilizers sources for the eight older SDI systems that were evaluated in West Texas.

Site	Dripline Brandname	Dripline Size mm (inches)	Nitrogen fertilizer	Phosphorus fertilizer
K	Netafim Python	22 (0.875)	32-0-0	None
L	Netafim Python	22 (0.875)	32-0-0	Phosphoric Acid
M	Netafim Python	22 (0.875)	32-0-0	None
N	Netafim Python	25 (1.00)	32-0-0	12-48-08 Solugro humic acid & calcium sulfate
O	Netafim Python	22 (0.875)	32-0-0	None
P	Netafim Python	22 (0.875)	32-0-0	Phosphoric Acid
Q	Netafim Python	22 (0.875)	32-0-0	None
R	Netafim Python	22 (0.875)	32-0-0	None

Maintenance Programs

The most common maintenance practices were flushing of the filters, periodic flushing of manifolds and periodic injections of chlorine and sulfuric acid. Most of the farmers flushed the filters daily, except for three farmers that flushed every two days (two systems in 2008 and one in 2009) [Table 4a and 4b]. The filter flushing time varied from 1 to 1.66 minutes. The manifolds were generally flushed once a year, although three farmers did it once every two years and another once every three years. The most common chemical injections were chlorine and sulfuric acid. There was a great variability in the chlorine injection practices. Some farmers have never injected chlorine and three injected every other year. Two other farmers injected the chlorine after 7 and 8 years of use. Farmer P, who had the least DU_{LQ} (57.2%) and least CUC (27.2%) had not injected chlorine in his 9 years-old system which may help explain the clogging of the emitters. Two farmers injected chlorine after every 40 cm of water applied, and stopped the injection, once the strip paper indicated free chlorine of 10 mg/L. The chlorine used was Univar's sodium hypochlorite, which is 12% concentration. They apply it at approximately 0.47 L/ ha (1/2 gallons for 10 acres). Most of the farmers injected the sulfuric acid by lowering the pH below 3.5 once a year, except farmer P. The sulfuric acid that most farmers use is 95% concentration and they apply it at approximately 0.94 L/ha^{-1} (1 gal/10 acres). One farmer injected N-pHuric instead of sulfuric acid.

Table 4.a. 2008 typical maintenance practices for the ten older SDI systems that were evaluated in West Texas as indicated by the producers.

Site	Filter flushing regimen		Manifold flushing	Chlorine injection	Sulfuric acid injection (interval and amount)
	Interval (hr)	Duration (min)			
A	24	1.50	Annual	Never	N-pHuric
B	24	1.33	Annual	Never	Annually lowering pH down to 3.0
C	24	2.00	Annual	Bi-annually	Annually lowering pH down to 2.0
D	48	2.50	Annual	First after 8 years	Annually lowering pH down to 3.5
E	48	2.50	Annual	First after 7 years	Annually lowering pH down to 3.5
F	24	1.00	Every 2 years	none	Every 2 years lowering pH down to 3.0
G	24	1.66	Every 3 years	Every 3 years	Every 3 years lowering pH down to 3.1
H	96	2.0	Twice per year	Every 16 inches of irrigation to concentration of 10 mg/L	Every 16 inches of irrigation lowering pH down to 3.0
I[1]	NA	NA	NA	NA	NA
J	48	4.0	Annual	Every 16 inches of irrigation to concentration of 10 mg/L	Every 16 inches of irrigation lowering pH down to 3.5

[1] Maintenance information for system I was not available (NA).

Table 4.b. 2009 typical maintenance practices for the ten older SDI systems that were evaluated in West Texas as indicated by the producers.

Site	Filter flushing regimen		Manifold flushing	Chlorine injection	Sulfuric acid injection (interval and amount)
	Interval (hr)	Duration (min)			
K	12	0.50	Once/Year	None for past 2 years	None for past 2 years
L	24	1.50	Once/Year	Annually to concentration of 10 mg/L	Annually lowering pH to 3.7
M	24	1.50	Every other year	Every 2 years to concentration of 20 mg/L	Every 2 years lowering pH to 3.5
N	48	0.67	Every other year	Annually	Annually lowering pH to 2.0
O	24	2.50	Once/Year	Every 2 years to concentration of 20 mg/L	Every 2 years lowering pH to 3.5
P	24	1.50	Once/Year	None	None
Q	48	1.50	Once/Year	One time to concentration of 20 mg/L	One time lowering pH to 3.5
R	24	0.67	Two times	Two times to concentration of 20 mg/L	Two times lowering pH down to 3.5

Summary and Conclusions

Ten older SDI systems that had been installed over 8 years ago were evaluated in 2008 and eight systems over 6 years old were evaluated in 2009 for emitter performance. The Christiansen's uniformity coefficient (CUC) for 2008 systems was greater than 79.3%. However, the uniformity was low for two of the systems evaluated in 2009 with CUC of 57.2 and 61.8%. No fully-clogged emitters were observed in the 2008 evaluated systems probably due to the good maintenance practices and the good water quality of the aquifer. One of the systems evaluated in 2009 had several clogged emitters because of the lack of chlorine and sulfuric injects. Another system evaluated in 2009 that had low uniformity was being operated under very low pressure (22 KPa). Most of the farmers flushed their sand filters every day or twice per day for at least one minute. Most of the farmers flushed their manifolds once a year and injected sulfuric acid to lower the pH of the water to less than 3.5 at least once a year to prevent or reduce emitter clogging. The injection of chlorine was highly variable from site to site, applied yearly, biannually, triennially or after seven or more years. The farmer that had the most clogging problems never injected chlorine.

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[1] Mention of tradenames is for informational purposes only and does not constitute endorsement by the authors or by the institutions they serve.

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