Morrill Industries Ecoflow™ Soil Column Study

FINAL REPORT

Submitted to
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Introduction

Morrill Industries contracted with The Center for Irrigation Technology (CIT) to conduct a study to explore the influence of the Morrill Industries Ecoflow™ water conditioner device on hydraulic conductivity and ion transport in the soil domain. The trials were conducted on three soil types: De Luz, CIT (sandy loam) and Valley.

Objective

The primary objective of this study was to evaluate the effect of the Ecoflow™ unit on hydraulic conductivity and ion species distribution in the soil domain and applied water under soil wetting through flow under a constant pressure head.

Materials and Methods

A total of 18 soil columns (height: 61 cm, diameter: 11.4 cm) were used to test three soil types: De Luz, CIT sandy loam, and Valley. These sets were then split with three connected to the Ecoflow™ unit (3/4" size) and three designated as control columns that received no treatment (water passed through a dummy unit 3/4" size). To ascertain the water discharge rate, records were kept of the volume of water that left the system every 24 hours. Two tanks were used to provide the columns with water. Both tanks were located at an identical fixed elevation above the columns to supply a constant pressure head to the columns below. Darcy's Law was used to convert the flow rates into hydraulic conductivity values shown in Table A. Samples for chemical analysis were collected at days 4, 23 and 37 of the trial and the ionic concentrations are detailed in Tables B, C, and D.

Results

1. Flow Rate/ Hydraulic Conductivity (Table A, E)
    a. For the De Luz and CIT (Sandy Loam) soils, a statistically significant difference between the treated and control hydraulic conductivity was observed.
2. Chemical Analysis
    a. De Luz Soil
        i. A statistically significant difference was observed in the initial samples for sodium, carbonate/bicarbonate, and nitrate between the treated and control columns
        ii. The langelier index (L.I.) also showed a statistically significant difference between treated and control.
    b. CIT (Sandy Loam)
        i. A statistically significant difference in bicarbonate/carbonate concentration was observed in the initial sampling round.
    c. Valley Soil
        i. No significant difference was evident for the valley soil initially, but after day 37, a statistically significant difference was observed for the L.I. between control and treated samples.

CIT Tables

Hydraulic Conductivity (K_{sat}) for varying soil columns over time (cm/day) (± SE)							
		De Luz		CIT (Sandy Loam)		Valley	
Date	Day	Trt	Ctrl	Trt	Ctrl	Trt	Ctrl
9/6/2011	1	6.63 *(1.17)*	4.06 *(0.97)*	3.64 *(0.71)*	2.52 *(0.86)*	0.09 *(-)*	0.22 *(-)*
9/7/2011	2	10.0 *(1.97)*	7.60 (*1.75)*	6.07 (*1.00)*	5.27 (*1.50)*	0.80 *(-)*	1.81 *(-)*
9/7/2011	2	8.60 *(1.85)*	6.29 *(1.43)*	5.09 *(0.81)*	4.51 *(1.23)*	2.33 *(0.35)*	2.85 *(0.87)*
9/8/2011	3	6.08 *(1.40)*	4.53 *(1.29)*	4.38 *(0.77)*	3.82 *(1.10)*	2.66 *(0.28)*	3.05 *(0.79)*
9/9/2011	4	3.51 *(1.37)*	3.40 *(0.97)*	2.76 *(0.69)*	2.64 *(0.69)*	2.18 *(0.25)*	2.42 *(0.60)*
9/12/2011	7	3.48 *(0.65)*	2.81 *(0.61)*	3.34 *(0.82)*	2.81 *(0.85)*	1.76 *(0.23)*	1.91 *(0.39)*
9/13/2011	8	3.19 *(0.61)*	2.35 *(0.36)*	3.07 *(0.63)*	2.79 *(0.84)*	1.72 *(0.26)*	1.74 *(0.37)*
9/14/2011	9	2.85 *(0.57)*	2.25 *(0.53)*	3.13 *(0.75)*	2.61 *(0.76)*	1.53 *(0.26)*	1.59 *(0.33)*
9/15/2011	10	2.68 *(0.57)*	2.10 *(0.42)*	2.98 *(0.71)*	2.49 *(0.71)*	1.40 *(0.25)*	1.50 *(0.32)*
9/16/2011	11	2.58 *(0.52)*	2.21 *(0.49)*	3.16 *(0.78)*	2.62 *(0.76)*	1.62 *(0.34)*	1.66 *(0.35)*
9/19/2011	14	2.10 *(0.42)*	1.81 *(0.37)*	2.68 *(0.63)*	2.28 *(0.66)*	1.26 *(0.27)*	1.29 *(0.24)*
9/21/2011	16	1.97 *(0.41)*	1.81 *(0.41)*	2.60 *(0.61)*	2.24 *(0.62)*	1.22 *(0.31)*	1.26 *(0.25)*
9/26/2011	21	1.87 *(0.40)*	1.73 *(0.40)*	2.49 *(0.62)*	2.03 *(0.59)*	1.16 *(0.30)*	1.14 *(0.21)*
9/28/2011	23	1.68 *(0.38)*	1.62 *(0.39)*	2.37 *(0.56)*	1.87 *(0.55)*	1.06 *(0.30)*	1.05 *(0.20)*
9/30/2011	25	1.82 *(0.39)*	1.72 *(0.43)*	2.55 *(0.62)*	1.94 *(0.55)*	1.22 *(0.36)*	1.20 *(0.24)*
10/4/2011	29	1.58 *(0.34)*	1.50 *(0.38)*	1.90 *(0.35)*	1.55 *(0.43)*	0.95 *(0.29)*	0.91 *(0.20)*
10/10/2011	35	1.52 *(0.32)*	1.44 *(0.36)*	2.11 *(0.45)*	1.60 *(0.44)*	1.04 *(0.30)*	1.00 *(0.25)*
10/12/2011	37	1.50 *(0.32)*	1.40 *(0.38)*	2.07 *(0.42)*	1.59 *(0.43)*	0.99 *(0.29)*	0.94 *(0.25)*
10/14/2011	39	1.41 *(0.32)*	1.35 *(0.37)*	2.03 *(0.41)*	1.56 *(0.43)*	0.93 *(0.31)*	0.87 *(0.25)*
10/17/2011	42	1.39 *(0.31)*	1.33 *(0.38)*	1.97 *(0.39)*	1.50 *(0.41)*	0.89 *(0.28)*	0.87 *(0.26)*
10/19/2011	44	1.40 *(0.32)*	1.41 *(0.43)*	1.99 *(0.44)*	1.12 *(0.17)*	1.60 *(0.97)*	0.98 *(0.35)*
10/20/2011	45	1.37 *(0.31)*	1.34 *(0.41)*	2.41 *(0.83)*	1.49 *(0.43)*	0.84 *(0.29)*	0.82 *(0.25)*
10/21/2011	46	1.33 *(0.30)*	1.30 *(0.37)*	2.23 *(0.64)*	1.47 *(0.41)*	0.88 *(0.31)*	0.82 *(0.28)*
10/24/2011	49	1.23 *(0.28)*	1.22 *(0.34)*	2.03 *(0.54)*	1.39 *(0.40)*	0.81 *(0.28)*	0.75 *(0.25)*
10/26/2011	51	1.35 *(0.29)*	1.32 *(0.40)*	2.06 *(0.58)*	1.38 (0.41)	0.87 *(0.27)*	0.78 *(0.25)*
10/27/2011	52	1.39 *(0.32)*	1.41 *(0.40)*	2.21 *(0.61)*	1.45 *(0.42)*	0.94 *(0.30)*	0.92 *(0.32)*

Table A: Hydraulic Conductivity (K_{sat}) values from the soil column trials.

Morrill Soil Column Water Analysis Data (1st Round). Data are means (± SE)									
	De Luz		CIT Sandy Loam		Valley		P-Values (Initial)		
	Treated	Control	Treated	Control	Treated	Control	De Luz	CIT	Valley
EC (dS/m)	1.56 *(0.23)*	2.23 *(0.09)*	4.65 *(0.38)*	6.52 *(1.12)*	5.05 *(1.71)*	4.35 *(1.35)*	0.06	0.19	0.76
Ca (meq/L)	6.62 *(1.65)*	9.94 *(1.45)*	24 *(2.95)*	33 *(6.38)*	28.7 *(13.1)*	20.0 *(5.38)*	0.20	0.27	0.57
Mg (meq/L)	4.04 *(1.01)*	5.91 *(0.58)*	14.1 *(1.07)*	18.8 *(3.63)*	10.0 *(3.66)*	7.30 *(2.13)*	0.18	0.28	0.56
Na (meq/L)	5.47 *(0.15)*	7.9 *(0.23)*	7.6 *(0.71)*	10.1 *(1.97)*	12.5 *(3.96)*	11.8 *(4.45)*	0.001	0.30	0.92
SAR	6.33 *(0.68)*	8.00 *(0.52)*	5.67 *(0.39)*	6.9 *(0.89)*	9.50 *(2.35)*	9.20 *(3.07)*	0.12	0.27	0.94
Cl (meq/L)	2.4 *(0.50)*	3.53 *(0.18)*	4.73 *(0.57)*	6.67 *(1.59)*	9.37 *(4.43)*	9.10 *(5.77)*	0.10	0.32	0.97
CO_3+ HCO_3 (meq/L)	6.97 *(0.35)*	8.80 *(0.50)*	11.6 *(0.91)*	16.5 *(0.61)*	12.2 *(2.94)*	7.33 *(2.36)*	0.04	0.01	0.27
SO_4 (meq/L)	1.83 *(0.38)*	2.57 *(0.17)*	4.03 *(0.41)*	4.70 *(0.49)*	6.87 *(2.69)*	5.67 *(1.37)*	0.15	0.36	0.71
B (mg/L)	0.76 *(0.08)*	0.92 *(0.05)*	0.75 *(0.08)*	0.72 *(0.01)*	0.87 *(0.18)*	0.80 *(0.10)*	0.17	0.74	0.72
NO_3-N (mg/L)	34.8 *(8.86)*	74.5 *(5.30)*	353 *(71.6)*	484 *(123)*	174 *(78.5)*	105 *(51.3)*	0.02	0.41	0.50
Fe (mg/L)	1.74 *(0.61)*	1.71 *(0.59)*	0.51 *(0.17)*	0.38 *(0.07)*	2.68 *(1.72)*	2.64 *(0.59)*	0.98	0.55	0.98
Mn (mg/L)	2.48 *(0.39)*	3.49 *(1.14)*	5.07 *(2.35)*	4.65 *(0.56)*	12. 0 *(4.78)*	16.3 *(3.95)*	0.45	0.87	0.52
pH	7.3 *(0.10)*	7.37 *(0.15)*	7.43 *(0.22)*	7.8 *(0.06)*	7.57 *(0.32)*	6.8 *(0.26)*	0.72	0.18	0.14
L.I.	0.47 *(0.07)*	0.83 *(0.09)*	1.33 *(0.32)*	1.87 *(0.07)*	1.43 *(0.33)*	NA	0.03	0.18	-

Table B: Chemical analysis results of soil column water after day four of the trial run. The Anova: Single Factor test was run to observe the variance on data from the treated and untreated samples. P-values below 0.05 (highlighted in green), indicate a statistically significant difference, in which cases we can reject the null hypothesis and conclude a significant difference between the treatment and control samples.

Morrill Soil Column Water Analysis Data (2nd Round). Data are means (± SE)						
	De Luz		CIT Sandy Loam		Valley	
	Treated	Control	Treated	Control	Treated	Control
EC (dS/m)	0.36 *(0.03)*	0.45 *(0.00)*	0.50 *(0.01)*	0.65 *(0.06)*	0.48 *(0.07)*	0.34 *(0.05)*
Ca (meq/L)	1.58 *(0.35)*	2.06 *(0.20)*	1.87 *(0.08)*	2.98 *(0.52)*	3.03 *(0.92)*	1.94 *(0.52)*
Mg (meq/L)	0.95 *(0.24)*	1.26 *(0.15)*	1.5 *(0.09)*	2.44 *(0.35)*	1.02 *(0.27)*	0.6 *(0.13)*
Na (meq/L)	1.73 *(0.18)*	2.07 *(0.29)*	0.97 *(0.07)*	0.93 *(0.03)*	1.33 *(0.32)*	1.1 *(0.26)*
SAR	2.97 *(0.41)*	3.43 *(0.62)*	1.50 *(0.10)*	1.37 *(0.03)*	2.13 *(0.52)*	1.8 *(0.46)*
Cl (meq/L)	0.33 *(0.03)*	0.33 *(0.03)*	0.33 *(0.03)*	0.30 *(0.00)*	0.37 *(0.03)*	0.4 *(0.00)*
CO_3+ HCO_3 (meq/L)	3.97 *(0.38)*	5.17 *(0.03)*	4.83 *(0.24)*	7.90 *(1.07)*	5.27 *(1.13)*	3.17 *(0.67)*
SO_4 (meq/L)	0.10 *(0.00)*	0.00 *(0.00)*	0.10 *(0.00)*	0.00 *(0.00)*	0.03 *(-)*	0.10 *(0.06)*
B (mg/L)	0.23 *(0.01)*	0.31 *(0.04)*	0.14 *(0.01)*	0.17 *(0.01)*	0.19 *(0.03)*	0.16 *(0.02)*
NO_3-N (mg/L)	0.30 *(0.00)*	0.33 *(0.03)*	0.43 *(0.03)*	0.30 *(0.15)*	0.37 *(0.03)*	0.30 *(0.00)*
Fe (mg/L)	0.45 *(0.14)*	0.82 *(0.39)*	0.05 *(-)*	0.03 *(0.01)*	0.65 *(0.19)*	1.20 *(0.41)*
Mn (mg/L)	1.6 *(0.27)*	2.1 *(0.19)*	0.87 *(0.34)*	0.97 *(0.25)*	2.57 *(0.35)*	2.15 *(0.31)*
pH	8.3 *(0.06)*	8.4 *(0.06)*	8.10 *(0.15)*	8.17 *(0.15)*	8.33 *(0.12)*	7.80 *(0.06)*
L.I.	0.80 *(0.17)*	1.07 *(0.03)*	0.70 *(0.15)*	1.17 *(0.27)*	1.13 *(0.37)*	0.20 *(-)*

Table C: Chemical analysis results of soil column water after day 23 of the trial run.

Morrill Soil Column Water Analysis Data (Final Round). Data are means (± SE)									
	De Luz		CIT Sandy Loam		Valley		P-Values (All Points)		
	Treated	Control	Treated	Control	Treated	Control	De Luz	CIT	Valley
EC (dS/m)	0.35 *(0.03)*	0.4 *(0.01)*	0.45 *(0.01)*	0.54 *(0.01)*	0.42 *(0.05)*	0.31 *(0.06)*	0.48	0.58	0.79
Ca (meq/L)	1.56 *(0.31)*	1.98 *(0.23)*	1.73 *(0.05)*	2.25 *(0.03)*	2.98 *(0.69)*	1.81 *(0.56)*	0.63	0.60	0.59
Mg (meq/L)	0.93 *(0.22)*	1.17 *(0.15)*	1.33 *(0.12)*	1.83 *(0.04)*	1.04 *(0.23)*	0.62 *(0.19)*	0.61	0.58	0.60
Na (meq/L)	1.33 *(0.12)*	1.57 *(0.27)*	0.97 *(0.03)*	0.9 *(0.00)*	0.83 *(0.12)*	0.77 *(0.15)*	0.65	0.70	0.92
SAR	2.23 *(0.27)*	2.53 *(0.50)*	1.50 *(0.00)*	1.37 *(0.03)*	1.23 *(0.18)*	1.30 *(0.26)*	0.94	0.79	0.93
Cl (meq/L)	0.33 *(0.03)*	0.33 *(0.03)*	0.30 *(0.00)*	0.30 *(0.00)*	0.37 *(0.03)*	0.37 *(0.03)*	0.55	0.65	0.98
CO_3+ HCO_3 (meq/L)	3.6 *(0.38)*	4.37 *(0.15)*	4.30 *(0.21)*	5.9 *(0.15)*	4.53 *(0.82)*	3.00 *(0.73)*	0.97	0.14	0.15
SO_4 (meq/L)	0.00 *(0.00)*	0.00 *(0.00)*	0.03 *(-)*	0.00 *(0.00)*	0.00 *(0.00)*	0.00 *(0.00)*	0.51	-	0.83
B (mg/L)	0.17 *(0.01)*	0.23 *(0.03)*	0.09 *(0.01)*	0.12 *(0.01)*	0.13 *(0.02)*	0.11 *(0.01)*	0.26	0.96	0.82
NO_3-N (mg/L)	0.00 *(0.00)*	0.00 *(0.00)*	0.00 *(0.00)*	0.00 *(0.00)*	1.53 *(-)*	0.03 *(-)*	0.35	0.69	-
Fe (mg/L)	0.64 *(0.40)*	0.72 *(0.41)*	0.1 *(0.09)*	0.05 *(0.03)*	0.36 *(0.07)*	0.43 *(0.25)*	0.93	0.59	0.79
Mn (mg/L)	1.57 *(0.26)*	1.91 *(0.21)*	0.95 *(0.35)*	0.88 *(0.17)*	2.90 *(0.57)*	1.95 *(0.44)*	0.85	0.91	0.77
pH	8.37 *(0.03)*	8.40 *(0.06)*	8.17 *(0.13)*	8.2 *(0.12)*	8.33 *(0.09)*	8.00 *(0.12)*	0.06	0.37	0.05
L.I.	0.77 *(0.12)*	1.03 *(0.03)*	0.7 *(0.15)*	0.97 *(0.15)*	1.10 *(0.23)*	0.50 *(0.25)*	0.50	0.08	0.002

Table D: Chemical analysis results of soil column water after day 37 of the trial run. P- values in green indicate a statistically significant difference between control and treated columns. The Anova: Single Factor test was run to observe the variance on data from the treated and untreated samples. For the L.I., with F = 13.8 and a P-value of 0.002, we can reject the null hypothesis and conclude that there is a statistically significant difference between the treated and control column samples.

t-Test: Paired Two Sample for Means	Soil Type					
	De Luz		CIT (Sandy Loam)		Valley	
	Trt	Ctrl	Trt	Ctrl	Trt	Ctrl
Mean	2.87	2.36	2.82	2.25	1.26	1.32
Variance	6.64	3.48	1.86	1.98	0.57	0.93
Observations	78	78	78	78	78	78
Pearson Correlation	0.96		0.94		0.62	
Df	77		77		77	
t Stat	4.66		10.15		-0.70	
P(T<=t) one-tail	6.59E-06		3.68E-16		0.24	
t Critical one-tail	1.66		1.66		1.66	
P(T<=t) two-tail	1.32E-05		7.36E-16		0.48	
t Critical two-tail	1.99		1.99		1.99	

Table E: Results of hydraulic conductivity (K_{sat}) t-test between treated and control columns. An independent samples t-test was used to determine if there was any significant difference between treated and control columns. The Pearson correlation suggests that for the De Luz and CIT soils, the two groups were significantly different ($p = 6.59E^{-06}$ and $3.68E^{-16}$ respectively). Conversely, results of the two-tailed t-test for the Valley soil showed a P value of 0.24, for which we can accept the null hypothesis and conclude that there is no significant difference between the two groups.