XVIIth World Congress of the International Commission of Agricultural and Biosystems Engineering (CIGR)

Hosted by the Canadian Society for Bioengineering (CSBE/SCGAB)
Québec City, Canada June 13-17, 2010

WATER TABLE RESPONSE TO DRAINAGE WATER MANAGEMENT IN SOUTHEAST IOWA

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CSBE100138 – Presented at ASABE's 9th International Drainage Symposium (IDS)

ABSTRACT A key component in managing subsurface drainage is controlling water table depth to limit excess drainage off site. The objectives of this work were to evaluate the impact of drainage water management through controlled drainage and shallow drainage on subsurface drainage volumes, water table depths, and crop yields. This research was conducted at the Iowa State University Southeast Research Farm and consisted of four paired management schemes for a total of eight plots. Plots consisted of a corn-soybean rotation with half of the plot planted in corn and half planted in soybeans each year. Preliminary findings for three years show undrained plots had a high occurrence of elevated water tables. Controlled and shallow plots had elevated water tables in the early spring and early fall in accordance with the rainfall and management protocols for controlled drainage. Water table response was quick with drawdown to tile depth within 2 to 3 days after significant rain events. Total annual drainage from the shallow and controlled plots was approximately equal and ranged from 20 to 40% of rainfall, while the conventional plots typically drained greater than 40% of the rainfall. There was no statistically significant difference between drained plots in terms of corn and soybean yield for the study period. Undrained plots, however, had slightly lower yields for both corn and soybeans. Overall, during the period of the study drainage water management through controlled drainage or shallow drainage reduced overall drainage volume while maintaining crop yield.

Keywords: Controlled drainage, Crop yield, Water table depth.

INTRODUCTION Drainage water management, in the context of subsurface agricultural drainage, consists of managing outflow with a goal of reducing drainage volume. The reduction in subsurface drainage volume has generally ranged from 10% to 40% (Gilliam and Skaggs, 1986; Fouss et al., 1987; Evans et al., 1995; Skaggs et al., 1995a, 1995b; Drury et al., 1997; Amatya et al., 1998; Tan et al., 1998; Drury et al., 2001). Due to less water leaving the system, a corresponding nitrate-nitrogen reduction can be expected, although concentrations tend to be similar when compared to conventional drainage.

Nitrate-nitrogen, as it relates to water quality in the Midwest, is tied to hypoxia in the Gulf of Mexico (Turner and Rabalais, 1994). Economic impacts due to loss of fishing in the Gulf along with environmental protection are a primary driver for reducing nitrate loads being delivered by the Mississippi River. Since a significant portion of nitrate-nitrogen export originates from subsurface drainage systems there is a need to implement practices that have the potential to reduce subsurface drainage volumes and nitrate-nitrogen export. The objective of this work was to determine the impact of drainage water management on drainage outflow, water table depth, and crop yields for drainage systems in Iowa.

MATERIALS AND METHODS Research is being conducted on modified drainage management systems on the Southeast Research Farm (SERF) in Crawfordsville, IA USA (41.19 N, 91.48 W). The site consists of Taintor (silty clay loam, fine, smectitic, mesic Vertic Argiaquolls) and Kalona (silty clay loam, fine, smectitic, mesic Vertic Endoaquolls) soils. The research site has 8 plots with two replications for each treatment (Figure 1). Individual plots range in size from approximately 1.2 to 2.4 ha (3 to 6 ac) in size for a total project area of 17 ha (42 ac). Plots are split down the middle and cropped east to west in both corn and soybeans each year. The eight plots include two undrained plots and six plots consisting of the following:

- 2 plots with conventional drainage (1.2 m tile depth with 18 m spacing)
- 2 plots with shallow drainage (0.76 m tile depth with 12.2 m spacing)
- 2 plots with controlled drainage (1.2 m tile depth with 18 m spacing with controls during the winter and summer and free flow during planting and harvesting).

Tiles lines are laid out in a north-south orientation with interior tiles being continuously monitored for flow rate with a V-notch weir and pressure transducer. Border tiles on each plot are to prevent flow from adjacent plots and these tiles are not monitored. The control gates for the controlled drainage plots are opened late April to early May prior to planting and closed after planting is completed generally in the 1st two weeks of June. Control gates are then reopened in early to mid-September prior to harvest and closed again after fall tillage is completed generally in early November. Water table monitoring wells for determining the depth to water able were established mid-way between an interior set of tile lines in each plot of the northern block except for the undrained area where the monitoring well was located in the middle of the plot. The wells were located approximately at the boundary between the corn and soybeans at the center of the plot. Depth to water table was monitored continuously using pressure transducers. Water samples were taken by grab sampling outflow on a weekly basis for assessment of nitrate-nitrogen levels.

Precipitation at the site was collected with three different instruments: tipping bucket approximately 1 km from the plots, tipping bucket at the site, and a catch gauge. Data was collected from March through November to avoid freezing.

Statistical analyses were conducted using Statistical Analysis System software (SAS, 2003). The general linear model (GLM) procedure was used to determine the statistical significance of treatment effects on subsurface drainage and crop yield. The mean values

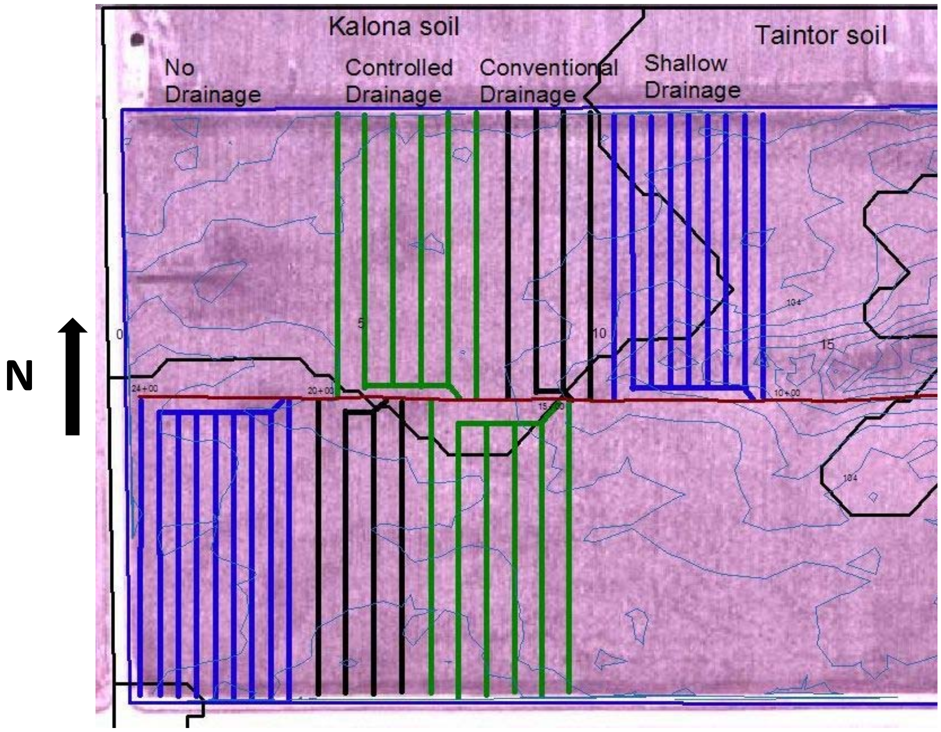

Figure 1. Aerial view of plots and layout of drainage treatments at the Crawfordsville, IA research site.

for the subsurface drainage and corn yield were separated using a least significance test at p = 0.05(LSD$_{0.05}$).

RESULTS

Weather

Precipitation, Drainage and Water Table Precipitation data shows that there was less rainfall during the growing season in 2008 than in 2007 and nearly 25 cm more rainfall than the average in 2009 (Table 1). However, all years (2007-2009) had more annual precipitation than the 10-yr average annual precipitation. Monthly and annual drainage in the conventional tile plots was higher than drainage from the shallow and controlled tile systems (Table 2 and 3); however, major variation in a given year between plots showed no significant differences between any of the treatments with the exception of shallow drainage in 2008 (Table 3). However, when flows are averaged for the three years there was statistically greater drainage volume from the conventional drainage treatment than the shallow and controlled drainage treatments. Groundwater monitoring showed shallow and controlled drainage plots trace similarly throughout the year with nearly a 20 cm difference in average groundwater depth between conventional drainage and both the controlled and shallow plots (Table 4).

Table 1. Ten-yr average monthly precipitation, monthly total precipitation, and monthly total deviation from the 10-yr average. Unavailable data is indicated with NA.

	10yr Av	**2007**	**Deviation**	**2008**	**Deviation**	**2009**	**Deviation**
	--------------------	--------------------	--------------------	cm	--------------------	--------------------	--------------------
January	3.9	2.2	-1.7	0.8	-3.1	NA	NA
February	4.6	4.5	-0.1	0.3	-4.3	NA	NA
March	5.9	9.2	3.4	2.3	-3.6	10.8	4.9
April	9.3	12.7	3.3	13.6	4.2	5.7	-3.6
May	12.9	8.5	-4.4	13.6	0.7	15.1	2.2
June	9.6	19.1	9.5	15.9	6.3	21.9	12.3
July	7.4	10.7	3.3	8.5	1.1	12.3	4.9
August	10.6	19.1	8.5	9.7	-1.0	24.8	14.2
September	7.7	5.1	-2.6	20.7	13.0	3.5	-4.2
October	7.7	9.8	2.1	6.0	-1.7	18.2	10.4
November	4.1	1.5	-2.6	0.5	-3.6	NA	NA
December	4.2	NA	NA	NA	NA	NA	NA
Year	88.0	102.4	14.4	91.8	3.8	112.3	24.3

Table 2. Monthly drainage (cm) from the 3 treatments. North and south plots were averaged. Conv is conventional drainage, CD is controlled drainage, and SH is shallow drainage. Unavailable data is indicated with NA. Monthly means within years with a different letter are significantly different (p=0.05). Only months where there were significance differences have letter included.

	Monthly subsurface drainage (cm)								
	2007			**2008**			**2009**		
Month	**Conv**	**CD**	**SH**	**Conv**	**CD**	**SH**	**Conv**	**CD**	**SH**
January	NA	NA	NA	0.0	0.0	0.0	0.8	NA	0.4
February	NA	NA	NA	0.1	0.0	0.0	0.5	0.1	0.1
March	NA	NA	NA	0.0	1.4	0.0	5.0	2.2	4.9
April	0.0	0.1	0.0	6.0ab	7.7a	3.5b	4.6a	3.8ab	1.1b
May	3.0	5.6	3.2	6.8	5.8	3.0	8.7ab	10.3a	4.8b
June	9.8	6.9	8.4	9.5	3.3	3.0	13.7	6.3	8.7
July	0.2	0.2	0.2	1.7	0.0	0.0	4.8	2.1	3.2
August	4.4	2.1	3.2	0.0	0.0	2.2	NA	NA	NA
September	0.0	0.1	0.0	5.7	4.9	2.4	NA	NA	NA
October	4.1a	3.0b	3.1b	0.6a	0.0b	0.1b	NA	NA	NA
November	0.0	0.0	0.0	0.3	0.0	0.0	NA	NA	NA
December	4.2	NA	NA	NA	NA	NA	NA	NA	NA

Table 3. Annual drainage from the three treatment types. North and south plots were averaged. Means within years or for the 3-yr average with a different letter are significantly different (p=0.05).

	Drainage (cm)			
Treatment	2007	2008	2009	3-Year Average
Conventional	25.7a	30.7a	38.1a	31.5a
Controlled	17.9a	23.2ab	24.7a	22.0b
Shallow	18.2a	14.3b	23.1a	18.5b

Table 4. Monthly groundwater depth for all treatments. UD is undrained, Conv is conventional drainage, CD is controlled drainage, and SH is shallow drainage. Unavailable data is indicated with NA.

	Groundwater Depth (cm)											
	2007				2008				2009			
Month	UD	Conv	CD	SH	UD	Conv	CD	SH	UD	Conv	CD	SH
January	NA	NA	NA	NA	86	131	101	114	113	140	132	128
February	NA	NA	NA	NA	120	145	141	131	112	143	134	127
March	NA	NA	NA	NA	96	138	118	123	73	127	94	111
April	NA	NA	NA	NA	71	127	100	110	94	127	114	115
May	NA	NA	NA	NA	90	129	116	112	68	124	114	103
June	NA	NA	NA	NA	70	124	100	103	16	115	88	82
July	123	175	160	163	NA	NA	NA	NA	37	125	110	103
August	115	174	149	110	123	173	160	159	55	131	127	126
September	105	142	125	135	94	143	121	127	54	137	134	132
October	85	126	102	116	106	139	126	126	43	118	107	101
November	114	140	133	129	105	135	122	120	0	128	93	102
December	104	136	123	120	104	136	125	118	NA	NA	NA	NA
Average	108	149	132	129	97	138	121	122	60	129	113	112

Yields Yields of similar treatments were averaged for a total yield per treatment value (Fig. 3 and 4). Average yields varied widely over the years and treatments. However, 2008 showed less variability in yields than 2007 or 2009. In 2007, all treatments except for the no drainage treatment with corn were greater than in 2008 for both corn and soybeans. In 2007, corn and soybean yields were the lowest in the no drainage treatment and highest in the conventional drainage treatment. In contrast, 2008 yields for the no drainage treatment were the highest amongst all the treatments which was probably due to the rainfall experienced in 2008 that was close to the 10-year average. Corn yields in 2009 were lower than in 2007 or 2008, which was likely due to high rainfall during 2009. Soybean yields in 2009 were higher in the drained plots than in the undrained plots likely due to less water stress during the growth period of the soybeans. As noted from the groundwater depth information, the greatest difference in average water table depth between the undrained and drained treatments was observed in 2009.

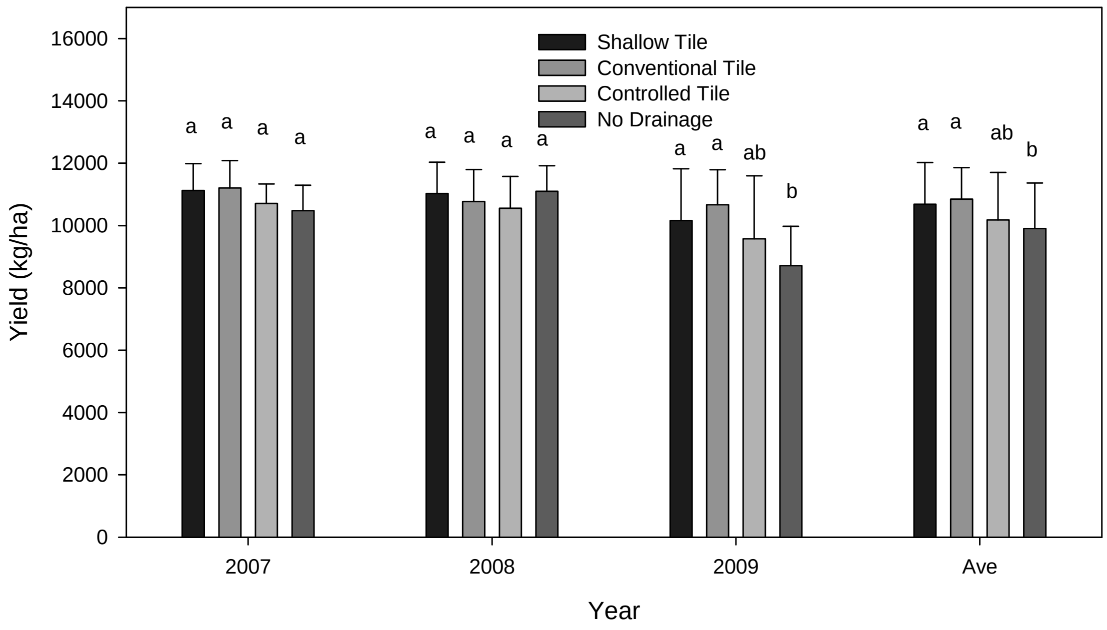

Figure 3. 2007-2009 corn yields with standard deviations. Means within years or for the 3-yr average with a different letter are significantly different (p=0.05).

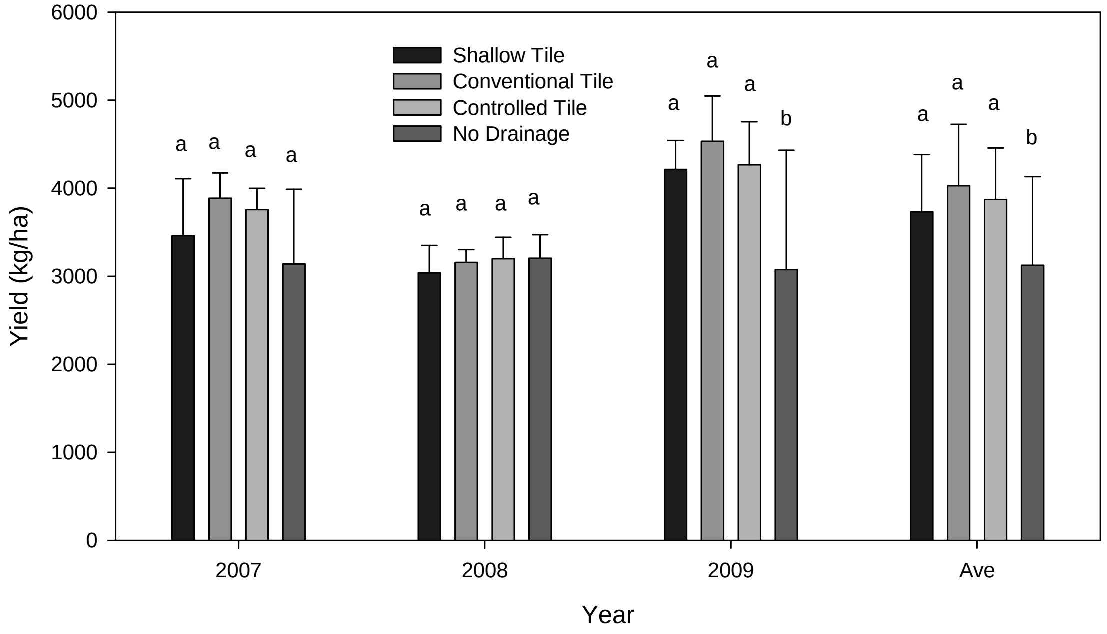

Figure 4. 2007-2009 soybean yields with standard deviations. Means within years or for the 3-yr average with a different letter are significantly different (p=0.05).

CONCLUSIONS From the three-year monitoring period, drainage water management through controlled or shallow drainage significantly reduced overall drainage by 30 to 40%. For the controlled drainage compared to the conventional drainage treatments, the primary periods for reduction in drainage volumes were from June through August, whereas volume reductions were observed during most months when comparing the conventional and shallow drainage treatments. The undrained plots consistently had shallower water tables. This was especially the case in the wet year of 2009. In this year, the undrained plots had significantly lower crop yield than the drained plots. Over the three-year study period, the drainage water management treatments did not have significantly different crop yields than the conventional drainage treatment.

Acknowledgements. This project has been supported by a USDA-NRCS Conservation Innovation Grant and the Agricultural Drainage Management Coalition.

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