

Table 5

Mean and its standard error of annual crop yield for conventional drainage (CNV) and drainage water management (DWM) for 2006 to 2009 and the two year averaged yields for each crop.

Yield (Mg ha ⁻¹)	2006 corn	2007 soybean	2008 corn	2009 soybean	Average corn	Average soybean
CNV	11.17 ± 0.18	3.90 ± 0.04	14.16 ± 0.21	3.80 ± 0.08	12.66 ± 0.47	3.85 ± 0.04
DWM	11.52 ± 0.34	4.21 ± 0.05	13.98 ± 0.14	4.11 ± 0.06	12.75 ± 0.57	4.16 ± 0.07

Note: Bolded numbers in the same column are significantly different at $p = 0.05$.

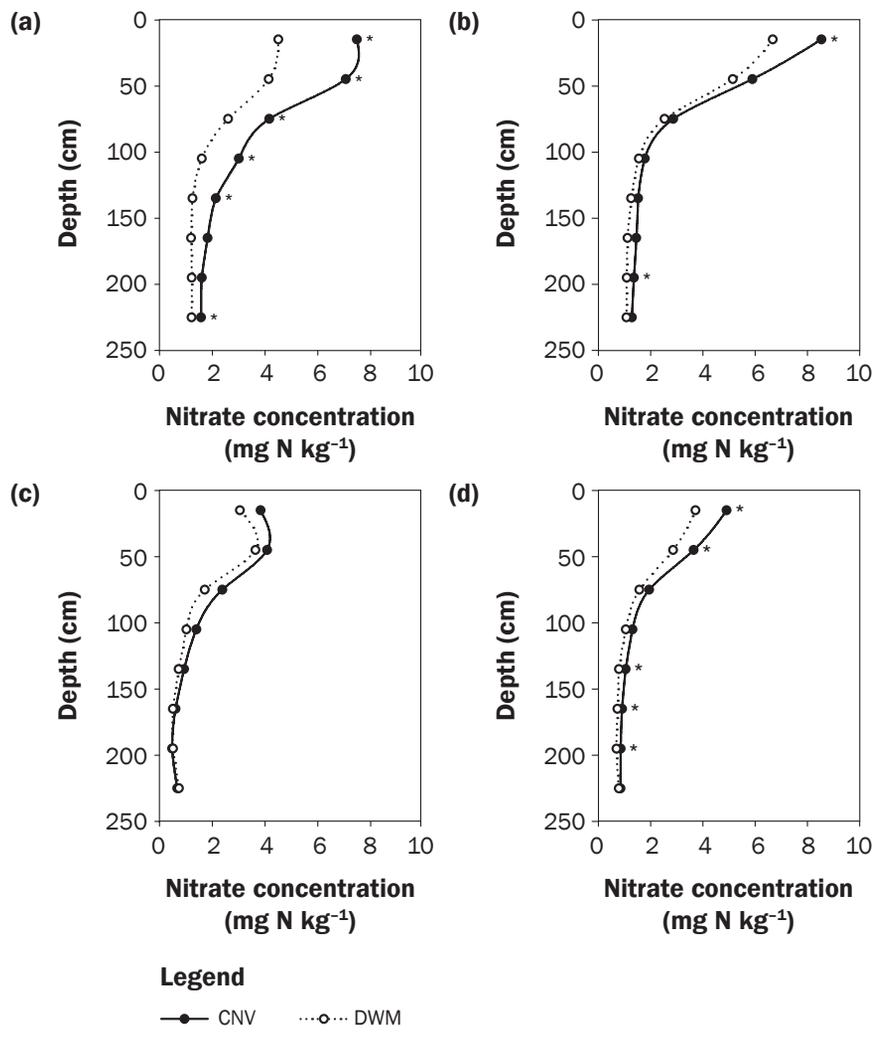
ferences by drainage treatment significant, increasing by about 8% averaged over the two soybean years. In 2008, DWM actually resulted in a 0.18 Mg ha⁻¹ (2.9 bu ac⁻¹) lower yield than CNV. This may have been due to the relatively wet weather throughout the growing season in 2008, negating any advantage DWM would have for storing water to use when ET exceeded rainfall and soil water storage. There was no significant difference in yields for corn in either 2006 or 2008 or for the corn years combined.

The lack of corn yield response to DWM found here is similar to that found for corn by Fausey et al. (2004) in Ohio and Grigg et al. (2004) in Louisiana. Fausey et al. (2004) also found no yield response for soybean, while in this study, soybean yields were significantly greater for DWM in 2007 and for 2007 and 2009 combined. Greater yields for DWM compared to CNV were also observed for small grains in two of three years in southern Sweden (Wesström and Messing 2007) with yield increases ranging from 9% to 18%, whereas CNV resulted in 14.5% greater corn yields than DWM in small plots in Nova Scotia, Canada (Smith and Kellman 2011).

The lack of consistent yield responses for DWM may be because DWM holds the water table higher within the soil only when there is excess precipitation. The inability to hold a consistently higher water table may limit DWM compared to systems where a consistently higher water table is maintained through a combination of DWM and subirrigation and in which yield increases of 10% to 64% have been reported for corn and soybean (Fisher et al. 1999; Barnett et al. 1997). However, corn and soybean yields appear to be sensitive to the depth to which a constant water table is held with the greatest yields observed when the water table is at least 0.9 m (3 ft) below the soil surface (Kalita and Kanwar 1993; Busscher et al. 1992). The modest to absent yield benefits observed here for DWM are consistent with modeling studies of DWM across the Midwest that show only about a 3% to 4% yield increase

Figure 4

Residual soil nitrate concentrations after harvest by soil depth in (a) 2006, (b) 2007, (c) 2008, and (d) 2009, averaged for conventional tile drainage (CNV) and for drainage water management (DWM). The * indicates depths where the differences are significant ($p = 0.05$).



with DWM over CNV for corn and soybean with considerable variability across years and locations (Thorp et al. 2008; Ale et al. 2009).

Soil Nitrogen. Residual soil NO₃ content after harvest was greater in the CNV treatments than the DWM for most depths and

years (figure 4). For most depths in 2006 and 2009, the differences were significant ($p = 0.05$), but differences were significant for only two depths in 2007 and no depths in 2008. Residual soil NO₃ contents tended to decrease with depth, perhaps reflecting the

Table 6

Mean (kg N ha⁻¹) and its standard error for residual soil nitrate (NO₃), ammonium (NH₄), and mineral N (NO₃ + NH₄) remaining in the top 1.2 m of the soil profile after harvest for 2006 to 2009 and averaged over all four years.

Variable	2006 corn	2007 soybean	2008 corn	2009 soybean	Average all years
Residual soil NO ₃					
CNV	54.0 ± 4.0	46.1 ± 2.1	28.4 ± 2.8	27.2 ± 1.2	38.9 ± 1.7
DWM	33.4 ± 2.7	38.2 ± 2.8	22.2 ± 1.7	22.9 ± 1.6	29.2 ± 1.4
Residual soil NH ₄					
CNV	11.2 ± 1.1	11.4 ± 1.6	8.2 ± 1.1	9.6 ± 0.8	10.1 ± 0.6
DWM	15.4 ± 2.2	16.4 ± 2.6	11.5 ± 1.0	10.4 ± 0.6	13.4 ± 0.9
Residual mineral N					
CNV	65.2 ± 4.2	57.5 ± 2.3	36.6 ± 3.2	36.7 ± 1.5	49.0 ± 1.8
DWM	48.8 ± 3.3	54.6 ± 3.5	33.6 ± 1.6	33.3 ± 1.5	42.6 ± 1.7

Notes: Bolded numbers in the same column are significantly different at $p = 0.05$. CNV = conventional drainage. DWM = drainage water management.

greater soil organic carbon content of the surface and greater amount of decomposing plant residues. Differences in residual soil NO₃ were much more pronounced in 2006 than in the other years. There were greater differences in the drainage treatments in the soybean years of 2007 and 2009 than found by Jaynes and Colvin (2006) for differences by treatment in an N rate and timing experiment conducted earlier on this field. When summed over the top 1.2 m (4 ft) of the soil, the residual soil NO₃ was significantly less for DWM than for CNV in every year except for 2008 and for all years combined (table 6). Conversely, residual soil NH₄ was significantly greater in the DWM plots than in the CNV plots in 2006 and for all years combined (table 6). Lower NO₃ and higher NH₄ concentrations may indicate that the soil environment in the DWM plots was more reducing than in the CNV plots thus favoring the reduced form of N. Less well oxygenated soil would be expected in the soils of the DWM plots due to the generally higher water tables.

Overall, there was less residual mineral N (NO₃ + NH₄) in the soil of DWM plots than the CNV plots. This is in contrast to Lalonde et al. (1996) who measured no significant difference in either NO₃ or NH₄ concentrations at three depths within the soil. The differences observed here may have been due to greater uptake of N by the crops in the DWM plots. However, there was no significant difference in grain N content between the drainage treatments for any year (data not shown). Grain N content averaged 12.2, 55, 10.5, and 53 g kg⁻¹ (6.1, 27.5, 5.3, 26.5 lb tn⁻¹) or 1.22%, 5.5%, 1.05%, and 5.3% for 2006 to 2009, respectively. The residual soil NO₃ differences may have been due to

differences in yield, but yield was only significantly greater for DWM than for CNV in the 2007 soybean year and for the soybean years combined (table 5) and not in the corn years, such as 2006, when the greatest difference in residual soil NO₃ was found. Conversely, more N may have been lost from the soil in the DWM treatment because of increased denitrification (Kliewer and Gilliam 1995). Wesström and Messing (2007) also observed less mineral N in the soil profile at harvest for DWM than for CNV and attributed much of the difference to higher N uptake by the crop.

Summary and Conclusions

During four years (2006 to 2009) of monitoring tile flow from a production field in central Iowa, there was a statistically significant 21% decrease in average tile flow, no significant decrease in average FWANC, and a significant 29% reduction in average NO₃ leaching for DWM compared to CNV. No yield benefits were observed for two years of corn (2006 and 2008), but a significant increase of 8% was observed for the two year (2007 and 2009) average soybean yield. The operation of the DWM systems in this study was based on the scenario described in Skaggs and Gilliam (1981). Modifications of the outlet heights within the control structures and the timing of the raising and lowering of the set heights may have affected the performance for DWM at this site (Ale et al. 2009). However, we are unaware of any research for optimizing the operation of DWM for the soils, climate, and crops in central Iowa.

From the limited four year dataset of this study, it is unclear if the yield increase for soybean versus no increase for corn was due

to weather patterns during 2006 to 2009 or because corn and soybean responded differently to the raised water table. Using the 2010 average price for soybean (~\$385 Mg⁻¹ [\$349 tn⁻¹]), the soybean yield increase from DWM would return on average \$65 y⁻¹ for the 1.1 ha (2.7 ac) area under the influence of the three control structures installed in this study. Given that the cost of the structures and installation is on the order of \$3,000 (Jaynes et al. 2010), the modest yield increase for soybean in this study would not be sufficient to encourage the farmer to adopt DWM just for the yield benefits. Thus, if DWM is to be widely implemented for the water quality benefits it provides, either locations where a greater area of the field is under the influence of the control structures need to be identified (fields with < 0.8% slope studied here), or incentive programs that share the cost of installation and management of the control structures need to be developed to increase the adoption rate.

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Disclaimer

Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA

implies no approval of the product to the exclusion of others that may also be suitable.

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