Date of Annual Report: 08/02/2011

Report Information:

- Annual Meeting Dates: 06/07/11 to 06/09/11
- Period the Report Covers: 06/2010 to 07/2011

Participants:

MEMBERS PRESENT: Larry Brown (OH), Larry Geohring (NY), Christopher Hay (SD), Matt Helmers (IA), Tim Harrigan (MI), Dan Jaynes (IA), Eileen Kladivko (IN), Kelly Nelson (MO), Mohamed Youssef (NC), Xinhua Jia (ND), and Roxanne Johnson (ND).

GUESTS PRESENT: Paul Sweeney (NRCS), Jerry Walker (NRCS), Phil Algreen (IA), Mark Dittrich (MN), Gary Feyereisen (USDA, MN), Jeppe Kjaersgaard (SD), Bill Schuh (ND), Keith Western (ND), Frank Casey (ND), Thomas Scherer (ND), Dean Steele (ND), Lyle Prunty (ND), Bruce Shewfelt (Canada), and R. Sri Ranjan (Canada).

Brief Summary of Minutes of Annual Meeting:

The NCERA 217 committee held its eighth annual meeting on June 7-9, 2011 in Fargo, North Dakota. A mini-symposium and a tour were also conducted on June 8 to highlight some Red River Valley drainage research projects. Business meetings and individual station reports, chaired by Larry Geohring, were given on June 7 and 9, 2011. During the business meeting, committee members were informed by its administrative Advisor, Ramesh Kanwar, that the mid-term review report would be due at the end of the year. USDA and NRCS representatives also gave comments to the committee. A new committee secretary, Tim Harrigan, from Michigan was elected for 2011-2012.

Full meeting minutes is attached.

Accomplishments and Impacts by Station:

1. Iowa Station Report:

(1) IA (ARS National Laboratory for Agriculture and the Environment, Ames), submitted by Dan Jaynes.

Bioreactors and Cover Crops:

Accomplishment: Nitrate in water removed from fields by subsurface drain (‘tile’) systems is often at concentrations exceeding the 10 mg N L^{-1} maximum contaminant level (MCL) set by the USEPA for drinking water and has been implicated in contributing to the hypoxia problem within the northern Gulf of Mexico. Because previous research shows that N fertilizer management alone is not sufficient for reducing NO_3 concentrations in subsurface drainage below the MCL, additional approaches are need. In a continuing field study, we are comparing the NO_3 losses in tile drainage from a conventional drainage system (CN) consisting of a free-flowing pipe installed 1.2 m below the soil surface to losses in tile drainage from four alternative drainage designs. The alternative treatments are a denitrification wall bioreactor (BR), where trenches excavated parallel to the tile and filled with woodchips serve as additional carbon sources to increase denitrification and a rye (*Secale cereale L.*) winter cover crop seeded each year near harvest and then chemically killed before planting the main crop the next following spring, a oat cover crop overseeded at crop maturity and allowed to winter kill, a living mulch composed of red clover, and a rotation with a non-nodulating soybean so we can measure the contribution to N leaching from N fixation. Four replicate 30.5 x 42.7-m field plots were installed for each treatment in 2006.

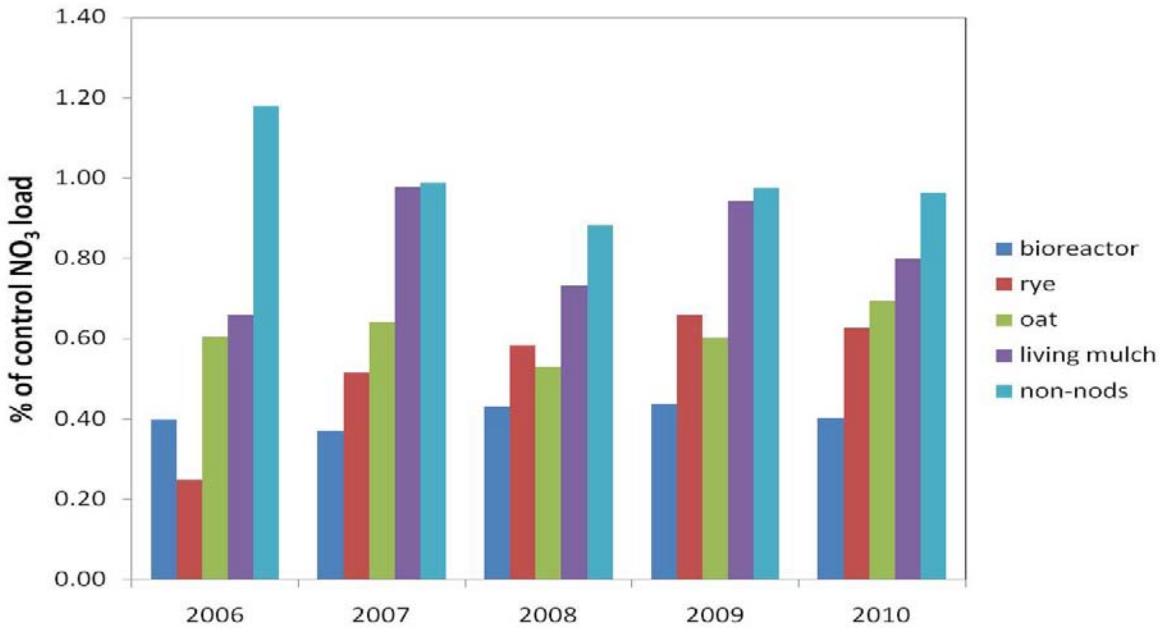


Figure 1. Reduction (%) in mass of nitrate loss in tile drainage by treatment and year.

<u>Outcome:</u> Over the past 5 yr the bioreactor and fall cover crop have reduced NO3 mass losses (kg N yr^{-1}) from 34 to 75%. There has been no trend in the bioreactor efficacy indicating that the woodchips are still supporting denitrification at rates similar to when were first installed. Relatively lower removal rates in 2009 and 2010 reflect overall lower nitrate concentrations from all plots including the conventionally drained plot most likely due to much increased precipitation from 2007 - 2010. Oat cover crops are less effect than rye for removing nitrate and the red clover living mulch used here was less effective than the oat, most likely because of poor clover establishment. The non-nodulating soybean results indicate that N fixation from soybean contributes little to the overall leaching loss of nitrate.

<u>Impact:</u> This research has quantified the potential water quality benefits from using fall-planted cover crops in Iowa and bioreactors for keeping nitrate out of tile water.

Re-Saturating Riparian Buffers:

<u>Accomplishment:</u> In this project we are investigating the efficacy of reconnecting tile drainage to shallow ground water flow through riparian buffers for removing nitrate. By diverting a fraction of the tile discharge through a distributary tile installed along the top of the buffer, we are diverting a fraction of the tile water into shallow ground water flow through the buffer. Within the shallow ground water, both denitrification and sequestration processes known to be active in buffers will remove nitrate before it can enter the adjacent stream. We have connected a diverter box to an existing field tile that exits through a riparian buffer before emptying into Bear Creek. The diverter box is used to divert a fraction of the tile discharge into the distributary tile installed along the field side of the buffer. The diverted water flows as shallow groundwater to the stream and the nitrate contained within the water is subjected to denitrification and plant uptake and sequestration in the buffer.

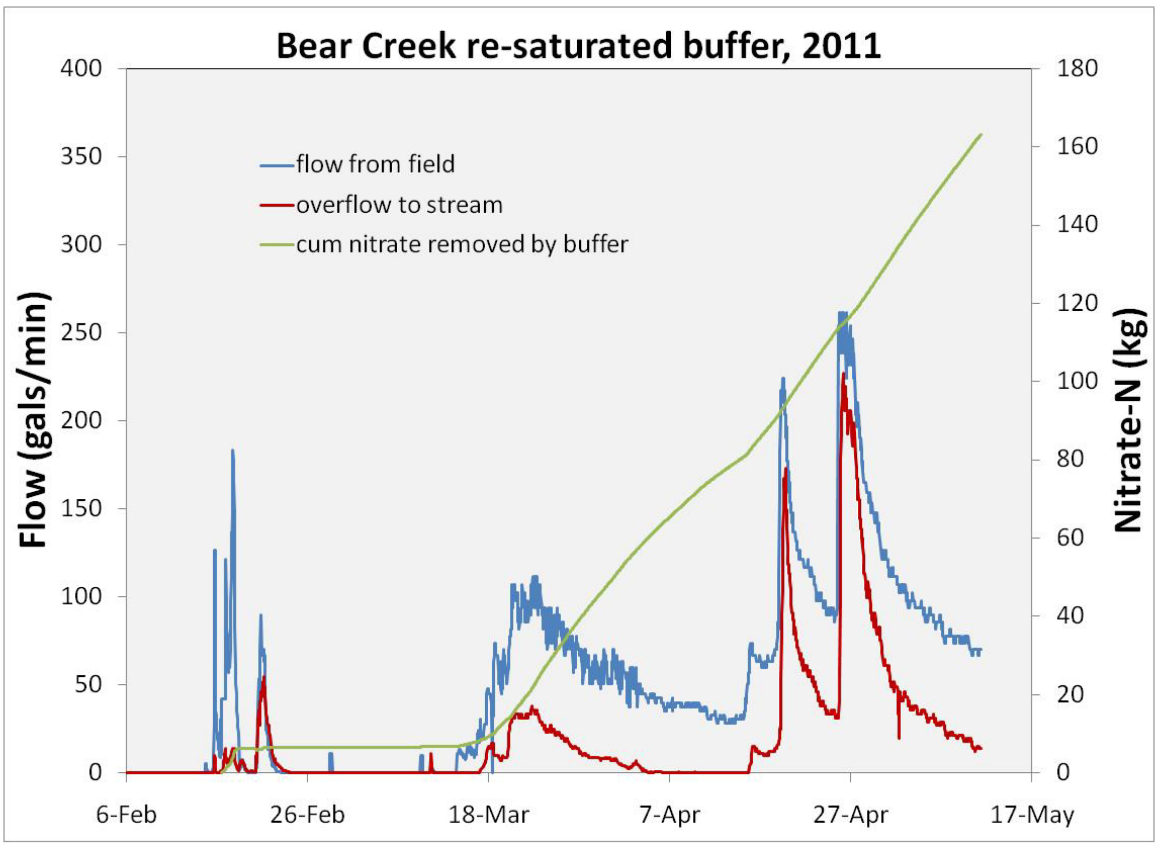


Figure 2. Results for first 3 months for re-saturating Bear Creek riparian buffer.

<u>Outcome:</u> We are measuring the water volume and nitrate concentration diverted into the buffer and following the fate of the nitrate through four transects of wells as it moves to the stream. Tile flow diverted into the buffer rather than flowing into the stream has been measured since fall of 2010. The diversion of flow for this spring is shown in Figure 2 where flows from the field into the diverter box and distributory tile and out of the diverter box to the stream are shown.

The cumulative nitrate load diverted into the buffer is also shown and amounts to about 65 kg-N for the 3 month period shown. During this early flow period the buffer was able to absorb about 50 gallons per minute of the tile drainage leaving the field. Thus, overall the system appears to be functioning as hypothesized in the proposal for this research. It will be critical to see how much of the tile flow the buffer can absorb during the peak tile flow period normally encountered in late spring and early summer. It will also be critical to determine if the nitrate entering the buffer continues to be removed before flowing to the stream in the shallow groundwater. Currently, none of the nitrate being diverted into the buffer appears to be reaching the stream. Continued monitoring will determine if this continues after the prolonged tile flow conditions anticipated for spring and summer.

Impact: This research has quantified the potential nitrate removal capacity and water quality benefits from reconnecting a portion of field tile flow to riparian buffers.

(2) IA (Iowa State University), submitted by Matt Helmers

Research and extension efforts at Iowa State University relative to drainage design and management practices to improve water quality continue to center on nutrient export from tile drainage systems and nutrient management practices to minimize this export of nutrients, specifically nitrate-nitrogen. Work is also continuing that is evaluating drainage water management and cropping practice impacts on drainage volume and drainage water quality. New work is specifically examining impacts of various biomass production systems including continuous corn with stover removal and a diverse restored native prairie system. Water quality and water quantity are being monitoring from seven drainage water quality research sites.

From field plot studies based on four years of data we found little impact of timing of nitrogen application on nitrate concentrations in drainage water in north-central Iowa. Based on this same study it was found that various land covers including continuous living mulch, winter cover crop, and perennial grass have some potential to reduce nitrate loss. In addition, the continuous living cover and perennial grass resulted in lower soil water storage during the spring and early summer of the year. This lower soil water storage would be expected to have positive impacts on drainage and surface water runoff. This work examining cropping system impacts on nitrate loss has been accepted for publication in the Journal of Environmental Quality. The drainage and crop production data specifically for the annual cover crop systems in a corn-soybean rotation have been used to test RZWQM. This has also included long-term predictions of the impact of including a winter rye cover crop in the corn-soybean system. Initial modeling has indicated a potential to reduce over drainage volume by about 10%.

Preliminary results of work examining impacts of perennial based biomass production either restored native prairie or monoculture switchgrass on subsurface drainage water quality indicate dramatic reductions in nitrate concentrations and losses in drainage water with the perennial based systems. This was even the case when nitrogen fertilizer was applied to the perennial based systems. This work is important for assessing environmental impacts/benefits of perennial based biomass production strategies.

Work has continued examining the potential for subsurface drainage bioreactors as treatment systems for nitrate from drainage water. This work is examining lab-scale, pilot-scale, and field-scale performance. Initial results indicate 40-60% nitrate-nitrogen concentration reduction at retention times of 4-8 hours. This work has been used in designing numerous bioreactors within Iowa.

Extension work has focused on disseminating information relative to drainage water quality and economic design of drainage systems. This has included statewide, regional, and local programming events. In collaboration with colleagues at the University of Minnesota, the IA-MN Drainage Research Forum was held in November 2010 and was attended by approximately 80 stakeholders. In July 2010, an Iowa Drainage School was held near Nashua, IA that focused on hands-on design of drainage systems. Approximately 35 individuals participated in this event.

Impacts: The research work on nitrate concentration as a result of cover crops, living mulch, perennial cover, and timing and rate of nitrogen application is being used by the Statewide Nutrient Strategy Technical Team within the State of Iowa. This strategy will be important for developing a course of action for Iowa to meet the Hypoxia reduction goals.

An outcome from the IA-MN Drainage Research Forum is that we are providing research-based information on drainage water quality to stakeholders including state agency personnel in Iowa and the Midwest with a goal of improving the knowledge of drainage water quality issues and practices that can be used to minimize drainage water quality impacts. Feedback from the IA-MN Drainage Research Forum continues to indicate attendees valued the research based presentations, the cooperation of Iowa State University and the University of Minnesota on drainage issues, and the mix of basic and applied studies that were presented at the meeting.

With Greg Brenneman and Kapil Arora the 4^{th} Iowa Drainage School was organized. Participants rate this program as good to excellent and nearly all participants indicate that the program will help them design more effective drainage systems that will improve their bottom line.

The work on subsurface drainage bioreactors has been used in designing numerous bioreactors within Iowa. Overall, the work on bioreactors by many in the state of Iowa including ISU, USDA-ARS, local watershed groups, and the Iowa Soybean Association has dramatically increased the producer level interest in this practice.

2. ***Michigan Station Report submitted by Tim Harrigan, Kelvin Wong, and Irene Xagoraraki. Of Michigan State University:***

Evaluation of Viral Contaminants in Drainage Water from Biosolid Application on Sandy-Loam Soil

Activities: The specific objectives of this work were to: 1) evaluate the movement of biosolid-indigenous viruses (somatic phage and adenovirus), and anionic (chloride) and microbial (P-22 bacteriophage) tracers through the soil under nearly saturated conditions, and 2) evaluate the viral concentration of ponded surface water after land application of biosolids.

Six stainless steel containment lysimeters enclosing a monolith of undisturbed soil were installed in large experimental plots (600 m^2) on a *Kalamazoo fine-loamy, mixed mesic Typic Hapludalfs* soil at the Kellogg Biological Station of Michigan State University (MSU) in southwest Michigan. Biosolids from the Plainwell (2008) and St. Clair (2009) wastewater treatment (WWTP) plants (Michigan, US) were applied to the surface (56,100 L/ha) of the lysimeters during the growing season. Immediately before application the biosolids were spiked with P-22 bacteriophage to a concentration of 3.00×10^{11} and 1.25×10^{10} PFU/100ml in 2008 and 2009, respectively. Leachate samples were collected in 2008 and 2009; surface water and core soil samples were collected in 2009. Leachate and surface samples were monitored for somatic phage (2009), P-22 and adenovirus.

Salmonella phage (P-22) was used as a microbial tracer. Water samples were concentrated to achieve a larger equivalent volume during the qPCR reaction for adenovirus detection.

Viral analysis of soil samples: Intact soil cores (3.8 cm diameter) were extracted to a depth of about 90 cm after completion of the rainfall simulation experiments in 2009 (volumes of soil core ranged from $6.9\text{-}10.3\times10^2$ cm^3). The soil probe was only able to extract the soils above the 90 cm depth since the soil below that depth was primarily unconsolidated sand and the probe was not able to retain an intact core. The soil cores were subdivided based on identifiable changes in soil color or texture. Soil physical and chemical properties and residual virus concentrations (L4, L5, L6) were analyzed. No virus analyses were performed on L1 and L2 soil samples because the core soil samples were taken more than one year after the completion of the 2008 experiments. Analysis of the soil physical and chemical properties (Table 2) was done by the Soil and Plant Nutrient Laboratory at MSU.

Lysimeter effluent: The peak concentration occurred near 0.3 PV for all lysimeters and remained above background levels throughout the sampling period. No adenovirus or somatic phage was recovered from the leachate samples. P-22 was recovered from L2 (orchardgrass), L5 (switchgrass) and L6 (continuous corn) leachate, but none was detected in L1 (orchard grass) or L4 (switchgrass). There was a three- to four-log reduction of P-22 from the initial concentration in the spiked biosolids to the peak concentration in the leachate. The P-22 removal rate (λ) for L2, L5 and L6 was 2.4, 3.2 and 1.8 log/m, respectively.

Soil cores were extracted and evaluated for P-22, somatic phage and adenovirus. No somatic phage or adenovirus was detected, but P-22 was detected in all samples. Interestingly, no P-22 was detected in L4 leachate, but the concentration of P-22 extracted from the L4 soil samples was greater than in L5 and L6 at nearly every depth.

Surface water: The greatest viral concentration in the ponded water was at the start of the simulated rainfall and the samples with the greatest concentration were about 1 to 10% of the initial concentration in the spiked biosolids. Adenoviruses were detected in all surface water samples but no decay trend was observed. The average concentration of adenovirus in the surface water from all sampling events was $2.94 \pm 3.05 \times 10^3$ copies/100ml, about 4 logs lower than the initial concentration in the biosolids. It took longer for P-22 to reach non-detectable levels (>21 days), likely because the initial concentration was 6 logs greater than the concentration of somatic phage.

The rapid, peak breakthrough of the anionic and microbial tracers (<1PV) indicated transport through preferential flow paths. The removal of the P-22 bacteriophage in three of the lysimeters (1.83 to 3.21 log/m) was similar to the removal rate reported by Jiang et al. (2008; 1.92 to 2.80 log/m) and Carlander et al. (2000; 3.76 log/m). This indicates that a sandy loam soil with a vegetative cover can be an effective filter for removing enteric viruses for water quality protection, but depth of the soil profile is important.

The low recovery of P-22 from the leachate and soil cores indicates that most viruses are sorbed to organic matter or soil particles and are retained in the soil matrix or die-off. There was a three- to four-log reduction in the P-22 from the initial concentration in the spiked biosolids to the peak concentration in the leachate. The initial concentration of somatic phage in the biosolids was relatively low (8.00×10^2 PFU /ml) and somatic phage was effectively retained in the soil matrix. Adenoviruses were not detected.

Based on the results of our work, the virus concentration in ponded surface water can be as great as 1% to 10% of the initial virus concentration in the biosolids. These virus concentrations represent a considerable threat to water quality from surface runoff if biosolids are allowed to remain on the soil surface after application. The biosolid-associated pathogens may exist for several days under wet conditions.

Impacts: The results of this work support the promotion of best management practices for the land application of manure and biosolids on drained land that encourage: 1) the use of pre-tillage to disrupt the continuity of macro-pores, 2) controlled (low) application rates, and 3) timing biosolids/manure application rates to avoid application on wet ground, when tiles are flowing, or when there is a chance of significant rainfall (> 0.5 inches) within the next few days.

References

Carlander, A., P. Aronsson, G. Allestam, T. A. Stenstrom, and K. Perttu. 2000. Transport and retention of bacteriophages in two types of willow-cropped lysimeters. Journal of Environmental Science and Health Part a-Toxic/Hazardous Substances & Environmental Engineering 35:1477-1492.

Jiang, S., G. D. Buchan, M. J. Noonan, N. Smith, L. P. Pang, and M. Close. 2008. Bacterial leaching from dairy shed effluent applied to a fine sandy loam under irrigated pasture. Australian Journal of Soil Research 46:552-564.

3. Minnesota Station Report submitted by Gary Sands of University of Minnesota:

Three modeling efforts are currently being conducted in Minnesota with the purpose of helping improve the design and management of subsurface drainage systems throughout the state. Two of those projects, funded by the Corn Growers Association of Minnesota, are located in the Minnesota River Basin (southern Minnesota); the third project, funded by the U.S. Army Corps of Engineers, is located in the Red River Basin (northwestern Minnesota). Predominant soil types and representative locations for each basin are being considered. The modeling tools used are DRAINMOD and DRAINMOD-NII. The goal of the projects are to create drainage design tables for both southern and northwestern Minnesota based on the principle of maximizing net return on investment and, at the same time, conserving water and nutrients in the field. Two of the projects are based on a hydrological approach only; the third one, additionally, includes different Nitrogen application rates and sources. The first project in the Minnesota River Basin (MRB) is near its completion: all major soils were identified, sampled, and lab tested; three representative locations were selected; most parameters needed by DRAINMOD (crops, soils, and climate) were measured and/or estimated, and long-term simulations with start soon. The second project in the MRB will build on the first project (crops-soils-locations): additional input files will be created to incorporate the Nitrogen cycle, for more sophisticated DRAINMOD-NII long-term simulations; the project is expected to be completed by December 2012. The project in the Red River Basin started recently: major soils have been identified, and will be sampled and lab tested this summer; nine representative locations have been selected, and climate data files are being created to be used by DRAINMOD; the project is expected to be completed by December 2011.

4. Missouri Station Report submitted by Kelly Nelson of University of Missouri:

Managed drainage has been utilized as a best management system to reduce NO_3-N loss through subsurface drain tiles. Field research was initiated on claypan and silty clay soils to evaluate the impacts of managed drainage systems for crop and livestock production from 2009 to 2012 and is ongoing. Soybean research has evaluated integrated water management systems from 2003 until 2006, and interactions with fungicide management in 2009 and 2010.

Integrated water management systems using drainage plus subirrigation (DSI) have reduced nitrate-loading of drainage water flow and may increase soybean yield. Shallow drain tile depths and narrow spacings are recommended for claypan soils. Field research (2003 to 2006) evaluated the effects of drainage (DO) and DSI on planting date and the effects of DO and DSI at 6.1 and 12.2 m spacings on soybean yield compared to non-drained (ND) and non-drained delayed planting (NDDP) controls on claypan soils. Soybean was planted up to 17 d earlier with DO or DSI systems. Plant populations were reduced 29 to 52% in the non-drained control due to poor drainage in three of the four years. Grain yield, water applied through the DSI system, and water level depth were similar at a 6.1 or 12.2 m drain tile spacing. Average yield increase with DSI at 6.1 and 12.2 m spacings was 12 to 29% (410 to 910 kg ha^{-1}) while DO at the same spacings increased yield 9 to 22% (300 to 710 kg ha^{-1}) compared to ND or NDDP controls. In a dry year (2005), drainage plus subirrigation increased yield up to 1,200 kg ha^{-1} compared to DO. Plant population variability at harvest was lower with the DO or DSI systems compared to ND or NDDP controls. Yield variability over the four years was lower with DSI compared with DO or ND controls, which was affected by the spring-summer precipitation regimes and is important to farmers for a more predictable soybean marketing strategy.

Although pyraclostrobin has been used to protect soybean [*Glycine max* (L.) Merr] from foliar diseases, its interaction with drainage water management (DWM) systems was unknown. Field research during two wet years (95 to 97 mm greater than the past decade) evaluated the effects of pyraclostrobin application timing (R3, R5, R3+R5, and R3+R5+lambda-cyhalothrin) and DWM system [non-drained and drainage only (DO) or drainage plus subirrigation (DSI) at 6.1 and 12.2 m drain tile spacings] on soybean yield, grain quality, and severity of Septoria brown spot (SBS) (*Septoria glycines*) and frogeye leaf spot (FLS) (*Cercospora sojina*). Grain yields increased 18 to 22% with DO or DSI at 6.1 and 12.2 m spacings compared to a non-fungicide treated, non-drained control. In the absence of drainage, pyraclostrobin with or without lambda-cyhalothrin increased yields 20 to 27% compared to the non-drained, non-fungicide treated control. The combination of DWM and pyraclostrobin increased grain yields up to 36%. Pyraclostrobin plus lambda-cyhalothrin at R3+R5 increased yield 8 to 12% except with DO at 12.2 m compared to similar non-fungicide treated DWM systems. A DWM and pyraclostrobin interaction was detected for grain oil and protein concentration, but differences were minimal. Pyraclostrobin with or without lambda-cyhalothrin reduced severity of SBS and FLS 2 to 8% depending on the year, but DWM did not affect severity of these diseases. The greatest synergistic yield increase on a claypan soil occurred when foliar disease management and DWM systems were used together in years with higher than normal rainfall.

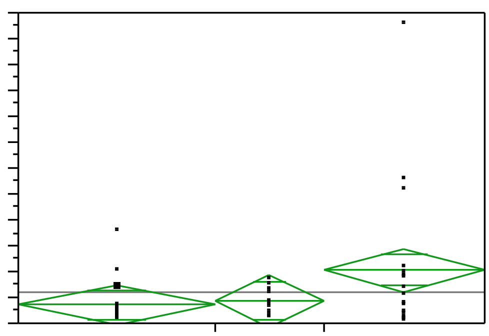
The Missouri Drainage Workshop was held in February 2011 with 50 people attending and a waiting list of 45. Contractors were trained on drainage and managed drainage design.

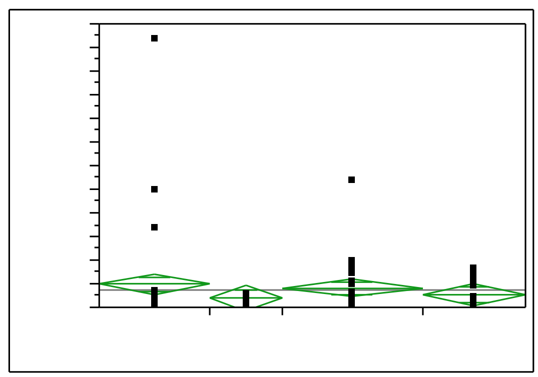
5. ***New York Station Report submitted by Larry Geohring of Cornell University***

<u>**Accomplishment –** Laboratory study relating phosphorus loss from manure and soil macropore size:</u> Leaching experiments were conducted using twenty-four soil columns containing an Odessa silt loam soil (Fine, illitic, mesic *Aeric Endoaqualfs)* which was obtained from the same field as the farm cooperator site in the Finger Lakes Region where a controlled drainage structure was installed. The soil columns were repacked and set up in duplicate with three artificially created macropore configurations: 1 and 3 mm diameter, and one with no macropores. The soil columns were gradually soaked from the bottom-up in tap water for 24 hours to saturation, and then were allowed to freely drain for 24 hours to emulate soil conditions at field capacity water content. Then four different phosphorus (P) application treatments (tap water control – no P,

inorganic P fertilizer (P_2O_5) dissolved in tap water, and liquid dairy cow manure at 3.5% and 7% solids – also obtained from the cooperator farm) were applied at rates equivalent to the amount of P that would be applied at an application rate of 5,000 gal/acre of liquid dairy cow manure. The rain simulation and leaching experiments were carried out until on average an entire pore volume of water passed through all the columns. Leachate was initially collected every hour, and then at reduced intervals as time progressed, and analyzed in a timely manner for inorganic soluble reactive phosphorus (SRP). Given the low sprinkler application rate and flow through the soil columns, the particulate P was assumed negligible.

Although there was substantial variability in experimental results, the results suggest that the 3 mm diameter macropore columns transported more SRP load, and more SRP load was also discharged from the 3.5% solids liquid manure application (See Figures). The bulk of the SRP loss also occurred more quickly in the effluent breakthrough in the 3 mm macropore column with the 3.5% solids liquid manure application.





<u>Impact</u> – These results indicate soils exhibiting preferential flow are vulnerable to SRP leaching losses, and surface applications of liquid manure with a low solid content are more vulnerable to being transported to subsurface drains. Producers are being encouraged to take management precautions to disturb (i.e., pre-till or incorporate) soils exhibiting preferential flow and/or reduce (split) liquid manure application rates. Phosphorus application amounts allowed by nutrient management plans and based on the nutrient value of manure containing different solids content typically allows for higher application volumes as the solids content drops. This further exasperates and increases the risk of preferential transport if application rates are not properly managed.

<u>**Accomplishment** – controlled drainage demonstrations and investigations on cooperator farms:</u> In New York, controlled drainage is being demonstrated and investigated as a best management practice on two private farms and at the W.H. Miner Agricultural Research Institute. The controlled drainage structure was installed at the farm in the Finger Lakes Region where monitoring is on-going for a paired- control drainage versus a non-control tile line emanating from the same field. Nine drainage control structures were previously installed in the Lake Champlain Region on a cooperator farm and at the Miner Institute for Agricultural Research. The emphasis of the monitoring is to determine if the controlled versus freely draining drains

reduce nutrient concentrations and discharges, and subsequently reduce the impact of liquid manure applications to tile drained fields. Drain monitoring is now currently underway at all sites using V-notch weirs and recording water level pressure transducers. Special V-notch weir plates were made to fit inside the in-line Agri-Drain drainage control structures to better quantify low flows. Preliminary data suggest that P concentrations spikes can be reduced with controlled drainage, especially following a period of soil drying, which also appears to reduce the P load discharged from the drain. Data collection and analysis are on-going.

Impact - Outreach efforts consisted of a field day during the construction of the controlled drainage structure in the Finger Lakes Region, presentation of a poster at the Northeast Region Agronomy Society's Meeting, and conducting training sessions on "Soil Hydrology and Drainage" at the annual Northeast Certified Crop Advisors Conference. Other extension activity included responding to tile drainage discharge water quality violations, whereby the drainage discharge was discolored from preceding manure applications. This resulted in making several presentations at farmer meetings and to the Agricultural Environmental Management Certification Subcommittee, a joint committee of the New York State Departments of Agriculture and Markets and Environmental Conservation, which addresses policy implications of CAFO's and provides training and certification of CNMP's (Comprehensive Nutrient Management Planners). Extension materials were also developed regarding manure management and subsurface drainage best management practices. Drainage contractors, farmers, farm advisors, and agency personnel are beginning to learn of the potential water quality benefits of implementing controlled drainage. The outreach activities have resulted in greater awareness of the potential water quality impacts of tile drain discharges, so producers and nutrient management planners are paying more attention to identifying vulnerable tile outlets and adjusting their manure application methods, rates and timing accordingly. About 150 people attended the various meetings and training sessions.

6. Indiana Station Report submitted by Eileen Kladivko and Jane Frankenberger of Purdue University

The Drainage Water Management research site at the Davis-Purdue Agricultural Center will be continued for the next five years, as part of the AFRI-CAP project led by Iowa State University on Climate and Corn Systems. New sensors and improved instrumentation will be installed in summer 2011, to obtain more reliable flow measurements and correct some problems that plagued the earlier years of this project. Baseline soil samples collected for this new project will be compared to measurements made in 2005 and 2008 as part of the previous research efforts.

The long-term SEPAC drainage study is continuing to measure drainflow, nitrate loads, and crop growth and yield. New in-line sensors were installed in two of the six drainlines in winter 2011 and are showing very good results during the time periods when the culverts are flooded and the tipping buckets for flow measurement are inoperable. This will increase the accuracy and value of the data during high-flow events.

The potential impact of drainage water management on Indiana farms was estimated with DRAINMOD. Simulations were run on 10 representative soil types across the state, under five cropping systems and four drain spacings. Results are being prepared for presentation in an

Extension bulletin, to provide estimates of nitrate-N loads under different scenarios and the potential for drainage water management to reduce those loads.

In addition to the research, numerous Extension efforts educated farmers, agencies, and the public about improved drainage management practices. A field day was held in conjunction with Indiana Land Improvement Contractors Association (INLICA) at SEPAC, as a new drainage water management system was installed in a newly-acquired field. Extension talks at other field days and winter meetings included education about the basic need for drainage and that good agronomic practices (no-till, cover crops) do not replace the need for adequate drainage. Other topics included in Extension presentations were drain spacing, cover crops, and two-stage ditches and their effects on reducing nitrate losses to surface waters.

Impacts: Research has resulted in a better understanding of nitrogen and yield impacts of drainage water management. Hundreds of farmers and contractors have increased their knowledge of drainage water quality issues and the potential of drainage water management to reduce nitrate losses.

7. *South Dakota Station Report submitted by Christopher Hay of South Dakota State University*

Accomplishments: Extension activities were focused on educating producers and the public on drainage and the impacts of drainage on hydrology and water quality. These activities have included a number of local and regional presentations and events. A Tri-State Agricultural Drainage Forum was held on January 26, 2011 in Brookings, SD in collaboration with colleagues from the University of Minnesota and North Dakota State University, which was attended by approximately 180 people representing diverse interests. A series of three drainage design workshops were held in North Dakota and South Dakota in collaboration with colleagues from the University of Minnesota and North Dakota State University during February and March to educate producers and contractors on the principles of drainage design. Total participation in the three workshops was over 150. South Dakota Cooperative Extension collaborated with University of Minnesota and Iowa State University colleagues to present the MN-IA Drainage Research Forum in Owatonna, MN on November 23, 2010, which was attended by approximately 75 people. An Agricultural Drainage Forum was held in Huron, SD that was attended by approximately 100 people. A presentation was given on drainage fundamentals, benefits, and impacts to 133 certified crop advisers at the SD Agri-Business Association Agronomy Conference in Sioux Falls, SD on December 15, 2010. Twelve additional presentations were made at various events for producers, contractors, county commissioners, state legislators, and other interested stakeholders that reached another approximately 340 individuals.

Impact Statement: Participants in the drainage forums rated the programs good to excellent. Participants indicated that they received a better understanding of drainage, issues associated with drainage, and conservation drainage practices. Producers indicated that they would be able to reclaim land into production with information gained at the forum. Participants in the drainage design workshops rated the programs as very useful or useful. Participants indicated that they gained knowledge on drainage system layout, drainage calculations, and drainage design considerations. They also indicated that this knowledge would give them more confidence in designing drainage systems and help them avoid mistakes.

8. ***North Dakota Station Report submitted by Hans Kandel, Thomas Scherer, and Xinhua Jia of North Dakota State University:***

(1) ND (North Dakota State University), submitted by Hans Kandel

Subsurface Drainage in clay soils in a northern climate and its effect on various soybean cultivars and soil properties.

The Red River Valley of the North in North Dakota and Minnesota is a region with unique, clay soils. Since 1993, the region has seen increased annual rainfall which has caused seasonal soil waterlogging, inhibiting crop yield potential. Prolonged waterlogging may cause debilitating physiological and chemical problems in plants. Subsurface (tile) drainage is relatively new to the region and offers an option farmers are exploring to help reduce excess water in the rootzone. The objective of this research was to identify the effect of subsurface drainage on soybean productivity using various cultivars and to evaluate differences in soil temperature, soil penetration resistance, and water table depth between drainage treatments.

Two experiments (2009-2010) were conducted in the Red River Valley. Soybean cultivars were selected based on iron chlorosis resistance, phytophthora root rot tolerance, and growing capability in wet soils. Penetrometer readings and water table depth were measured weekly. Soybean yields between sub-surface drained and undrained treatments were not significantly different according to the combined analysis. However, in 2010, the non-GMO soybean cultivars and the cultivars chosen for their resistance to Phytophthora sojae were significantly better on the drained soil. In 2009 and 2010, drained treatments had a significantly higher soil penetration resistance, indicating that the drained soil is capable of a higher soil penetration resistance compared to the undrained soil. The water table was lower on drained soil compared to the undrained soil early and late in the growing season, causing the differences in soil penetration resistance.

Results and findings about the tile drainage are annually presented at a regional tile drainage design workshop and numerous county meetings. The interest in tile drainage in the Red River Valley is increasing rapidly and local contractors are fully booked for 2011.

(2) ND (North Dakota State University), submitted by Thomas Scherer

Educational Activities: The tile drainage education by NDSU Extension Service personnel has been very successful. In a collaborative effort between NDSU Extension, the University of Minnesota Extension and South Dakota State University Extension, two 2-day tile drainage design workshops were held in Wahpeton, ND in February and March of 2011. Class size was limited to 52 at each workshop and both were filled in a very short period of time. In addition, Extension agronomy specialist, Dr. Hans Kandel and Dr. Thomas Scherer have organized more than 15 workshops about tile drainage at many locations across North Dakota. Over 175 people attended a tile drainage forum organized by NDSU Extension in collaboration with the University of Minnesota and South Dakota State University in February of 2010. Part of the forum was a panel discussion of federal, state and local rules and laws in North Dakota and Minnesota regarding tile drainage.

In 2009, as part of a 319-funded grant, weekly tile water quality monitoring was initiated at 8 tile drainage sites, one in each of 8 counties. In addition, flow measurement instrumentation was installed at 5 of the sites and rain recording instrumentation at all 8 sites. Local soil conservation district personnel in the eight counties take the water quality samples every week from April to November. In a face-to-face meeting, data from the first full year of the project (2010) has been explained and shared with each participating farmer. Some of the information has also been used in presentations.

Impacts: Over 70% of the participants of the tile drainage design workshops rated the workshop as very useful to their business (the highest ranking).

As a result of the tile drainage forum, the ND legislature made changes to the North Dakota Century Code (state laws) that specifically adds language about tile drainage to the existing drainage laws. This has resulted in the changes to local water board drainage permit requirements as well as alterations to the ND State Water Commission water permit application.

Illinois Station Report: no written report available.

Louisiana Station Report: no written report available.

Maryland Station Report: no written report available.

North Carolina Station Report: no written report available.

Ohio Station Report: no written report available.

Wisconsin Station Report: no written report available.

Publications

Peer Reviewed Journal Publications

Christianson, L., A. Bhandari, and M. J. Helmers. Pilot-scale evaluation of denitrification drainage bioreactors: Reactor geometry and performance. *Journal of Environmental Engineering.* Accepted.

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Helmers, M.J., X. Zhou, J.L. Baker, S.W. Melvin, and D.W. Lemke. Nitrogen loss on tile-drained Mollisols as affected by nitrogen application rate under continuous corn and corn-soybean rotation systems. *Canadian Journal of Soil Science.* Accepted.

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Qi, Z., M.J. Helmers, R.D. Christianson, and C.H. Pederson. Crop uptake of nitrogen and nitrate-nitrogen losses from various land covers in a subsurface drained field in Iowa. *Journal of Environmental Quality*. Accepted.

Scherer, T. F., and X. Jia. 2010. A simple method to measure the flow rate and volume from tile drainage pump stations. *Applied Engineering in Agriculture*. 26(1):79-83.

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Zhang, W., V.L. Morales, M.E. Cakmak, A.E. Salvucci, L.D. Geohring, A.G. Hay, J-Y Parlange, and T.S. Steenhuis. 2010. Colloid transport and retention in unsaturated porous media: Effect of colloid input concentration. *Environmental Science and Technology* 44 (13):4965–4972.

Zhang, X., X. Jia, J. Yang, and L. Hu. 2010. Comparison of sensible heat flux measured by eddy-covariance and large aperture scintillometer over a corn field with subsurface drainage. *Journal of Agricultural and Forest Meteorology*. 150:1182-1191.

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