APPLICATION FOR COMPONENT ADDITION TO NRCS

NRCS Practice Standard 442

For Inclusion of Adaptive Irrigation Technology

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APPLICATION FOR COMPONENT INCLUSION IN NRCS PRACTICE STANDARD 442:

Adaptive Irrigation Technology

REQUEST

As environmental, regulatory, and legal pressures surrounding nutrient management on dairy farms continue to grow, an increasing number of technologies are being introduced as potential solutions. However, dairy producers often navigate these options with information primarily provided by technology vendors, making it challenging to assess their effectiveness objectively. To address the needs identified by both the USDA's Natural Resources Conservation Service (NRCS) and dairy farmers, Washington State University, in partnership with Newtrient, developed a standardized evaluation framework. This framework, originally aligned with the NRCS Conservation Practice Standard (CPS) Waste Treatment (629), has been adapted by Newtrient to assess technologies under the Sprinkler System Practice Standard (442).

Adaptive irrigation technology presents a promising approach for improving nutrient management by delivering manure and other nutrient sources in alignment with crop demand. By applying nutrients more precisely throughout the growing season, these systems have the potential to reduce nutrient losses through leaching, runoff, and volatilization while enhancing soil health and crop productivity. However, factors such as nutrient concentration variability, flow rate consistency, and field conditions can influence application accuracy and environmental outcomes. To better understand these dynamics, Newtrient conducted an evaluation of an adaptive irrigation system on a farm in east-central Wisconsin, assessing nutrient application accuracy and nitrogen leaching impacts.

Newtrient submits this report for consideration under NRCS Conservation Practice Standard 442, highlighting the potential benefits of adaptive irrigation technology in advancing precision nutrient management. We believe these systems align with NRCS objectives by applying water and nutrients to irrigated lands more efficiently and uniformly.

BRIEF DESCRIPTION OF COMPONENT CLASS

Adaptive irrigation technology integrates water and nutrient management into a single system, allowing for precise application based on crop needs and environmental conditions. These systems are designed to work in a variety of field configurations, including irregularly shaped fields and areas with physical obstacles such as trees and tile risers. By enabling adjustable water application rates, adaptive irrigation supports more efficient moisture management throughout the growing season. Additionally, these systems facilitate the targeted application of nutrients and manure, aligning nutrient delivery with crop uptake to reduce the risk of loss through leaching, runoff, and volatilization. The ability to apply manure during the growing season also offers an opportunity to improve nutrient utilization while managing storage limitations. Adaptive irrigation technology further enhances resilience by allowing for real-time adjustments in response to weather variability, drought, and other agronomic challenges. These characteristics position adaptive irrigation as a potential tool for improving nutrient use efficiency, minimizing environmental impacts, and supporting sustainable agricultural production.

DETAILED DESCRIPTION

Adaptive irrigation technology expands the capabilities of traditional irrigation systems by integrating water and nutrient application into a single, responsive platform. These systems use mobile or hose-based delivery mechanisms that can be customized to fit a variety of field conditions, including irregular shapes and fields with physical obstacles. By improving water distribution, adaptive irrigation enhances moisture availability while enabling precise in-season nutrient applications, reducing reliance on pre-plant or post-harvest fertilization strategies.

A significant function of adaptive irrigation technology is its ability to incorporate manure applications directly into the irrigation process. This integration allows for the controlled delivery of liquid manure during critical periods of crop nutrient uptake, during the growing season, potentially improving efficiency and reducing environmental risks associated with nutrient volatilization, runoff, and leaching. Some systems include specialized components such as filtration mechanisms, impellers for breaking down solids, and distribution manifolds to ensure uniform application. While system capabilities vary, many adaptive irrigation technologies can handle a range of manure types, including separated liquid manure, leachate water, and other nutrient-rich effluents, provided solid content is within operational thresholds. These features enable the use of diverse nutrient sources while maintaining operational reliability.

Beyond nutrient management, adaptive irrigation technology provides a scalable solution for improving water use efficiency and responding to variable climatic conditions. The ability to adjust water and nutrient application rates throughout the growing season allows farmers to better align inputs with crop needs, ultimately supporting more sustainable production systems. By integrating irrigation with nutrient application, these technologies offer a multifaceted approach to enhancing soil fertility, optimizing resource utilization, and addressing both agronomic and environmental challenges.

Figure 1: Photo of 360 RAIN with custom 120-foot boom

THE PROCESS

Adaptive irrigation technology operates through a combination of automated movement, controlled nutrient application, and real-time monitoring to optimize water and fertilizer delivery throughout the growing season. These systems are designed to navigate various field conditions while ensuring precise and efficient distribution of liquid inputs.

The process begins with the irrigation unit being connected to a central water source, such as a well or hydrant, through a flexible hose. In the case of systems like 360 RAIN (Figure 1), a vertical hose reel mechanism manages hose deployment and retrieval as the unit moves through the field. The machine follows predetermined paths, often aligning with planting rows to minimize soil compaction and ensure consistent coverage.

Using cellular and real-time kinematic positioning (RTK) networks, the system navigates accurately, even in irregularly shaped fields or those with obstacles.

As the irrigation unit moves, a manifold distributes liquid through drop nozzles positioned along a boom structure, applying water and nutrients in a concentrated band directly over the root zone (Figure 2). This targeted approach reduces evaporation losses common in traditional irrigation methods. The system’s speed is adjusted based on the desired application rate, ensuring even distribution of inputs across the field.

One of the key advantages of adaptive irrigation is its ability to integrate multiple liquid input sources. Manure effluent, silage leachate, collected runoff, or clean water can be blended based on soil and crop requirements. A manure manifold with an impeller helps manage solid content, reducing the risk of plugging, though more screening is typically required at the pump to prevent larger debris from entering the system. While specific capabilities vary, many adaptive irrigation technologies can handle a range of manure types, provided the solid content remains within operational thresholds.

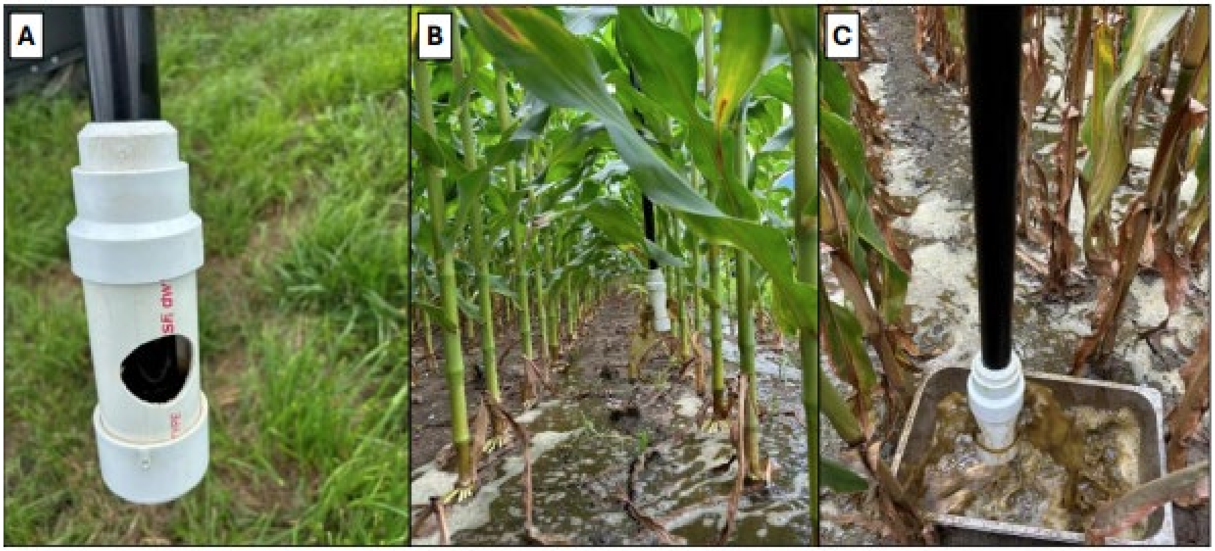

Figure 2: Delivery system, A) close up of nozzle, B) nozzle between corn rows, and C) nozzle passing over collection pan during application.

HOW PROPOSED SYSTEM ACCOMPLISHES PURPOSES OF THE STANDARD

The integration of adaptive irrigation technology aligns with NRCS Practice Standard 442 (Sprinkler System) by applying water and nutrients to irrigated lands more efficiently and uniformly to promote sustainable nutrient management on dairy farms. These systems enable precise application of water and nutrients, such as manure effluent and leachate, directly to the crops based on real-time field conditions. This targeted approach reduces nutrient losses through leaching, runoff, and volatilization, while ensuring that nutrients are applied to align with the four "R's" of nutrient management – right source, right rate, right time, and right place – to maximize crop uptake. By minimizing the reliance on synthetic fertilizers and optimizing the use of available nutrient-rich liquids, adaptive irrigation technologies contribute to more efficient and environmentally responsible nutrient management. This innovative solution directly supports the objectives of NRCS Practice Standard 442 by optimizing nutrient application, reducing nutrient loss, and improving nutrient use efficiency, making it a strong candidate for inclusion as a proven tool for advancing sustainable nutrient management and irrigation on dairy farms.

Newtrient (https://www.newtrient.com/), a company sponsored by the dairy industry and committed to enhancing value and sustainability in manure management, has conducted a thorough assessment of technology systems and practices within the field, focusing on their impact on critical environmental metrics, specifically water quality. The information in this report is based on a University of Wisconsin-Madison evaluation of the technology on a farm located in east-central Wisconsin.

In support of this discussion, Appendix A offers a brief discussion on the significant impact of adaptive irrigation technology on key environmental indicators related to water quality, air emissions, and other relevant factors aligned with the objectives of Standard 442. Also, Appendix B presents data from an adaptive irrigation technology evaluation, offering visual representations and nutrient profiles that quantify the intended nutrient application rates compared to measured field results, while monitoring nitrogen leaching to assess the potential environmental impacts of integrating this technology within a comprehensive manure management approach. Additionally, Appendix C contains the final report of the study conducted by the University of Wisconsin-Madison, providing further insights into the effectiveness and benefits of adaptive irrigation technology. Appendix D includes an abstract presented by The Ohio State University and Iowa State University at the 2025 Waste to Worth Conference, highlighting findings from a multi-year study on the 360 RAIN adaptive irrigation technology.

<u>Reducing nutrient content, organic strength</u>

An adaptive irrigation system doesn't directly reduce nutrient content or organic strength but instead helps to manage them more effectively. By delivering water and nutrients precisely to the crop root zone, the system minimizes nutrient runoff, leaching, and volatilization, ensuring more efficient nutrient use by plants. When organic materials like manure are incorporated into the irrigation, it ensures even distribution, preventing excessive buildup and promoting the breakdown of organic matter. In this way, the system helps avoid nutrient excess and reduces the environmental impact of organic materials, supporting more sustainable nutrient management.

Reducing odor and gaseous emissions

Adaptive irrigation systems can help reduce odor and gaseous emissions by efficiently applying manure and other organic materials in a controlled manner. By incorporating these materials directly into the soil or applying them as a band over the root zone, the system minimizes the exposure of nutrients to the air, which can otherwise lead to volatilization of ammonia and other gases. This precise application reduces the time manure and effluent are exposed to the atmosphere, thereby limiting the production of odors and harmful gaseous emissions, such as methane and nitrous oxide.

Facilitating desirable waste handling and storage

The adaptive irrigation system facilitates desirable waste handling and storage by efficiently incorporating manure and organic materials directly into the soil during the growing season. This approach reduces the need for prolonged storage or excessive handling, allowing waste storage facilities like holding ponds and pits to be emptied more effectively. By applying nutrients in a controlled, timely manner, the system minimizes the volume of waste that requires storage, reducing the risk of overflow and the potential for improper handling. The adaptive irrigation system simplifies waste management by reducing the need for extra equipment, making the process more efficient and sustainable.

Producing value added byproducts that facilitate manure and waste utilization

The adaptive irrigation system does not produce a direct byproduct in the traditional sense. However, it significantly enhances the utilization of manure and waste materials by integrating them into the irrigation process. This allows for more efficient nutrient distribution, turning these materials into valuable resources for crop production. By optimizing the use of manure and organic material, the system supports plant growth, improves soil health, and can reduce the need for external fertilizer inputs used to offset nutrient losses typically seen in traditional application systems. Ultimately, this approach helps close the loop on nutrient recycling, fostering a more sustainable, circular, and efficient system.

RANGE OF VOLUMETRIC AND MASS FLOW CAPACITIES AS WELL AS HYDRAULIC RETENTION TIME

The following section provides an overview of key parameters related to the performance of the Adaptive Irrigation system in manure management:

- *Volumetric Flow*: Accurate measurement and reporting of volumetric flow are critical to understanding the performance and nutrient delivery rates in adaptive irrigation systems. These systems typically utilize specialized manure or water pumps to move liquids through long hoses to the application zone. For example, the Razor pump (2 Horsepower (HP), 5.56” impeller) delivers approximately 40 gallons per minute (GPM) at 35 pounds per square inch (PSI), while the Blade pump (5 HP, 5.25” impeller) is capable of delivering 80 GPM at 38 PSI. These flow rates determine how quickly and consistently nutrients are applied across the field. In contrast, source water supplies such as waste storage facilities, holding ponds, reservoirs, or wells may provide significantly higher flow potential (200-250 GPM), but the effective field flow rate is constrained by the pump's specifications, system design, hose length, and pressure loss. For accurate reporting, flow should be measured at the point of application using flow meters or calibrated runtime estimates based on pump specifications, pressure conditions, and field distance (360 RAIN, 2025).

- *Mass Flow*: With a flow rate of 250 GPM for water and using the fact that water has a density of approximately 8.34 pounds per gallon, the mass flow rate for water is 2,085 pounds per minute. For liquid manure flowing at 80 GPM and using an updated density of 8.4 pounds per gallon, the mass flow rate for manure is 672 pounds per minute. When combining the mass flow rates for both water and manure, the total mass flow rate becomes 2,757 pounds per minute. The system is designed to handle up to 10% solids in the manure stream, provided the particle size is smaller than 3/4 inch.

- *Hydraulic Retention Times (HRT):* The HRT for the 360 RAIN system with 3,000 feet of 3-inch hose (1,101.6 gallons) is approximately 4.4 minutes***.*** This estimate is based on the internal volume of the hose and an assumed total flow rate near 250 GPM, representing the combined delivery of water and manure through the adaptive irrigation system. This residence time is important for understanding the lag between pump activation and nutrient delivery at the field outlet, and it can influence system responsiveness and sampling accuracy.

DESIRED FEEDSTOCK CHARACTERISTICS

The desired feedstock characteristics for adaptive irrigation systems like 360 RAIN, particularly when handling manure or other organic materials, include the following:

1. **Appropriate Solid Content**: The system can handle up to 10% solids, with the particle size limited to less than 3/4 inch. This ensures that the system can process and apply the material without clogging or damaging the equipment. Manure with excessive solid content may require additional processing or filtration before being used in the system.

2. **Nutrient Composition**: The feedstock should have a nutrient profile suited for crop application. For example, dairy manure or leachate water, which typically contains nitrogen, phosphorus, and potassium macronutrients, is ideal for nutrient applications. These nutrients support plant growth and can reduce the need for synthetic fertilizers.

3. **Liquid/Slurry State**: The feedstock should ideally be in a liquid or slurry form to ensure efficient distribution through the irrigation system. While the system can handle a wide range of manure types (including leachate water, separated liquid manure from waste storage facilities or holding ponds, and pure manure), it works best with liquid or semi-liquid materials that can flow through the hose and reach crops efficiently.

4. **Viscosity**: The feedstock should have low viscosity, which allows it to flow smoothly through the system's pumps, hoses, and nozzles. If the material is too thick, it may cause blockages or inefficient nutrient distribution.

5. **Low Contaminants**: The feedstock should be free from large debris, rocks, or foreign objects that could damage the system or disrupt the nutrient application process. This is particularly important for solids that exceed 3/4 inch in size.

EXPECTED SYSTEM PERFORMANCE

Adaptive irrigation technology is designed to optimize nutrient management by efficiently integrating nutrient-rich water sources, such as manure effluent, leachate, and other organic materials, directly into the irrigation process. This system enhances nutrient reuse for agricultural applications, promoting the efficient delivery of water and nutrients to crops while minimizing nutrient loss to the environment. Its performance can be evaluated based on its ability to improve nutrient distribution, reduce nutrient leaching, and prevent contamination of both surface and groundwater.

- *Changes in form or handling characteristics*
    - The adaptive irrigation system doesn't fundamentally change the form or physical properties of manure or organic waste itself, but it does modify how these materials are handled and applied. By integrating the manure into the irrigation process, the system facilitates a more efficient use of the waste, utilizing it in a form that's easier to manage for application to crops. For example, liquid manure or manure with a higher solid content is combined with irrigation water, reducing the need for separate handling and storage, and enabling a more controlled, consistent application to the soil. This integration changes the handling by simplifying logistics and ensuring the waste is applied directly to the root zone without the need for further treatment or handling steps that might be required if the materials were applied separately. However, the system itself doesn't alter the intrinsic physical properties of the manure—it primarily changes the way it is distributed and managed within the irrigation process.
- *Nutrient fate or end use projections*
    - The adaptive irrigation system, specifically the 360 RAIN, plays a key role in optimizing nutrient management by improving the efficiency of nutrient delivery to crops. By directly applying manure, leachate, and well water to the root zone, the system ensures that crops receive the right amount of nutrients at the right time, enhancing crop growth while reducing nutrient losses. This targeted application method helps to minimize nutrient runoff or volatilization, which are familiar challenges in traditional irrigation and fertilization systems.

      The system's-controlled delivery of nutrients facilitates better management of nitrogen, phosphorus, and potassium, among other essential elements. Nutrient application data from the 360 RAIN system demonstrates consistent delivery of nitrogen (TKN and NH_4-N), phosphorus, and potassium across multiple sample events. Specifically, NH_4-N application rates ranged from 13.2 to 70.7 lbs/acre, while total nitrogen applied ranged from 23.7 to 103.8 lbs/acre. Phosphorus and potassium were applied at rates from 8.4 to 25.9 lbs/acre and 24.3 to 83.9 lbs/acre, respectively. This precise nutrient application allows for better nutrient reuse within the agricultural system, optimizing crop yields.

- *Macro-nutrient reductions or transformations*
  - For macro-nutrient reductions or transformations, see the previous explanation on nutrient delivery, where adaptive irrigation facilitates efficient nutrient application, transformation, and uptake, leading to optimized crop health and minimized nutrient waste.
- *Pathogen reductions or eliminations*
  - Adaptive irrigation does not specifically focus on pathogen reduction or elimination. However, by applying nutrients directly to the root zone and avoiding excessive water application, it may reduce the risk of waterborne pathogens that can be introduced through runoff, leaching, or over-irrigation. The efficient use of manure and other organic waste in the system could potentially help minimize the movement of pathogens into the broader environment, but further research would be needed to confirm specific pathogen impacts.
- *Air emissions*
  - Adaptive irrigation may help reduce air emissions by minimizing nutrient runoff and volatilization. By applying nutrients directly to the root zone, the system reduces the chances of ammonia, other volatile compounds, and particulates from being released into the atmosphere. This targeted application of manure, leachate, and other organic materials can also minimize the need for additional fertilizer applications, further lowering the potential for air emissions associated with synthetic fertilizers. However, like with pathogens, more research would be needed to quantify the system's specific impacts on air quality and emissions reduction.
- *Water quality*
  - Adaptive irrigation systems significantly reduce water quality concerns by efficiently delivering water and nutrients directly to the root zone, minimizing runoff and leaching. This targeted application approach ensures that water and nutrients are absorbed by crops, rather than being lost to the environment through surface runoff or leaching. By reducing

nutrient and water loss, the system helps prevent contamination of nearby water sources, such as rivers and groundwater, with excess nitrogen, phosphorus, and other contaminants.

In field evaluations, nitrogen leaching was assessed using resin cartridges. In a 360 RAIN field, 173 lbs. of nitrogen per acre were applied (including 110 lbs. of N via UAN and 63 lbs. of N from in-season liquid manure), while a control field received 180 lbs. of N per acre. Despite the increased water application in the 360 RAIN field, resin cartridge data showed comparable nitrogen leaching between the two fields, with 58 lbs/acre in the 360 RAIN field versus 56 lbs/acre in the control field. This suggests that while additional water was applied, nitrogen leaching rates remained similar. It should be noted that the control field in the evaluation received much less water than the 360 RAIN field. The resin cartridges were installed after manure applications on the control field which may have missed some of the leaching in this field.

PROCESS MONITORING AND CONTROL SYSTEM REQUIRMENTS

Process monitoring and control systems are crucial for optimizing the performance of adaptive irrigation technology. These systems enable real-time monitoring and control of key parameters, ensuring efficient and effective operation.

- *Required monitoring*— While the system is operating, the owner must actively monitor the following:
    - **Water, Nutrient, and Manure Flow**: Ensure consistent and accurate application through real-time flow and pressure readings from up to four sensors.
    - **System GPS Tracking**: Monitor GPS location and movement to ensure proper path coverage and alignment with field mapping.
    - **Hose Performance**: Observe for any kinks, blockages, or leaks that may impact fluid distribution.
    - **Pump Operation**: Check that the well pump, booster pump, and injector pumps are functioning properly and maintaining required pressure levels.

- **Boom Coverage**: Verify that the boom is applying liquid accurately to ensure full field coverage.

- **System Communication & Connectivity**: Confirm that cellular data transmission is functioning for remote monitoring and that line-of-sight communication is maintained.

- **Power Supply**: Ensure that the system's 110V AC power source and battery levels are stable for uninterrupted operation.

- **Engine & Fuel Levels**: Track fuel consumption of the diesel engine (0.5 gal/hour estimate) to prevent unexpected downtime.

- **Speed & Application Rate**: Monitor speed (0.05 to 0.45 miles per hour (MPH)) and distribution plumbing size (3 in main line) to maintain even application of water, nutrients, and manure.

- *Required control*— During operation, the owner must actively control the following:
  - **Pump Activation & Deactivation**: Control up to six on/off relays for well, booster pump, injector pumps, and valves to regulate fluid application.

  - **Flow Rate Adjustments**: Adjust flow rates (e.g., 250 GPM at 115 PSI for 2,000-foot hose) to match field conditions and application needs.

  - **Boom Height & Positioning**: Manage boom clearance (up to 10 feet) to ensure even coverage and prevent damage.

  - **GPS & Route Optimization**: Adjust GPS settings to maintain alignment with field paths and avoid overlapping or missed areas.

  - **Speed Control**: Modify speed settings within the system's 0.05 - 0.45 MPH range to ensure proper distribution.

  - **Engine Performance**: Control diesel engine settings (24 HP) and fuel supply to optimize efficiency.

- **Manure & Nutrient Application**: If using manure, regulate the Razor or Blade pump to achieve precise nutrient placement (e.g., 40 GPM at 35 PSI for Razor Pump).

- **Power System Management**: Ensure proper functioning of 12V and 56V control system voltage for electric motors (drive, reel, dispenser, manure motor).

- **Relay Adjustments**: Control electrical relays for various system components to adjust system operation as needed.

- *Equipment included for monitoring*— The system includes the following tools for monitoring performance:
  - **Planter GPS Package** (Receiver, GPS Tower, Mount System) – Tracks system location and movement.
  - **Lift Switch & Harness** – Monitors height and operation of system components.
  - **Base Station Package** – Ensures proper communication between GPS and control system.
  - **Pressure & Flow Sensors** (up to 4) – Monitors real-time liquid application rates.
  - **Water Flow Meter** – Tracks water and nutrient distribution accuracy.
  - **Cellular Data Plan** – Enables remote monitoring and system adjustments via 360 Yield Center.
  - **Communication Kit & 900 MHz Antenna** – Supports line-of-sight machine communication for real-time data exchange.

- *Equipment included for controlling*— The system includes the following tools for controlling operations:

- **On/Off Relays** (up to 6) – Controls pumps, injector pumps, booster pumps, and valves.
- **GPS-Controlled Machine Controls** – Adjusts system movement and liquid application based on field mapping.
- **110V AC Power Supply** – Supports system operation and control mechanisms.
- **Electric Motors** (Drive, Reel, Dispenser, Manure Motor) – Controls hose retrieval, liquid distribution, and system movement.
- **Booster Pump & Well Pump Options** – Provides required pressure for liquid application (30 HP booster pump with 200 GPM at 147 PSI).
- **Speed & Flow Rate Controllers** – Allows adjustments to match field conditions and optimize application efficiency.
- **Relay System** – Controls electrical functions across system components.

TYPICAL OPERATIONS/MAINTENANCE PLAN WITH MONITORING REQUIREMENTS AND REPLACEMENT SCHEDULE

Adaptive irrigation technologies like the 360 RAIN system are designed to optimize water use efficiency and improve crop health through precision control and automation. However, the benefits of such advanced systems can only be fully realized with consistent, proper operation, thorough monitoring, and adherence to a routine maintenance and replacement schedule. Preventative service not only ensures operational continuity but also extends the life of critical components and minimizes costly downtime during the growing season.

System Monitoring

Regular monitoring is essential for reliable system operation. Key areas to monitor include:

- **App & Account Setup**
  - Ensure app is properly configured and updated with correct path data.
  - Confirm user access and functionality of manual controls and keypad.

- **Base Station & Connectivity**
    - Verify system provisioning, connectivity to riser, and accurate GPS signal.
    - Check communication between the app and machine in real-time.
- **Infrastructure & Field Operation**
    - Monitor riser placement and alignment for unobstructed movement.
    - Observe initial passes to confirm path accuracy and system auto-calibration.
- **Hydraulics & Fluids**
    - Inspect hydraulic pressure, oil levels, and temperature gauges.
    - Check for visible leaks or unusual noises during operation.
- **Mechanical Systems**
    - Observe belt and chain tension, gear rotation, and brake pad condition.
    - Visually inspect the reel, dispenser gearbox, and wear blocks for damage.
- **End-of-Season Protocols**
    - Review system logs and maintenance records.
    - Ensure flushing and draining of fluids to prevent off-season degradation.

Replacement Schedule

To maintain optimal performance, follow this replacement schedule:

- **Every 500 Hours**
    - Grease all lubrication points.
    - Inspect planetary oil during break-in (first 500 hours).
- **Every 1,000 Hours or During Greasing/Fueling**
    - Check all fluid levels including hydraulic and engine oil.
- **Every 1,250 Hours or Annually**
    - Replace hydraulic oil (AW46 – 4 gallons).
    - Replace engine air filter if needed.

- **Every 2,500 Hours**
    - Replace engine oil (10W-30 Synthetic – 9.5 quarts).
    - Replace engine coolant.
    - Replace planetary oil (75W-90 Gear Oil – 2 quarts).
    - Replace dispenser gearbox oil (ISO VG220 – 0.5 quarts).
    - Inspect and replace belts and filters as needed (use Filter Kit 578000 and Belt Kit 578005).
- **Every 10,000 Hours (Estimated)**
    - Replace liquid manifold gearbox oil (ISO VG220 – 2 quarts).
- **End-of-Season Maintenance**
    - Replace or inspect the following components:
        - Dispenser Chain (577078)
        - Brake Pads (577367)
        - Manure Blade Assembly (577530) and Wear Blocks (574591)
        - Reel Shield Wear Blocks (577689)
        - Swivel Seal Kit – 3" (577220)
    - Flush and replace all fluids regardless of hours, as a best practice.

CHEMICAL INFORMATION

- Adaptive irrigation technology does not use any chemicals in its operation.

ESTIMATED INSTALLATION AND OPERATION COST

<u>Equipment and Installation Capital Costs</u>

As of 2025, the estimated initial capital cost of a 360 RAIN system is between $280,000-$300,000. Operation expenses are approximately $82 per day, which equates to around $3.25 per acre per pass. Typical maintenance costs are expected to be about $1,200 per year. Factors such as system size, capacity, market conditions, and additional features may influence these costs.

Operation and Maintenance Costs (O&M)

- ***Diesel Fuel —*** Powered by a 24-horsepower diesel engine, the 360 RAIN consumes approximately 0.5 gallons of diesel fuel per hour to drive its propulsion and operational systems. For a typical 80-acre field requiring 15 inches of net irrigation water annually (adjusted to 17.65 inches gross at 85% application efficiency), the system operates for approximately 1,600 hours per season. At an average U.S. diesel price of $3.75 per gallon (October 2025), this results in an estimated annual fuel consumption of about 800 gallons, equating to approximately $3,000 in diesel costs. These costs, primarily for propulsion, may vary based on regional fuel prices, field size, topography, and seasonal irrigation needs. Efficient scheduling and maintenance of the diesel engine can optimize fuel use, ensuring cost-effective operation throughout the crop year.
- ***Electrical—*** While specific cost data for electrical usage is not currently available, adaptive irrigation systems such as 360 RAIN typically require moderate electrical input to power onboard systems, control units, sensors, and communication interfaces. The majority of power demand is driven by the movement and operation of pumps, valves, and control electronics. Users can expect electrical costs to vary depending on field size, operating duration, and local utility rates. Efficient design and automation can help reduce wasteful usage, and users should plan for baseline electrical infrastructure to support continuous, remote operation during the growing season.
- ***Labor—*** Precise labor cost estimates are not provided at this time, as they will depend on factors such as operator experience, field size, and frequency of deployment. However, adaptive irrigation systems are designed to reduce manual intervention through automation, remote monitoring, and app-based controls. While initial setup—including app configuration, system calibration, and physical deployment—may require more hands-on involvement, ongoing operation generally requires minimal labor. Users should anticipate periodic checks, seasonal service, and on-site monitoring during system initialization or troubleshooting.
- ***Maintenance Replacement—*** Although exact maintenance and replacement costs are not currently available, users can expect routine maintenance to include periodic fluid changes, greasing, and inspection of wear items such as belts, filters, brake pads, and gearboxes. Over time, components subject to heavy use—such as the dispenser chain, manifold gearbox, and swivel seals—may require replacement based on service hour thresholds. To manage long-term costs, users

should follow the recommended service intervals outlined in the manufacturer's maintenance schedule and plan for an annual end-of-season service. Proactive maintenance helps prevent premature failure and minimizes unplanned downtime.

EXAMPLE WARRANTY

Limited Warranty for Adaptive Irrigation Technology

Limited Warranty Coverage
Subject to the terms, conditions, and limitations set forth herein, the manufacturer ("Seller") warrants to the original purchaser ("Buyer") that the adaptive irrigation product(s) ("Product") will be free from defects in material and workmanship under normal use and service for a period of **one (1) year** from the date of delivery (the "Original Warranty Period"). This warranty covers the Product's ability to operate in accordance with its published specifications, excluding normal wear and tear.

Exclusions and Limitations
This Limited Warranty does **not** apply to:

- Any component, accessory, or part of the Product that is manufactured by a third party ("Third-Party Component"), including but not limited to GPS modules, hydraulic systems, or mobile app devices.
- Any consumable or serviceable component intended for regular replacement, such as filters, belts, brake pads, or lubricants.
- Damage resulting from misuse, improper installation, unauthorized modifications or repairs, lack of proper maintenance, or use outside of the recommended operating guidelines.
- Environmental damage (e.g., lightning strikes, flooding, rodents) or damage caused by acts of God.

Product Registration Requirement
To activate this Limited Warranty, Buyer must register the Product with Seller **within thirty (30) days** of the delivery date. Failure to do so will void this warranty.

Remedy
If a defect covered by this Limited Warranty is reported within the warranty period, Seller will, at its sole discretion, repair or replace the defective part or Product. This shall be the exclusive remedy under this Limited Warranty.

Disclaimer of Other Warranties
Except as expressly provided above, **Seller makes no other warranties**, express or implied, including any implied warranties of merchantability or fitness for a particular purpose. This Limited Warranty shall not be extended, altered, or varied except by a written instrument signed by an authorized representative of Seller.

Limitation of Liability
In no event shall Seller be liable for incidental, consequential, special, or punitive damages arising out of or related to the use or inability to use the Product, even if Seller has been advised of the possibility of such damages.

RECOMMENDED RECORD-KEEPING FOR ADAPTIVE IRRIGATION TECHNOLOGY

Effective record-keeping is essential for ensuring the reliability, performance, and longevity of adaptive irrigation systems. Keeping accurate and up-to-date records not only supports preventative maintenance and troubleshooting but also helps with warranty compliance, performance analysis, and regulatory documentation. Users are strongly encouraged to maintain the following records:

- **System Setup and Configuration**
    - Initial installation details, including dates, GPS coordinates of riser locations, and field layout maps.
    - App registration, user accounts, and path set data entered into the control software.
    - Equipment serial numbers and provisioning confirmation.
- **Operational Logs**
    - Dates and times of system operation, including nutrient applications, and characteristics such as path set activations, irrigation duration, nutrient application rate, manure analysis, liquid sources, and blend percentages.
    - Notes on weather conditions, field conditions, and any interruptions or anomalies during operation.
    - Performance metrics such as flow rates, pressure readings, and any alerts from the app.
- **Maintenance Records**

    - Service dates and service type (e.g., greasing, fluid replacement, filter changes).
    - Hours of operation logged at each maintenance interval.
    - Parts replaced, including part numbers and serial numbers when applicable.
    - End-of-season maintenance reports and fluid flush confirmation.
- **Repairs and Modifications**
    - Documentation of any mechanical or electrical repairs, including cause, solution, and who performed the work.
    - Any aftermarket upgrades, system reconfigurations, or field adjustments.
- **Warranty and Compliance**
    - Product registration confirmation and warranty start/end dates.
    - Copies of warranty claims and correspondence with the manufacturer or dealer.
    - Compliance documentation, if applicable for government or environmental reporting.

ALTERNATIVES FOR THE USE OF BYPRODUCTS

Adaptive irrigation technologies like 360 RAIN introduce an innovative opportunity for nutrient recycling by allowing dairy producers to apply manure directly to growing crops during the season. This approach effectively transforms what would traditionally be considered a byproduct—such as holding pond effluent or silage leachate, separated liquid manure, or raw manure—into a valuable input that boosts silage and forage tonnage while reducing the need for synthetic fertilizers.

As part of this system, the manure is not treated as a waste product, but rather as a nutrient-rich resource applied with precision. The technology accommodates a range of manure types with up to 10% solids, provided particles are under 3/4 inch, minimizing the need for additional pre-treatment or waste disposal. In this context, traditional byproducts from dairy operations are redirected into the nutrient cycle, enhancing both environmental and economic sustainability.

Any residual solids that settle out during storage, filtration, or transport (such as grit or fibrous material exceeding the system's size tolerance) should be collected and managed according to local nutrient management regulations. These materials may be suitable for composting or land application if handled properly. Overall, adaptive irrigation systems minimize waste and maximize the utility of dairy byproducts by converting them into seasonally timed, crop-available nutrients.

INDEPENDENT VERIFIABLE DATA DEMONSTRATING RESULTS/CREDENTIALS

Appendix A is a summary of the expert opinion and technical data available for this class of technology and how it relates to key performance indicators within NRCS Standard 442. This information is available through Newtrient.

Appendix B provides a summary of data from a Newtrient-managed third-party review of adaptive irrigation at a farm located in east-central Wisconsin. The data comes from a system performance analysis conducted by the University of Wisconsin-Madison but has not been peer-reviewed.

Appendix C contains the full University of Wisconsin-Madison report detailing the third-party review at a farm located in east-central Wisconsin.

Appendix D includes an abstract presented by The Ohio State University and Iowa State University at the 2025 Waste to Worth Conference, highlighting findings from a multi-year study on the 360 RAIN adaptive irrigation technology.

CONTACT INFORMATION—VENDOR

The list below includes a single company based in Illinois.

1. **360 Yield Center**
   Address: 180 Detroit Ave. Morton, IL 61550
   Phone: 309-245-7514
   Website: https://www.360yieldcenter.com/
   Company Information: With a team of experienced and passionate farmers, agronomists, and engineers – 360 Yield Center develops solutions to help you maximize yield efficiently. 360 Yield Center is fueled by their love of farming, innovation, and technology. After a 2012 drought devastated the Sauder family farm in Tremont, IL, Gregg Sauder went to work to find ways to be profitable regardless of the extremes of Mother Nature. Starting with a new and more efficient nitrogen application method, they've tested and developed new processes and products on their farms until they are perfected and ready to be used on farms around the world. Today, they proudly offer efficient and effective ways to reduce risk and add bushels and profit. They genuinely believe that agriculture can change so that all farm families win.

CONTACT INFORMATION—USER

Adaptive Irrigation Technology

Double S Dairy – Markesan, WI

Green Top Acres – Continental, OH

Bel-Lyn Dairy – Lynden, WA

OTHER CONSIDERATIONS

The NRCS documentation specifies that a third-party review shall contain 15 specific items that comprise the report above, but as part of working with the farm(s) and the technology provider during the evaluation period there are often other important and valuable learnings that may be helpful for NRCS and others as they consider this technology. Below is a list of Other Considerations that should be included in the evaluation of this technology. These points offer valuable insight into both the practical application and future refinement of adaptive irrigation systems like the 360 RAIN:

- **Inconsistent Nutrient Application Measurements**
  Discrepancies were observed between calculated and field-measured nutrient application rates—particularly with nitrogen and ammonium—raising questions about current accuracy in field sampling techniques. This highlights a need for improved methodologies (e.g., larger sampling areas, more frequent measurements) to better quantify application rates.

- **Timing of Resin Cartridge Installation**
  Delays in resin cartridge installation potentially missed key early season leaching events, affecting data interpretation. Future studies should synchronize cartridge deployment with the timing of initial nutrient applications to ensure accurate leaching assessments.

- **Integration with Manure Management Plans**
  Adaptive irrigation introduces an opportunity to apply manure in-season, aligning nutrient delivery with crop demand. However, this also requires updates to nutrient management plans and potential modifications to regulatory reporting systems.

- **Field Accessibility and Terrain Limitations**
  System performance may be affected by field slope, uneven terrain, or obstacles

(e.g., trees, fence lines). Proper field surveying and pre-installation planning are critical to avoid path interruptions or mechanical strain.

- **Dependence on Reliable Connectivity**
  The system relies heavily on app-based control and data transfer, which may be impacted by poor cellular reception in remote areas. Backup operation protocols or signal boosters may be needed.

- **Manure Solids Handling and Filtration**
  While the system handles up to 10% solids, consistent filtering is necessary to prevent clogging or uneven distribution. Regular maintenance of filters and solids separators is required, particularly when switching between manure sources or types.

Supporting Research: Collaborative Field Demonstrations by Ohio State University and Iowa State University

For detailed findings, see Appendix D for the full abstract.

In addition to the findings presented in this evaluation, field research conducted by Ohio State University (OSU) and Iowa State University (ISU) offer valuable insights into the performance of adaptive irrigation technologies—specifically High Clearance Robotic Irrigation (HCRI) systems—for nutrient and water management in row crop systems. This research, which began in 2023 and is planned to continue through at least 2025, includes a series of multi-year field demonstrations at the Beck's Hybrid Site and the Molly Caren Agricultural Center (MCAC). These trials are designed to evaluate the effectiveness of in-season nutrient delivery through irrigation in improving crop yield, water-use efficiency, and environmental outcomes. The study includes both paired watershed setups for detailed water quality monitoring and randomized complete block design (RCBD) strip trials to assess agronomic impacts under controlled treatment conditions. HCRI systems are being used to deliver commercial N and P fertilizers in precise alignment with crop nutrient uptake curves, as determined by growing degree days (GDD), across multiple treatment strategies and field scales.

At the MCAC site, a 2024 corn study showed that adaptive irrigation led to yield increases of 44 to 48 bushels per acre compared to non-irrigated treatments. The highest yield observed—237 bu/ac—was achieved using only two-thirds of the recommended N rate (136 lbs/ac), indicating that reduced fertilizer inputs, when precisely timed through in-season irrigation, can maintain or even enhance productivity. Both irrigated treatments, which received 5.5 inches of water, significantly outperformed the non-irrigated control (189 bu/ac), emphasizing the agronomic advantage of synchronizing nutrient availability with crop uptake stages.

In addition to improved yield, the study provides important insights into resource use. Across 71 acres, the adaptive irrigation system delivered seasonally timed nutrient applications through 5.5 inches of water, offering both water-use and nutrient-use efficiency benefits. Energy use for the 2024 growing season was also tracked, with the system consuming 25,739 kWh of electricity to operate pumps and infrastructure and 773 gallons of diesel to power the irrigator. These figures offer valuable context for evaluating the environmental and economic efficiency of adaptive irrigation systems in large-scale production.

Although certain operational limitations in 2023 (e.g., late system deployment) limited the scope of results in some early trials, the 2024 data provide robust, statistically significant support for adaptive irrigation as a practical alternative to traditional fertilizer application methods. These results complement this report's core findings and suggest that broader adoption of adaptive irrigation technologies could result in measurable improvements in nutrient efficiency, crop yield, and sustainable manure management practices.

Conclusion

Adaptive irrigation is a promising advancement in nutrient and water management, offering producers the ability to apply liquid manure, leachate, and water directly to growing crops with precision and control. By enabling in-season application, these systems help better align nutrient delivery with crop demand, potentially reducing fertilizer dependency and enhancing overall nutrient use efficiency. This approach not only supports improved crop productivity but also contributes to environmental sustainability by minimizing off-season applications that are more prone to runoff, leaching, and volatilization.

While adaptive irrigation technologies—such as 360 RAIN—are still undergoing refinement, initial evidence suggests they can deliver manure and water without compromising crop health or significantly increasing nitrogen leaching with the potential for decreasing nitrogen leaching potential. Operational challenges, such as optimizing application accuracy and improving early-season monitoring, are key areas for continued research and development. However, these issues are not unique to adaptive irrigation and are common in the adoption of any emerging agri-tech system.

As adoption grows, adaptive irrigation is poised to become a key tool in integrated manure management systems. Its ability to distribute applications throughout the growing season offers a unique opportunity to synchronize nutrient availability with plant uptake, which can lead to increased yields, reduced environmental impacts, and improved economic returns for producers. Continued field testing, data collection, and technology optimization will be essential to fully realizing the benefits of this innovative approach.

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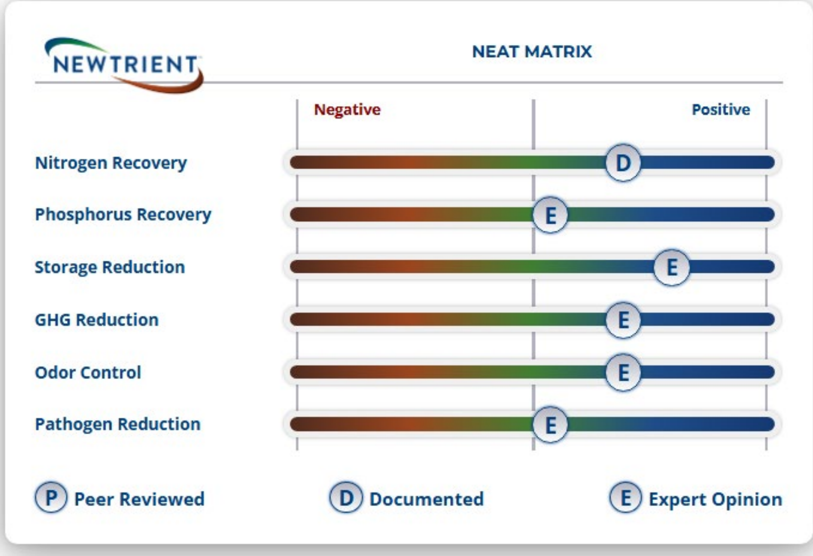
360 RAIN. (2025). https://www.360rain.com/

Appendix A

NEWTRIENT CRITICAL ANALYSIS – ADAPTIVE IRRIGATION



Overall Summary

Adaptive irrigation technology, such as 360 RAIN, functions as a supporting component within broader integrated manure management systems, rather than serving as a standalone manure management type. While its individual impact on manure treatment or nutrient processing may be difficult to quantify in isolation, adaptive irrigation plays a critical role in enabling the in-season application of liquid manure—helping to deliver nutrients directly to growing crops with precision and efficiency. Most manure management projects incorporate various support technologies like this to optimize the effectiveness of the core system. Adaptive irrigation is not a primary manure processing technology, therefore it has not been fully evaluated as an independent component in the Newtrient NEAT Matrix, however by reducing the need for synthetic fertilizer and improving water utilization it has been given a rating that is considered additive when used in conjunction with other manure handling or treatment technologies.

Appendix B

Third-Party Review of Adaptive Irrigation Technology at Double S Dairy – Markesan, WI (Report Summary)

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MARCH 2025

BACKGROUND

Effective management of manure nutrients is critical for maximizing the fertilizer value of manure while minimizing environmental losses. Traditional manure application methods in the non-growing season often result in nutrient losses due to prolonged exposure to environmental factors before crops can utilize them. This delay increases the likelihood of nutrient runoff, leaching, and gaseous losses, reducing the overall value of manure as a fertilizer and potentially contributing to environmental concerns such as water quality degradation.

In-season manure application has emerged as a promising strategy to improve nutrient use efficiency by aligning nutrient availability with crop demand. Delivering manure nutrients during key growth stages can increase nutrient uptake, reduce nutrient losses, and improve overall crop productivity. However, the system and accuracy of in-season manure application methods, particularly those utilizing automated or autonomous systems, require further evaluation to determine their effectiveness and potential environmental impacts.

360 RAIN is an adaptive irrigation machine that autonomously delivers water, nutrients, manure, byproduct, and other resources, banded or broadcast, across the entire field during the growing season – even in irregular shaped fields. However, there is limited data assessing the accuracy of manure nutrient application and potential nutrient losses associated with this system. Understanding how closely the intended nutrient application matches the actual nutrients delivered, as well as the system's impact on nitrogen leaching, is critical for determining its value in improving manure nutrient management.

INTRODUCTION

This study aimed to evaluate the performance of an in-season, adaptive irrigation machine, the 360 RAIN, to better understand its effectiveness in delivering manure nutrients to crops and its potential impact on nutrient leaching. Specifically, the study focused on comparing the intended versus actual nutrient application rates and measuring nitrogen leaching beneath the crop root zone. Assessing these factors is essential to determine if in-season manure application can improve nutrient use efficiency and reduce environmental losses compared to traditional manure application practices.

The 360 RAIN system presents an opportunity to apply manure during periods of high crop nutrient demand, potentially reducing the time nutrients remain exposed to loss pathways such as leaching and runoff. However, variability in nutrient concentrations, flow rates, and field conditions can influence the accuracy of applied nutrients and their subsequent environmental fate. This research sought to quantify these variables by comparing the intended nutrient application rates of manure with measured field results and monitoring nitrogen leaching to understand potential environmental impacts.

By examining the effectiveness of in-season manure application using the 360 RAIN system, this research contributes to a broader understanding of how autonomous systems can optimize nutrient management. Ultimately, the findings from this study will help inform future nutrient management strategies, improve nutrient use efficiency, and reduce potential environmental losses associated with manure applications. Further data collection and long-term evaluations will be necessary to establish best management practices for in-season manure application systems.

Figure 1: Photo of 360 RAIN.

THE PROCESS

The 360 RAIN system (Figure 1) is an adaptive irrigation system designed to autonomously deliver nutrients directly to crops during the growing season. It operates using a long hose connected to a central source called a Field Riser. A vertical reel on the machine lays out and retrieves the hose as the machine moves, allowing it to cover large field areas without the need for any frequent repositioning. Equipped with a boom and multiple drops, the machine travels along crop rows, applying liquid nutrients with desired rates controlled via an app. Liquid applications are at or near the soil surface reducing particulate drift and nitrogen volatilization (Figure 2).

One of the key features of the 360 RAIN system is its ability to blend and apply liquid from multiple input sources. These sources can include water, manure effluent from dairy cows or hogs, collected runoff, silage leachate, fertilizer, and digestate depending on availability and management goals. By adjusting the source and ratio of inputs, the system allows for tailored nutrient application throughout the growing season. This flexibility enables producers to optimize nutrient delivery, potentially increasing nutrient uptake by crops, improving yield as well as enhancing crop and soil health, while reducing the risk of nutrient losses to the environment.

Figure 2: Photo of 360 RAIN banded drop applying manure to growing corn.

The speed of the machine is adjusted according to the desired application rate, ensuring even distribution of nutrients across the field. The system's capacity to apply nutrients directly to growing crops minimizes the time nutrients remain vulnerable to runoff or leaching, promoting improved nutrient use efficiency. Additionally, its ability to operate from a centralized location with an extended hose length allows for efficient coverage of both large-sized and abnormally shaped field areas. This innovative approach to nutrient application has the potential to enhance crop performance while reducing environmental impact.

METHODOLOGY

Farm Details:

The 360 RAIN system was evaluated on a farm located in east-central Wisconsin, focusing on two adjacent fields. The first field, a 100-acre corn silage field, was selected for the study, while the second field, a 75-acre hay field, was also utilizing the 360 RAIN system but was not part of the evaluation. The farm milks approximately 1,500 dairy cattle housed in freestall barns bedded with composted dairy manure fiber. Manure is collected from the freestall barns, passed through screw press separators to remove fiber, and then stored in a holding pond until it is ready for land application.

NOTE: This farm purchased a 2022 model of the 360 RAIN system and custom built their own boom extensions (Figure 3). 360 Yield Center does not endorse the custom boom. The drops are also not factory available (Figure 4).

The system drew from three primary input sources: post-separated manure liquid from the storage pond, silage leachate and farmstead runoff from a leachate pond, and well water.

Figure 3. Custom boom size and drops used for study – not advised by 360 Yield Center.

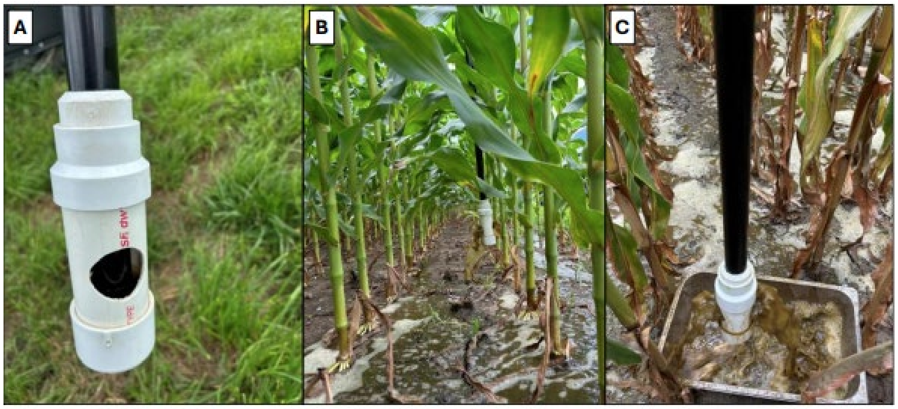


Figure 4. A) close up of drop, B) application occurring between corn rows, and C) drop passing over collection pan during application. This drop style is not factory-available with 360 RAIN systems.

Sample Collection and Monitoring:

To assess the effectiveness of the customized 360 RAIN system, liquid samples were collected from the three input sources—manure storage, leachate storage pond, and well water. These samples were analyzed by A&L Great Lakes Laboratories for 21 parameters, including moisture, total solids, total Kjeldahl nitrogen (TKN), phosphorus (P), potassium (K), sulfur, calcium, magnesium, sodium, iron, aluminum, manganese, copper, zinc, organic carbon, and ammonium-nitrogen (NH_4-N), among others.

The 360 RAIN system was deployed on the 100-acre corn field seven times during the growing season. Each deployment took approximately five days to cover the entire field (20 acres per day). To collect data on the applied liquid, five sampling events were conducted throughout the season. During each event, stainless steel collection pans were placed randomly within the application path of the 360 RAIN machine. After the application, the pans were weighed, and composite samples were collected for further analysis.

One of the five sampling events was specifically dedicated to the collection of well water, and all samples were shipped to A&L Great Lakes Laboratories within one week of sampling for analysis using the M7 Manure Analysis Package plus pH.

Additionally, resin cartridges were deployed to measure nitrogen cycling and leaching. These cartridges were placed in both the 100-acre cornfield receiving 360 RAIN applications and an adjacent 20-acre cornfield that received a one-time manure application using traditional methods for comparison. The resin cartridges were buried in undisturbed soil at depths of 0-5 cm, 5-6 cm, and 6-10 cm to capture inorganic nitrogen concentrations over the course of 106 days.

Calculations:
Nitrogen leaching was assessed by analyzing the resin cartridges, following the methods described by Bischoff (2007) and Grahmann et al. (2018). After the cartridges were retrieved, they were divided into three layers, and nitrogen concentrations were measured. The nitrogen leaching flux was calculated by subtracting the internal blank layer (5-6 cm) nitrogen concentrations from the first layer (0-5 cm), which captured the accumulated nitrogen leached from the soil.

To measure nitrogen concentrations, a 10-gram subsample from each of the first two layers was extracted using 2 M potassium chloride (KCl) and agitated for 60 minutes. The samples were filtered and stored at -10°C for later analysis of ammonium-nitrogen (NH_4^+-N) and nitrate-nitrogen (NO_3^--N) concentrations. Moisture content was also determined for each layer to correct the nitrogen concentrations.

The cumulative nitrogen leaching flux was estimated using the equation from Wey et al. (2022), which allowed for quantification of nitrogen loss over the 106-day sampling period.

DISCUSSION OF RESULTS

The results from the evaluation of the 360 RAIN system provide valuable insights into its effectiveness as a nutrient management tool for in-season application. The data collected from both the application events and resin cartridge sampling offer a comprehensive understanding of the system's performance in managing nutrients under real-world conditions. In this section, we will analyze the impact of the 360 RAIN system on nutrient distribution, crop health, and environmental sustainability, comparing it with traditional nutrient management methods to assess potential benefits and areas for improvement.

Efficient Nutrient Delivery: The system's nutrient application is precisely targeted, offering a controlled method for delivering nutrients across the field. By applying nutrients consistently and precisely over time, the 360 RAIN system supports not just the growth of healthy crops, but also the long-term health of the soil. Consistent nutrient application helps maintain an optimal nutrient balance in the soil, promoting soil microbial activity and preventing nutrient deficiencies or toxicities that can occur from uneven or excessive fertilizer applications. Over the course of seven application events, 67,388 gallons per acre were applied, with 14.4% manure holding pond liquid, 54.1% well water, and 31.5% leachate pond liquid, which contributes to nutrient load. The use of multiple sources allowed for a more balanced nutrient distribution (Table 1), helping to sustain healthy crop growth while optimizing nutrient use efficiency. A starter nitrogen fertilizer was also used on the 360 RAIN field.

Table 1. Application rates using the RAIN360 across the 2024 cropping season.

Sample Events			A & B	C		D		Annual Total
360RAIN Application	1	2	3	4	5	6	7	
	gal/acre							
Manure Lagoon	1,000	1,000	1,000	2,500	2,500	1,700	0	9,700
Leachate Pond	0	4,397	4,276	12,543	0	0	0	21,216
Well Water	3,839	0	0	0	10,313	11,615	10,705	36,472
Event Total	4,839	5,397	5,276	15,043	12,813	13,315	10,705	67,388

Improved Nutrient Distribution: The 360 RAIN system enhances the efficiency of nutrient delivery by directly applying nutrients to the root zone, ensuring that crops receive the right amount of nutrients at the right time. This targeted application method minimizes nutrient loss due to runoff or volatilization and allows for more precise management of manure, leachate, and well water. The nutrient application data from the 360 RAIN system (Table 2) demonstrates consistent delivery of N (TKN and NH_4-N), P, and K across different sample events, with NH_4-N application rates ranging from 13.2 to 70.7 lbs/acre and total N from 23.7 to 103.8 lbs/acre. P and K were applied at rates from 8.4 to 25.9 lbs/acre and 24.3 to 83.9 lbs/acre, respectively. This controlled delivery helps minimize both over-application and under-application of nutrients, leading to improved crop health, higher yields, and reduced reliance on synthetic fertilizers.

Table 2: Land applied N-P-K calculated using pan field data.

Sample Event	Nitrogen, Total Kjeldahl (TKN)	Nitrogen, Ammonium (NH_4-N)	Total Phosphorus (P_2O_5)	Total Potassium (K_2O)
Units	lbs/acre			
A	24.8	13.2	8.4	25.9
B	23.7	14.8	10.0	24.3
C	103.8	70.7	19.6	72.2
D	71.9	47.9	25.3	83.9
Total for A-D* (event 3, 4, & 6)	202.7	134.3	55.7	186.5

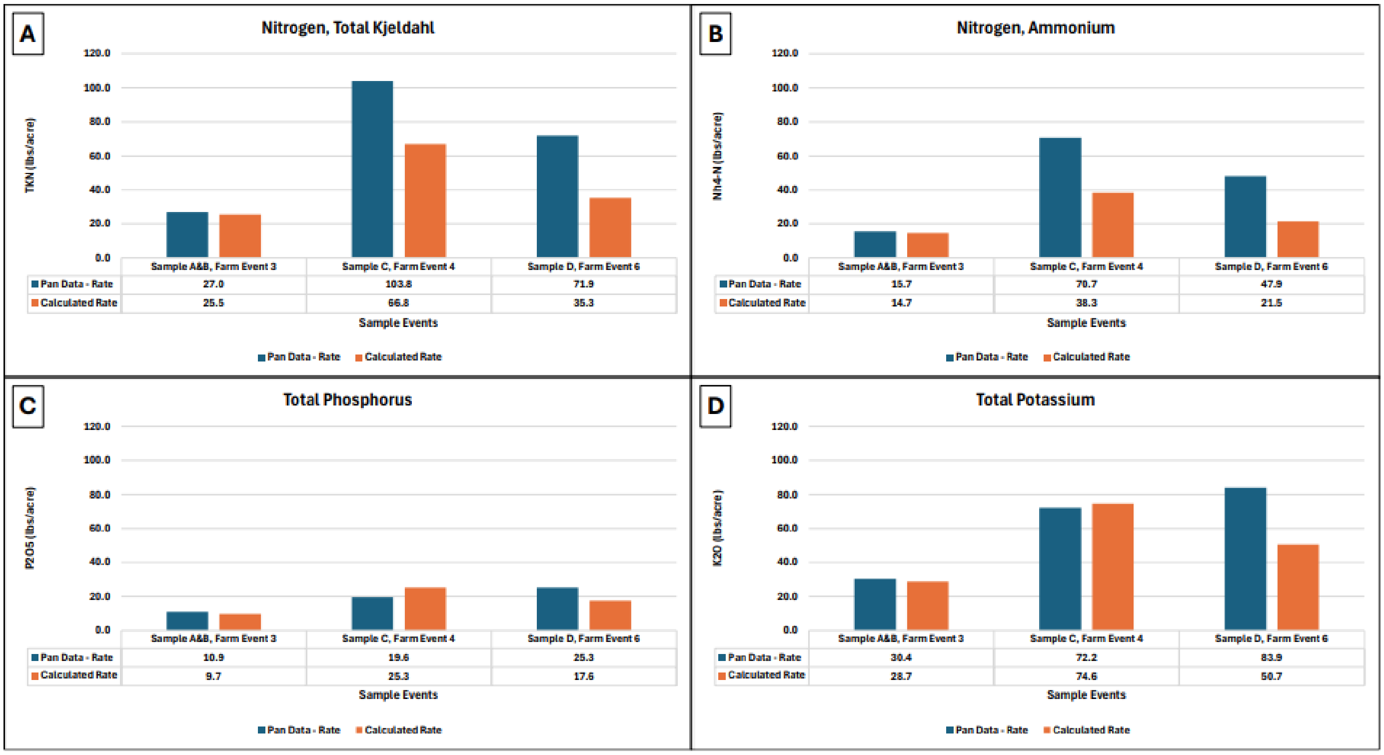
*A and B are different samples from the same event so averaged A&B before totaling A-D

Comparable Nitrogen Leaching Despite Increased Water Application: Nitrogen leaching was evaluated using resin cartridges. The 360 RAIN field received 110 lbs. of N per acre via Urea Ammonium Nitrate (UAN) (before data collection began) and 8,700 gallons of in-season liquid manure (equivalent to 63 lbs. of N per acre), for a total of 173 lbs. of N applied per acre. In comparison, the control field received 180 lbs. of N per acre. Resin cartridge data showed similar N leaching between the two fields, with an average leaching rate of 58 lbs/acre for the 360 RAIN field and 56 lbs/acre for the control field. This indicates that despite the additional water applied in the 360 RAIN field, which tends to increase leaching, nitrogen leaching rates were comparable between the two fields. However, it should be noted that the resin cartridges were deployed after spring manure and commercial fertilizer was applied to the control field, which likely missed some nitrogen leaching that occurred earlier in the season.

EVALUATION KEY CHALLENGES AND ISSUES

Inconsistent Application Measurements: One of the key challenges observed in this evaluation was the inconsistency between the calculated application rates and the measured application using pans (Figure 3). Nitrogen leaching and nutrient application showed considerable discrepancies in measurements, particularly for total nitrogen (45% difference) and ammonium (57% difference), indicating that current methods for measuring nutrient application may not be fully accurate or reliable. Future sampling methodologies should use larger sampling areas to reduce variability and improve accuracy.

Figure 3. Comparison of application rates from the pan data compared to calculated rates for A) TKN, B) NH_4-N, C) P_2O_5, and D) K_2O.



Timing of Resin Cartridge Installation: The timing of the resin cartridge installations, which occurred after the manure application on the control field, may have missed critical leaching events early in the season. This delay in data collection could have led to discrepancies in nitrogen leaching estimates between the two fields, especially in the early stages of nutrient application. Future studies should consider more precise timing of resin cartridge placement to capture a full picture of leaching patterns across different application methods.

IMPLICATIONS

The results of this study offer strong evidence that the 360 RAIN system can effectively apply in-season manure and water without compromising crop health or dramatically increasing nitrogen leaching. The ability to apply liquid manure, leachate pond water, and well water directly to growing crops presents a significant opportunity for improving nutrient utilization, reducing fertilizer dependency, and enhancing crop productivity. Additionally, the system's capacity to distribute manure applications throughout the season offers potential benefits for both environmental sustainability and farm profitability.

While the study identified some operational and measurement challenges, including higher-than-expected nutrient application rates and potential underestimation of early-season leaching, these challenges are addressable with further research and system optimization. The fact that nitrogen leaching rates remained comparable despite the 360 RAIN field receiving significantly more water is particularly promising, suggesting that in-season manure applications have the potential to better synchronize nutrient availability with crop demand.

As more farms continue to adopt the 360 RAIN system, additional research and field trials will be critical to further refine application strategies, optimize nutrient delivery, and better understand long-term environmental impacts. While this study provides valuable insights into the potential of 360 RAIN for nutrient and water management, it also highlights opportunities for improved measurement techniques and more accurate assessments of early-season nutrient losses. With continued research and adaptation, the 360 RAIN system has the potential to significantly enhance sustainable manure management practices and further support farmers in maximizing the value of their manure nutrients.

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Appendix C

Third-Party Review of Adaptive Irrigation Technology at Double S Dairy – Markesan, WI (Full Report)

Evaluation of the in-season manure application using the 360Rain system

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[1]Nelson Institute for Environmental Studies, University of Wisconsin-Madison

Abstract

Manure nutrients can be lost to the environment following land application reducing manure fertilizer value. Applying manure in season has the potential to improve nutrient uptake, and thus nutrient use efficiency, as well as reduce losses to the environment. This research was conducted to assess an in-season autonomous manure application system, the 360RAIN, to determine accuracy of nutrients applied versus intended and to assess nitrogen leaching. The system is able to blend manure with other liquid sources for land application including silage leachate, collected farmstead runoff, and well water. The nutrients applied as calculated from sampling the influent source concentrations and system flow data varied from the measured concentrations collected in pans in the field. The intended application determined by the calculated method versus the measured applied resulted in a difference of 6% for phosphorus, 19% for potassium, 45% for TKN, and 47% for ammoniacal nitrogen. This variability, while high for some parameters, is similar to variability in measured in more traditional manure application systems. Resin cartridges buried at a depth of 3 ft within the field indicate that 26% of the nitrogen applied in-season leached from the system as ammoniacal nitrogen and nitrate (58 lbs/acre leached from 226 lbs/acre applied). Most of the nitrogen leached was nitrate (92%). The leaching was similar to the control field that received 173 pounds per acre of nitrogen throughout the season, but received much less water. Initial data indicates that the system is capable of multiple in-season applications of nutrients. Additional leaching data is critical, particularly management of nutrient applications at times most critical to plant growth and comparisons to traditional manure application methods, to assess this system over time to determine the overall impact to manure nitrogen management.

Intro

Manure land application systems serve to return manure nutrients to cropping systems improving sustainability. Unfortunately manure constituents, including manure nutrients, are lost to the environment reducing the fertilizer value of manure and negatively affecting ecosystems. Timing of manure applications relates to manure nutrient losses. Current application practices of applying manure in the fall after harvest or early spring before planting allows increased time for manure nutrients to be lost when there is no growing crop. Applying manure in-season has the potential to reduce nutrient losses and improve nutrient use efficiency as the nutrients can be uptaken by the plants leaving less time for the manure to be subjected to losses before the plant uptakes the nutrients (and subject to environmental events such as rainfall that increases leaching and runoff). Further research is needed to assess the impact of in-season manure applications and the impact to leaching and nutrient use efficiency. This work begins to assess these issues by evaluating the nutrient application of an in-season manure system while also assessing nutrient leaching.

Methods

The 360RAIN is an autonomous irrigation system that can be used by farmers as a nutrient management tool for in-season application, applying water and nutrients directly to the base of crops throughout the growing season. The 360RAIN system was evaluated at a farm in east-central Wisconsin that has been using the system in two adjacent fields, the first a 100 acre field and the second a 75 acre field. For this evaluation, the 100-acre field planted with corn silage was used to evaluate the 360RAIN. The 75-acre hay field was also being used with the 360RAIN but was not part of our evaluation. The farm milks approximately 1,500 head of dairy cattle in free-stall barns that are bed with composted dairy manure fiber. Manure is collected from the free-stall barns and is first passed through screw press separators to remove fiber for use as animal bedding. The remaining liquid is then placed into a holding pond until it can be land-applied. The 360RAIN used at this farm (Figure 1) is a 2022 360RAIN model and uses a 120-foot boom with 35 spray nozzles (Figure 2) for application in the cornfield. The machine speed is based on application rate with a typical range of 1 to 8 inches per second, with an average speed of 4 inches per second and travels with the direction of the corn rows. The hose length is 3,000 ft, therefore this systems design has the potential to cover a 200 acre area from a central location.

Figure 1. Photo of 360RAIN with 120-foot boom

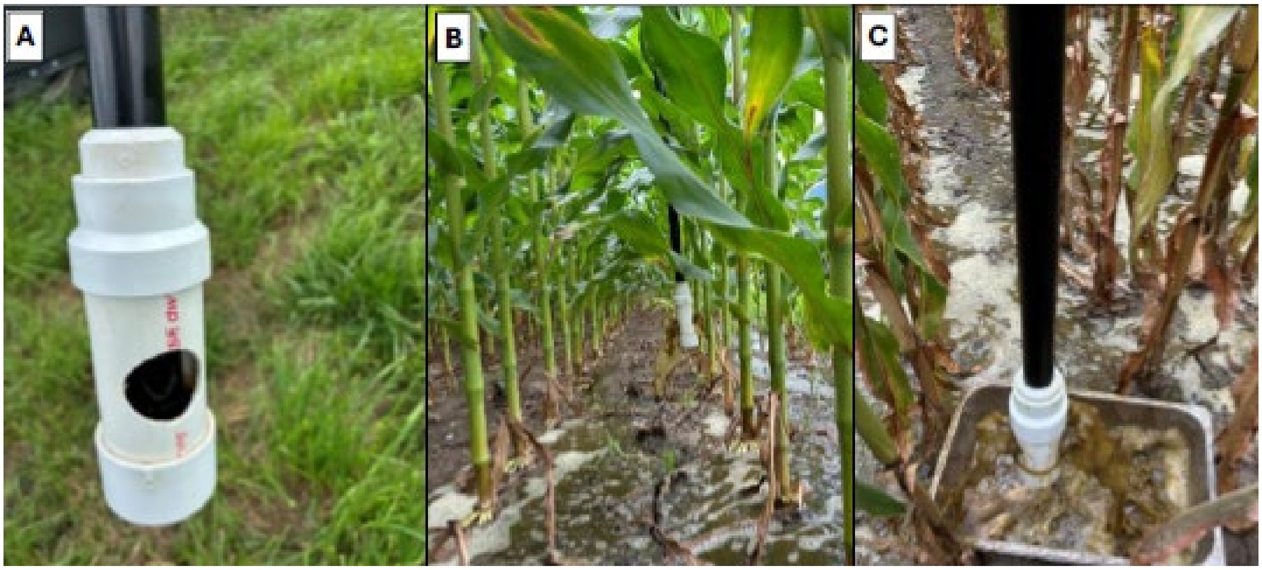

Figure 2. Photo of spray nozzles, A) close up of nozzle, B) application occurring between corn rows, and C) nozzle passing over collection pan during application

The 360RAIN system can draw from three potential input sources at this farm for field irrigation. The first source is the manure storage, consisting of post-separated manure liquid, urine, and parlor water. The second source is the leachate storage pond, which contains silage leachate and farmstead runoff. The third source is well water. The farm controls the source and ratio of inputs applied by the 360RAIN, based on crop needs, ambient conditions during the growing season, previous year's nutrient data, and compliance with the farm's nutrient management plan. Samples from all three sources were collected and analyzed for 21 parameters by A&L Great Lakes Laboratories.

The 360RAIN was deployed on the cornfield seven times during the season. Data on input sources (manure, leachate, well water) and application rates (gallons per acre) were provided by the farm. Each deployment took approximately five days to cover the entire 100-acre field (20 acres per day). Five sampling events were conducted to collect liquid samples directly applied by the 360RAIN, where one of the sampling events was only well water. Stainless steel collection pans were randomly placed in the field within the 360RAIN application path. After application, the pans were weighed and composite samples collected (3 for each event) for analysis at A&L Great Lakes Laboratories.

All samples were shipped to A&L Great Lakes Laboratories within one week of sampling date. Samples were analyzed for the M7 Manure Analysis Package plus pH. The package includes moisture, total solids, total Kjeldahl nitrogen (TKN), phosphorus (P), potassium (K), sulfur, calcium, magnesium, sodium, iron, aluminum, manganese, copper, zinc, ash, organic carbon, volatile solids, C:N ratio, and ammonium-nitrogen (NH_4-N).

In addition to the samples collected from the 360RAIN application events, resin cartridges were also deployed to gather additional data on nitrogen cycling and migration via leaching. Resin cartridges were placed in both the study field (100-acre cornfield) with 360RAIN application and an adjacent 20-acre cornfield that received manure pre season using traditional application methods in a one-time event for comparison. The resin cartridges were deployed on June 26, 2024, and retrieved 106 days later on October 10, 2024, after the corn harvest was completed.

Nitrogen leaching was calculated using the resin cartridges (Self Integrating Accumulators) as described by Bischoff (2007) and Grahmann et al (2018). The cartridges were made from PVC material of dimensions of 10 cm in both height and diameter. The bottom of each resin cartridge was sealed with a mesh membrane to hold the mixture of mixed bed resin of a strong acid cation and strong base anion (Amberlite™ MB20 H/OH, Wilmington, DE, USA) and high grade cleaned quartz sand that was mixed in a volume ratio of 1:2 respectively (Willich et al, 2016).

During deployment of the resin cartridges, a pit of up to 1 m3 was dug and a horizontal tunnel would be excavated at 0.9 m depth to fit each cartridge after which the pit was filled with the excavated soil. This method ensures that the cartridges are buried in undisturbed soil to avoid disturbance of the soil hydraulic system (Grunwald et al., 2019; Bischoff et al., 2007). Within each field three different pits were dug and within each pit, three resin cartridges separated by 0.50 m from each other were deployed. These were left underneath the ground for a duration of 106 days after which they were unearthed and taken to the lab for further handling and analysis.

Each resin cartridge was divided into three layers (*i.e.,* 0-5, 5-6 and 6-10 cm) for assessment of inorganic N concentrations. The last layer was disregarded on grounds that it acts as a buffer for any upward movement of nutrients due to capillarity rise and side convection from the soil underneath the resin cartridges (Bischoff et al., 2007; Grahmann et al., 2018). The middle layer was used as an internal blank whose N concentrations would be subtracted from those of the first layer which would capture the accumulated N leached. A subsample weighing 10 g of the mixture content of each of the two first layers was extracted with 2 M KCl, agitated at 200 rpm during 60 minutes after which they were filtered using Ahlstrom 642 (2 µm) filter paper into a sample bottler which was stored in a freezer at -10 °C for later analysis of NH_4^+-N and NO_3^--N concentrations. Also, a subsample of each layer was collected for determination of moisture content for correction of the N concentrations.

The estimated cumulative N leaching flux was calculated using the following equation (Wey and Hunkuler, 2022);

$$\text{Nitrogen flux } (kg\ N\ ha^{-1}) = \frac{C\ x\ V\ x\ M_{layer}}{M_{subsample} * A}\ x\ 10^{-2}$$

Where C: measured N concentration (mg N L^{-1}), V: volume of the extracting solution (0.1 L), M_{layer}: weight of the resin-sand mixture layer, $M_{subsample}$: weight of resin-sand mixture extracted (10 g) and A: area of the resin cartridge (0.0079 m^2).

Results

During the season, seven application events were conducted on the 100-acre cornfield using the 360RAIN system. A cumulative total of 65,717 gallons per acre was applied, consisting of 14.4% manure lagoon liquid, 31.5% leachate pond liquid, and 54.1% well water. Of the total gallons applied, 31,942 gallons per acre were applied during our four sampling events (A–D), consisting of 15.5% manure lagoon liquid, 50.0% leachate pond liquid, and 34.5% well water. Details on the sources and amounts applied are listed in Table 1.

Table 1. Application rates using the RAIN360 across the 2024 cropping season

Sample Events			A & B	C		D		Annual Total
360RAIN Application	1	2	3	4	5	6	7	
	gal/acre							
Manure Holding Pond	1,000	1,000	1,000	2,500	2,500	1,700	0	9,700
Leachate Pond	0	4,397	4,276	12,543	0	0	0	21,216
Well Water	3,839	0	0	0	10,313	11,615	10,705	36,472
Event Total	4,839	5,397	5,276	15,043	12,813	13,315	10,705	67,388

Influent samples were collected from the manure holding pond, leachate pond, and well head, and analyzed for 21 individual parameters. As expected, the highest concentrations of each parameter were observed in the manure holding pond, followed by the leachate pond, with the well water containing the lowest overall concentrations. A summary of the primary characteristics is listed in Table 2, with additional information available in Appendix A.

Table 2. Application input primary characterization (manure, leachate, well)

Source	Total Solids	Volatile Solids	Nitrogen, Total Kjeldahl (TKN)	Nitrogen, Ammonium (NH_4-N)	Total Phosphorus (P_2O_5)	Total Potassium (K_2O)
Unit	%		lbs/1,000 gal			
Manure Holding Pond	3.76	2.72	18.7	11.3	7.6	22.3
Leachate Pond	0.12	0.07	1.6	0.8	0.5	1.5
Well Water	0.07	0.01	0.3	0.2	0.4	1.1

Composite samples were also collected during the 360RAIN sample events and analyzed for 21 individual parameters. A summary of the primary characteristics from the four sample events is listed in Table 3, with additional information available in Appendix A.

Table 3. Characterization of land applied samples by event

Sample Event	Total Solids	Volatile Solids	Nitrogen, Total Kjeldahl (TKN)	Nitrogen, Ammonium (NH_4-N)	Total Phosphorus (P_2O_5)	Total Potassium (K_2O)
Units	%		lbs /1000 gal			
A	0.86	0.53	4.7	2.5	1.6	4.9
B	0.92	0.63	4.5	2.8	1.9	4.6
C	0.85	0.57	6.9	4.7	1.3	4.8
D	0.98	0.69	5.4	3.6	1.9	6.3

Using the laboratory results from our composite samples from the four sampling events (A–D) and the farm's application rate data, the total N-P-K applied per acre was estimated, Table 4. For comparison, the N-P-K application rates for all seven 360RAIN application events were calculated using the farm's application data and the laboratory results from the three input sources, Table 5. The total application rate for N-P-K for events A-D was higher when using the measured pan data than the calculated. As both calculations relied on the flow data, this difference is attributed to the sampling methods of the applied nutrients. The pan application rate was highly variable, with an observed coefficient of variation between 39 and 62%, indicating the methodology of the pans has concerns for use as the total application rate. This was also visualized during sampling events where the application system commonly came into contact with corn and therefore had inconsistent application in the small pan areas. It is recommended for future sampling that larger sampling collection areas be used to determine application rates.

Table 4. Land applied N-P-K calculated using pan field data

Sample Event	Nitrogen, Total Kjeldahl (TKN)	Nitrogen, Ammonium (NH_4-N)	Total Phosphorus (P_2O_5)	Total Potassium (K_2O)
Units	lbs/acre			
A	24.8	13.2	8.4	25.9
B	23.7	14.8	10.0	24.3
C	103.8	70.7	19.6	72.2
D	71.9	47.9	25.3	83.9
Total for A-D* (event 3, 4, & 6)	202.7	134.3	55.7	186.5

*A and B are different samples from the same event so averaged A&B before totaling A-D

Table 5. Land applied N-P-K calculated using system application

Farm Application Event	Nitrogen, Total Kjeldahl (TKN)	Nitrogen, Ammonium (NH_4-N)	Total Phosphorus (P_2O_5)	Total Potassium (K_2O)
Units	lbs/acre			
1	19.9	12.1	9.1	26.5
2	25.7	14.8	9.8	28.9
3	25.5	14.7	9.7	28.7
4	66.8	38.3	25.3	74.6
5	49.8	30.3	23.1	67.1
6	35.3	21.5	17.6	50.7
7	3.2	2.1	4.3	11.8
Total for A-D (event 3, 4, & 6)	127.6	74.5	52.6	154.0
Total Season Application	226.3	133.9	98.9	288.3

When comparing the application rates for the sample event data as calculated from the nutrient concentration applied in the pans as compared to those calculated rates for those same events using the source nutrient data, Figure 3, there were differences in the in the intended (source data) and applied (pan data) for N, P, and K. Total P had the smallest percentage difference at only 6%, followed by K at 19%. Much larger differences were observed for TKN (45%) and ammonium (57%). This indicates there are sampling differences are greater for nitrogen.

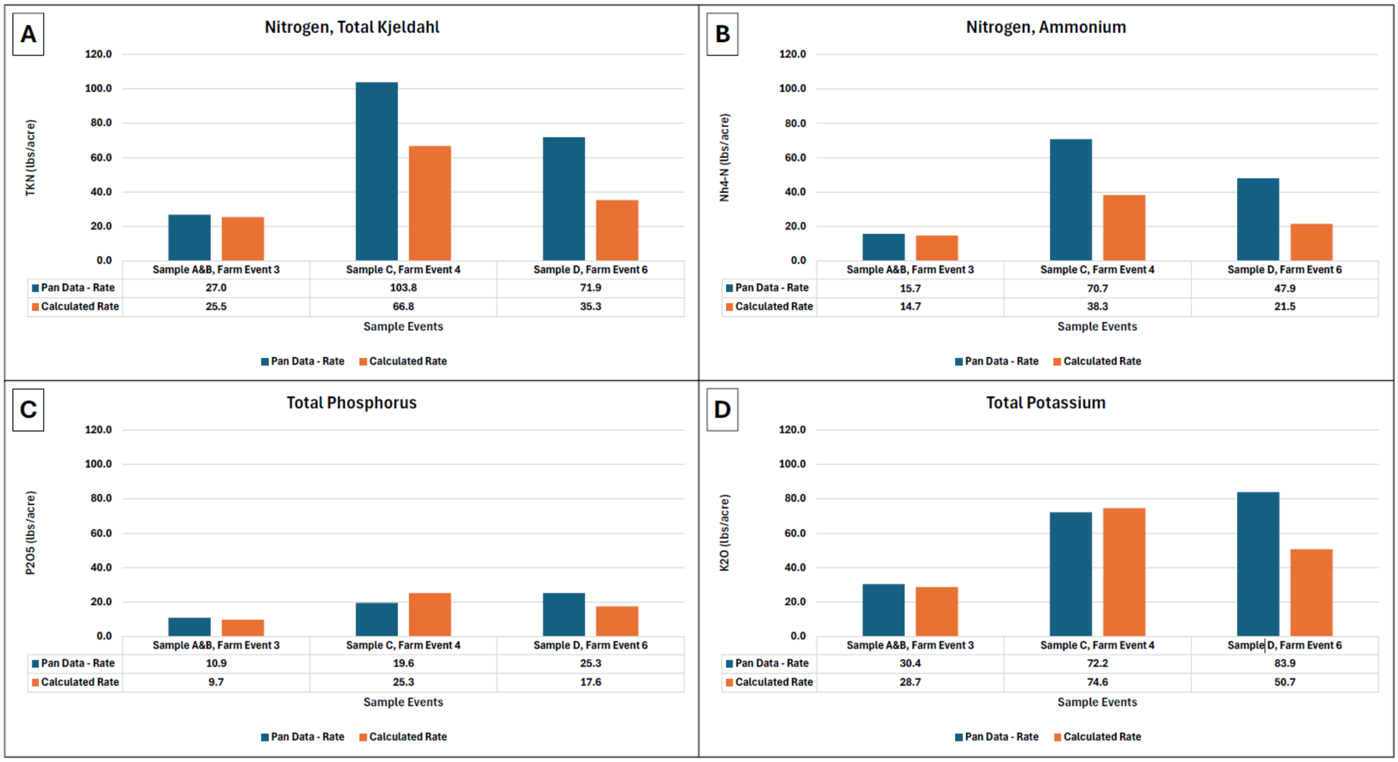

Figure 3. Comparison of application rates from the pan data compared to calculated rates for A) TKN, B) NH4-N, C) P2O5, and D) K2O.

The control field received 80 pound of nitrogen per acre units via Urea Ammonium Nitrate (UAN) and 10,000 gallons of manure in the spring (about 80 lbs of N per acre) for a total of 180 pounds of nitrogen per acre applied (information supplied from farm). The 360RAIN field received 110 pounds of nitrogen per acre via UAN and 8,700 gallons of in season (63 lbs of N per acre) for a total of 173 pounds of nitrogen per acre applied (information supplied from farm). Resin cartridges measured similar average N leached from both the control (56 lbs/acre) and 360 RAIN fields (58 lbs/acre), Table 6. This indicates that 26% of the applied N over the season was leached at nitrate and ammonical N (58 of 226 lbs/acre applied). This percent of leaching is similar to that used by international standards for nitrogen leaching. In both fields, over 92% of the total N leached was as nitrate (NO3-N). While the fields were similar in nitrogen leaching, it should be noted that the control field received much less water (increased water applications increases leaching) and because of the start date of the project, resin cattridges were installed after manure applications on the control field which likely lead to missed N leaching from the control fields.

Table 6. Resin Cartridge Data

Resin Location	Field	NH4-N flux (lbs N/acre)	NO3-N flux (lbs N/acre)	Accumulative N leached (lbs N/acre)	Mean (lbs/acre)	STDEV
1	360RAIN	6.02	85.49	91.50	57.94	29.40
2	360RAIN	2.56	42.96	45.52		
3	360RAIN	5.64	31.14	36.78		
C1	Control	3.39	45.53	48.92	55.91	20.17
C2	Control	3.03	37.14	40.17		
C3	Control	3.28	75.37	78.65		

Conclusions

The 360RAIN is an autonomous irrigation system used for in-season nutrient and water application directly to growing crops. This research evaluated the impact of the 360RAIN on a 100-acre field growing corn silage in Wisconsin applying separated manure liquids, a leachate pond, and well water. The 360Rain system was capable of separating the manure application events throughout the growing season without a detriment to the growing crop. Field collected samples indicated a higher application rate than the intended determined using calculations, but the method for measurement may need to be adapted to cover a larger area. Regardless the manure nutrients applied did not have greater variation for the intended application rate than traditional land application methods. Resin cartridges measured similar nitrogen leaching in a field that received spring manure applications versus the in-season applications. However, the 360RAIN field received a greater amount of water which is known to increase leaching, and the cartridges were applied in the field well after the spring manure application likely resulting in missed nitrogen leaching from the control field. In-season manure technologies require additional sampling to assess the impact to nitrogen leaching and cycling in fields to reduce losses.

Appendix A

Table A 1. Additional Analytical Results

		Moisture	Ash @ 550C	Organic Matter (LOI @ 550C)	Organic Carbon (LOI @ 550C)	S	Mg	Ca	Na	Al [ppm]	Cu [ppm]	Fe [ppm]	Mn [ppm]	Zn [ppm]	pH
	Units	%				lbs per 1000 gallons				ppm					
Sample Event A	Average	99.14	0.33	0.53	0.31	0.47	1.57	2.27	1.70	23.00	0.67	18.67	3.23	3.33	7.47
	Standard Deviation	0.07	0.05	0.05	0.03	0.06	0.15	0.25	0.10	6.24	0.06	6.66	0.46	0.12	0.06
Sample Event B	Average	99.08	0.29	0.63	0.36	0.50	1.57	2.53	1.40	22.33	0.67	20.67	3.73	3.73	7.37
	Standard Deviation	0.04	0.03	0.01	0.01	0.00	0.06	0.06	0.10	4.16	0.06	4.73	0.47	0.23	0.06
Sample Event C	Average	99.15	0.28	0.57	0.33	0.67	1.27	2.40	1.30	17.00	0.57	14.33	2.43	3.43	8.00
	Standard Deviation	0.07	0.01	0.06	0.04	0.06	0.06	0.10	0.17	4.58	0.06	4.16	0.55	0.25	0.00
Sample Event D	Average	99.02	0.29	0.69	0.41	0.57	2.07	2.97	2.07	12.33	0.80	10.63	2.67	4.17	7.47
	Standard Deviation	0.05	0.02	0.07	0.04	0.06	0.06	0.15	0.15	1.53	0.17	1.18	0.42	0.32	0.06
Manure Lagoon	Average	96.24	1.04	2.72	1.58	2.15	6.55	10.73	6.80	44.50	3.28	36.50	11.00	17.00	7.23
	Standard Deviation	0.19	0.05	0.22	0.12	0.06	0.26	0.41	0.74	3.32	1.09	1.91	0.82	2.71	0.19
Leachate Pond	Average	99.88	0.05	0.07	0.04	0.10	0.40	0.75	0.10	2.85	0.15	3.65	0.45	0.50	7.30
	Standard Deviation	0.00	0.01	0.01	0.00	0.00	0.00	0.07	0.00	0.49	0.07	0.21	0.07	0.14	0.00
Well	Average	99.93	0.06	0.01	0.00	0.30	0.60	1.00	0.30	3.50	0.20	3.30	0.40	0.80	7.7

Appendix B

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To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 68064
Sample ID: COMPOSITE A
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 9/16/2024
Date Received: 9/16/2024
Date Reported: 9/20/2024 Page: 1 of 8

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal**	First Year Availability @ Pounds Per 1,000 Gal
Moisture	%	98.97	8244	
Solids	%	1.03	86	
Ash @ 550 C	%	0.26	21.4	
Organic Matter (LOI @ 550 C)	%	0.77	64.3	
Organic Carbon (LOI @ 550 C)	%	0.45	37.3	
Carbon:Nitrogen Ratio (C:N)	-		6.2:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.072	6.0	4.7 *
Nitrogen, Ammonium (NH_4-N)	%	0.050	4.2	4.2 *
Nitrogen, Organic (N)	%	0.022	1.8	0.5 *
Phosphorus (P)	%	0.010	1.9 (as P_2O_5)	1.9 * (as P_2O_5)
Potassium (K)	%	0.057	5.7 (as K_2O)	5.7 * (as K_2O)
Sulfur (S)	%	0.01	0.6	0.5 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
** Manure density assumed to be 8.33 lb/gallon

Report Approved By: [signature] Approval Date: 9/20/2024
David Henry - Agronomist / Technical Services - CCA

Report Number
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To: NEWTRIENT LLC - SIG GRANT
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WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 68064
Sample ID: COMPOSITE A
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 9/16/2024
Date Received: 9/16/2024
Date Reported: 9/20/2024

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal**	First Year Availability @ Pounds Per 1,000 Gal
Magnesium (Mg)	%	0.02	2.1	0.9 #
Calcium (Ca)	%	0.04	3.1	1.8 #
Sodium (Na)	%	0.02	1.9	
Aluminum (Al)	ppm	12	0.1	
Copper (Cu)	ppm	1.0	<0.1	<0.1 #
Iron (Fe)	ppm	12	0.1	0.1 #
Manganese (Mn)	ppm	3.0	<0.1	<0.1 #
Zinc (Zn)	ppm	4.4	<0.1	<0.1 #
pH	-	7.5		

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
** Manure density assumed to be 8.33 lb/gallon

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WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 68065
Sample ID: COMPOSITE B
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 9/16/2024
Date Received: 9/16/2024
Date Reported: 9/20/2024 Page: 3 of 8

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal **	First Year Availability @ Pounds Per 1,000 Gal
Moisture	%	99.07	8253	
Solids	%	0.93	77	
Ash @ 550 C	%	0.30	24.7	
Organic Matter (LOI @ 550 C)	%	0.63	52.8	
Organic Carbon (LOI @ 550 C)	%	0.37	30.6	
Carbon:Nitrogen Ratio (C:N)	-		6.0:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.061	5.1	3.8 *
Nitrogen, Ammonium (NH_4-N)	%	0.040	3.3	3.3 *
Nitrogen, Organic (N)	%	0.021	1.7	0.5 *
Phosphorus (P)	%	0.009	1.7 (as P_2O_5)	1.7 * (as P_2O_5)
Potassium (K)	%	0.069	6.9 (as K_2O)	6.9 * (as K_2O)
Sulfur (S)	%	0.01	0.5	0.5 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
** Manure density assumed to be 8.33 lb/gallon

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WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 68065
Sample ID: COMPOSITE B
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 9/16/2024
Date Received: 9/16/2024
Date Reported: 9/20/2024
Page: 4 of 8

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal **	First Year Availability @ Pounds Per 1,000 Gal
Magnesium (Mg)	%	0.02	2.0	0.9 #
Calcium (Ca)	%	0.03	2.8	1.4 #
Sodium (Na)	%	0.03	2.1	
Aluminum (Al)	ppm	11	0.1	
Copper (Cu)	ppm	0.7	<0.1	<0.1 #
Iron (Fe)	ppm	9.9	0.1	0.1 #
Manganese (Mn)	ppm	2.2	<0.1	<0.1 #
Zinc (Zn)	ppm	3.8	<0.1	<0.1 #
pH	-	7.4		

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
** Manure density assumed to be 8.33 lb/gallon

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WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 68066
Sample ID: COMPOSITE C
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 9/16/2024
Date Received: 9/16/2024
Date Reported: 9/20/2024 **Page:** 5 of 8

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal**	First Year Availability @ Pounds Per 1,000 Gal
Moisture	%	99.02	8248	
Solids	%	0.98	82	
Ash @ 550 C	%	0.30	24.6	
Organic Matter (LOI @ 550 C)	%	0.68	57.0	
Organic Carbon (LOI @ 550 C)	%	0.40	33.1	
Carbon:Nitrogen Ratio (C:N)	-		6.6:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.060	5.0	3.8 *
Nitrogen, Ammonium (NH_4-N)	%	0.040	3.3	3.3 *
Nitrogen, Organic (N)	%	0.020	1.7	0.5 *
Phosphorus (P)	%	0.010	2.0 (as P_2O_5)	2.0 * (as P_2O_5)
Potassium (K)	%	0.063	6.3 (as K_2O)	6.3 * (as K_2O)
Sulfur (S)	%	0.01	0.6	0.5 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
** Manure density assumed to be 8.33 lb/gallon

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WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 68066
Sample ID: COMPOSITE C
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 9/16/2024
Date Received: 9/16/2024
Date Reported: 9/20/2024 Page: 6 of 8

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal **	First Year Availability @ Pounds Per 1,000 Gal
Magnesium (Mg)	%	0.03	2.1	1.4 #
Calcium (Ca)	%	0.04	3.0	1.8 #
Sodium (Na)	%	0.03	2.2	
Aluminum (Al)	ppm	14	0.1	
Copper (Cu)	ppm	0.7	<0.1	<0.1 #
Iron (Fe)	ppm	10	0.1	0.1 #
Manganese (Mn)	ppm	2.8	<0.1	<0.1 #
Zinc (Zn)	ppm	4.3	<0.1	<0.1 #
pH	-	7.5		

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993   # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
** Manure density assumed to be 8.33 lb/gallon

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Account Number
63570

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3505 Conestoga Dr.
Fort Wayne, IN 46808
260.483.4759
algreatlakes.com

To: NEWTRIENT LLC - SIG GRANT
11510 LAURIE DR
WHEATFIELD, IN 46392-7364

For: UW-MADISON

Attn: MARK STOERMAN

Purchase Order: UW-MADISON

Lab Number: 68067
Sample ID: MANURE
Manure Type: DAIRY, LIQUID PIT (20)

Date Sampled: 9/16/2024
Date Received: 9/16/2024
Date Reported: 9/20/2024 Page: 7 of 8

MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal **	First Year Availability @ Pounds Per 1,000 Gal
Moisture	%	96.46	8035	
Solids	%	3.54	295	
Ash @ 550 C	%	1.11	92.8	
Organic Matter (LOI @ 550 C)	%	2.43	202.1	
Organic Carbon (LOI @ 550 C)	%	1.41	117.2	
Carbon:Nitrogen Ratio (C:N)	-		6.6:1	
Nitrogen, Total Kjeldahl (TKN)	%	0.212	17.7	13.5 *
Nitrogen, Ammonium (NH_4-N)	%	0.140	11.7	11.7 *
Nitrogen, Organic (N)	%	0.072	6.0	1.8 *
Phosphorus (P)	%	0.039	7.4 (as P_2O_5)	7.4 * (as P_2O_5)
Potassium (K)	%	0.247	24.7 (as K_2O)	24.7 * (as K_2O)
Sulfur (S)	%	0.03	2.2	1.4 #

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
** Manure density assumed to be 8.33 lb/gallon

Report Number
F24260-6501
Account Number
63570

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MANURE ANALYSIS

Analysis	Unit	Analysis Result (As Received)	Pounds Per 1,000 Gal**	First Year Availability @ Pounds Per 1,000 Gal
Magnesium (Mg)	%	0.08	6.9	3.7 #
Calcium (Ca)	%	0.12	10.2	5.5 #
Sodium (Na)	%	0.09	7.9	
Aluminum (Al)	ppm	42	0.3	
Copper (Cu)	ppm	2.9	<0.1	<0.1 #
Iron (Fe)	ppm	35	0.3	0.2 #
Manganese (Mn)	ppm	10	0.1	0.1 #
Zinc (Zn)	ppm	16	0.1	0.1 #
pH	-	7.5		

@ Estimate of first-year availability does not account for incorporation losses. Consult MWPS-18, "Livestock Waste Facilities Handbook" for additional information.
* Source: MWPS-18, Livestock Waste Facilities Handbook, 1993 # Source: A3411, "Manure Nutrient Credit Worksheet", University of Wisconsin
** Manure density assumed to be 8.33 lb/gallon

Appendix D

Supplemental Information – Ohio State & Iowa State Case Study

OBJECTIVE

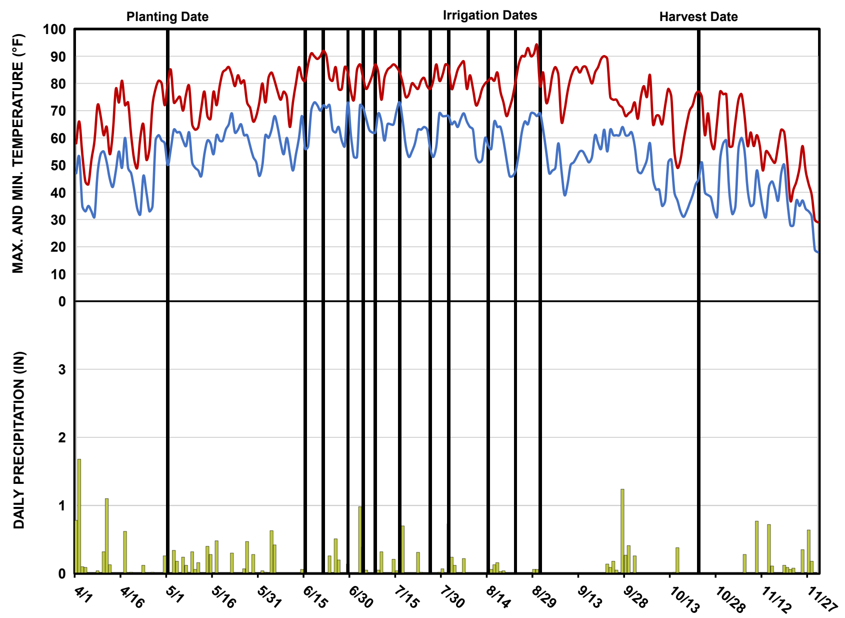
Demonstrate in-season application of commercial nutrient sources and water application as a unified strategy to reduce nutrient losses while improving profitability with increased grain yields.

Molly Caren Agricultural Center
OARDC
Madison County

STUDY INFORMATION

Planting Date	5/2/2024
Harvest Date	10/21-23/2024
Hybrid	USA1093GT
Population	35,000 sds/ac
Acres	140
Treatments	3
Reps	8
Treatment Width	160 ft. strips
Tillage	Strip-Till
Management	Fertilizer, Fungicide, Herbicide
Previous Crop	Soybean
Row Spacing	30 in.
Soil Type	Crosby-Lewisburg Silt Loams, 63% Kokomo Silty Clay Loam, 37%

WEATHER INFORMATION



Growing Season Weather Summary

	APR	MAY	JUN	JUL	AUG	SEP	Total
Precip (in.)	5.29	3.72	2.28	3.20	1.86	2.38	18.73
Cumulative GDDs	247	759	1411	2101	2751	3279	3279

STUDY DESIGN

Field demonstrations was laid-out in a RCBD strip trial design with 160 feet wide blocks and treatments that include: in-season nutrient management of nitrogen to determine the mineralization rate differences based on irrigated versus non irrigated treatments. There were three treatments with two of the treatments receiving full nitrogen application per Tri-State Fertilizer recommendations and the third irrigated treatment getting only two-thirds of the nitrogen. The irrigated treatments received the nitrogen through fertigation at 15 gal/ac. The 360 Yield Center Rain Irrigator unit was used to apply water in a 7-inch band at the base of the corn plant during the growing season.

The robotic irragator disperses water towards the base of the plants during the duration of the growing season in a 7-inch band.

OBSERVATIONS

This crop was planted in the early planting window. This year did not receive adequate rain through the summer and area was in drought. The irrigator began watering in mid-June and completed in the early part of September. In-season applied nitrogen was injected into the water stream and put on at a rate of 15 gal/ac. The corn crop exhibited drought and heat stress for all treatments throughout the growing season. This caused yield loss for the crop. The irrigated portion of the field was watered 11 times throughout the growing season. Total nitrogen applied for irrigated and non-irrigated treatments was 180 lbs/ac and irrigated two-thirds nutrients was 136 lbs/ac.

SUMMARY

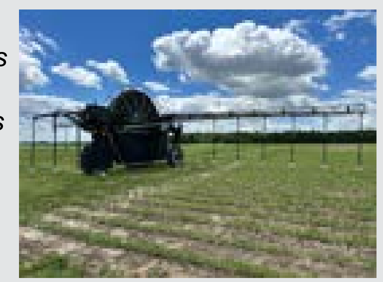
- Irrigation had a statiscally significant affect on yield over all treatments. 48 bu/ac between irrigated two-thirds nutrients and non-irriated and 44 bu/ac between irrigated and non-irrigated.
- A total of 773 gallons of diesel was used to run the irrigator for this trial for 2024 cropping season across 71 acres.
- A total of 25,739 kWh were used to run the electric pumps, base station, and well for 2024 growing season across 71 acres.

RESULTS

Treatments	Water Applied (in.)	Nitrogen (lbs/ac)	Moisture (%)	Yield (bu/ac)
Irrigated	5.5	180	14.7	233 a
Irrigated (2/3) Nutrients	5.5	136	14.7	237 a
Non-irrigated	0	180	13.7	189 b
Treatment Means with the same letter are not significantly different according to Fisher's Protected Least Significant Differences (LSD) test at alpha = 0.1.				LSD: 10 CV: 5.3%

TOOLS OF THE TRADE

The 360 RAIN has a 80-foot boom that covers 32 rows and applies water through Y-DROP like hoses. This method of irrigation increases efficiency by reducing the amount of water used. It is also advantageous to use in a field that is irregular shaped and cannot fit a standard center pivot.



PROJECT CONTACT

For inquiries about this project, contact Andrew Klopfenstein (klopfenstein.34@osu.edu), John Fulton (fulton.20@osu.edu), Scott Shearer (shearer.95@osu.edu), or Elizabeth Hawkins (hawkins.301@osu.edu).

Project Funded by NRCS, ODA, and 360 Yield Center.

High Clearance Robotic Irrigator

OBJECTIVE

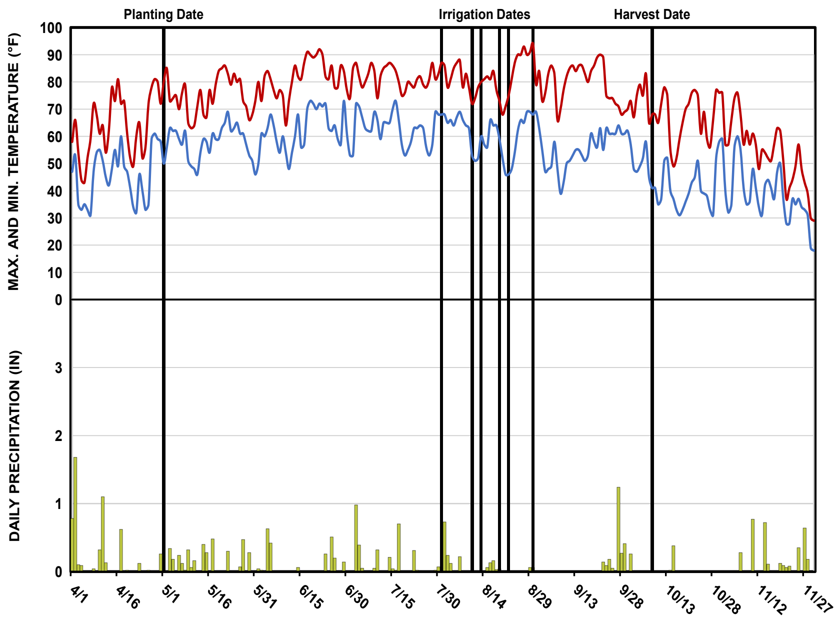
Demonstrate in-season application of commercial nutrient sources and water application as a unified strategy to reduce nutrient losses while improving profitability with increased grain yields.

Molly Caren Agricultural Center
OARDC
Madison County

STUDY INFORMATION

Planting Date	5/1/2024
Harvest Date	10/8/2024
Variety	Croplan CP3550XF
Population	135,000 sds/ac
Acres	25
Treatments	2
Reps	7
Treatment Width	80 ft.
Tillage	Vertical
Management	Fertilizer, Fungicide, Herbicide
Previous Crop	Corn
Row Spacing	30 in.
Soil Type	Crosby-Lewisburg Silt Loams, 64% Kokomo Silty Clay Loam, 36%

WEATHER INFORMATION



Growing Season Weather Summary

	APR	MAY	JUN	JUL	AUG	SEP	Total
Precip (in.)	5.29	3.72	2.28	3.20	1.86	2.38	18.73
Cumulative GDDs	247	759	1411	2101	2751	3279	3279

STUDY DESIGN

Field demonstrations was laid-out in a RCBD strip trial design with treatments that include: in-season irrigated versus non irrigated treatments for soybeans. There were no nutrients applied to the soybean crop during the 2024 growing season. The 360 Yield Center Rain Irrigator unit was used to apply water in a 7-inch band at the base of the soybean plant during the growing season. These beans were planted on 30-inch spacing.

360 Rain Unit irrigating soybean crop during August of growing season..

OBSERVATIONS

This crop was planted in the early planting window. This year did not receive adequate rain through the summer and area was in drought. The irrigator began watering in late August at pod fill R4/5 and completed in the early part of September. The soybean crop exhibited drought and heat stress for the non-irrigated treatment. This caused yield loss for the crop. The irrigated portion of the field was watered 6 times for a total of 4.5 inches of applied water. Additionally, the hurricane that was recieved in late fall caused significant losses in non-irrigated treatments with shatter losses from previous drought conditions. There were no losses from the hurricane in the irrigated treatment.

SUMMARY

- Irrigation had a statistically significant affect on yield over non-irrgated.
- A total of 211 gallons of diesel was used to run the irrigator for this trial for 2024 cropping season across 11 acres.
- A total of 3,475 kWh were used to run the electric pumps, base station, and well for 2024 growing season across 11 acres.

RESULTS

Treatments	Water Applied (in.)	Moisture (%)	Yield (bu/ac)
Irrigated	4.5	9.3	86 a
Non-irrigated	0	9.4	50 a
Treatment Means with the same letter are not significantly different according to Fisher's Protected Least Significant Differences (LSD) test at alpha = 0.1.			LSD: 6 CV: 4.0%

PROJECT CONTACT

For inquiries about this project, contact Andrew Klopfenstein (klopfenstein.34@osu.edu), John Fulton (fulton.20@osu.edu), Scott Shearer (shearer.95@osu.edu), or Elizabeth Hawkins (hawkins.301@osu.edu).

Project Funded by NRCS, ODA, and 360 Yield Center.

OBJECTIVE

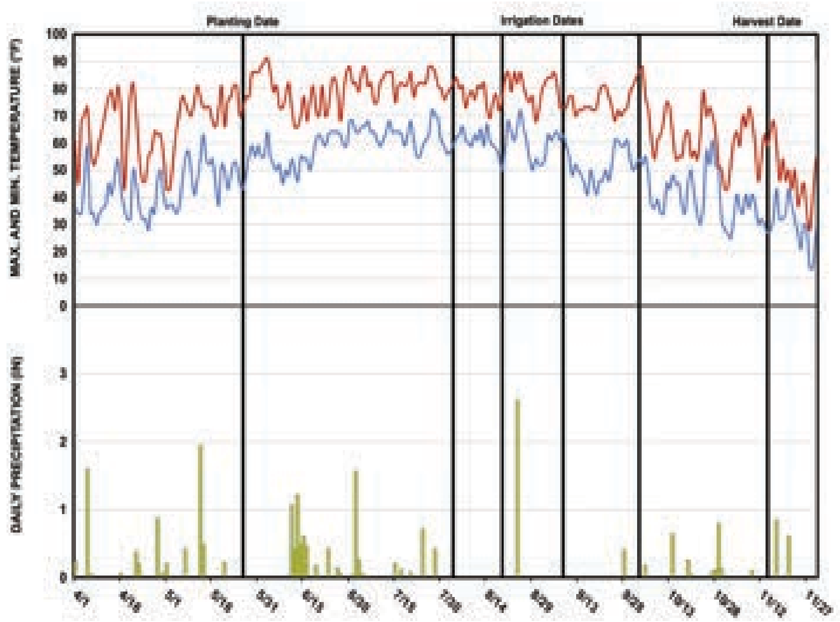
Demonstrate the in-season application of commercial nutrient sources and water application as a unified strategy to reduce nutrient losses while improving profitability with increased grain yields.

eFields Collaborating Farm
Beck's Hybrids
Madison County

STUDY INFORMATION

Planting Date	5/26/2023
Harvest Date	11/14/2023
Variety	Beck's 5647Q
Population	34,000 sds/ac
Acres	77
Treatments	2
Reps	1
Treatment Width	Split Field
Tillage	Minimum
Management	Fertilizer, Herbicide, Insecticide
Previous Crop	Soybeans
Row Spacing	30 in.
Soil Type	Crosby-Lewisburg Silt Loams, 39% Kokomo Silty Clay Loam, 15% Miamian-Eldean Silt Loams, 14%

WEATHER INFORMATION



Growing Season Weather Summary

	APR	MAY	JUN	JUL	AUG	SEP	Total
Precip (in.)	3.51	3.31	5.08	3.56	2.61	0.45	18.52
Cumulative GDDs	217	607	1118	1825	2425	2887	2887

STUDY DESIGN

This site was subdivided in accordance with the sub-watershed boundaries and managed with two treatments: 1) conventional commercial fertilizer application in accordance with the Tri-State Fertilizer recommendations, and 2) in-season nutrient management (N and P) using the HCRI and Tri-State Fertilizer Recommendations with the exception nutrient application will be match with plant nutrient uptake rates as judged by GDD. This site is instrumented as a paired watershed that is instrumented for both surface water and subsurface tile drainage. Further, these watersheds are monitored for precipitation, flow, and water quality (nitrate, nitrite, total phosphorus and DRP).

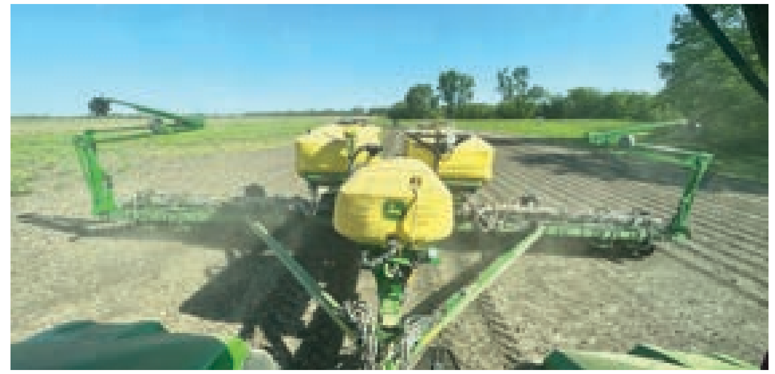
360 Yield Center RAIN Irrigator getting ready to irrigate the corn field.

OBSERVATIONS

This crop was planted in the later planting window and then did not receive adequate rain through the early part of June. The irrigator came later than expected and first watering was in August. This caused issues with preferred application methods for nutrients and water. The corn crop also had delayed nitrogen application due to weather. This caused yield loss for the crop. The irrigated portion of the field was watered five times.

SUMMARY

- There was 8 bushel difference between irrigated and non-irrigated treatments.
- Nitrogen was injected using the 360 RAIN unit and put on crop for first application and use of the rain unit.
- Not having the rain unit in June made a large difference in this study.

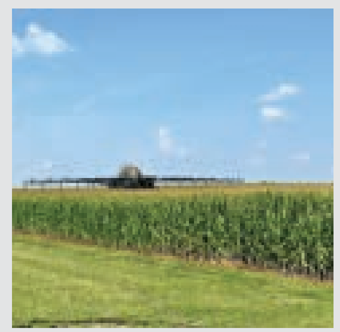


RESULTS

Treatments	Water Applied (in)	Moisture (%)	Yield (bu/ac)
Irrigated	1.47	20.1	226
Non-irrigated	0	18.9	218

TOOLS OF THE TRADE

The 360 RAIN has a 80-foot boom that covers 32 rows and applies water through Y-DROP like hoses. This method of irrigation increases efficiency by reducing the amount of water used and allows for injection of nutrients into the water stream. This machine allows for use in any shape field.



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Project funded by Beck's Hybrids, NRCS, ODA, and 360 Yield Center.

OBJECTIVE

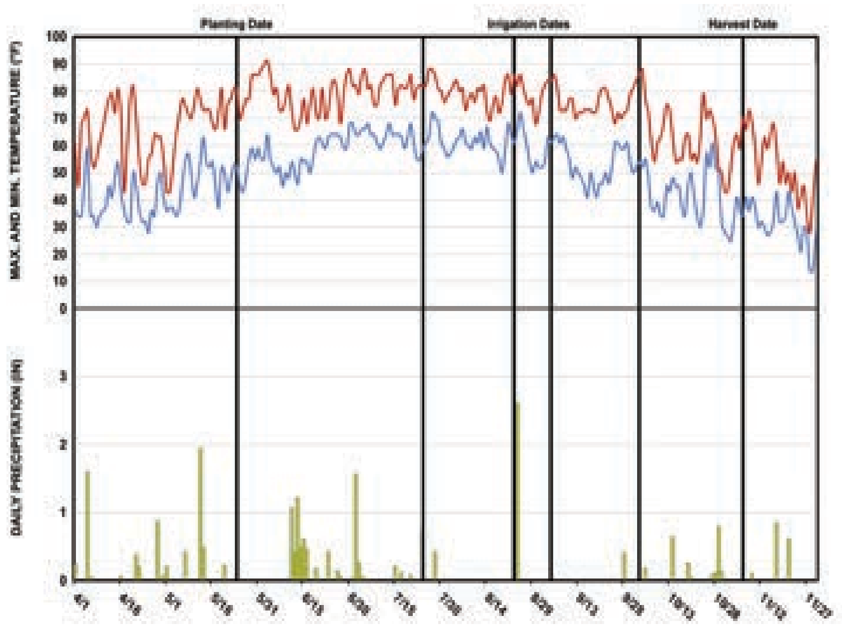
Demonstrate the in-season application of commercial nutrient sources and water application as a unified strategy to reduce nutrient losses while improving profitability with increased grain yields.

Molly Caren Ag Center
OARDC
Madison County

STUDY INFORMATION

Planting Date	5/24/2023
Harvest Date	11/6/2023
Variety	Brevant 13A10AM
Population	34,000 sds/ac
Acres	112
Treatments	6
Reps	8
Treatment Width	80 ft.
Tillage	Strip-Till
Management	Fertilizer, Fungicide, Herbicide, Insecticide
Previous Crop	Soybeans
Row Spacing	30 in.
Soil Type	Crosby-Lewisburg Silt Loams, 65% Kokomo Silty Clay Loam, 35%

WEATHER INFORMATION



Growing Season Weather Summary

	APR	MAY	JUN	JUL	AUG	SEP	Total
Precip (in.)	3.51	3.31	5.08	3.56	2.61	0.45	18.52
Cumulative GDDs	217	607	1118	1825	2425	2887	2887

STUDY DESIGN

Field demonstrations was laid-out in a RCBD strip trial design with treatments that include: in-season nutrient management nitrogen at different rates to determine the mineralization rate differences based on irrigated versus non irrigated treatments. The 360 Yield Center RAIN Irrigator unit was used to apply water in a 7 inch band at the base of the corn plant during the growing season.

This unit disperses water near the base of the plant.

OBSERVATIONS

This crop was planted in the later planting window and then did not receive adequate rain through the early part of June. The irrigator came later than expected and first watering was in July. This caused issues with preferred application methods for nutrients and water. Thus, traditional nitrogen sidedress occurred to keep nitrogen deficiency from occurring, instead of injecting nitrogen through the irrigation unit. The irrigated portion of the field was watered four times.

SUMMARY

- Irrigation had a statistically significant affect on yield over all treatments.
- Nitrogen had statistical significance from 120 versus 170 and 220 units on nitrogen treatments.
- 170 lbs of nitrogen was the optimal amount of nitrogen for all treatments.
- Not having the irrigator installed in early June caused there to be less yield in irrigated treatments.

RESULTS

Treatments	Water Applied (in)	Nitrogen (lb/ac)	Moisture (%)	Yield (bu/ac)
1	1.31	220	23.6	246 a
2	1.31	170	24.0	245 a
3	1.31	120	23.9	220 c
4	0	220	22.3	235 b
5	0	170	22.5	238 b
6	0	120	22.8	210 d
Treatment Means with the same letter are not significantly different according to Fisher's Protected Least Significant Differences (LSD) test at alpha = 0.1.				LSD: 5 CV: 2.6%

PROJECT CONTACT

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