What to Expect

From Soil and Edge-of-Field Water Quality Monitoring of Poultry Litter Utilization in Rice Production with Conservation Agriculture Programming

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Poultry litter contains valuable nutrients that can enhance crop production, but excess phosphorus in runoff can accelerate eutrophication of freshwater bodies such as streams and lakes, which can diminish water quality and may affect their designated uses. Managing nutrients in poultry litter applications to meet crop needs while ensuring that off-site impacts on water quality are minimized is challenging for several reasons.

First, poultry litter cannot be easily manipulated with respect to its nitrogen (N)-phosphorus (P)- potassium (K) ratio to match crop needs, unlike commercial fertilizer, whose N-P-K ratio, represented as N-P2O5-K2O, is manufactured at commonly needed ratios or blended to match the recommended ratio. It's not uncommon to find poultry litter that has an N-P2O5-K2O ratio near 1:1:1, while crops often need much more N and K as opposed to P. This can lead to overapplication of P if the poultry litter application is tailored to meet either N or K needs.

Second, the nutrient content of poultry litter can be highly variable depending on how the litter was managed and handled in the poultry houses. Without utilizing poultry litter testing for nutrient content, the rate (mass/area) of nutrients applied cannot be determined.

Lastly, most nutrients in raw poultry litter occur in organic forms and must be mineralized to be available to plants. Mineralization rates are strictly dependent on highly variable environmental conditions such as temperature, moisture, microbial activity, and other dynamic factors that can result in challenges with predicting the release of nutrients from applied litter. Although this slow-release characteristic of organic amendments can present uncertainty in the timing of nutrient availability, slow-releasing nutrient amendments aim to build a reserve supply of soil fertility that can supplement chemical fertilizers and prevent sudden deficiencies. Poultry litter can contain relatively small amounts of soluble plant available nutrient forms, which may be inconsequential to crop growth, but can be critically impactful on runoff water quality.

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Edge-of-Field Monitoring of Runoff Water Quality

While meeting crop nutrient needs is an essential part of nutrient management, so is minimizing nutrient losses in runoff. Therefore, reducing impacts on water quality in poultry litter fields can be challenging due to the chemical characteristics of organic material. In addition, transport mechanisms to move nutrients to the edge of and out of a field via runoff are highly variable and dependent on hydrological and soil characteristics that can impair efforts to quantify and account for nutrient losses.

Edge-of-field monitoring of runoff using automated samplers triggered by storm events in conjunction with flow volume measuring devices such as calibrated flumes can be utilized to monitor nutrient losses. The USDA NRCS provides financial assistance to producers in selected watersheds to conduct conservation and evaluation monitoring activities (CEMA), including CEMA 201: Edge-of-Field Water Quality Monitoring.

Edge-of-field monitoring of runoff can provide a variety of information regarding a particular agricultural field, including the following:

- Quantify nutrient loss from the agricultural field being monitored
- Evaluate and improve performance of conservation practices intended to reduce nutrient loss
- Provide producers with data-driven information to see the effect of their management on nutrient loss/retention
- Quantify runoff and define periods of greatest runoff potential
- Collect baseline data of the impact of agriculture on natural resources that can be used to develop, verify, and calibrate field-scale models that predict nutrient loss for a given management system for the purposes of nutrient management planning
- Help producers improve profitability by increasing nutrient use efficiency

While edge-of-field monitoring of runoff can help improve in-field nutrient management, costs, maintenance, equipment malfunctions, and most importantly, relating and connecting results from a single or a few fields to off-site impacts at the watershed scale present limitations. The fate of nutrients from the edge of the field to the watershed outlet is not well established due to landscape and hydrological variability. Nonetheless, edge-of-field monitoring of nutrient loss is an important strategy in understanding how agricultural practices may affect water quality.

Case Example: Monitoring Nutrients in Soil and Runoff Water for Row Crop Fields Fertilized with Poultry Litter

New poultry integrators have established vertically integrated operations with contracted, independent poultry producers in Northeast Arkansas. The closer proximity of the poultry operations to row crop producers, who farm corn, cotton, peanuts, rice, and soybeans, reduces the transportation costs of poultry litter making it an economical complement or alternative to commercial fertilizer.

As poultry litter utilization in row crops has dramatically increased during the last decade in Northeast Arkansas, it has created water quality concerns, especially given the widely publicized litigation of using poultry litter on permanent pasture in Northwest Arkansas. While poultry litter as a fertilizer source for crops such as corn, cotton, rice, and soybeans has been evaluated agronomically, little information is available on how it might impact off-site water quality. A demonstration and education program was implemented by the University of Arkansas Division of Agriculture's Discovery Farms Program in 2022.

Monitoring Design

Poultry litter was applied to three rice fields on a private Discovery Farm near Newport in Northeast Arkansas during late April 2022 and 2023 and again in October of 2023 for the 2024 rice crop. Application rates included 2, 3, and 4 tons/acre applied annually to fields: Field 3 (32 acres), Field 2 (17 acres), and Field 1 (15 acres), respectively. Field 3 was furrow irrigated (FIR), keeping the soil muddy but not saturated while fields 1 and 2 were flood irrigated.

Soil samples were collected from 1-acre grids, 6 inches deep, each spring before planting using a Falcon automated soil sampler, and samples were analyzed by the University of Arkansas Division of Agriculture's Soil Testing and Research Lab using Mehlich-3 extractant.

Water samples were collected with ISCO automated samplers at field outlets while runoff volumes were determined utilizing ISCO's 750 area velocity meters in drainage pipes using open channel flow principles. One 10-liter composite sample (maximum) was collected from one hundred 100 ml subsamples using flow pacing to distribute sample collection as uniformly as possible under both the rising and falling limb of the resulting hydrograph. This method provides a physical representation of a flow-weighted average. Water samples were collected and analyzed in accordance with EPA standards for nitrate-nitrite (NO3-N), total nitrogen (TN), soluble reactive phosphorus (SRP), total phosphorus (TP), and K by the University of Arkansas's Water Resources Center Water Quality Lab.

What the Water Quality Data Showed – Nitrogen (N)

The concentrations of all nitrate and TN measurements in runoff across the entire sampling period for each field were lognormally distributed characterized by a large frequency of small concentrations with a few occurrences of much higher concentrations outside the 95 percent confidence intervals (Figure 1). The median nitrate concentrations for Fields 1, 2, and 3 were 0.21, 0.03, and 0.18 ppm, respectively. The median TN concentrations for Fields 1, 2, and 3 were 1.34, 2.97, and 1.69 ppm, respectively. The greatest frequency for nitrate concentration was 1 ppm or less for all three rates while the greatest frequency for TN was 5 ppm or less.

The nitrate load was less than 1 lb/acre in all fields, with two exceptions of nitrate greater than 3 ppm in Field 3, which was FIR and was immediately following irrigation events (Figure 2). Data indicates greater potential of nitrate loss in runoff from FIR as compared to flood-irrigated rice despite minimal losses overall. This is likely because FIR did not saturate fully during irrigation events, allowing more N to remain in the soil as nitrate (less denitrification) and move with runoff, whereas nitrate quickly dissipated to very low concentrations in floodwater in the other two fields. Poultry litter rate seemingly did not affect nitrate loading values as they did not differ although concentrations were significantly different. This may imply that differences in soil hydrology and runoff volumes need to be considered and not just the source.

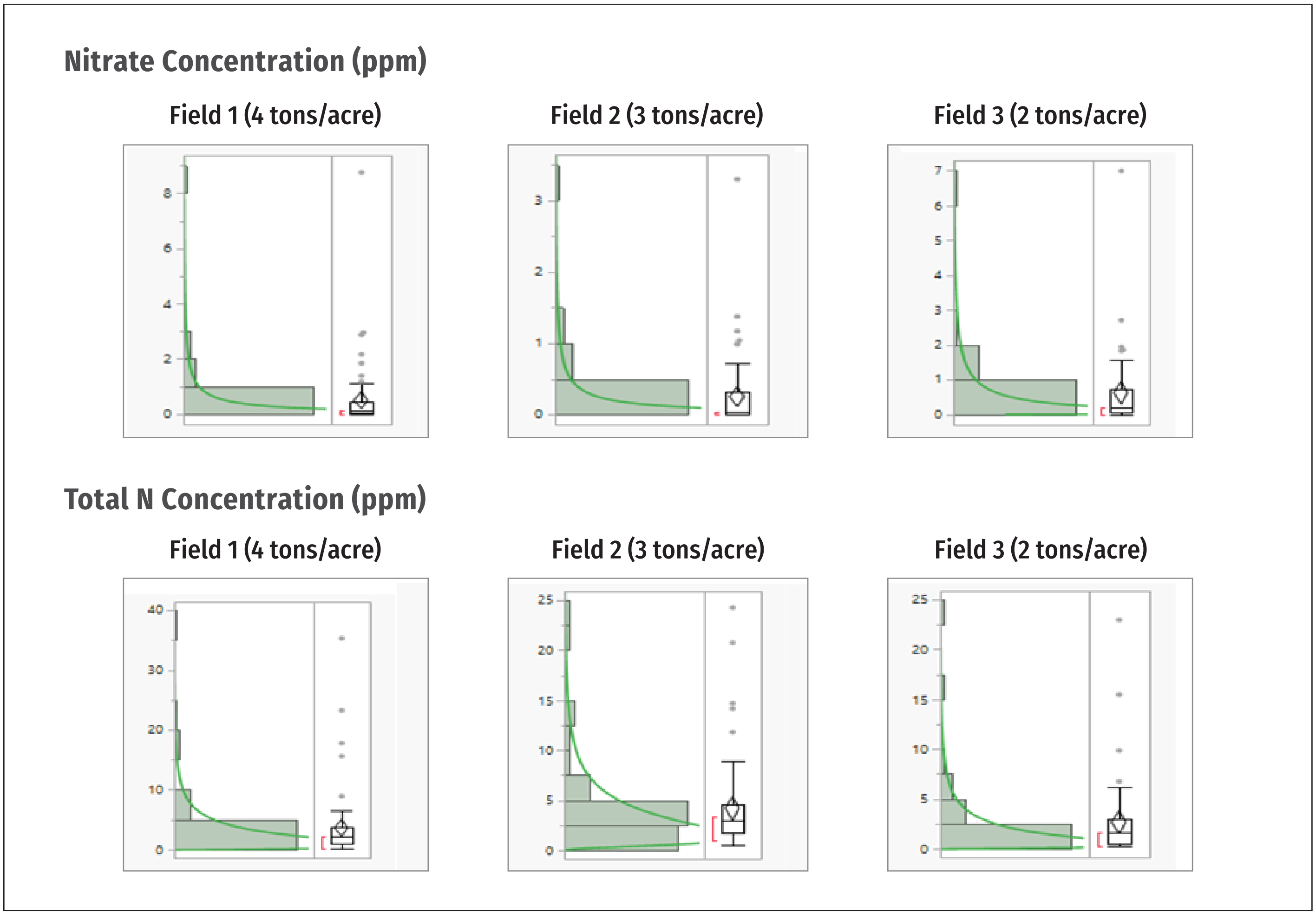

Figure 1. Sample distribution of nitrate (top row) and TN (bottom row) concentrations across sampling times for each poultry litter application rate.

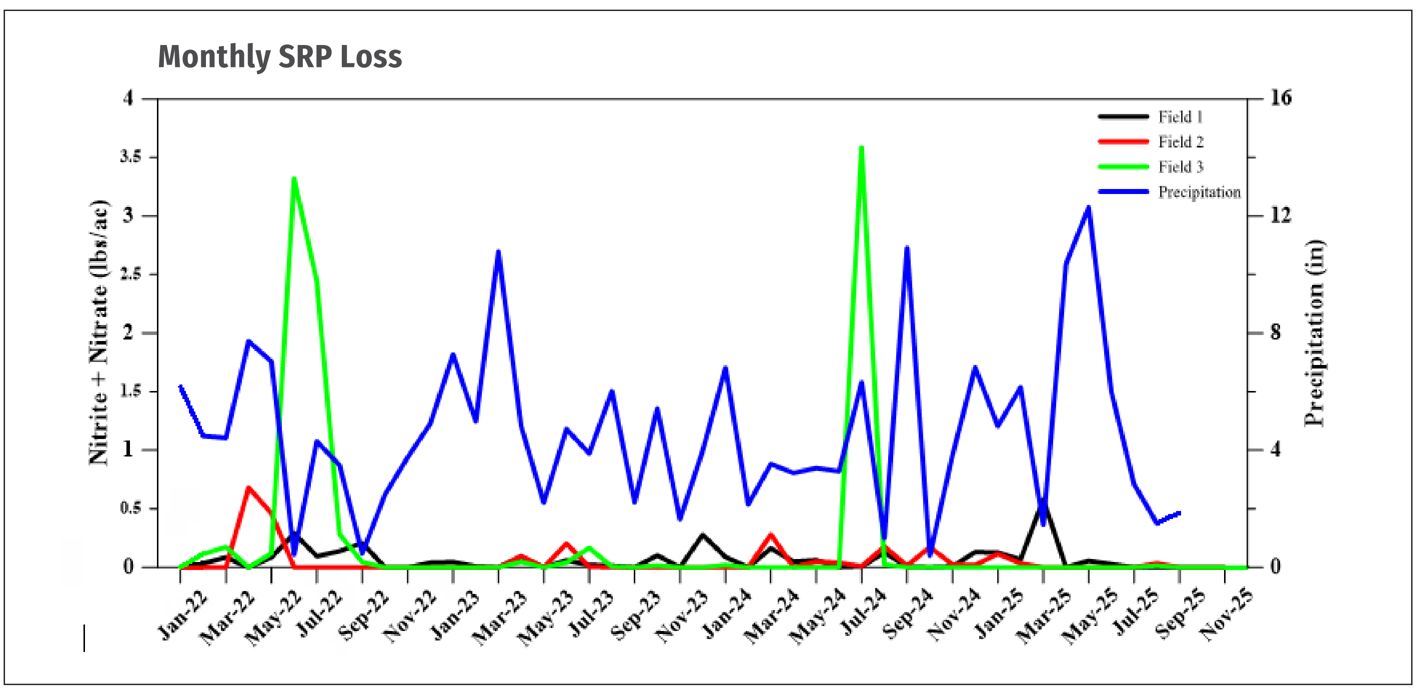

Figure 2. Nitrate load from each field for the sampling period as it compares to rainfall.

What the Water Quality Data Showed – Phosphorus (P)

The greatest frequency of SRP concentrations was 2.5 ppm or less for Field 1 (4 tons/acre) and was 1 ppm or less for Field 2 (3 tons/acre) and Field 3 (4 tons/acre), while the greatest frequency TP was 5 ppm or less for Field 1 and was 2 ppm or less for Field 2 and Field 3 (Figure 3). Median SRP were 0.05, 0.06, and 0.03 ppm for Fields 1, 2, and 3, respectively, while median TP concentrations were 0.25, 0.74, and 1.6 ppm for Fields 1, 2, and 3, respectively.

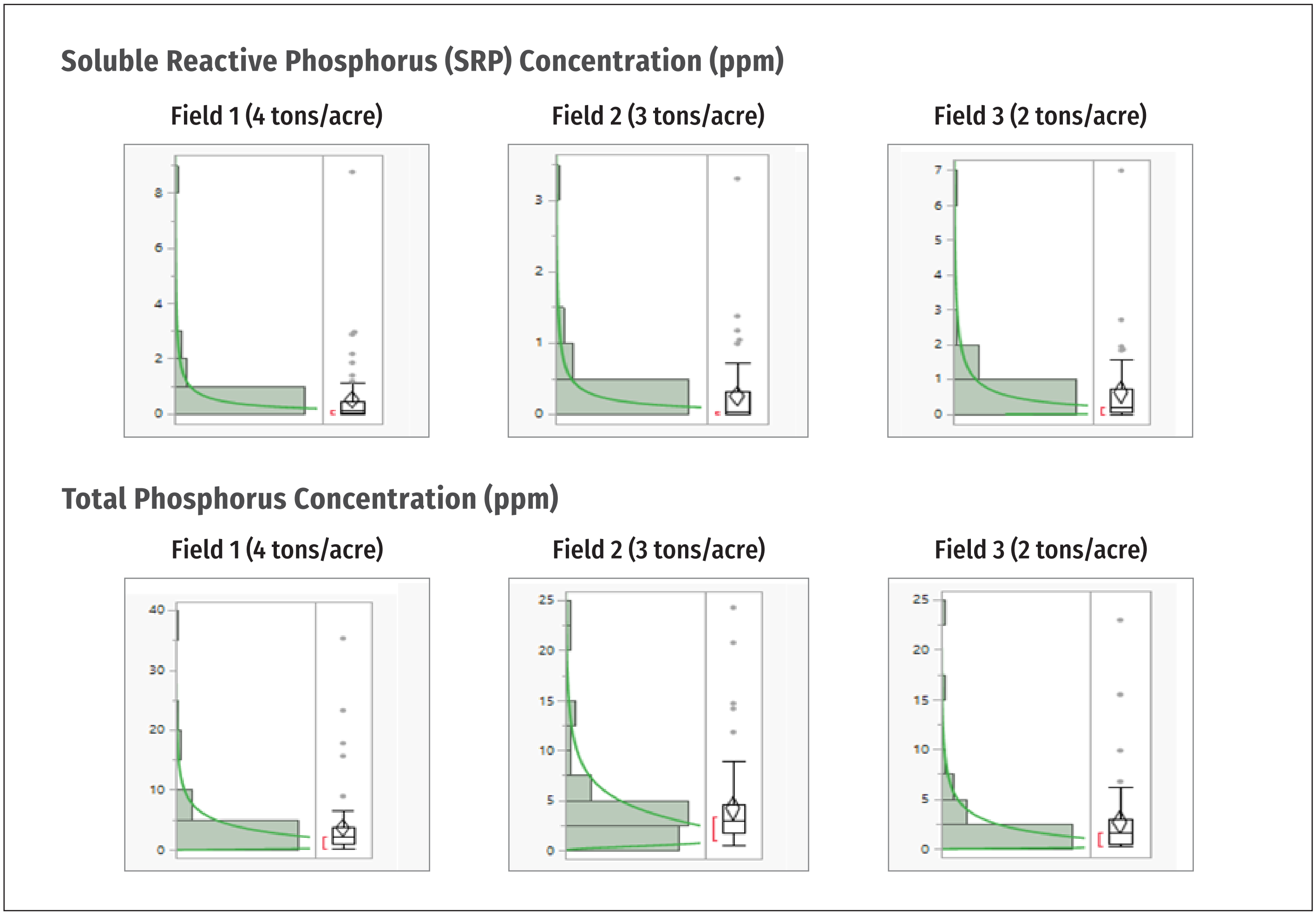

Figure 3. Sample distribution of SRP and TP concentrations (bottom row) across sampling times for each poultry litter application rate.

Losses of SRP were very small (<2 lbs/acre) for most months during 2022 through 2024, especially during the growing season (Figure 4). The larger SRP losses (although still relatively small) occurred in the flooded fields (Fields 1 and 2) during September through November. The September losses may have correlated with draining the floodwater from the rice to prepare for harvest, while the October losses may have been due to precipitation events after the fall application of litter as 60 percent of the TP loss was as SRP. The largest SRP concentrations in runoff were in the fall of 2024 after two precipitation events of greater than 1 inch rainfall 3 days apart.

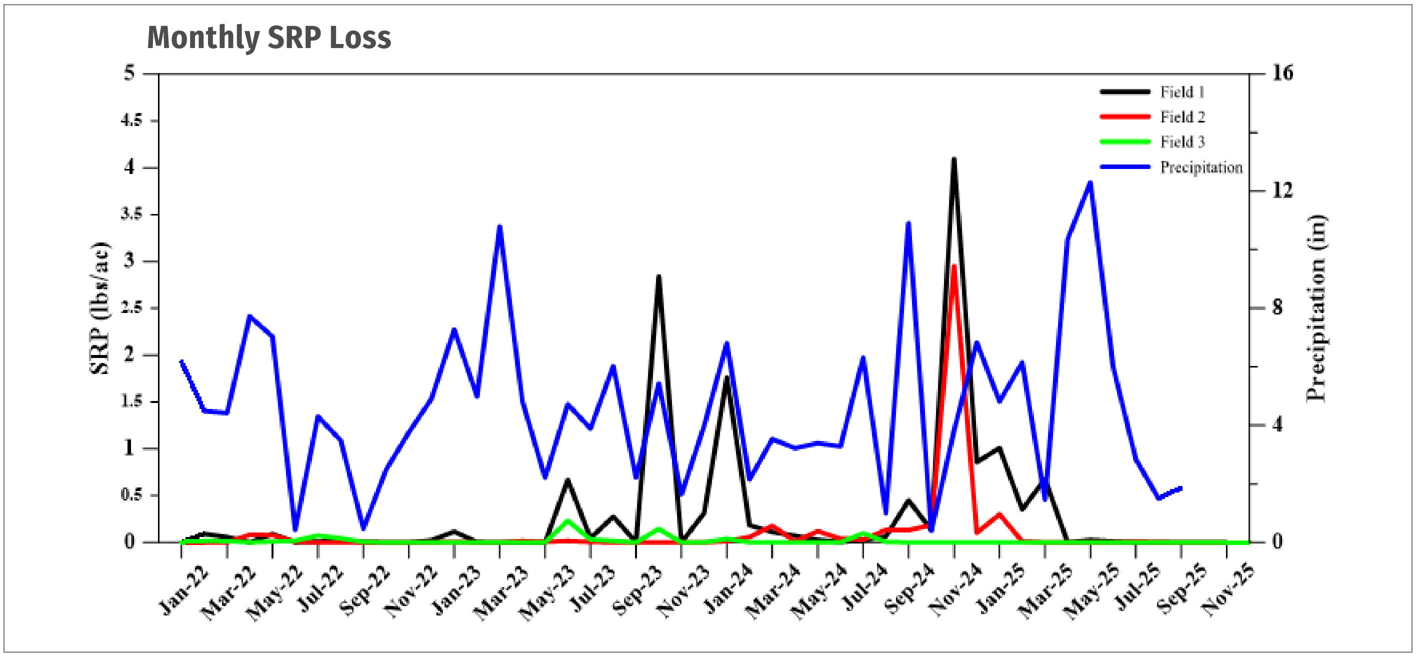

Figure 4. SRP load by runoff event from each field for the sampling period as it compares to rainfall.

What the Water Quality Data Showed – Potassium (K)

The greatest frequency of K concentrations was an order of 10 greater than for either N or P (Figure 5). While K is not a water quality concern, the magnitude of their losses could be of economic concern as K fertilizer is routinely added. Median K losses were 2.4, 9.0, and 1.3 ppm for Fields 1, 2, and 3, respectively.

K losses were generally less than 10 lbs/acre from Fields 2 and 3 during the growing season with the exception of May 2024 in Field 2 (flooded); however, K losses exceeded 10 lbs/acre from Field 1, the highest litter rate of 4 tons/acre (Figure 6). Apparently, the K application rate exceeded the rice crop needs and K was prone to loss to runoff. K losses were generally an order of magnitude larger than the N and P losses for the corresponding runoff events. Largest K losses occurred after the rice crop maturity and harvest in August through January with the largest losses (> 15 lbs/acre) from both flood-irrigated fields, Field 2 and Field 3, in September, October, and November, which could have been influenced by field drainage prior to harvest and subsequent runoff events. Rice residue on the surface as K is soluble in crop residue as it is not incorporated into the cell structure of the plant. K is not a water quality concern, but K losses may be of economic significance to the producer.

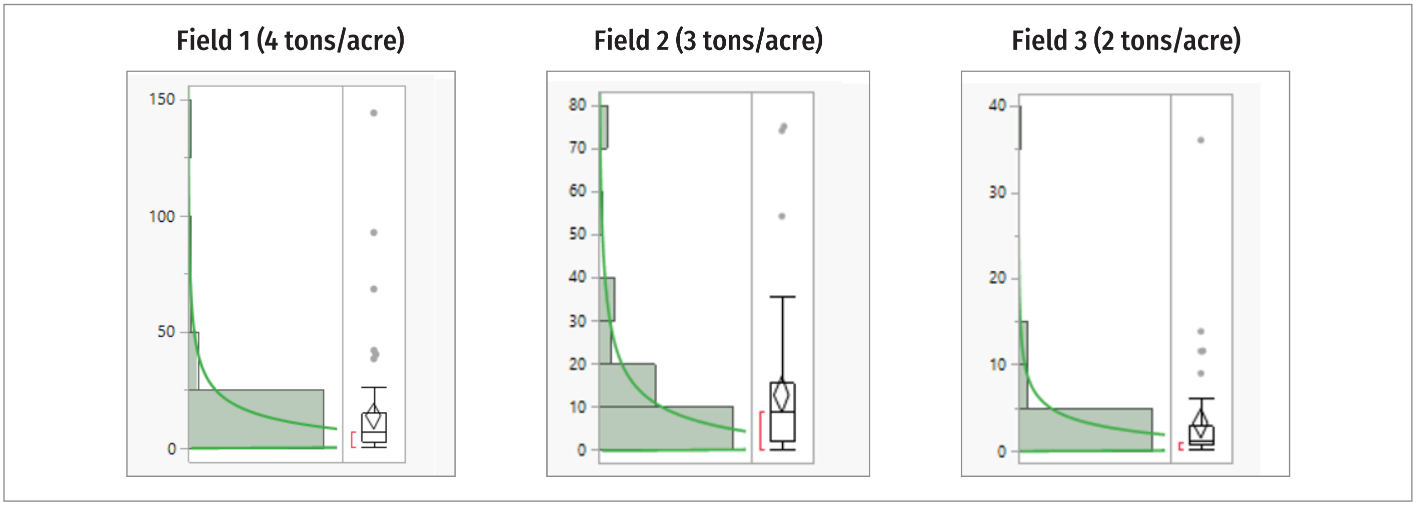

Figure 5. Sample distribution of potassium concentrations (bottom row) across sampling times for each poultry litter application rate.

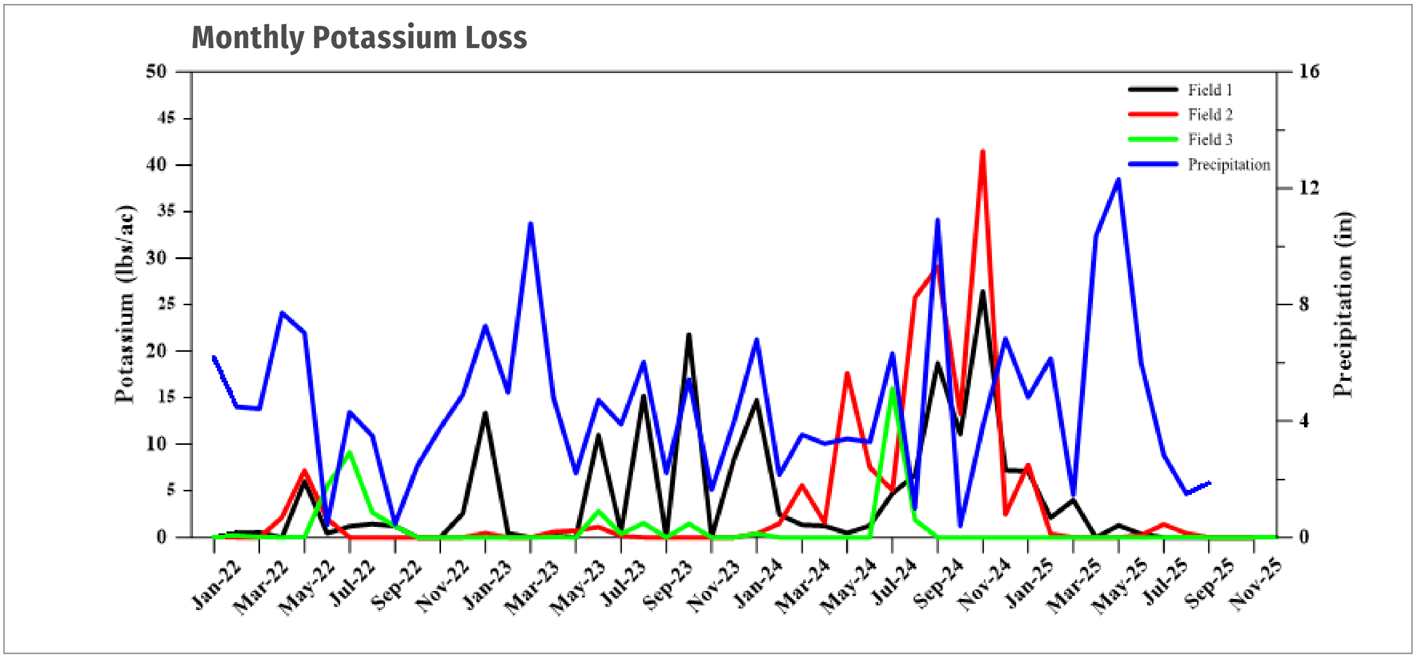

Figure 6. Potassium load by runoff event from each field for the sampling period as it compares to rainfall.

What the Soil Testing Showed

Soil test P (STP) and soil test K (STK), soil pH, and organic matter (OM) all increased slightly from 2022 to post-harvest fall of 2024 (Table 1).

Table 1-A, B, and C. Soil test summary for pH, phosphorus, potassium, and organic matter for years 2022 (prior to poultry litter applications) to post-harvest 2024 (poultry litter applications in fall 2022 and fall 2023) for each field.

Table 1-A: Field 1 (4 tons/acre)

Year	pH	Phosphorus (ppm)	Potassium (ppm)	% Organic Matter
2022	5.4	16	107	1.8%
2023	5.9	18	141	1.9%
2024	6.1	41	276	2.2%
2025	6.1	31	196	2.5%
Net Change from 2022 – 2025	**0.7**	**15**	**89**	**0.7**

Table 1-B: Field 2 (3 tons/acre)

Year	pH	Phosphorus (ppm)	Potassium (ppm)	% Organic Matter
2022	5.9	25	116	2.2%
2023	6.3	26	155	2.3%
2024	6.1	36	225	2.4%
2025	6.3	27	191	2.6%
Net Change from 2022 – 2025	**0.4**	**2**	**75**	**0.4%**

Table 1-C: Field 3 (1 ton/acre)

Year	pH	Phosphorus (ppm)	Potassium (ppm)	% Organic Matter
2022	5.9	23	115	2.4%
2023	6.4	24	161	2.3%
2024	6.3	39	211	2.6%
2025	6.3	27	183	2.8%
Net Change from 2022 – 2025	**0.4**	**4**	**68**	**0.4%**

STP increased slightly in all three fields. One concern with the use of poultry litter is the buildup of STP to levels that exceed soil adsorption capacity where P losses can increase in runoff water leading to advanced rates of eutrophication in freshwater bodies. However, the rate of increasing of STP at this point is of little concern, but further long-term monitoring of STP every 3 years might be warranted. Soil test results for the 2025 growing season indicated that no additional P fertilizer is needed. Soil testing indicated that STK levels would have called for all three fields to receive 60 units of K2O fertilizer, but after poultry litter applications, STK increased on average by 77 ppm (for which no K fertilizer would be recommended). Soil pH increased on average by 0.5 to an average of 6.2. When soil pH increases to 6.5 or greater, both P and zinc (Zn) in the soil become less available. Poultry litter can provide a liming effect, and continued application may increase pH above 6.5 and additional P fertilizer and Zn seed treatments may be needed.

Soil OM increased on average by 0.5 percent to an average of 2.6 percent, which can be very important to soil health by increasing infiltration, soil aggregate stability, and providing food for increased soil microbiology activity.


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Key Takeaways for Using Poultry Litter on Row Crops

- Many row crop producers are not legally required to obtain nutrient management plans for applying poultry litter to crops. Thus, education and technical assistance is needed to avoid natural resource and production concerns alike.
- Edge-of-field monitoring revealed that nutrient concentration in runoff water was most frequently low with only a few but notable higher concentrations above the upper 95 percent confidence interval.
- The average mass load (concentration x runoff volume) across all runoff events for TN (< 4 lbs/acre) and TP losses (< 2 tons/acre) are low relative to the nutrients applied via both poultry litter and commercial fertilizer.
- Although different litter application rates were applied, there were no clear trends among rates over the observation period implying that losses were not proportional to application rate. However, this trend could change in time with repeated poultry litter applications and anticipated increase in STP values where P fertilizers would no longer be warranted.
- There were clear increases in nitrate loss for FIR rice as compared to two flood irrigated fields.
- Although not of environmental concern, K losses were an order of magnitude larger than either N or P and may represent economically significant losses.
- Repeated annual applications of poultry litter did increase N, P, and K levels in soils; however, from a water quality standpoint, the rate of increase of STP over the observation period is not alarming. However, repeated soil testing at least every 3 years is strongly recommended to avoid increasing STP to levels that degrade water quality.
- From a production standpoint, poultry litter did increase soil pH to near 6.5. At pH greater than 6.5, seedling rice can be susceptible to both P and Zn deficiency. More research is needed to determine if poultry litter applications need to be reduced or stopped periodically to keep pH from increasing.
- Poultry litter did have a positive effect on soil health as OM generally increased 0.5 percent after repeated litter applications as well as improved water aggregate stability indicating the building of soil structure.

Beyond the data itself, edge-of-field monitoring has management value to producers who want to understand how they can make their nutrient management practices more efficient and economical. In this manner, producers can be more confident that management decisions do make a difference.

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