2025
Corn Science Research Report

University of Kentucky

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Evaluation of Fall Residual Herbicides and Cover Crops on Annual Ryegrass Control in No-Till Corn

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INTRODUCTION (objective)

Italian ryegrass (Lolium multiflorum) has become the most problematic weed in no-till corn in the state of Kentucky. Spring burndowns of ryegrass prior to no-till corn planting are increasingly resulting in failures and escapes. These failures or escape often result in follow-up applications that further fail to control the escapes, allowing for ryegrass to compete with corn as it emerges. In worst case scenarios, these escapes result in corn replant situations as herbicide options for controlling ryegrass become extremely limited once corn emerges. The University of Kentucky has conducted research over the past three years assessing the use of residual herbicides applied in the fall to control emerging ryegrass plants. The initial research has shown that residual herbicides applied in the fall can be a beneficial tool in reducing the number of ryegrass plants that need to be controlled in the spring. Although, it was also noted in this research that these fall applications left the soil baren and susceptible to erosion over the winter months. The following research was conducted to further investigate fall applied herbicides with and without the inclusion of cover crops.

METHODS & MATERIALS

Two research experiments were established in the fall of 2024 at the University of Kentucky Research and Education Center (UKREC) in Princeton, KY and on a producer's field in Simpson County, KY. Both fields had known populations of ryegrass. Residual herbicides containing pyroxasulfone (Zidua and Anthem Maxx), S-metolachlor (Dual II Magnum, Boundary), metolachlor (Helmet MTZ), and clomazone (Command) were applied in the fall of 2024 following double crop soybean harvest on Nov 1 and Nov 15 at the UKREC and Simpson County, respectively. Command was excluded from the Simpson County site as corn was planned to be planted in the field following the trial termination. Each residual herbicide was applied with either glyphosate (1.5 lb ae/A) or paraquat (0.75 lb ai/A), additionally Boundary and Helmet MTZ were also applied solo to evaluate the burndown potential of the metribuzin components of these two products.

A third research trial was initiated at the UKREC in the fall of 2024 evaluating fall residual herbicide applications for ryegrass control and establishment of wheat and cereal rye cover crops. The study included Zidua, Anthem Maxx, Dual II Magnum, and Boundary applied with glyphosate at the time of cover crop planting. Additional treatments were applied after cover crop emergence and included: Axiom, Boundary, and a tank mix of Zidua and metribuzin. Applications of the "at cover crop planting" treatments were applied on November 1, 2024, and cover crops were planted on Oct 30, 2024. The post-emergence treatments were applied to 2 leaf cover crops on November 18, 2024. A non-cover crop treatment with each herbicide treatment was also included.

Visual evaluations of percentage ryegrass control in comparison to an untreated check were taken for all trials in March 2025. Additionally, a visual estimate of cover crop injury was taken in the cover crop trial on March 17, 2025.

All data was subjected to analysis of variance using PROC GLIMMIX in SAS 9.4. Means separation was conducted using Tukey HSD with an alpha of 0.05.

RESULTS & DISCUSSION

Fall Burndown Residual Trials

Italian ryegrass visual control ranged from 26 to 84% at the UKREC site when evaluated on March 17, 2025 (Figure 1). Treatments that contained a residual herbicide resulted in 55 to 83% control as compared to the two burndown only treatments resulting in 26 and 30% control. Dual II Magnum applied with either Roundup PowerMAX3 or Gramoxone as well as Boundary applied with Roundup PowerMax3 resulted in the greatest control and were significantly greater than the Roundup PowerMax3 and Gramoxone alone treatments.

Visual control evaluations at the Simpson county site on March 7, 2025, ranged from 41 to 100% control (Figure 2). In contrast the UKREC site, The Roundup PowerMax3 and Gramoxone alone treatments resulted in control that was equal to the treatments that included a residual herbicide. Applications of Boundary and Helmet MTZ alone (without glyphosate or paraquat) resulted in the lowest control of all treatments.

At both locations, the inclusion of residual herbicide with the fall burndown or either glyphosate or paraquat resulted in greater than 55 percent control the following spring. While we typically think of 55% control as a failure in weed control, in this case we would consider this an advantage or better than 0% control if we had done nothing in the fall. In all cases the number of ryegrass plants that a farmer would have to deal with in the spring is significantly reduced indicating the value of a fall residual herbicide. Where differences occurred between the two sites is when only a burndown of glyphosate or paraquat was applied without a residual herbicide. At the UKREC site the fall burndown without residual treatments resulted in minimal control the following spring, whereas at Simpson County these treatments resulted in excellent control. The difference between the two sites can be attributed to the emergence patterns of the ryegrass populations at each site. At the UKREC site the population has a mixture of fall and spring emerging plants, whereas at the Simpson County site the population emerges primarily during the fall. Thus, when considering if a residual is needed or if fall burndown without residual is adequate a farmer must first assess the emergence patterns of their ryegrass populations. If in doubt a residual herbicide would be recommended.

Another highlight of this research would be the inclusion of Command as a residual herbicide at the UKREC location. At this location this product resulted in 59 to 60% control in the spring following the fall application. Command is unique as compared to all the other residuals as it is a different site of action that the rest. Clomazone is the active in Command and is a Group 13 herbicide whereas all the other herbicide evaluated are Group 15's. This is important as we rely heavily on Group 15 herbicides for control of ryegrass in our wheat acres as well, so the ability to use a different site of action is an advantage for the long term control of this weed species. Unfortunately, Command can only be applied in the fall prior to soybean, whereas the other herbicides evaluated can be applied prior to corn or soybean. If a farmer is looking to control ryegrass prior to their soybean crop, using Command offers a unique opportunity to break the cycle of relying on Group 15 residual herbicides.

Fall Residuals and Cover Crops Trial

Treatments receiving a residual herbicide in the fall resulted in 43 to 100% control of Italian ryegrass the following spring (Figure 3). All treatments receiving a residual herbicide, except for the Dual II Magnum with a wheat cover crop treatment, resulted in significantly greater control of Italina ryegrass as compared to the no residual herbicide treatment. The inclusion or exclusion of a cover crop with the residual herbicides did not influence control of Italian ryegrass, additionally the timing of the residual herbicide application did not influence overall ryegrass control.

This research further demonstrates the value of residual herbicide applied in the fall for controlling a population of Italian ryegrass with a mixed fall and spring emergence. The residual herbicide did not influence or harm cover crop establishment, regardless of the timing of the residual herbicide application (data not shown). This research further demonstrates that the inclusion of a wheat or rye cover crop does not impact overall Italian ryegrass control but would be beneficial in reducing soil erosion potential as compared to if a soil residual was applied and the soil left baren over the winter.

CONCLUSION

The use of soil residual herbicides in the fall prior to no-till corn or soybean planting can be beneficial in reducing ryegrass populations and reducing potential escapes when spring burndown applications are applied. Fields that have Italian ryegrass populations with a mixture of fall and spring emergence would benefit the most from the use of a residual herbicide applied int the fall. Whereas in fields with a predominantly fall emerging Italian ryegrass population can benefit simply by applying either glyphosate or paraquat in the late fall when ryegrass plants are still young and can be easily controlled. If a farmer is unsure about the emergence patterns of their population, it is advised to include a residual herbicide in the fall application to maximize success of ryegrass control the following spring.

The biggest drawback of the use of residual herbicides applied in the fall, is the field is left barren and prone to soil erosion over the winter months. This research demonstrates that a wheat or cereal rye cover crop can successfully be established in fields with a residual herbicide applied. These covers do not necessarily produce great amounts of biomass or contribute to ryegrass control itself, but rather simply provide cover for the field to reduce erosion potential. Additionally, the lack of biomass accumulation of a cereal rye cover (especially when terminated in March) is a desirable benefit on no-till corn acres in reducing the nutrient tie up that is typically associated with this cover crop species.

ACKNOWLEDGEMENTS

Thank you to the Kentucky Corn Growers Association for their continued support of this research.

FIGURES

Figure 1. Italian ryegrass control in the spring following a fall residual herbicide application on a no-till field at the UKREC. This population represents a primarily spring emerging population.

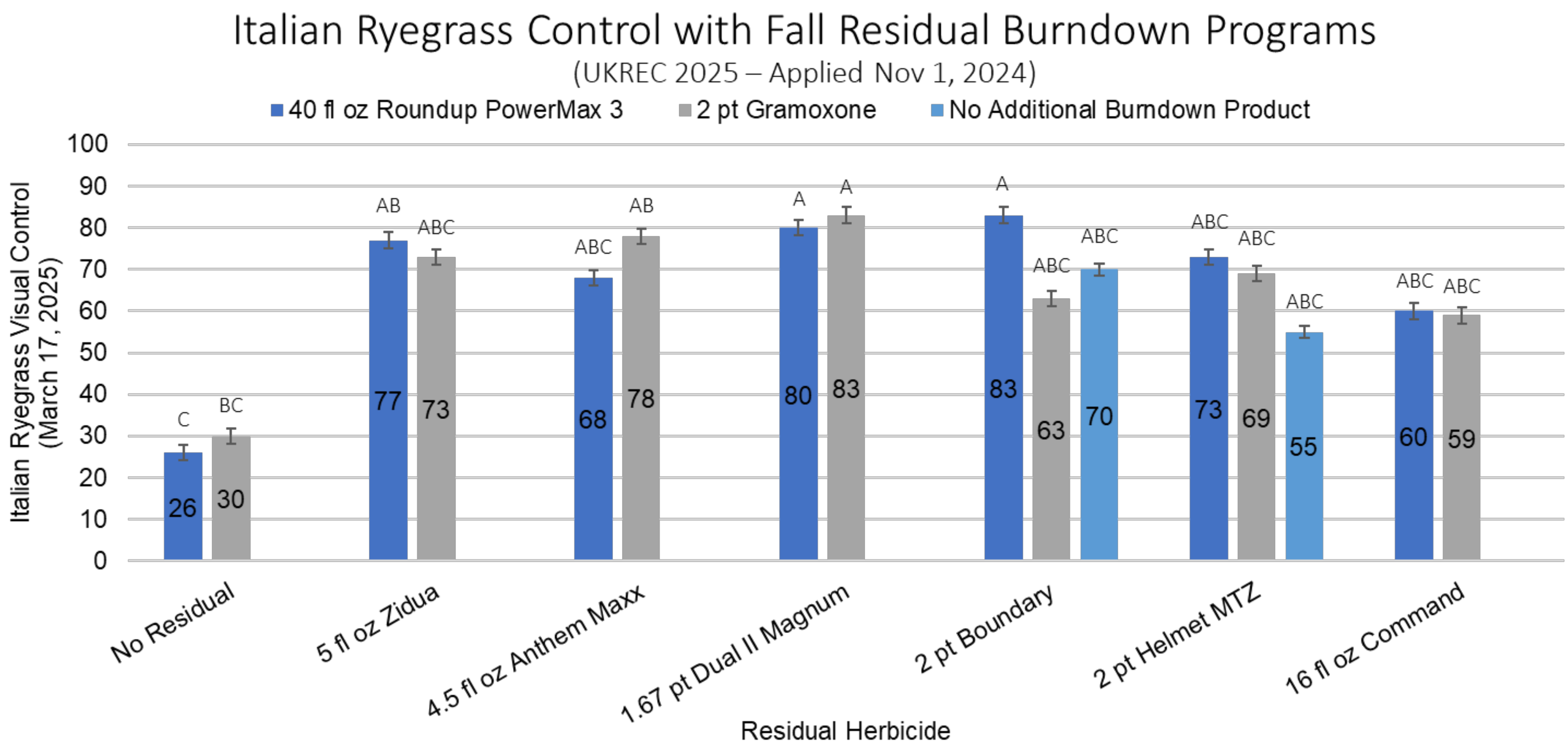


Figure 2. Italian ryegrass control in the spring following fall herbicide applications on a no-till corn field in Simpson County. This population represents a primarily fall emerging population.

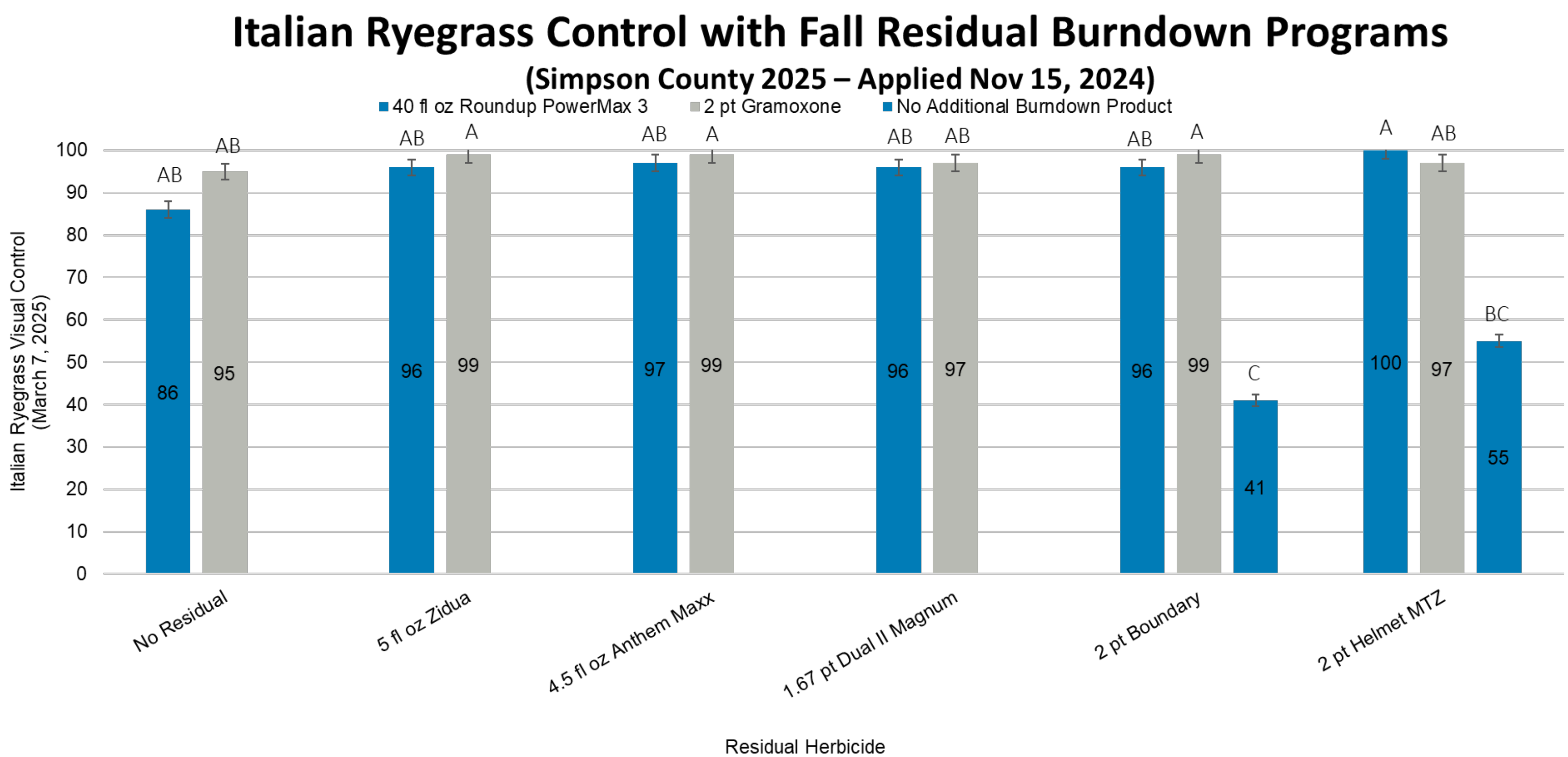
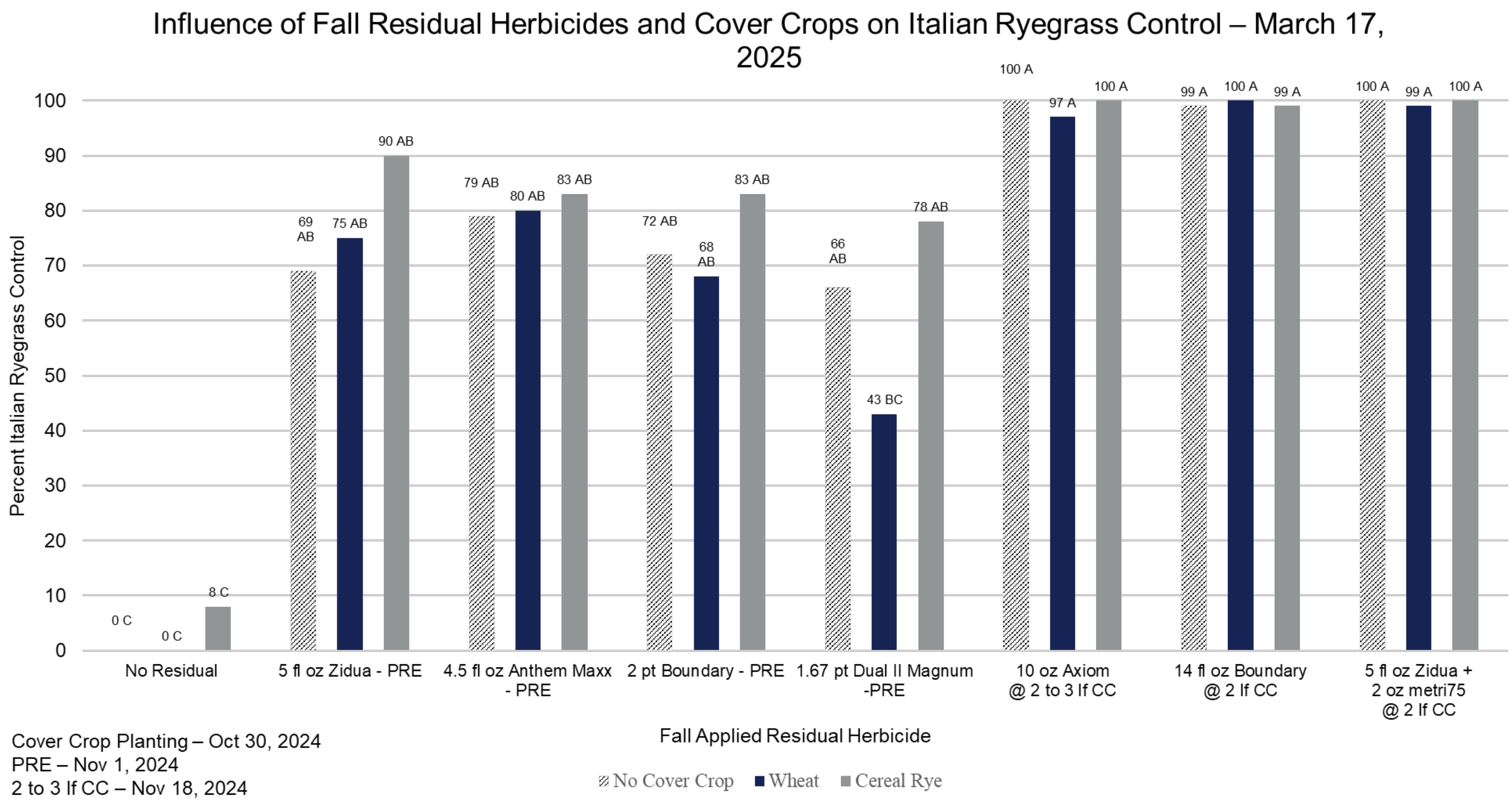


Figure 3. Italian ryegrass control in the spring as influenced by fall residual herbicides and cover crops.



Ground-Truthing Drone Fungicide Efficacy—Year 2

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INTRODUCTION (objective)

Unmanned aerial vehicle (UAV or drone) fungicide applications have become more common in Kentucky, allowing farmers that may not have access to high-clearance or aerial applicators to apply fungicides to corn. On-farm research initiated by the University of Kentucky in several counties has indicated that foliar fungicides applied by a drone at VT/R1 can effectively manage gray leaf spot in corn when using recommended spray carrier volumes. However, drone fungicide applications are anecdotally described by some as the "third-best option" behind fixed-wing or helicopter aerial application methods and high-clearance ground application, despite limited evidence of those claims. There are also questions about optimizing the swath width (spray width) of drones to prevent gaps in coverage on the edges of applications. Maximum swath widths are provided for each type of drone, but there is limited replicated research data on the reliability of these recommendations. Preliminary research from our program comparing drone vs. ground fungicide applications did indicate that both application methods provided similar levels of disease control and yield response, although disease pressure was low in these trials. Understanding how drone fungicide application parameters affect disease development will aid farmers in setting up their own drones and improve commercial applicator efficacy by providing optimized settings for application. The specific objectives of this research were to 1) compare fungicide spray coverage, deposition and efficacy of high-clearance ground applications to drone fungicide applications, 2) examine fungicide spray coverage and deposition at different carrier volumes for drone applications, and 3) determine the impact of spray parameters on drone sprayer swath coverage for fungicide applications.

METHODS & MATERIALS

Research trials were established at the University of Kentucky Research and Education Center in Princeton, KY in 2025. In each trial, the spray solution consisted of the fungicide prothioconazole + trifloxystrobin + fluopyram (Delaro Complete; 8 fl oz/A), non-ionic surfactant (0.25% v/v), 1,3,8-pyrenetetrasulfonic acid (PTSA; 600 ppm), and acid blue 009 (1% v/v) applied to corn at tasseling/silking (VT/R1) using a DJI T-10 drone or a ground sprayer. Experimental plots were eight rows (20 ft) by 70 ft in length and treatments in each trial were replicated four times in a randomized complete block design. To compare the effect of spray application method on fungicide efficacy, the fungicide spray solution was applied to experimental plots via drone or ground application methods using carrier volumes of 2.5 and 15 gallons per acre (gpa), respectively. To compare the effect of spray carrier volume on fungicide efficacy, spray solution was applied to experimental plots via drone using carrier volumes of 1, 2, and 5 gpa. A non-fungicide treated control was included in both experiments. In both experiments, fungicide coverage was determined by measuring the percentage of acid blue dye coverage on ten phytochrome spray cards per plot using image scanning and processing software. Fungicide spray solution deposited in the canopy was collected by rinsing selected leaves with isopropyl alcohol immediately after application and measuring isopropyl/PTSA mixture for fluorescence using a fluorometer. Three measurements were obtained per leaf and compared to a calibration curve. Leaf area of collected leaves was measured and fungicide deposition was verified by calculating the μl/cm2 of spray solution deposited from five leaves per plot.

To determine the impact of spray parameters on swath coverage, a spray solution of water + acid blue 009 at 1% v/v was applied at four different spray parameters and a carrier volume of 2.5 gpa (Table 1). To measure spray deposition and coverage across the swath in the corn canopy, spray cards and leaf samples were collected from the ear leaf or ear + 1 leaf across a 15-ft swath in the center of each experimental plot. Each card and leaf were labeled by position in the plot and along the width of the swath to determine if spray deposition or coverage were greater at any point along the length of the spray swath (Figure 1).

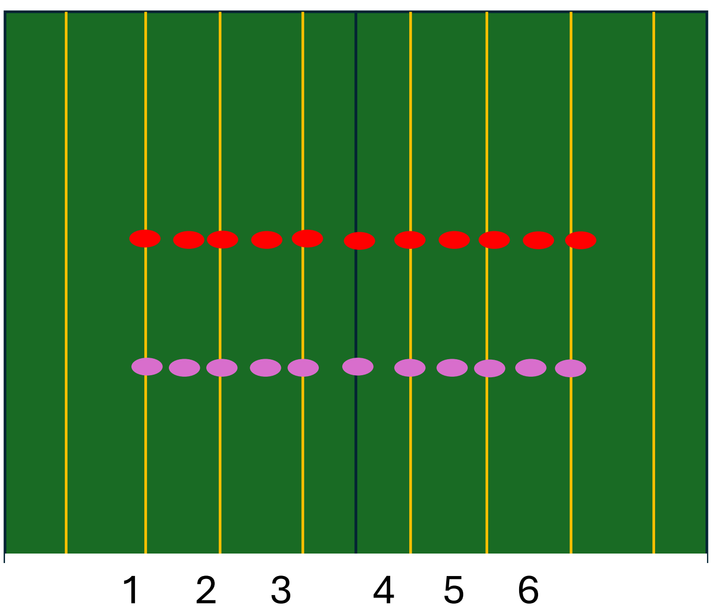


Figure 1. Example experimental sample plan for a research plot in a trial examining the effect of spray parameters on spray coverage and deposition and foliar disease at the University of Kentucky Research and Education Center in Princeton, KY, in 2025. Numbers indicate sampled rows of the experimental plot. Pink dots represent plants where ear leaves were sampled for spray deposition analysis, and red dots represent plants that had phytochrome spray cards placed on the ear and ear + 1 leaves.

Spray coverage and deposition for samples were measured as described above. For both trials, percent foliar disease severity on the ear leaf was rated for 10 plants per plot at dough (R4) foliar diseases at dough. Data were analyzed using mixed model analysis of variance in SAS (v. 9.4, Cary, NC) and treatment means separated using least square means.

RESULTS & DISCUSSION

Results in 2025 were similar to findings in 2024 for all experiments, indicating consistency in research findings. Spray deposition was greater with high-clearance ground spray applications compared to drone applications (Figure 2), and spray deposition was higher in treatments sprayed with a carrier volume of 5 gpa compared to carrier volumes of 1 or 2 GPA (Figure 3). Spray deposition was similar across flight speeds and heights, although our highest tested application speed (22 ft/s) is a lower speed than at which some commercial applications occur. Spray deposition observed along the swath width indicated that spray movement and pattern shift in the direction of the prevailing winds, even under lower wind speeds, and that spray deposition is not uniform across the width of the swath (Figure 5). Although conditions were favorable for disease development through tasseling, drought conditions through grain fill delayed disease development and dry conditions persisted through August and September. Gray leaf spot and southern rust were present at less than 1% disease severity, which limits the ability to determine the effect of application method and spray parameters on foliar disease control.

Figure 2. Effect of application method on spray deposition in a corn trial conducted at the University of Kentucky Research and Education Center in Princeton, KY, in 2025.

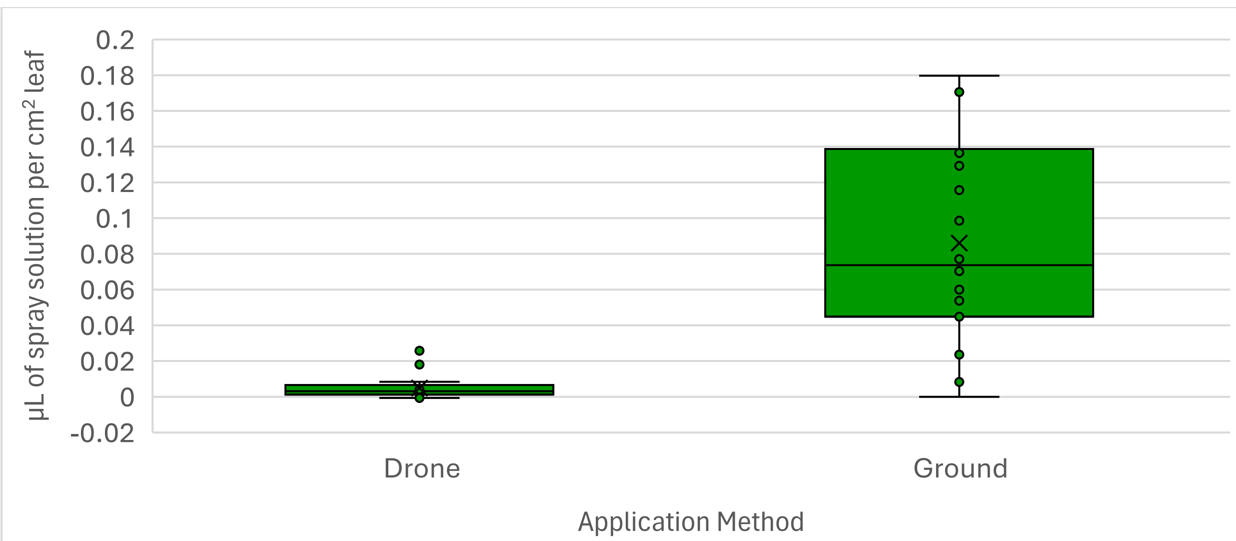


Figure 3. Effect of application carrier volume on spray deposition in a corn trial conducted at the University of Kentucky Research and Education Center in Princeton, KY, in 2025.

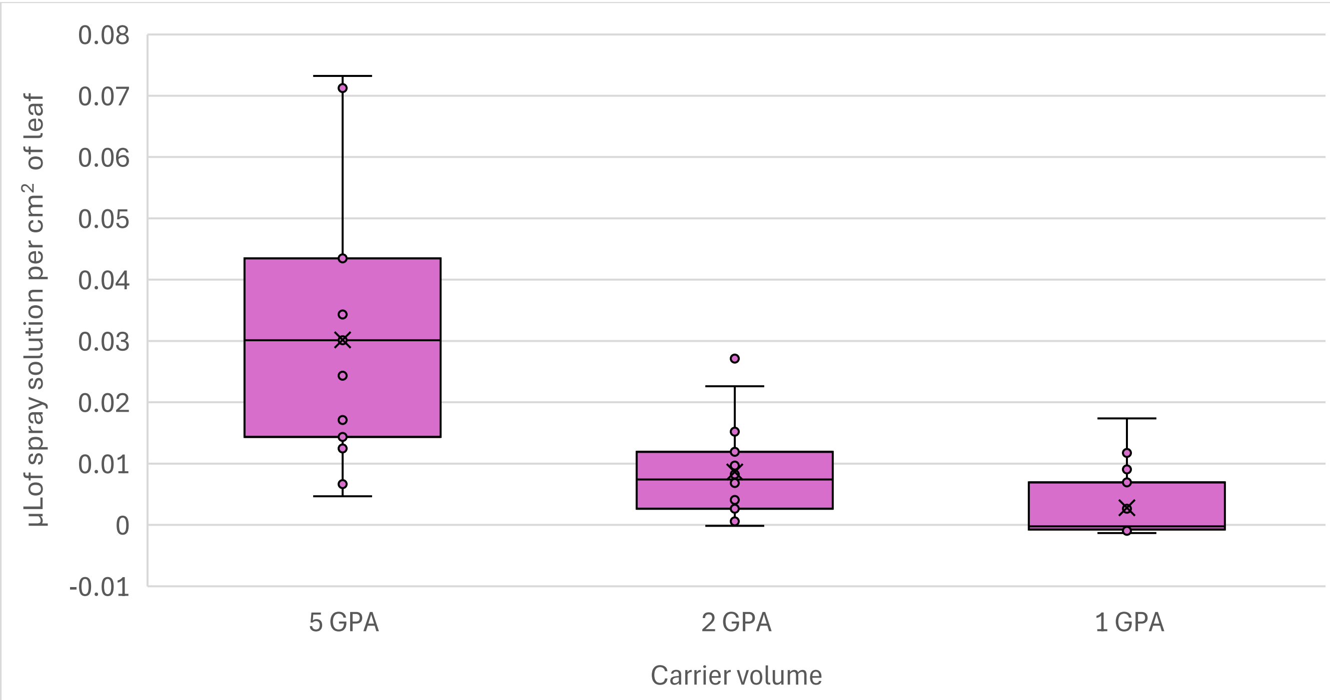


Figure 4. Effect of flight height in feet (ft) and speed in feet per second (ft/s) on spray deposition in a corn trial conducted at the University of Kentucky Research and Education Center in Princeton, KY, in 2025.

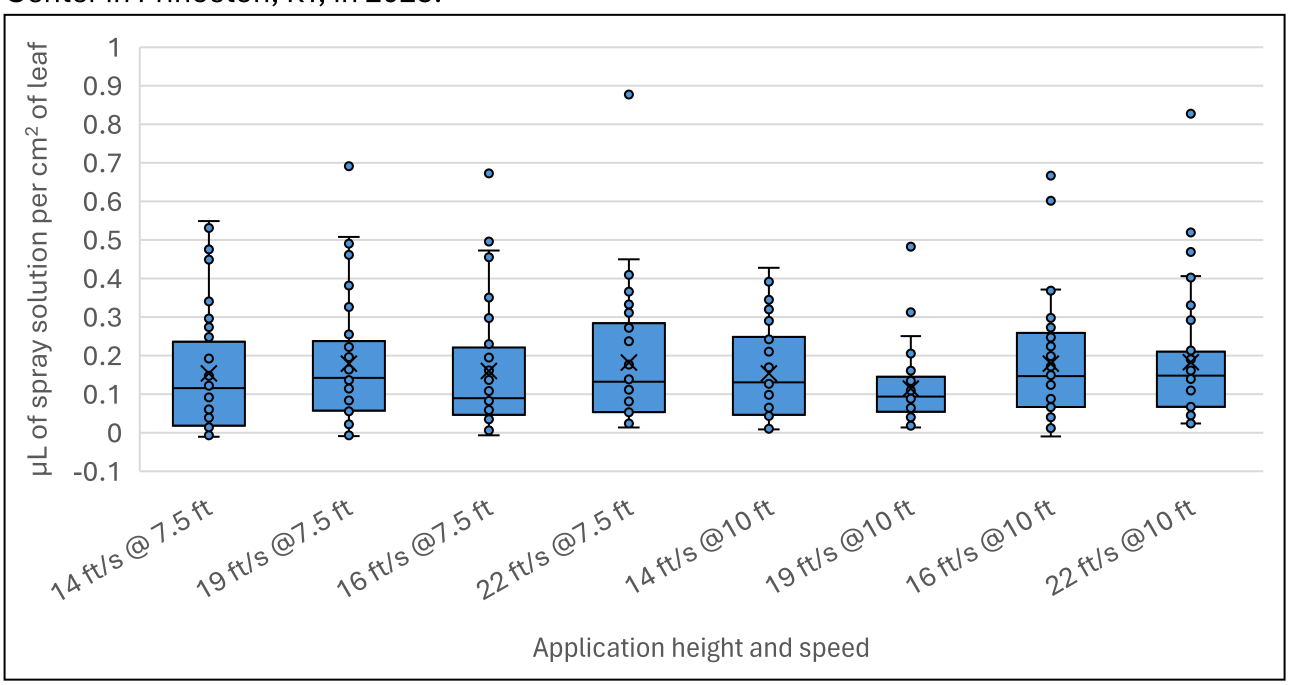
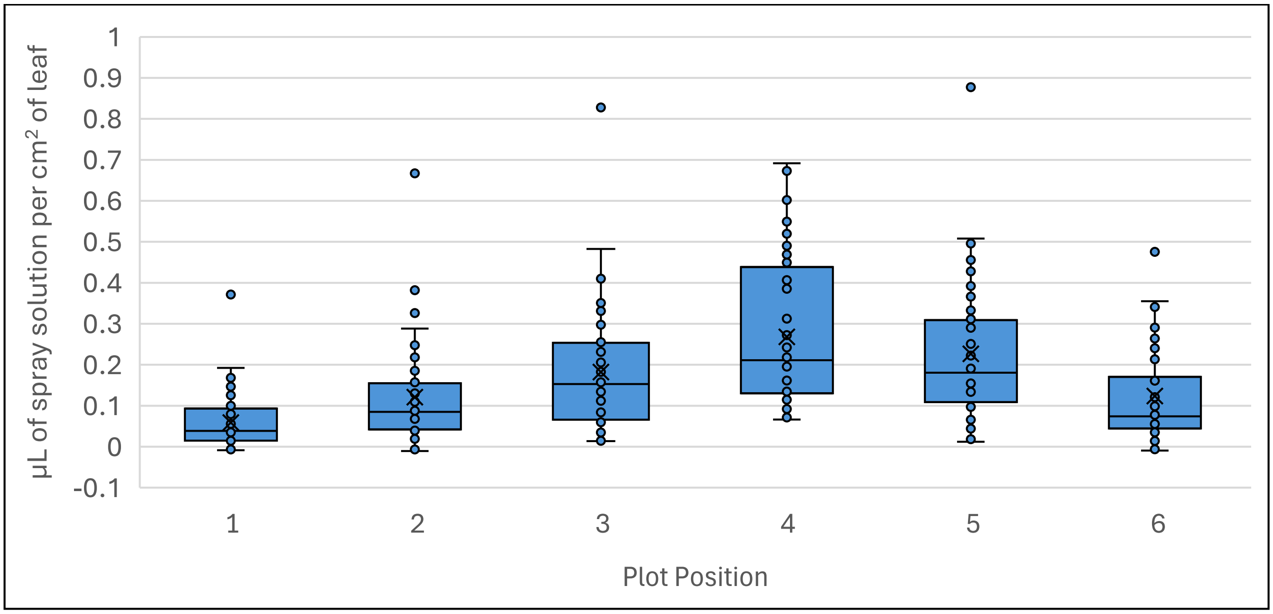


Figure 5. Distribution of spray solution deposited across the drone swath width for treatments applied at different heights and speeds in a corn trial conducted at the University of Kentucky Research and Education Center in Princeton, KY, in 2025. Plot position indicates the plant sampling position across a swath and indicating spray deposition from left to right in the plot (Fig.1).



CONCLUSION

- Ground application of fungicide resulted in greater spray deposition compared to drone application, and spray deposition was greater in drone applications with higher carrier volumes.
- In this study, drone height and speed did not affect spray deposition. However, spray deposition was not uniform across the width of the swath. This indicates spray movement occurred in all treatments, even under low wind speeds.
- Fungicide applications by drones are a viable way to apply fungicide in corn, but more research is needed to optimize the applications for disease control and yield benefits.

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We gratefully acknowledge the Kentucky Corn Growers Association for funding this research, and the UKREC Farm Crew, Luke Warner, Sean Booth, Hannah Young, and Ramita Badu for assistance in establishing and maintaining the research and aiding data collection.

Evaluating the Benefits of No-Tillage Systems on Soil Carbon Sequestration over Time

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INTRODUCTION

Temporal changes in soil carbon stocks are critical indicators of climate resilience, agricultural productivity, and carbon dynamics, including sequestration or release processes that shape the global carbon cycle. Among agricultural practices, no-tillage farming has gained recognition for its combined environmental and agronomic benefits. By reducing soil disturbance and erosions, no-till systems help conserve organic matter, maintain soil structure, and support long-term carbon retention.

Previous studies have highlighted the potential of regenerative practices to increase soil organic carbon (SOC) (Grace & Robertson, 2021; Wiltshire & Beckage, 2022). Evidence also suggests that no-tillage systems can significantly elevate SOC concentrations while reducing mineralization rates over time (Kan et al., 2021). However, translating these findings to Kentucky requires the implementation of research at the long-term no-till experiment plot due to the state's diverse agricultural practices.

This study aimed to determine the duration and extent to which no-till practices sequester carbon by depth in Kentucky corn systems, providing growers with insights into long-term benefits and sustainability. The specific objectives were to:

1. Characterize soil biogeochemical and physical properties influencing carbon dynamics, including bulk density, moisture content, mineralizable carbon, SOC, and total carbon;
2. Assess changes in soil carbon dynamics between 2008 and 2025;
3. Develop preliminary guidelines for carbon stock quantification tailored to Kentucky corn production; and
4. Establish a metrics framework based on SOC sequestration rates and related inputs to evaluate whether long-term no-till practices affect both sequestration rates and attainable carbon storage potential.

MATERIALS AND METHODS

Soil samples were collected from the University of Kentucky's Spindletop Research Farm in Lexington, KY. This long-term experiment has been under continuous corn production since 1970, managed with winter cover crops and nitrogen fertilizer applications under two tillage systems: no-tillage (NT) and conventional tillage (CT). Experimental plots measure approximately 5.5 m × 12 m and are arranged in a randomized block design (Figure 1). Nitrogen fertilizer was applied at four rates (0, 75, 150, and 300 lb/ac) across both tillage systems. The soil at this site is classified as Bluegrass-Maury silt loam, a deep, well-drained soil formed in loess over phosphatic limestone residuum. Also, some samples were collected from the area around the experimental plots as Sod treatment (the upper layer of soil bound together by grass and its roots). Sampling was conducted in spring 2025, prior to planting, using a soil auger from designated plots representing each tillage and nitrogen treatment combination.

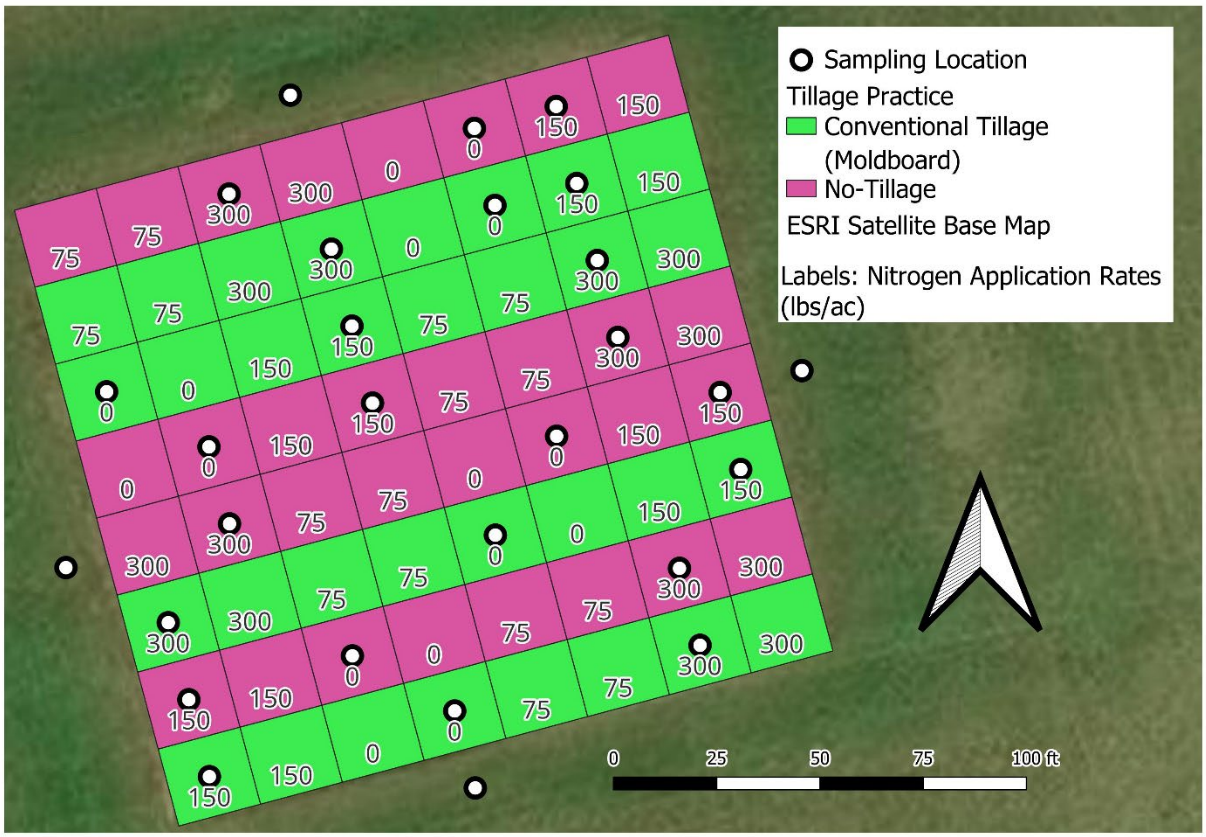

Figure 1. Blevin's field at the University of Kentucky's Spindletop Research Farm in Lexington

Bulk density (BD) was measured using the core method, and field moisture content was determined gravimetrically. These parameters are essential for calculating soil carbon stocks and assessing physical conditions that influence carbon retention. Soil samples were collected up to a depth of 100 cm by inserting a metal ring vertically into the ground. Soil cores were stored in labeled plastic tubes, with each label indicating the sampling site location for proper identification. In the laboratory, the cores were sliced into 10 cm segments using a jig saw and then weighed to determine their wet mass. The samples were then oven-dried at 100 °C for 72 hours to obtain their dry mass. BD at each depth was calculated by dividing the dry mass by the volume of the corresponding soil slice, enabling accurate assessment of soil structure and compaction.

Soil samples were collected from experimental plots to evaluate physical and biological properties associated with soil health and nutrient cycling. The following parameters were measured:

Permanganate Oxidizable Carbon (POXC, mg/kg) which was determined using the standard potassium permanganate oxidation method, which estimates the labile carbon fraction sensitive to management changes. Potentially Mineralizable Nitrogen (PMN, ppm) which was assessed through anaerobic incubation followed by extraction, providing an indicator of nitrogen availability for plants. Stable Aggregates (%) was measured using wet-sieving techniques to quantify the proportion of water-stable aggregates, reflecting soil structure and resistance to erosion. Soil texture was characterized by determining Total Clay (%), Total Silt (%), and Total Sand (%) using the hydrometer method. Further fractionation was performed to quantify Fine Silt (%), Coarse Silt (%), Very Fine Sand (%), Fine Sand (%), Medium Sand (%), Coarse Sand (%), and Very Coarse Sand (%), following USDA particle size classification standards. Aggregate Sand (%) was calculated as the proportion of sand retained within stable aggregates after wet-sieving.

Prior to analysis, soil samples were air-dried, gently ground, and sieved to 2 mm to remove coarse fragments and ensure uniformity. All measurements followed established protocols for soil health assessment. These properties collectively provide insight into soil organic matter dynamics, nutrient cycling potential, and physical structure stability under different management treatments.

RESULTS AND DISSCUSION

Table 1 presents the soil measurement results for the CT and NT treatments, along with three levels of nitrogen application. POXC values varied substantially across treatments, with means ranging from 115.39 mg/kg (150NT) to 156.45 mg/kg (300NT). No-till treatments generally exhibited higher POXC compared to CT, particularly at the highest nitrogen rate (300NT), which recorded the maximum POXC (890.93 mg/kg). This suggests that reduced soil disturbance combined with higher nitrogen inputs may enhance soil carbon, supporting soil health and microbial activity. PMN showed high variability (SD up to 34.48 ppm), with SOD and 150NT treatments having the highest mean values (20.02 and 19.85 ppm, respectively). No-till treatments consistently outperformed CT treatments, indicating that residue retention and minimal disturbance promote nitrogen mineralization potential. The extreme maximum value (170 ppm in 150NT) highlights localized hotspots of microbial activity. Stable aggregate percentages were highest under 0NT (31.45%) and SOD (30.21%), while CT treatments remained below 22%. This reinforces the positive effect of no-till and sod systems on soil structure. High variability in NT treatments (SD > 19%) suggests heterogeneity in aggregate formation, possibly influenced by residue distribution and root architecture. Across treatments, Total Clay ranged from 30.61% (300NT) to 38.09% (0CT), while Total Silt was highest in 300NT (63.85%). Sand fractions decreased slightly with increasing nitrogen under NT, indicating potential redistribution of fine particles due to management practices. Fine silt dominated the silt fraction, particularly in NT treatments, which may contribute to improved water retention and aggregate stability. Very fine and fine sand fractions remained relatively stable across treatments (mean ≈ 0.7% and 0.48%, respectively), while coarse sand showed slight reductions under NT at higher nitrogen rates (2.09% in 300NT vs. 2.77% in 0CT). This suggests that tillage may influence the exposure and breakdown of coarse particles over time.

CONCLUSION

Preliminary findings suggest that long-term no-tillage practices may positively increase active carbon depending on other management practices such as N application rates. Further analysis is necessary to understand if the long-term no-till practice brings which extent of benefits to growers in Kentucky. Future work will focus on the continuation of laboratory testing and in-depth statistical analysis for each parameter by treatments. We will also calculate carbon sequestration using different methods to understand the impact of long-term no-till practice on the carbon gain/release.

ACKNOWLEDGMENTS

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TABLES

Table 1. Soil measurement results for the CT and NT treatments with three levels of nitrogen

Treatment	**POXC(mg/kg)**				
	mean	median	SD	min	max
0CT	118.39	77.02	118.65	<0.01	424.09
0NT	122.22	94.98	109.89	<0.01	445.76
150CT	133.07	81.06	130.52	<0.01	488.66
150NT	115.39	74.03	123.01	<0.01	516.83
300CT	131.05	77.55	142.80	<0.01	587.81
300NT	156.45	98.38	181.87	<0.01	890.93
SOD	133.75	70.89	156.44	<0.01	605.86

Treatment	**PMN(ppm)**				
	mean	median	SD	min	max
0CT	9.83	2.50	13.45	0.50	43.50
0NT	17.88	4.25	25.22	<0.01	86.00
150CT	11.50	3.50	14.95	<0.01	45.00
150NT	19.85	3.50	34.48	0.50	170.00
300CT	15.92	2.50	27.18	0.50	130.00
300NT	16.91	2.50	28.69	<0.01	107.50
SOD	20.02	2.75	32.33	<0.01	140.00

Treatment	**Stable Aggregate (%)**				
	mean	median	SD	min	max
0CT	21.52	18.96	11.19	7.22	50.36
0NT	31.45	22.03	23.56	7.63	88.17
150CT	20.63	17.93	10.71	6.719	42.25
150NT	26.73	18.94	19.50	5.88	87.50
300CT	21.17	16.46	17.11	4.34	86.61
300NT	23.77	14.75	23.33	2.08	86.11
SOD	30.21	20.83	22.32	5.10	94.15

Treatment	**Aggregate Sand (%)**				
	mean	median	SD	min	max
0CT	9.07	8.00	3.04	4.66	17.00
0NT	8.60	7.00	4.46	3.33	22.66
150CT	9.86	9.16	4.33	3.66	21.66
150NT	8.26	6.83	3.90	4.00	19.33
300CT	9.98	9.00	3.20	5.00	16.33
300NT	7.18	6.33	3.91	1.66	17.33
SOD	7.25	5.66	3.79	3.00	18.00

Treatment	Total Clay (%)				
	mean	median	SD	min	max
0CT	38.09	40.45	8.77	24.20	51.50
0NT	34.25	34.20	9.66	18.80	48.90
150CT	36.61	38.00	9.38	21.50	52.60
150NT	35.15	37.15	8.60	20.10	48.30
300CT	36.20	38.70	7.78	23.00	46.30
300NT	30.61	28.80	8.27	19.60	47.50
SOD	34.27	33.95	8.93	21.50	50.100
Treatment	**Total Silt (%)**				
	mean	median	SD	min	max
0CT	54.31	51.90	9.99	38.40	70.10
0NT	58.22	58.25	11.35	41.70	75.60
150CT	55.90	53.95	11.08	33.80	71.90
150NT	57.92	56.30	9.92	41.90	74.10
300CT	57.06	54.70	8.36	43.90	71.30
300NT	63.85	66.40	9.18	43.10	75.20
SOD	58.52	59.10	10.23	42.70	72.40

Treatment	Total Sand (%)				
	mean	median	SD	min	max
0CT	7.59	7.65	1.40	5.50	10.30
0NT	7.52	7.20	2.02	4.10	12.20
150CT	7.48	7.05	2.18	4.60	14.40
150NT	6.91	6.65	1.60	4.60	11.90
300CT	6.73	6.25	1.38	4.90	9.80
300NT	5.53	5.25	1.39	3.70	9.70
SOD	7.20	6.85	1.87	4.60	11.10

Treatment	Silt Fine (%)				
	mean	median	SD	min	max
0CT	28.24	28.00	4.13	22.10	36.30
0NT	33.02	32.80	6.40	23.30	48.50
150CT	31.34	30.70	6.02	20.80	47.90
150NT	30.41	30.30	4.35	22.40	38.20
300CT	29.96	29.35	3.64	22.90	37.20
300NT	33.12	32.35	6.83	20.10	49.60
SOD	30.58	30.85	4.35	22.20	38.50

Treatment	Silt Coarse (%)				
	mean	median	SD	min	max

0CT	26.06	24.75	6.56	15.40	39.30
0NT	25.20	24.85	8.55	10.20	39.50
150CT	24.55	23.45	8.66	10.30	39.50
150NT	27.51	27.50	5.96	16.60	38.00
300CT	27.09	25.95	5.54	20.30	39.60
300NT	30.72	31.40	5.62	22.10	41.70
SOD	27.94	28.65	6.50	15.10	39.40

Treatment	**Silt Coarse (%)**				
	mean	median	SD	min	max
0CT	26.06	24.75	6.56	15.40	39.30
0NT	25.20	24.85	8.55	10.20	39.50
150CT	24.55	23.45	8.66	10.30	39.50
150NT	27.51	27.50	5.96	16.60	38.00
300CT	27.09	25.95	5.54	20.30	39.60
300NT	30.72	31.40	5.62	22.10	41.70
SOD	27.94	28.65	6.50	15.10	39.40

Treatment	**Sand VFine (%)**				
	mean	median	SD	min	max
0CT	0.71	0.70	0.12	0.10	0.90
0NT	0.72	0.70	0.08	0.60	0.90
150CT	0.70	0.70	0.13	0.10	0.90
150NT	0.70	0.70	0.13	0.10	1.00
300CT	0.73	0.80	0.20	0.00	1.30
300NT	0.70	0.70	0.17	0.40	1.30
SOD	0.68	0.65	0.12	0.50	1.10

Treatment	**Sand Fine (%)**				
	mean	median	SD	min	max
0CT	0.48	0.50	0.06	0.30	0.60
0NT	0.46	0.50	0.05	0.40	0.60
150CT	0.46	0.50	0.06	0.40	0.60
150NT	0.47	0.50	0.04	0.40	0.60
300CT	0.51	0.50	0.09	0.40	0.70
300NT	0.47	0.50	0.10	0.30	0.70
SOD	0.48	0.50	0.09	0.40	0.90

Treatment	Sand Med (%)				
	mean	median	SD	min	max
0CT	1.40	1.40	0.12	1.10	1.70
0NT	1.46	1.40	0.16	1.20	2.00
150CT	1.40	1.40	0.17	1.00	1.80
150NT	1.36	1.40	0.13	1.10	1.70
300CT	1.52	1.50	0.20	1.20	2.00
300NT	1.41	1.40	0.27	0.90	2.20
SOD	1.38	1.40	0.15	1.10	1.80

Treatment	Sand Coarse (%)				
	mean	median	SD	min	max
0CT	2.77	2.85	0.51	1.90	3.90
0NT	2.76	2.80	0.70	1.40	4.10
150CT	2.80	2.60	0.76	1.50	4.90
150NT	2.50	2.45	0.64	1.50	4.30
300CT	2.67	2.60	0.43	1.90	3.60
300NT	2.09	2.05	0.61	1.20	3.40
SOD	2.65	2.50	0.72	1.60	4.10

Innovative Technology for Assessing Soil Bulk Density Variability to Enhance Corn Production in Kentucky

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INTRODUCTION

Soil bulk density (BD) is a critical physical property for determining fertilizer application rates and monitoring soil carbon. However, sampling BD only at the surface fails to capture the variability that exists within a field. In Kentucky, where soil depth can vary significantly due to diverse conservation practices, understanding and managing BD is essential for optimizing corn yields. Additionally, Kentucky's distinct physiographic features, such as fragic soil layers, erosion-driven topographic variability, and unpredictable weather patterns, highlight the need for updated guidelines on soil sampling depth and sample quantity. These updates are crucial for accurate fertilizer recommendations and farm-level carbon credit assessments.

The objective of this study was to quantify the impact of spatial variability in soil BD on productivity and update fertilizer guidelines for sustainable corn production in Kentucky. The specific objectives were to: (1) assess spatial variability of soil BD across two corn fields in Kentucky; (2) test and validate innovative soil sensing technologies for efficient BD measurement; and (3) provide data-driven recommendations for fertilizer application based on BD variability.

MATERIALS AND METHODS

The soil core samples were collected at 10 cm intervals to a depth of 100 cm from approximately 120 acres across a commercial corn field (Field A) as well as University of Kentucky Spindletop Long-term No-till Experimental Plot in Kentucky. The first location was in New Hope, KY (Figure 1). The location for the Spindletop field was in Lexington, a site under continuous corn production since 1970 with winter cover crop rotations and consistent nitrogen fertilizer applications under both no-tillage and conventional tillage systems (Figure 2). The soil at this location is classified as Bluegrass-Maury silt loam, a deep, well-drained soil formed in loess over phosphatic limestone residuum. Sampling was performed in spring 2025, prior to planting, using a soil auger.

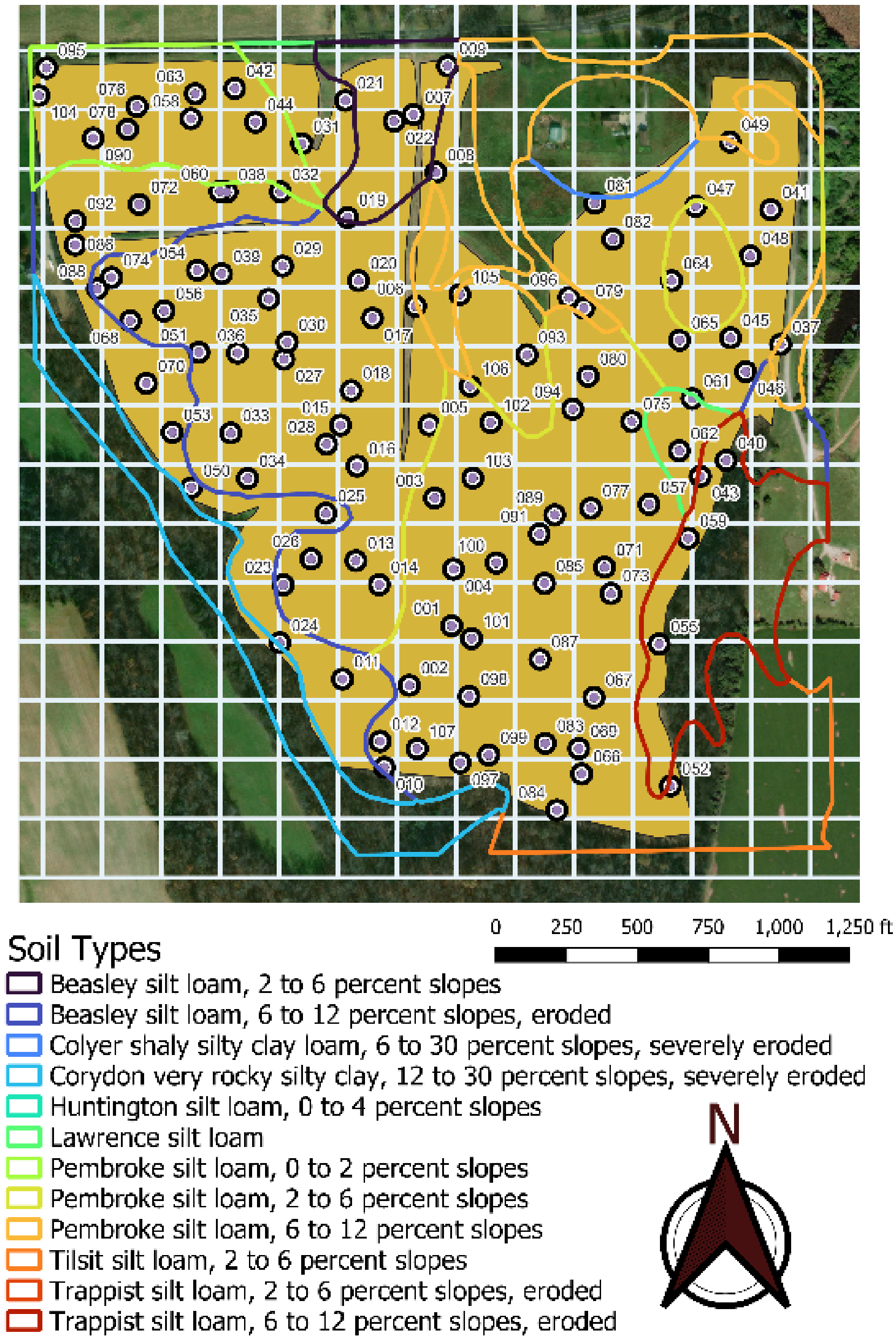

Figure 1. Field A at New Hope, KY

Figure 2. Blevin's field at the University of Kentucky's Spindletop Research Farm in Lexington.

To measure soil BD the core method was used. Soil samples were collected up to a depth of 100 cm by inserting a metal ring vertically into the ground. From each plot, three cores were extracted using a probe with a 4.2 cm diameter, which exceeded the manufacturer's recommended size for the gamma-ray sensor but was selected for the field convenience. To preserve core integrity during transport, samples were placed into rigid, labeled plastic tubes cushioned with foam inserts and packed horizontally in insulated containers to minimize vibration and mechanical disturbance. In the laboratory, the cores were sliced into 10 cm segments and weighed to determine their wet mass. The samples were then oven-dried at 100 °C for 72 hours to obtain their dry mass. BD at each depth was calculated by dividing the dry mass by the volume of the corresponding soil slice, enabling accurate assessment of soil structure and compaction.

We also tested a newly imported device: the RhoC5 sensor from Medusa Inc which operates based on the principles of gamma-ray attenuation. The RhoC5 sensor offers several advantages including being capable of operating efficiently across large areas, being cost-effective with an estimated operational cost of a few dollars per acre and being less sensitive to moisture variability.

To measure BD using the RhoC sensor, the device was inserted into the hole previously drilled for the core method. The sensor was positioned at the target depth using a guiding mount marked at 10 cm intervals, allowing placement down to 100 cm. Data was collected via an Android tablet application. The recorded variables included: Time, Depth (cm), Latitude, Longitude, Position Accuracy (m), Field BD (kg/L), Field BD Accuracy (kg/L), Dry BD (kg/L), Moisture (%), and User-Defined Moisture (%). Dry BD was calculated by subtracting volumetric soil moisture measured using a capacitance soil moisture sensor from the field BD.

Data collected from both devices was analyzed to compare measurement accuracy and consistency, and map BD variability across the sampled fields.

RESULTS AND DISCUSSIONS

The analysis of soil BD across the two sampled corn fields revealed distinct patterns of variability, both vertically and spatially, with implications for site-specific management.

Field A exhibited considerable variability in both BD and moisture content across depths and the field. The measured dry BD ranged from 0.80 to 1.86 g/cm^3, with an average of 1.31 g/cm^3. Gravimetric moisture content varied widely, from 3.62% to 37.81%, indicating heterogeneous soil water retention characteristics. Depth measurements ranged from 44 cm to 109.5 cm, suggesting uneven soil compaction and possible erosion effects. **If fertilizer recommendation assumes 1.47 g/cm^3 based on the general assumption that soil mass within 6in depth per acre is equivalent to 2 million pounds but actual is 1.31 g/cm^3, then application based on assumption over-applies by ~10.9%, which is equivalent to 39lbs Urea/ac or $11/acre (when $601/ton).**

The standard deviation of BD (0.14 g/cm^3) and moisture (3.42%) further supports the presence of spatial heterogeneity. These variations are likely influenced by topographic position and historical land management practices. In addition, the measured BD values were compared with predictions from the RhoC5 sensor, revealing only a weak association between the two (R^2 = 0.07). The regression line (y = 0.4335x + 1.1125) indicates that the sensor tends to overestimate BD values, especially at the lower end of the measured range. This weak correlation could be due to several factors, such as sensor calibration limitations, soil heterogeneity, or environmental conditions affecting sensor readings such as the air gap between the sensor and soil.

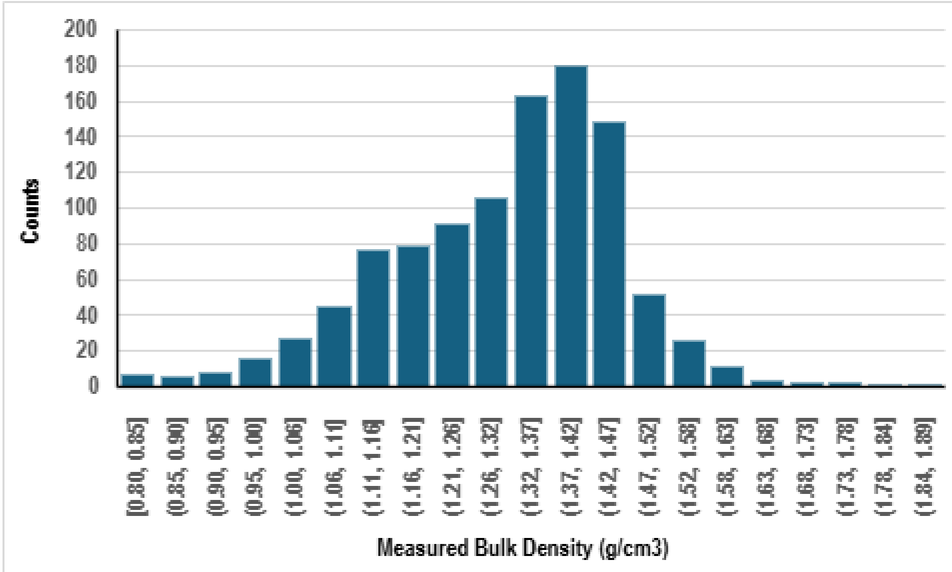

Figure 3. Histogram of the measured bulk density for Field A

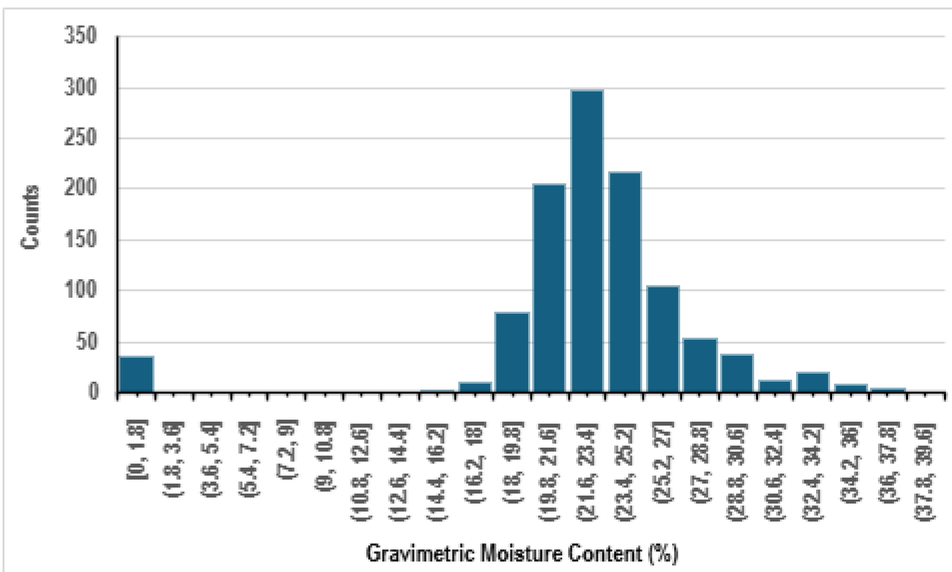

Figure 4. Histogram of the moisture content for Field A

Table 1. Summary of the measured dry bulk density, moisture content, and depth data for Field A

	Measured Dry Bulk Density (g/cm^3)	Measured Gravimetric Moisture Content (%)	Measured Depth (Core Length) (cm)
Minimum	0.80	3.62	44.00
Maximum	1.86	37.80	100.00
Average	1.31	23.52	96.86
Median	1.33	22.93	99.50
SD	0.14	3.42	8.91

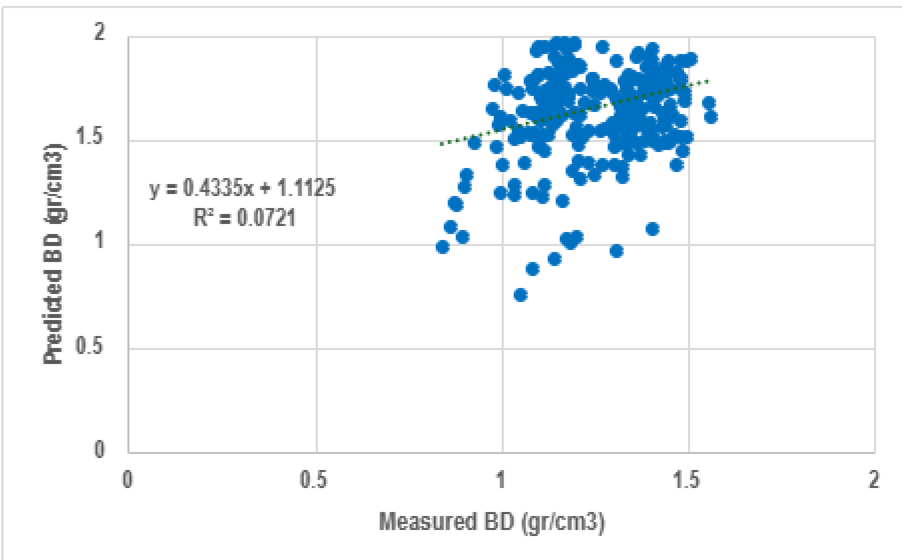

Figure 5. Measured vs. predicted bulk density for Field A

In contrast, the Blevins field in central Kentucky showed more uniform soil profiles. Dry BD showed an average of 1.44 g/cm^3 and a standard deviation of 0.13 g/cm^3. Moisture content was more consistent, ranging from 16.40% to 33.62%, with a lower standard deviation of 2.34%. All core samples reached the full depth of 100 cm, indicating minimal compaction or erosion.

The RhoC5 sensor predictions showed a good alignment with the measured BD values, as indicated by an R^2 of 0.50 and a RMSE of 0.19 g/cm^3. The regression trend suggests a positive linear relationship, although variability remains, particularly at lower BD values where some predictions deviate significantly. The RMSE of 0.19 g/cm^3 reflects a reasonable level of prediction error, implying that while the sensor captures general trends, it does not perfectly replicate measured values. This consistency across most data points suggests that the sensor performs reliably under conditions typical of limestone-derived soils with relatively stable moisture profiles. However, the observed scatter indicates that factors such as micro-scale soil heterogeneity, calibration constraints, or variations in soil texture may influence prediction accuracy. Overall, the sensor demonstrates potential for practical use, but further refinement or site-specific calibration could enhance precision.

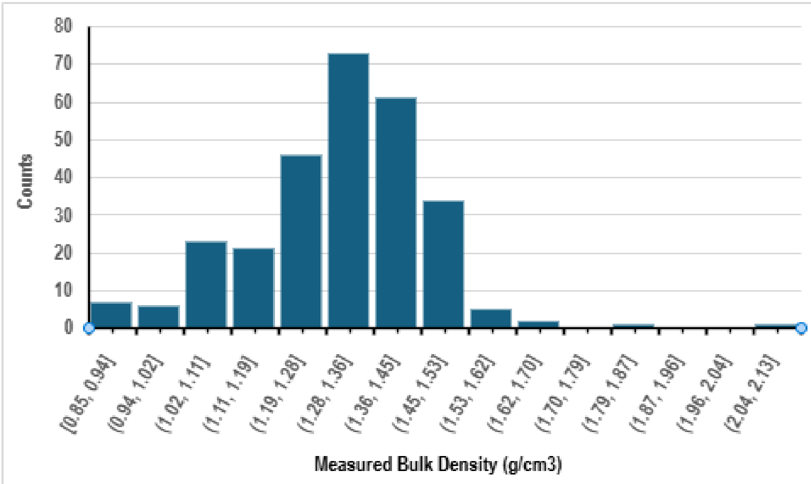

Figure 6. Histogram of the measured bulk density for the Blevin's field

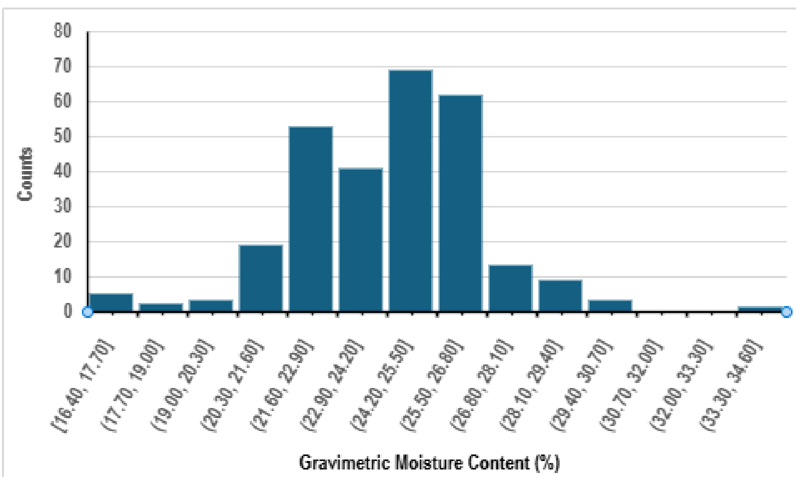

Figure 7. Histogram of the moisture content for the Blevin's field

Table 2. Summary of the measured dry bulk density, moisture content, and depth for Blevin's field

	Measured Dry bulk density (g/cm^3)	Measured Gravimetric Moisture content (%)	Measured Depth (Core Length) (cm)
Minimum	0.94	16.40	100.00
Maximum	2.25	33.61	100.00
Average	1.44	24.24	100.00
Median	1.45	24.51	100.00
SD	0.13	2.34	0.00

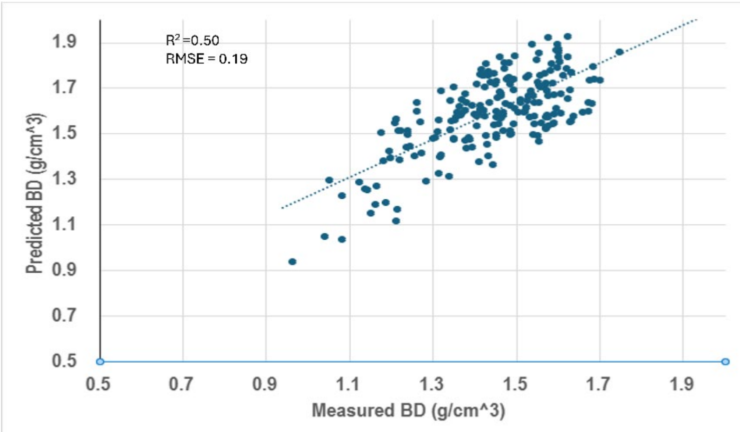

Figure 8. Measured vs. predicted bulk density for Blevin's field

Figure 9 illustrates the spatial variability of soil bulk density across Blevin's field at depths ranging from 10 cm to 100 cm using the Kriging interpolation method. Bulk density values generally increased with depth, with the shallow layers (20–40 cm) exhibiting lower densities (mostly between 1.30–1.55 g/cm^3) compared to deeper layers (90–100 cm), where values exceeded 1.80 g/cm^3 in several zones. High-density regions were consistently observed in the northeastern and northwestern portions of the field, while lower-density zones appeared in the southern and central areas, suggesting heterogeneity in soil compaction and texture. This trend indicates potential implications for root penetration and water infiltration, as higher bulk density at greater depths may restrict root growth and reduce soil porosity. The observed spatial patterns highlight the importance of site-specific management practices, such as targeted tillage or organic amendments, to mitigate compaction in high-density zones and improve overall soil health.

CONCLUSION

This study demonstrates the importance of accounting for soil BD variability in optimizing corn production in Kentucky. The results from both fields revealed substantial spatial and vertical variation in BD, with implications for root development, water retention, and nutrient availability. Field A exhibited greater variability in depth and moisture, likely due to topographic and soil structural differences, while the Blevins field showed more uniform profiles, consistent with its limestone-derived soils. The comparison between traditional core sampling and the RhoC5 sensor from Medusa Inc. showed promising alignment, with the sensor offering a cost-effective and scalable alternative for field-level BD assessment. Its reduced sensitivity to moisture and operational efficiency make it a viable tool for precision agriculture applications. These findings support the need to revise fertilizer application guidelines to incorporate BD variability, particularly in regions with complex soil profiles. Incorporating BD data into nutrient management plans can improve fertilizer use efficiency, reduce environmental impact, and enhance yield outcomes. Furthermore, accurate BD mapping contributes to more reliable carbon stock assessments, which are increasingly relevant for carbon credit programs. Future work should expand sampling across more physiographic regions and integrate BD data with yield maps and remote sensing imagery to develop predictive models for site-specific management. The adoption of innovative sensing technologies like the RhoC5 sensor can play a pivotal role in advancing sustainable and data-driven corn production in Kentucky.

ACKNOWLEDGMENTS

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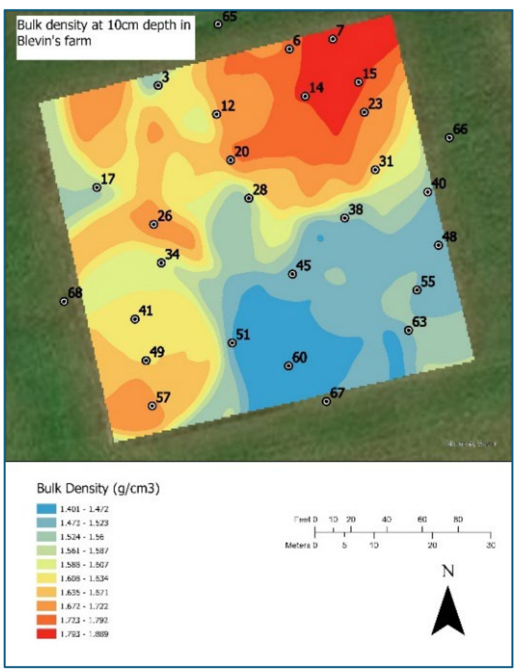
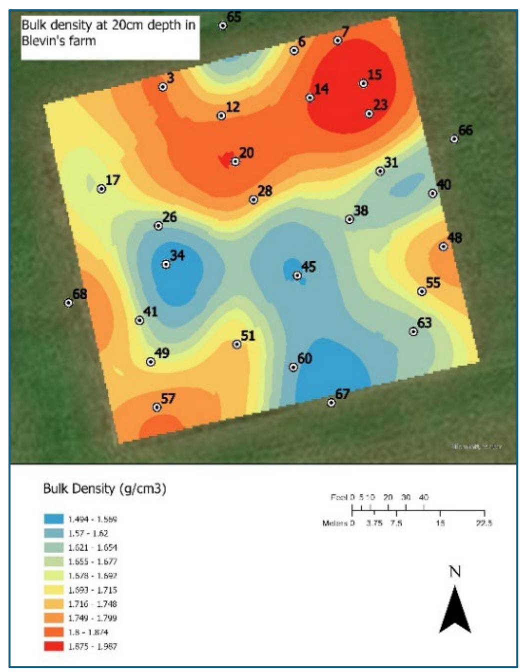
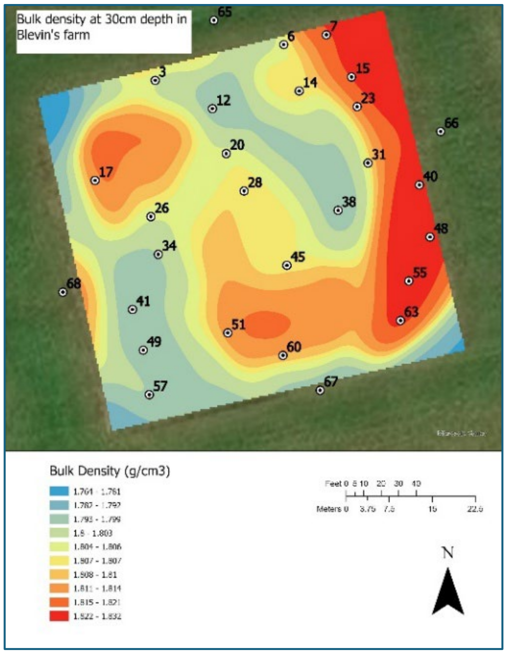
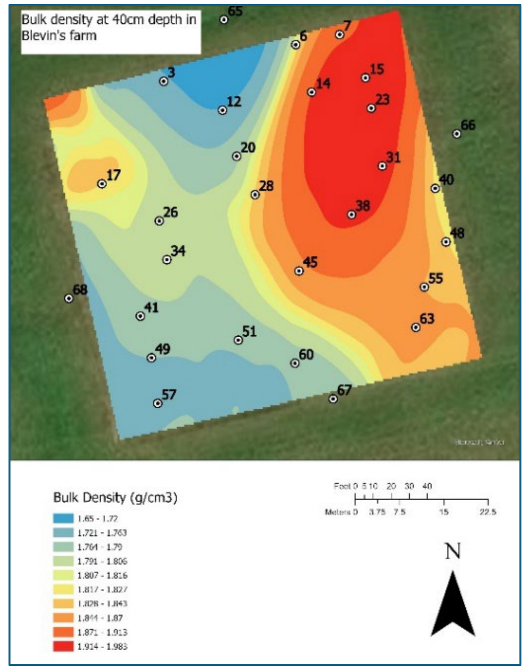
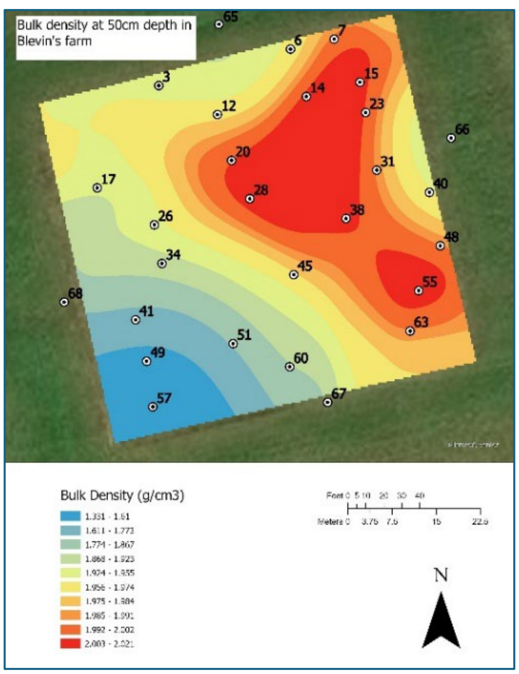
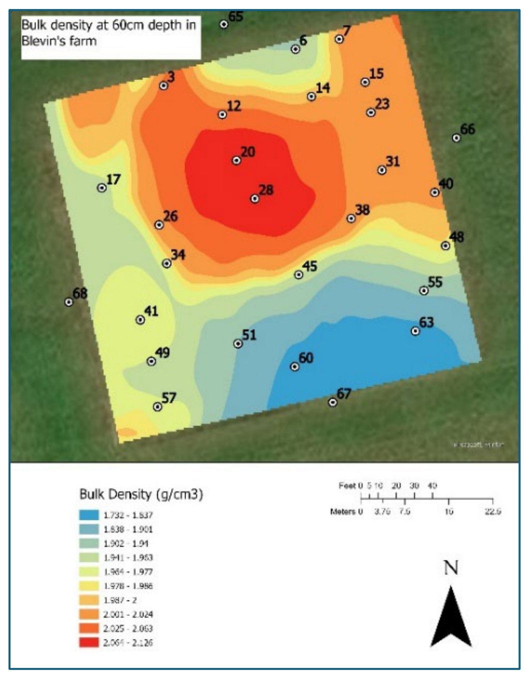





Bulk density at 30cm depth in Blevin's farm
Bulk Density (g/cm3)
1.764 - 1.781
1.782 - 1.792
1.793 - 1.799
1.8 - 1.803
1.804 - 1.806
1.807 - 1.807
1.808 - 1.81
1.811 - 1.814
1.815 - 1.821
1.822 - 1.832
Feet 0 5 10 20 30 40
Meters 0 3.75 7.5 15 22.5
N


Bulk density at 40cm depth in Blevin's farm
Bulk Density (g/cm3)
1.65 - 1.72
1.721 - 1.763
1.764 - 1.79
1.791 - 1.806
1.807 - 1.816
1.817 - 1.827
1.828 - 1.843
1.844 - 1.87
1.871 - 1.913
1.914 - 1.983
Feet 0 5 10 20 30 40
Meters 0 3.75 7.5 15 22.5
N


Bulk density at 50cm depth in Blevin's farm
Bulk Density (g/cm3)
1.331 - 1.61
1.611 - 1.773
1.774 - 1.867
1.868 - 1.923
1.924 - 1.955
1.956 - 1.974
1.975 - 1.984
1.985 - 1.991
1.992 - 2.002
2.003 - 2.021
Feet 0 5 10 20 30 40
Meters 0 3.75 7.5 15 22.5
N


Bulk density at 60cm depth in Blevin's farm
Bulk Density (g/cm3)
1.732 - 1.837
1.838 - 1.901
1.902 - 1.94
1.941 - 1.963
1.964 - 1.977
1.978 - 1.986
1.987 - 2
2.001 - 2.024
2.025 - 2.063
2.064 - 2.126
Feet 0 5 10 20 30 40
Meters 0 3.75 7.5 15 22.5
N

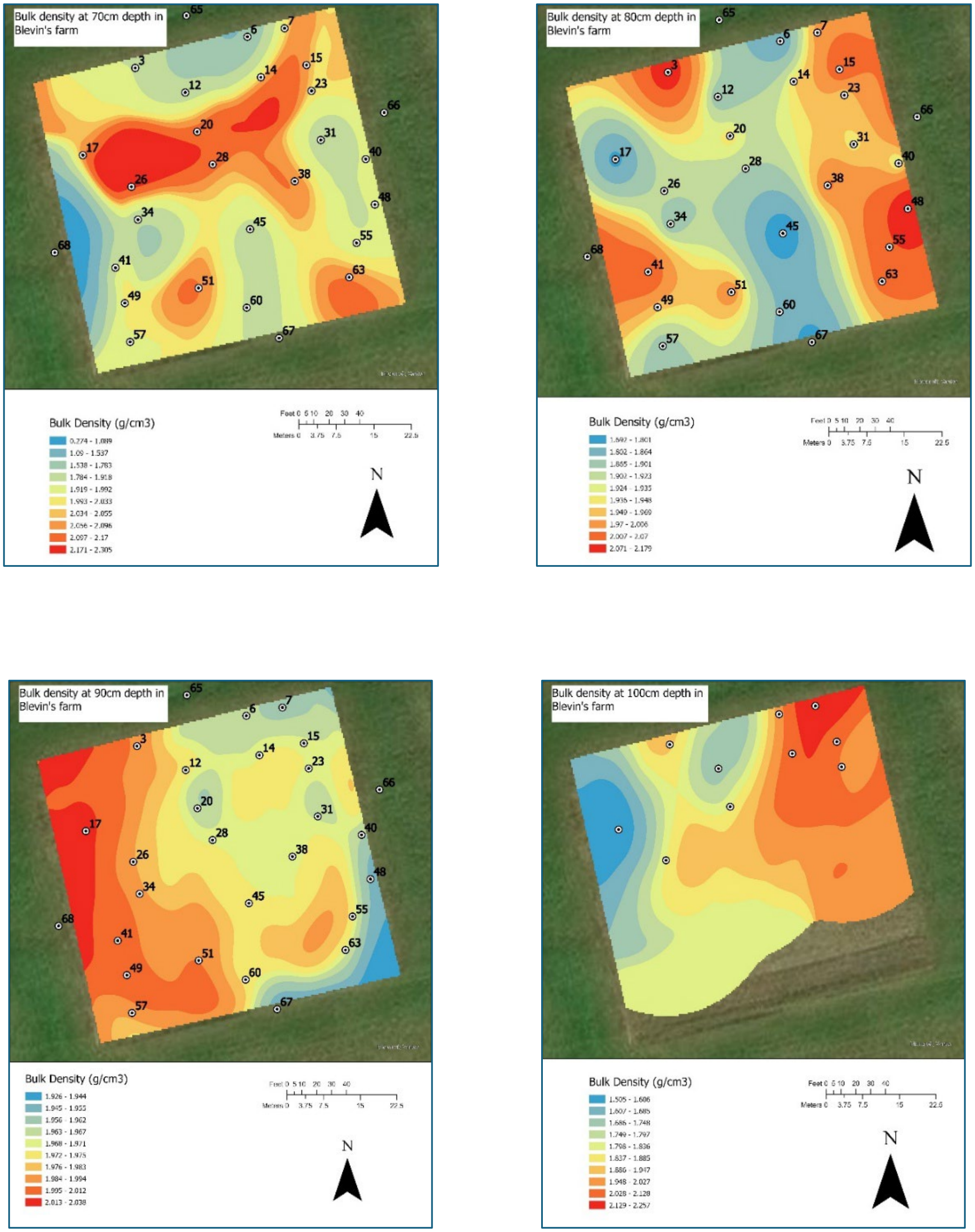


Figure 9. Bulk density maps for each depth for Blevin's field using Kriging method

Understanding Sulfur Deficiencies in Central Kentucky Corn Production

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INTRODUCTION

Trials over the past four years at University of Kentucky research farms suggest a growing need for sulfur fertilization in central Kentucky corn production. This is likely attributable to declining atmospheric sulfur deposition and increasing rates of sulfur removal in grain. While many corn farmers now apply sulfur, there is little recent research in Kentucky to guide sulfur management. This is a problem because the under- or over-application of sulfur fertilizer can lead to economic losses. The objectives of this study were to: 1) determine the effect of sulfur fertilization on corn yield in central Kentucky, and 2) determine the influence of previous crop on corn response to sulfur fertilization. The first objective was conducted on-farm while the second objective was conducted in a crop rotation study at University of Kentucky's Spindletop Farm.

METHODS AND MATERIALS

Objective 1 - On-farm research

The on-farm research was conducted at two locations – Hardin County (HC) and LaRue County (LC). The HC site was located on predominantly Pembroke silt loam, with some Crider silt loam, whereas the LC site was located on predominantly Otwood silt loam with some Nolin silt loam.

The experiment included two treatments – sulfur fertilization and no sulfur fertilization, in a randomized complete block design. The plots consisted of strips, with one control plot (no sulfur) and one treatment plot (sulfur) side-by-side to make up one replicate block. There were six replicates in HC and three replicates in LC.

Commodity yellow corn was planted at both locations on May 15, 2025 at 34,000 seeds per acre. The HC site received triple superphosphate and muriate of potash in the fall of 2024 to provide adequate phosphorus and potassium, and had been limed in 2022. The LC site received phosphorus and potassium in the spring of 2025 before planting. Neither of the fields received sulfur in 2024. Both sites used a seed treatment and Capture insecticide at planting as well as a late-season fungicide.

The entire experiment received 200 lb N/acre as a split application. The initial nitrogen application delivered 50 lb N/acre at planting. At HC, a 2x2 applicator was used, while at LC a 2x0 applicator was used for the initial application. The remaining 150 lb N/acre was applied at sidedress (~V6 growth stage). At HC, the sidedressed nitrogen was predominantly subsurface banded between rows (i.e., there were just Y-drops on the ends of the applicator) on June 12, 2025. At LC, the sidedressed nitrogen was shallowly subsurface applied both between rows and on rows on June 4, 2025. For the no-sulfur strips, the nitrogen source was 32-0-0-0 (32% urea ammonium nitrate), while for the with-sulfur strips, the nitrogen was applied with sulfur using 30-0-0-3 (combination of urea, ammonium nitrate, and ammonium thiosulfate; density = 11.06 pounds per gallon). This application provided 20 lb S/acre.

Soil sampling was conducted one week after planting (May 22-23, 2025), when corn had just emerged. We sampled two locations in each strip within four of the six replications at the HC site, and at three locations in each strip within all three replications at the LC site. At each location, we collected eight 1-inch-diameter cores within a 10 ft radius of the geo-located point. We took cores at 0-4 and 4-12 inches for the sulfur strips, and 0-4, 4-12, and 12-24 inches for the strips with no sulfur. The fresh samples were extracted for inorganic N, and the remaining soil was air dried, ground to pass a 2 mm sieve, and tested for pH, Mehlich 3 nutrients (including S), particle size distribution, soil C and N concentrations, and monocalcium phosphate S. The monocalcium phosphate extraction was completed in the Poffenbarger Lab and the extracts are awaiting analysis at Regulatory Services via the ICP method. Additional soil and topographic data (particle size distribution, soil organic matter, pH, CEC, depth of water table, depth of restrictive layer, and slope) were extracted for the sampling points using publicly available databases.

Plant tissue samples and SPAD readings were collected at the V6 growth stage after fertilization (June 20, 2025) and at the R1 growth stage (July 24, 2025). At the V6 stage, SPAD readings were taken on the uppermost collared leaves of eight plants, and eight whole plants were collected per sampling location. At the R1 growth stage, SPAD readings were taken on the ear leaves of eight plants, and eight separate ear leaves were collected for tissue analysis per sampling location. The tissue samples were dried, ground, and analyzed for elemental composition. For yield, a weigh wagon was used to collect grain weight and moisture content from each strip at the HC site, while a yield monitor was used to collect this information at the LC site. A yield map was produced for the LC site, which allowed us to examine the yield within ~100 square feet of each sampling location.

Objective 2 – Crop rotation study

We used an existing crop rotation study at the University of Kentucky Spindletop Farm to determine the effect of crop rotation on corn response to sulfur fertilization. The study is situated on a Bluegrass Maury silt loam soil. It includes continuous corn, corn-corn-soybean-soybean, and corn-wheat/double crop soybean rotations. There are six N rates applied to corn – 0, 40, 80, 120, 160, 200 lb N/acre. The plots receive potassium and lime according to University of Kentucky recommendations. They also received gypsum applications (18 lb S/acre) in 2023 and 2024.

In 2025, we planted commodity yellow corn at 32,000 seeds/acre on May 15, 2025. We divided each plot into split-plots and randomly assigned the treatments – no-sulfur and with-sulfur. The with-sulfur plots received 18 lb S/acre using gypsum that was hand-applied along with SuperU at the V4 growth stage on June 10, 2025.

Soil samples, consisting of eight 2-inch-diameter cores per plot, were collected in the 0 and 160 lb N/acre treatments prior to sulfur application on April 30, 2025. The cores were segmented into 0-4, 4-12, and 12-24 inches. The fresh samples were extracted for inorganic N, and the remaining soil was air dried, ground to pass a 2 mm sieve, and tested for pH, Mehlich 3 nutrients (including S), particle size distribution, soil C and N concentrations, and monocalcium phosphate S. The monocalcium phosphate extraction was completed in the Poffenbarger Lab and the extracts are awaiting analysis at Regulatory Services via the ICP method. For yield, we collected ears from two 10-foot lengths of row in each split-plot and measured their fresh weight. We then determined the moisture content and kernel fraction of a five-ear subsample from each split-plot, and used this information to convert the fresh weight of all ears to yield.

RESULTS AND DISCUSSION

The weather at the three sites in 2025 was characterized by a wet spring, which turned drier and slightly warmer in the latter part of the summer (Table 1).

Objective 1 - On-farm research

Considering total yields from the strips, we found a significant positive effect of sulfur addition on corn yield at both sites. The yield increased by 15 bu/acre with sulfur addition on average (Figure 1).

The SPAD, tissue sulfur concentrations (S%), and tissue nitrogen:sulfur (N:S) ratios collected at V6 and R1 responded to the sulfur treatments at both sites (Figure 2). The one exception was the N:S ratio measured in HC at the R1 stage, which did not show a significant change due to sulfur fertilization. We found that the critical levels of S% and N:S ratio reported by Camberato et al. (2023) effectively distinguished the no-sulfur control from the with-sulfur treatment at the V6 but not at the R1 stage (Figure 2).

In addition, the Mehlich 3 soil test levels increased in response to sulfur addition for the 0-4 and 4-12 inch samples. The response was significant for both depths at HC but only for the 4-12 inch depth at LC (Figure 3). The Mehlich 3 soil test levels generally fell below the critical soil test level reported by White et al. (2021).

We explored relationships between relative yield of corn and different plant and soil measurements taken from the sampling locations. With this limited dataset, the only variables to provide reasonable correlations (r > or < 0.30) were the V6 relative SPAD reading, V6 and R1 tissue S%, V6 and R1 tissue N:S ratio, and soil organic C% from 0-4 inches (Figures 4 and 5). Overall, results from the on-farm study suggest that sulfur fertilization can boost corn yields in central Kentucky, and that tissue measurements are moderately predictive of sulfur deficiency.

Objective 2 – Crop rotation study

In the crop rotation study, we did not detect a significant effect of sulfur fertilization on corn yield. Corn yield increased with nitrogen rate, with different responses depending on crop rotation. In particular, corn following corn (either in continuous corn or the second corn year in the corn-corn-soybean-soybean rotation) showed a linear response to nitrogen rate. In contrast, corn following soybean (either the first corn year in the corn-corn-soybean-soybean rotation or in the corn-wheat/double crop soybean rotation) showed a curvilinear response with an optimum between 150 and 200 lb N/acre. Crop rotation treatment did not affect corn yields except in the 80 lb N/acre treatment, which displayed higher yields for rotations in which corn followed soybean than those in which corn followed corn. There were no effects of crop rotation treatment on Mehlich 3 sulfur concentration, though we did note a depth effect, with the 4-12 inch depth showing less sulfur than the shallower and deeper depths.

We speculate that the lack of response to sulfur addition in the crop rotation study was due to the previous inputs of gypsum at the site in 2023 and 2024, which led to elevated sulfur concentrations at 12-24 inches in the spring of 2025.

ACKNOWLEDGEMENTS

We gratefully acknowledge the support of the Kentucky Corn Growers. We also thank our farmer collaborators, Laura Harris, Thomas Brigato, Thales Goes Prudenciano de Souza, Gustavo Herrera Rufatto, Gabriel Ponce, Riley McLaughlin, and Franklin Morales for their help with study implementation and data collection. We appreciate the analytical support of Emily Dorward and University of Kentucky Regulatory Services, and especially Solomon Kariuki and TJ Evans. We also thank John Grove and Edwin Ritchey for their help developing the protocols.

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TABLES

Table 1. Average weather conditions for the growing season, divided into two phases, for the three study locations.

Site	Average daily temp (°F)	Average daily low temp (°F)	Average daily high temp (°F)	Rainfall (inches)
	May 1 – July 15, 2025			
Hardin County	71.12	62.67†	80.97†	11.86
LaRue County	68.67	60.80	77.65	11.24
Rotation Study	70.22	61.41	79.53	16.37
	July 16 – Sept 30, 2025			
Hardin County	71.62	62.39	84.78	9.18
LaRue County	71.69	58.84	86.95	5.37
Rotation Study	72.78	62.04	84.27	7.55

†Daily low and high temperatures were derived from the Hardin County Mesonet station. All other data were derived from weather stations located next to the fields (Hardin County and LaRue County) or on the farm (Rotation Study).

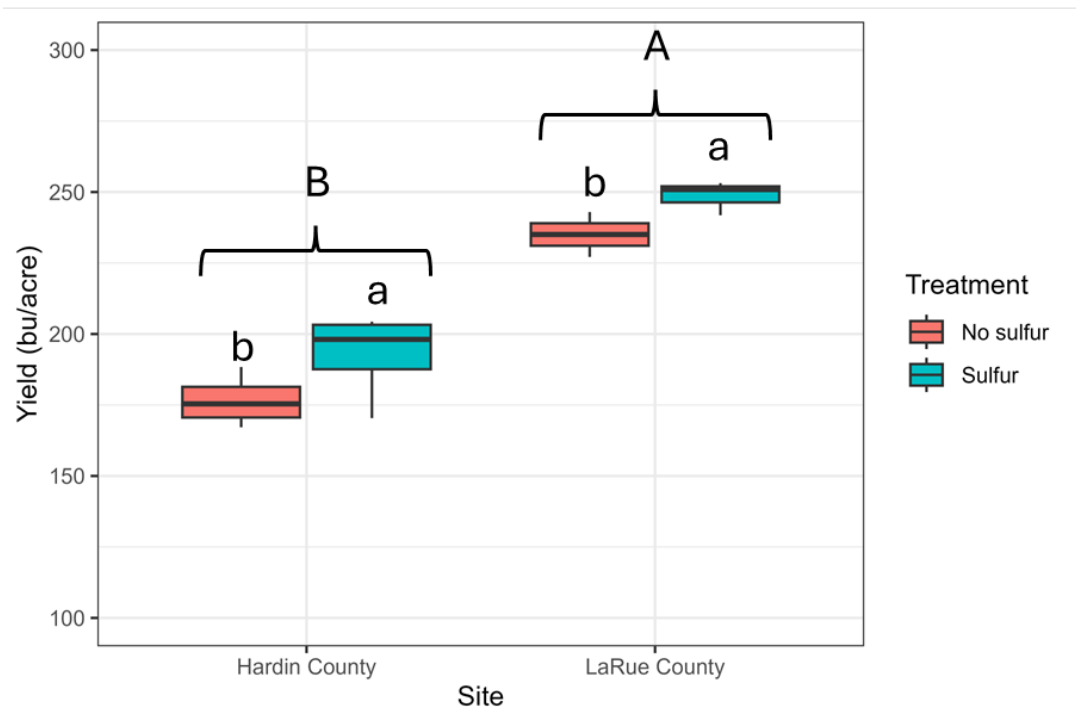

Figure 1. Corn yields in response to sulfur treatments at each on-farm site. Significant differences between treatments within each site are indicated by different lowercase letters, while significant differences between sites are indicated by different uppercase letters (p<0.05).

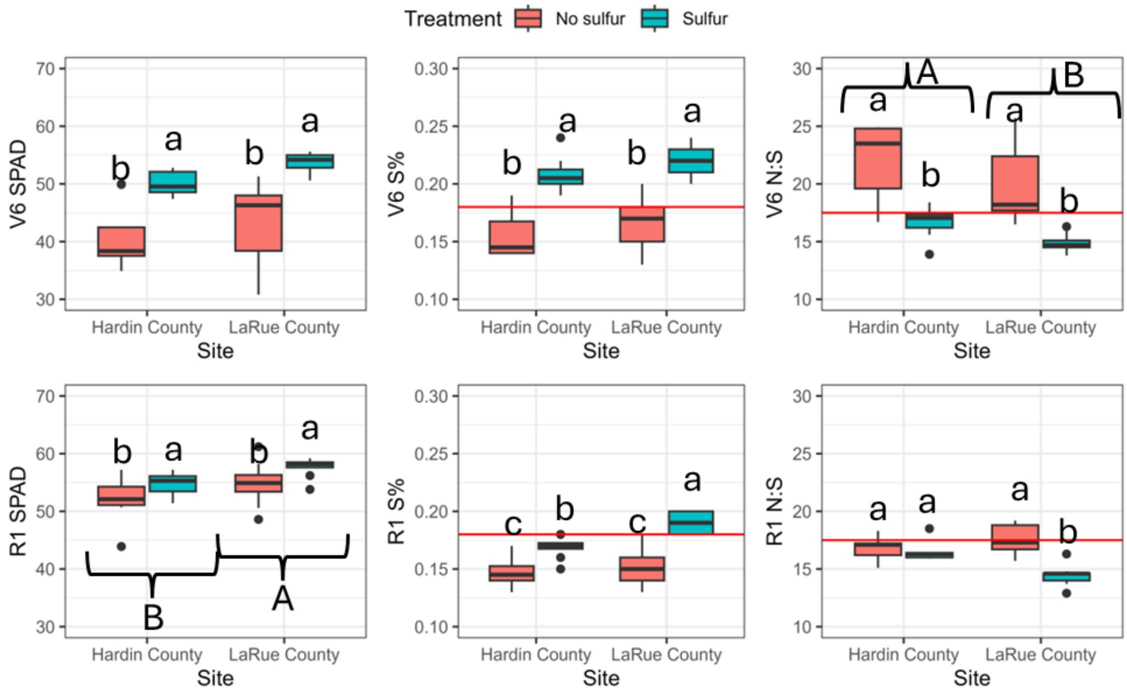

Figure 2. Indicators of sulfur deficiency measured on plants at the six-leaf stage (V6) and silking stage (R1) within experimental strips at Hardin County and LaRue County. Red lines indicate the critical levels based on research by Camberato et al. (2023). Differences between sulfur treatments are indicated by different lowercase letters, while differences between sites are indicated by different uppercase letters ($p<0.05$).

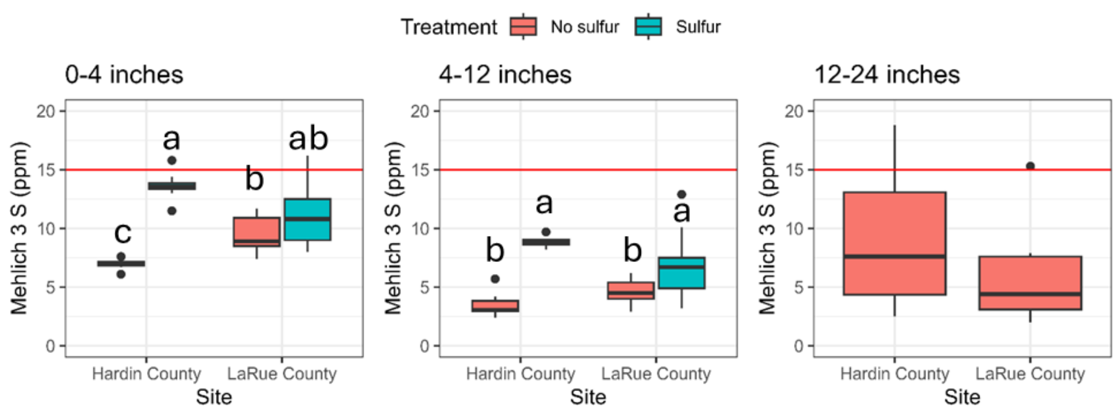

Figure 3. Mehlich 3 sulfur concentrations by treatment at each site for three depth increments. The red line indicates the critical soil test level based on research by White et al. (2021), since critical soil test levels have not been established for sulfur in Kentucky. Different lowercase letters indicate significant differences between the sulfur treatments ($p<0.05$). We did not measure Mehlich 3 sulfur in the sulfur-fertilized treatment at the deepest depth.

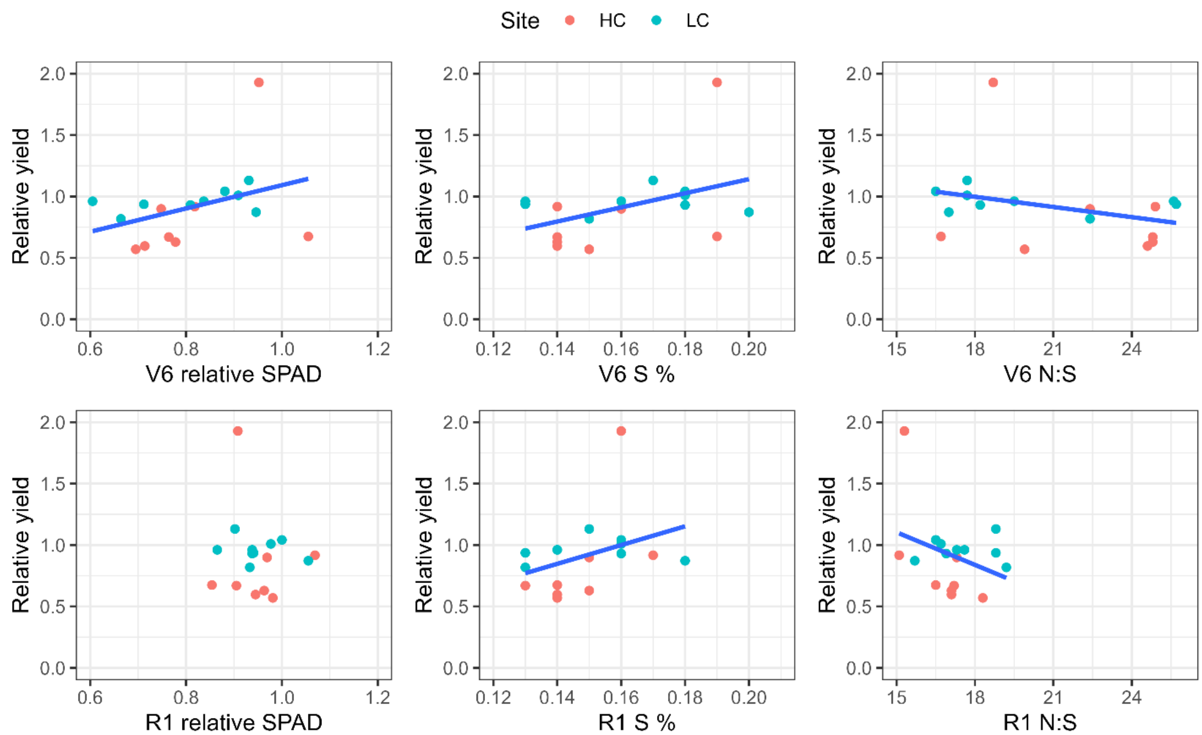

Figure 4. Relationships between plant tissue measurements taken in the no-sulfur strips at the six-leaf stage (V6) and silking stage (R1) and relative yield of corn at the Hardin County (HC) and LaRue County (LC) sites. Relative yield and relative SPAD readings were calculated as the ratio of the yield or SPAD reading in the strip with no sulfur to that in the corresponding strip with sulfur. Trend lines are shown for correlation coefficients greater than or less than 0.30.

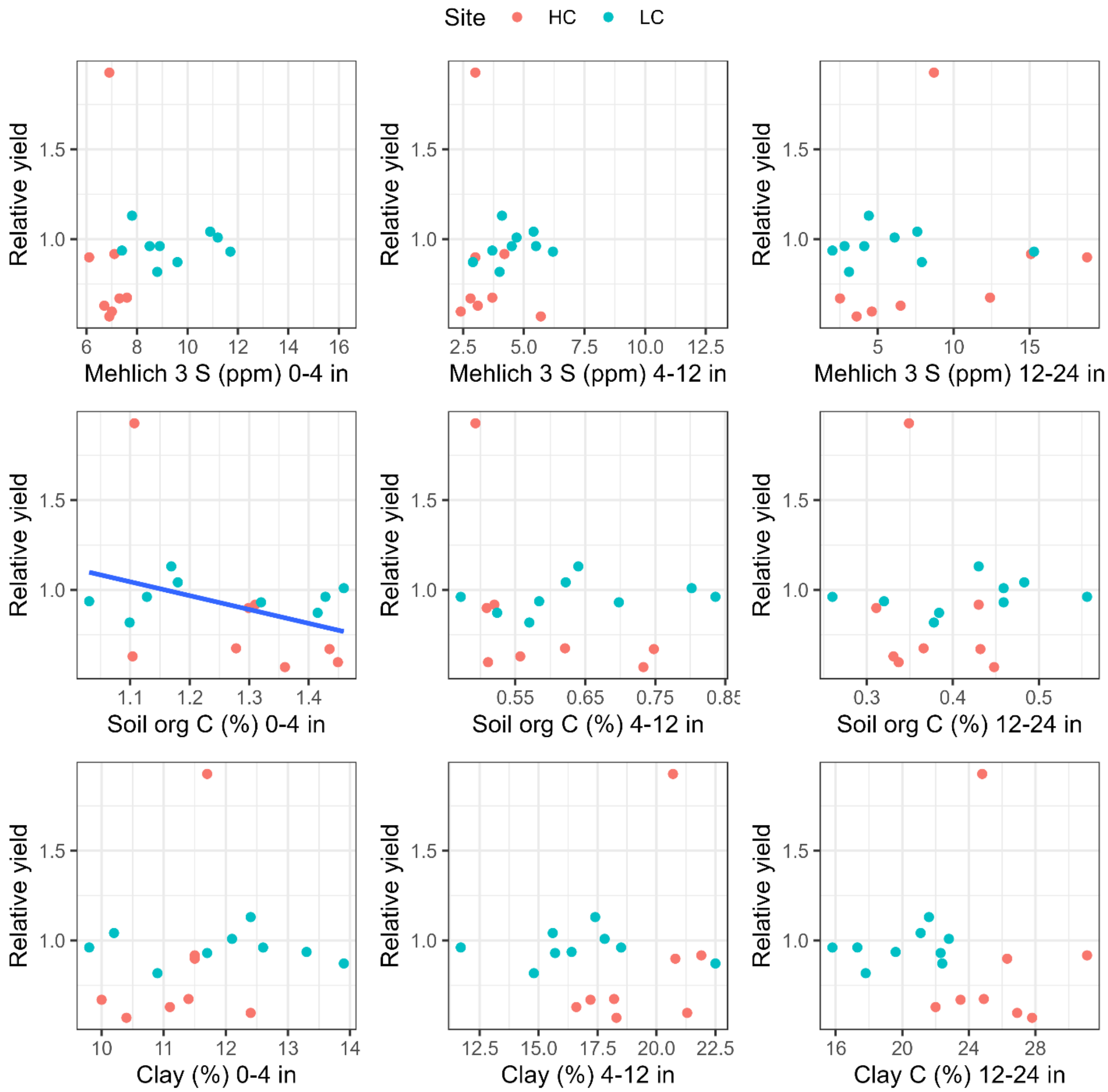

Figure 5. Relationships between soil measurements taken in the no-sulfur strips at corn emergence and relative yield of corn at the Hardin County (HC) and LaRue County (LC) sites. The relative yield of corn was calculated as the ratio of yield in the strip with no sulfur to the yield in the corresponding strip with sulfur. Trend lines are shown for correlation coefficients greater than or less than 0.30.

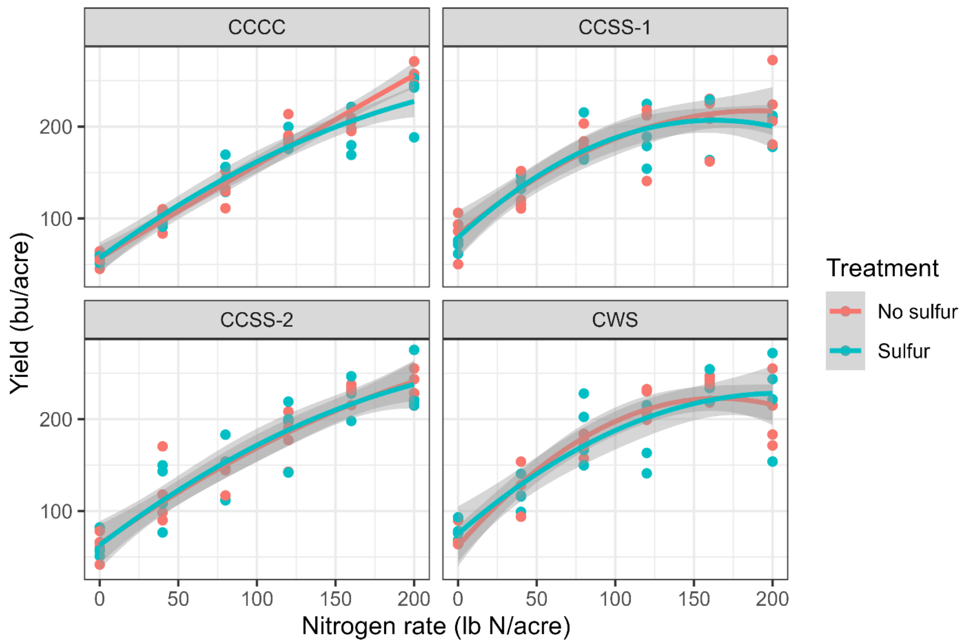

Figure 6. Corn yield in response to N fertilizer rate for two sulfur treatments within four crop rotations. CCCC = continuous corn; CCSS-1 = corn following soybean in corn-corn-soybean-soybean rotation; CCSS-2 = corn following corn in corn-corn-soybean-soybean rotation; CWS = corn-wheat/double crop soybean.

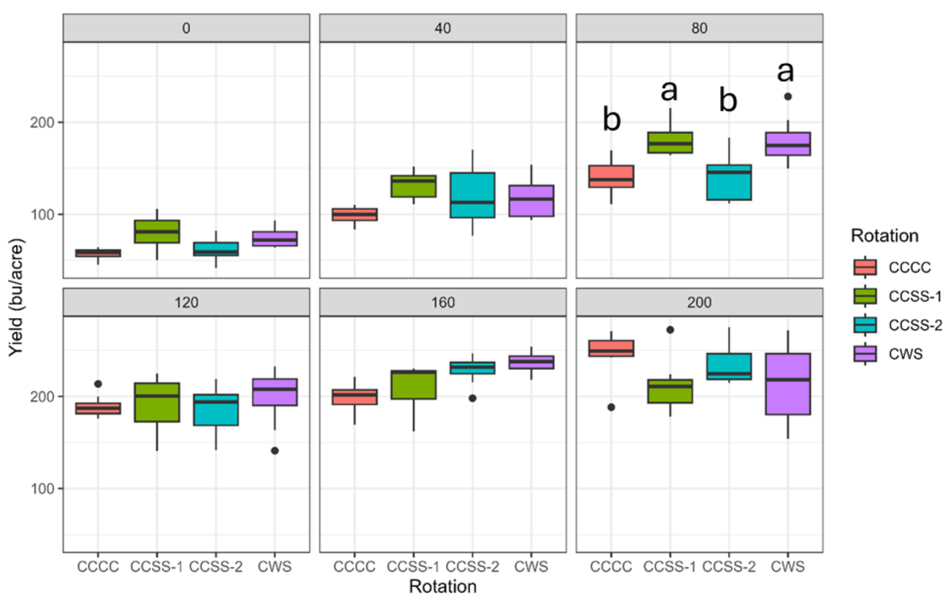

Figure 7. Corn yield in response to crop rotation treatment at six different nitrogen rates (0, 40, 80, 120, 160, 200 lb N/acre). CCCC = continuous corn; CCSS-1 = corn following soybean in corn-corn-soybean-soybean rotation; CCSS-2 = corn following corn in corn-corn-soybean-soybean rotation; CWS = corn-wheat/double crop soybean. Differences between rotation treatments within the 80 lb N/acre rate are indicated by different lowercase letters ($p<0.05$).

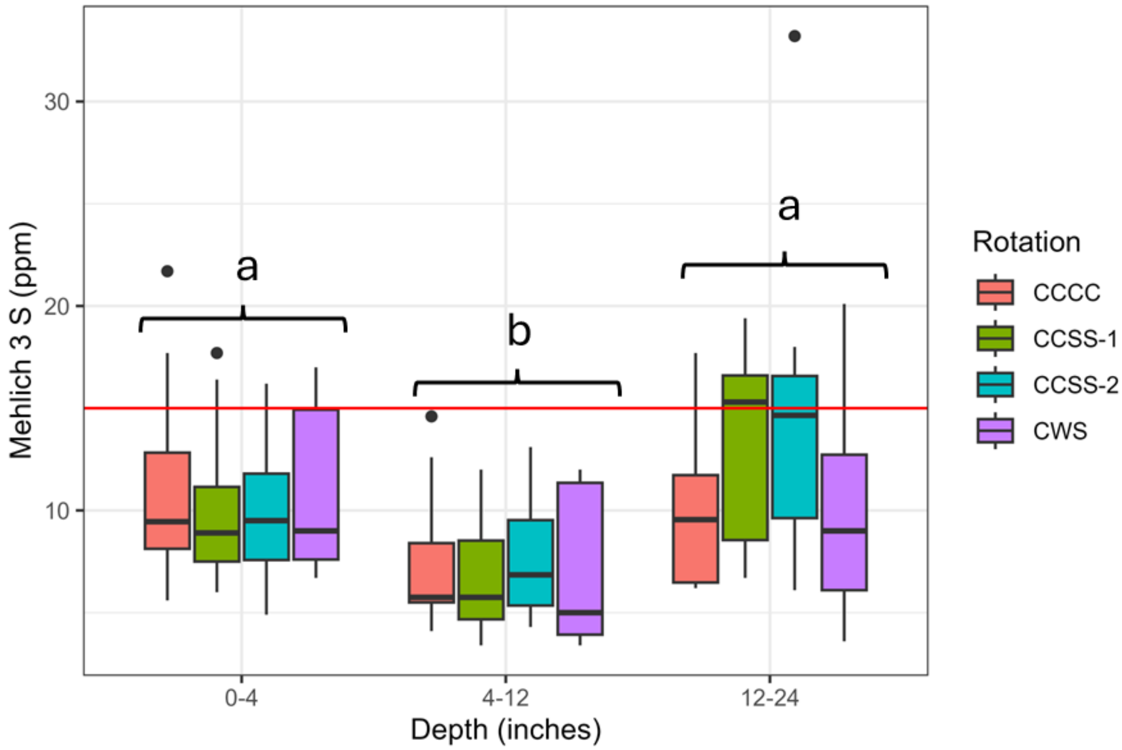

Figure 8. Mehlich 3 sulfur concentrations by depth for four crop rotation treatments. CCCC = continuous corn; CCSS-1 = corn following soybean in corn-corn-soybean-soybean rotation; CCSS-2 = corn following corn in corn-corn-soybean-soybean rotation; CWS = corn-wheat/double crop soybean. The red line indicates the critical soil test level based on research by White et al. (2021), since critical soil test levels have not been established for sulfur in Kentucky. Differences between depths are indicated by different lowercase letters ($p<0.05$).

Split/Delayed N: How Late and Still Maintain Maximum Yield Potential?

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INTRODUCTION/OBJECTIVE

Over 75% of the years in the past decade have seen wet weather between corn planting and when the crop reaches tasseling. These conditions can especially complicate corn nitrogen (N) application. Producers who intend to split/delay corn N will apply between 0 and 50 lb N/acre at planting, but logistics and the need for timely establishment have caused many to keep the early N application to a minimum. UK has long recommended split/delayed corn N application assuming this is done between “4 to 6 weeks after planting” but makes no recommendation or comment regarding the time at which the split/delayed N must be there by to avoid loss of maximum yield potential. The objective of the proposed research is to fill in this knowledge gap for Kentucky corn producers – to pinpoint when that later split/delayed N application needs to be made to maximize yield.

METHODS & MATERIALS

The 2025 sites (5) were planted within a 4-week period to a single corn hybrid (Table 1). Soil drainage ranged from well-drained to moderately well-drained. All sites were after soybean or wheat/double crop soybean. Pre-plant tillage was done at two sites. Our ‘core’ treatments were a factorial combination of two at-planting N rates (0 and 50 lb N/acre) and three growth stages (V3-V4, V6-V7 and V9-V10) for the remainder of the corn N (to total 150 lb N/acre). These six treatments were complemented by 0 lb N/acre check and 150 lb N/acre at-planting treatments. Four treatments; 50, 100, 200 and 250 lb N/acre at V6, were added for an N rate response. Soil samples were taken early to assess soil organic matter/early N status. Ear leaf tissue was taken at silking. Grain yield and moisture were found. Harvested kernel weight and kernel number/ft^2 were determined at N responsive locations (selected based on the ear leaf N response) to determine if there was N stress on photosynthesis during grain filling.

RESULTS & DISCUSSION

Among the core 8 treatments, treatment average grain yields ranged from 130 to 250 bu/acre and responded to N application at 4 of the 5 sites – site 5 was not responsive to the N treatments (Table 2). The yield response pattern was supported by leaf N data (not shown), where site 5 exhibited little leaf N increase with any applied N treatment. Sites 1 and 2 were similar in their grain yield response to the N treatments. It did not matter whether the 150 lb N/ acre was all applied at a single time or split between at-planting and another timing, nor a particular timing matter – all yields were statistically equal. Fertilizer N timing played a role in the yield responses observed at sites 3 and 4. At site 3, all treatments where a portion of the fertilizer N was applied at-planting (AP; treatments 5, 6, 7 and 8) gave superior yields to all treatments where no fertilizer N was applied at-planting. Site 4 grain yield exhibited a different timing preference – yields tended to be greatest when the bulk of the fertilizer N was all applied AP (treatment 8) or mostly applied at V9 (treatments 6 and 7) or V3 (treatments 2 and 5) and least when the bulk of the fertilizer N was applied at V6 (treatments 3 and 6).

Generally speaking, both yield components, kernel size (Figure 1) and kernel number (Figure 2), increased with increasing grain yield for the four locations (Sites 1 through 4) where kernel size and number were determined/calculated. Kernel size accounted for less of the yield increase (lower R^2 value) than kernel number. These results include the additional 4 treatments (no pre-plant N, but 50, 100, 200 and 250 lb N/acre applied at V6).

CONCLUSION

This season gave us a number of different responses to delayed N timing, from no response at all to significant yield response to N timing (V9 and V3 preferred over V6). We need at least another year, at multiple locations, to better appreciate these differences and possible reasons (soil N supply/site specific weather) for those responses. More producers are using split/delayed N applications and the need for more information to better guide that N management remains.

ACKNOWLEDGEMENTS

The authors are grateful for support from the Kentucky Corn Growers Association.

TABLES

Table 1. Site Information

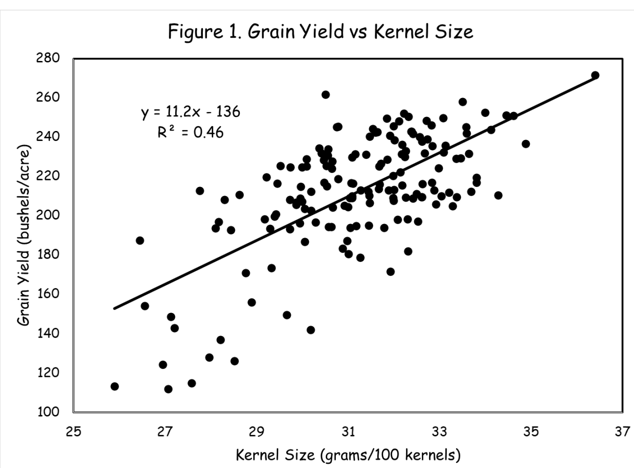
Site Number	County – Soil Series	Corn Hybrid	Planting Date
1	Christian – Pembroke	DeKalb C65-95	16 April
2	Robertson – Dickson	DeKalb C65-95	23 April
3	Caldwell – Crider	DeKalb C65-95	24 April
4	Warren – Pembroke	DeKalb C65-95	29 April
5	Nelson – Elk	DeKalb C65-95	10 May

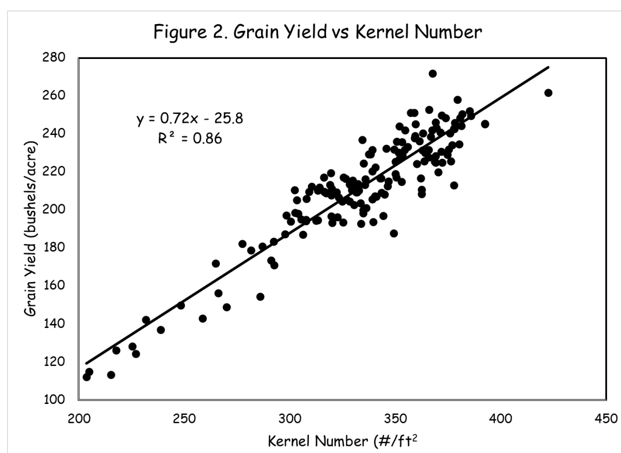
Table 2. Grain Yield Response to the Treatments – By Trial Site

Tmt* #	AP N	V3 N	V6 N	V9 N	Total N	Site 1	Site 2	Site 3	Site 4	Site 5
	---------- lb N/acre ----------					------------- bushels/acre -------------				
1	0	0	0	0	0	129b[†]	187b	132d	137c	211a
2	0	150	0	0	150	223a	239a	206c	210ab	207a
5	50	100	0	0	150	212a	244a	229ab	216a	188a
3	0	0	150	0	150	212a	237a	209c	200b	204a
6	50	0	100	0	150	216a	232a	233a	207ab	204a
4	0	0	0	150	150	212a	236a	212bc	213ab	208a
7	50	0	0	100	150	215a	236a	232a	215ab	202a
8	150	0	0	0	0	214a	247a	230ab	217a	203a
			Site Average Yield			204	232	210	202	203

*Treatments not in numerical order – are grouped by delayed N timing.

[†]For any site, treatment yield values followed by the same letter are not significantly different at the 90% level of confidence.





Effect of Cover Crop Management on Nutrient Availability in No-Till Corn

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Dr. Chad Lee, Department of Plant and Soil Science, University of Kentucky, Lexington

INTRODUCTION

Cover crops are needed following soybean harvest to prevent erosion that occurs over the winter. Corn following these cover crops can require more nitrogen and sometimes yield less. Barley produces less aboveground biomass than other comparable cereal grains, while still providing erosion protection (Nalley, 2024). The addition of a legume, like Austrian Winter Pea, is thought to reduce the competition for nitrogen between the cover and corn crops. Early termination of cover crops, 5 weeks before planting as compared to the standard timing of 2 weeks prior to corn planting, has the potential to further reduce this competition for nitrogen due to a lower amount of aboveground biomass present. The objectives for this study are to determine if barley mixed with a legume, as well as if early termination of cover crops will result in less nitrogen competition and/or yield depression.

METHODS & MATERIALS

This study was at the University of Kentucky's North Farm in Lexington, KY and at a private farm in Glendale, KY for both the 2024 and 2025 growing seasons, resulting in four site-years: LEX24, GLN24, LEX25, and GLN25. The focus of this report will be on the 2025 growing season. Treatments, outlined in Table 1, were arranged in a split-split-plot randomized complete block design where the main plot is cover crop, sub plot is cover crop termination timing, and the sub-sub plot is nitrogen rate, with four replications in Lexington and three replications in Glendale. Cover crops were terminated with 40 oz/ac of glyphosate (trade name Roundup WeatherMax). Urea ammonium nitrate (32% UAN) was surface applied at planting at 40 lb N/acre. The remaining nitrogen was applied side dress at V3. Drip irrigation and soil moisture sensors were installed in Lexington both years to limit water as a limiting factor. All plots were managed so that weeds, insects, and diseases did not adversely affect yield.

Cover crop biomass samples were taken from a 1 m^2 area from each cover crop replication and analyzed for biomass and nutrient composition. Soil Plant Analysis Development (SPAD) readings were taken at both the V10 and R1 growth stages as an estimation of chlorophyll and nitrogen content in the leaves. Soil samples were taken after V10 in 2024 and pre-plant in 2025 for analysis of nitrate and ammonium in the soil. Ear leaves were collected at R1 for nutrient analysis. Grain yield, kernel weight, and kernel number were determined after harvest.

Statistical analysis was conducted in R version 4.4.3 at a significance level of p=0.1. All site years were evaluated independently.

RESULTS & DISCUSSION

Cover Crop

Biomass was significantly lower for the 2025 season at both locations, due to harsher winter conditions limiting aboveground growth (Figure 1). Dry biomass was significantly lowered across all site years when terminated early at 5 weeks before corn planting, except for GLN25. Cover crop biomass was not significantly different for LEX25 while the weedy fallow had the most biomass at GLN25. Biomass samples were only separated by species in 2025. At both locations, barley and winter annual weeds outcompeted the winter peas, potentially reducing their ability to fix a measurable amount of nitrogen.

Corn

Corn yields were below expected yields at both locations in 2025, with yields of only about 130 and 180 bu/acre for adequately fertilized plots at GLN25 and LEX25, respectively. Even though irrigation was available at LEX25, an adequate amount of irrigation was not applied based on these yields.

Differences in corn grain yield due to cover crop type were only observed at Glendale. Corn following barley yielded significantly higher than corn following either the mixture or control (data not shown) at GLN24. At GLN25 the reverse was observed, with corn following barley yielding significantly lower than corn following the fallow. Corn grain yield was not affected by termination timing at Glendale either year.

Corn grain yield was significantly different due to nitrogen rate across all site years, except for LEX24 (data not shown). Corn at LEX25 yielded highest with 349 lb N/acre, while corn yields following 215 and 260 lb N/acre were not significantly different from the highest yields (Table 4). Corn at GLN25 reached a maximum yield at 170 lb N/acre and similar yields for higher nitrogen rates (Table 5).

CONCLUSION

Cover crop termination timing had a significant impact on aboveground biomass accumulation. However, those differences did not translate to differences in nitrogen availability in the plant or corn grain yield. The low biomass yields of cover crops combined with the high amount of rainfall between termination and corn planting might explain some of the observations. Cover crop residue at corn planting was minimal compared to previous years. Cover crop type effect on grain yield was variable between site years. Optimum nitrogen rate also varied between site years. For 2025, nitrogen rates needed to be at least 170 and 215 lb N/acre for GLN25 and LEX25, respectively.

ACKNOWLEDGEMENTS

We would like to thank the Kentucky Corn Promotion Council for funding this research. We thank technicians Joseph Bush and Celeste Nye, as well as fellow graduate student Allie

Mutter for their help with data collection and field management. Also, the USDA Hatch program partially funded some of this research.

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TABLES

Table 1. Treatment Table

Treatments	
Cover Crop	Barley
	Barley+ Austrian Winter Pea (Mix)
	Fallow Control
Termination	5 weeks before corn planting
	2 weeks before corn planting
Fertilization Rate	40 lb N/acre
	170 lb N/acre
	216 lb N/acre
	260 lb N/acre
	349 lb N/acre

Figure 1. Cover crop biomass by site-year

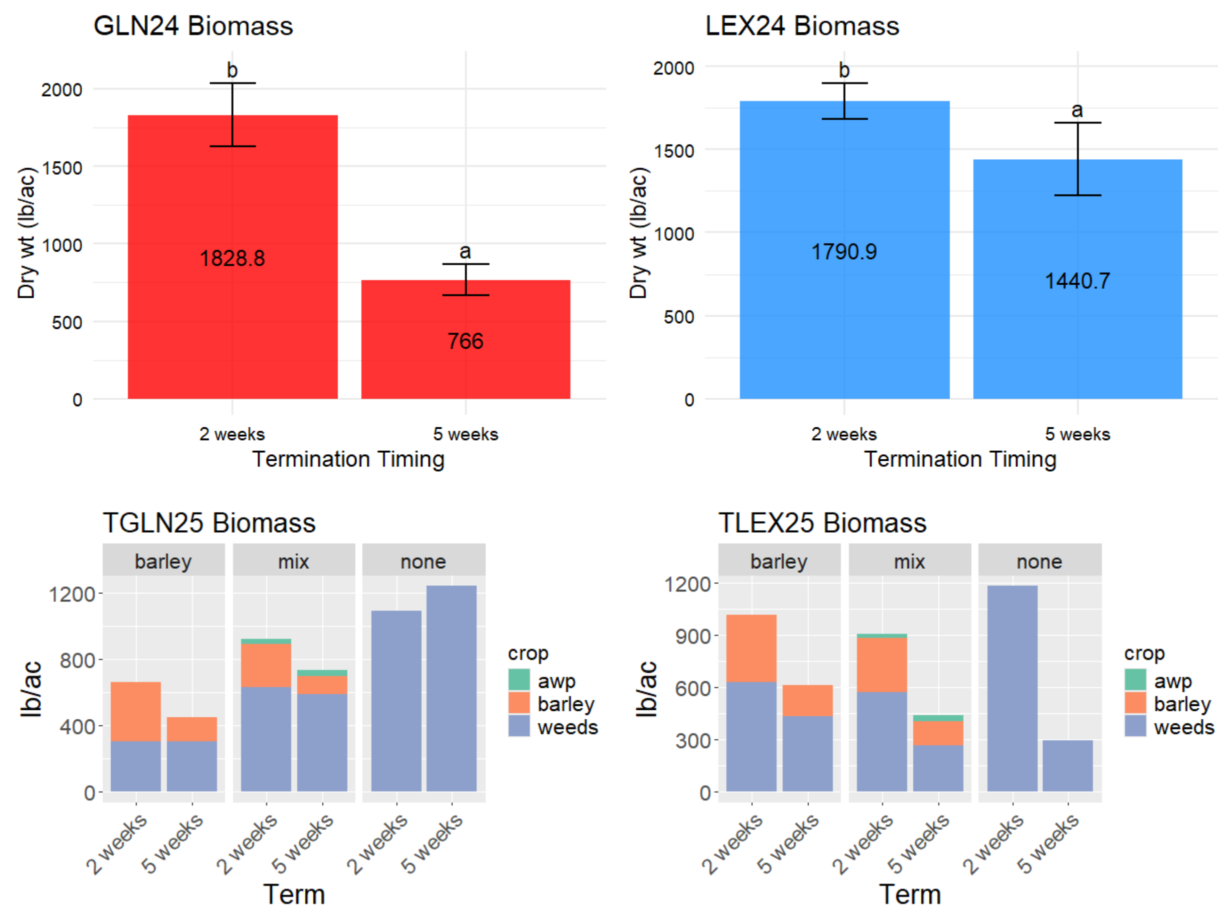

Table 2. LEX25 cover crop biomass

LEX25													
Treatment	**Biomass (lb/ac)**		**N (%)**		**S (%)**		**C(%)**		**C:N**		**N:S**		
Cover Crop													
Barley	816	a	1.59	a	0.142	a	27.8	a	17.7	a	11.18	a	
Mix	673	a	1.95	a	0.182	a	32.1	a	16.9	a	10.89	a	
None	739	a	1.73	a	0.21	a	27.7	a	16.5	a	8.97	a	
Termination													
Early	462	a	1.88	a	0.197	a	26.8	a	14.7	a	10.3	a	
Standard	1051	b	1.63	a	0.159	a	31.5	a	19.4	b	10.4	a	

Table 3. GLN25 cover crop biomass

GLN25													
Treatment	**Biomass (lb/ac)**		**N (%)**		**S (%)**		**C(%)**		**C:N**		**N:S**	
Cover Crop													
Barley	557	a	1.75	c	0.14	c	34.7	b	20.3	a	12.5	a
Mix	830	b	1.41	b	0.113	b	28.3	a	19.9	a	12.6	a
None	1168	c	1.09	a	0.085	a	27.3	a	25	b	13	a
Termination													
Early	810	a	1.45	a	0.108	a	26.4	a	19	a	13.5	b
Standard	894	a	1.39	a	0.118	a	33.7	b	24	b	11.9	a

Table 4. LEX25 in-season nitrogen and yield

LEX25								
Treatment	**Ear Leaf N(%)**		**V10 SPAD Chlorophyll**		**R1 SPAD Chlorophyll**		**Yield (bu/ac)**	
Cover Crop								
Barley	2.55	b	54.5	b	57.1	b	174	a
Mix	2.51	b	54	b	57	ab	182	a
None	2.39	a	52.1	a	55.4	a	173	a
Termination								
Early	2.46	a	53.6	a	56.5	a	176	a
Standard	2.51	a	53.5	a	56.5	a	177	a
Nitrogen Rate								
40	2.11	a	48.1	a	47.7	a	159	a
170	2.52	b	55.7	b	58.8	b	171	ab
215	2.57	b	54.8	b	58.9	b	180	bc
260	2.65	b	54.4	b	59.4	b	180	bc
349	2.57	b	54.8	b	57.9	b	192	c

Table 5. GLN25 in-season nitrogen and yield

GLN25									
Treatment	**Ear Leaf N(%)**		**V10 SPAD Chlorophyll**		**R1 SPAD Chlorophyll**		**Yield (bu/ac)**	
Cover Crop								
Barley	2.21	a	46.3	a	52.1	a	113	a
Mix	2.26	a	46.6	a	52.2	a	114	ab
None	2.17	a	46.9	a	52.8	a	122	b
Termination								
Early	2.18	a	46.7	a	52.3	a	115	a
Standard	2.26	a	46.5	a	52.4	a	118	a
Nitrogen Rate								
40	2.19	ab	37.6	a	38.8	a	69.7	a
170	2.26	ab	49	b	55.8	bc	128.6	b
215	2.05	a	48.6	b	54.5	b	123.7	b
260	2.24	ab	48.7	b	55.7	bc	131.9	b
349	2.34	b	49	b	57.1	c	128.9	b

Cover Crops and Sulfur Corn Yield

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Dr. Chad Lee, Department of Plant and Soil Science, University of Kentucky, Lexington

INTRODUCTION

Sulfur is classified as the fourth most important nutrient after nitrogen, phosphorus, and potassium (Aula et al., 2019). Sulfur deficiency in agricultural crops is becoming more common as the rate of sulfur deposition has declined over the past 20 years (Sharma et al., 2024). An application of sulfur has been shown to have the potential to increase corn yield in certain cases. However, there is limited research available on the demand of sulfur in a cover crop and how that affects availability of sulfur in the following corn crop. The objective of this study is to evaluate the effect of cover crop management on nitrogen and sulfur dynamics in no-till corn.

METHODS & MATERIALS

This study was at the University of Kentucky's North Farm in Lexington, KY and at a private farm in Glendale, KY for both the 2024 and 2025 growing seasons, resulting in four site-years: LEX24, GLN24, LEX25, and GLN25. The focus of this report will be on the 2025 growing season. Treatments, outlined in Table 1, were arranged in a split-split-plot randomized complete block design where the main plot is cover crop, sub plot is nitrogen fertilizer, and the sub-sub plot is sulfur fertilizer, with four replications. Cover crops were terminated with 40 oz/ac of glyphosate (trade name Roundup WeatherMax) five weeks before corn planting. Urea ammonium nitrate (32% UAN) was surface applied at planting at 40 lb N/acre. The remaining nitrogen was applied side dress at V3 growth stage. Sulfur, as gypsum (0-0-0-16), was applied by hand at or closely after planting. Drip irrigation and soil moisture sensors were installed in Lexington both years to limit water as a limiting factor. All plots were managed so that weeds, insects, and diseases did not adversely affect yield.

Soil Plant Analysis Development (SPAD) readings were taken at both the V10 and R1 stages as an estimation of chlorophyll and nitrogen. Ear leaves were collected at R1 for nutrient analysis. Grain yield, kernel weight, and kernel number were determined after harvest.

Statistical analysis was conducted in R version 4.4.3 at a significance level of p=0.1. All Site years were evaluated independently.

RESULTS & DISCUSSION

Chlorophyll content in the leaves increased between V10 and R1, but there was no difference due to the previous cover crop or its termination timing (Table 2). Sulfur did not affect grain yields at either location in 2025 (Table 3). Sulfur increased grain yields in 2024 at Glendale (data not shown). So over the four site-years, sulfur increased corn yields in only one site-year. Sulfur in the ear leaves was significantly higher in corn following barley at

GLN25 (Table 3). Ear leaf sulfur and nitrogen were mildly associated for 2025 (Figures 1 and 2), suggesting that as sulfur content increased, nitrogen content increased, also.

CONCLUSION

Sulfur increased grain yields in one of four site-years total and no sites in 2025. Sulfur increased ear leaf sulfur content at GLN25. The lack of rain during grain-filling stages of corn may have influenced the results for 2025.

ACKNOWLEDGEMENTS

We would like to thank the Kentucky Corn Promotion Council for funding this research. We thank technicians Joseph Bush and Celeste Nye, as well as fellow graduate student Allie Mutter for their help with data collection and field management. Also, the USDA Hatch program partially funded some of this research.

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TABLES AND FIGURES

Table 1. Treatments

Treatments	
Cover Crop	Barley Barley+ Austrian Winter Pea (Mix) Fallow Control (no cover crop)
Nitrogen Rate	130 lb N/acre 220 lb N/acre
Sulfur Rate	0 lb S/acre 30 lb S/acre

Table 2. LEX25 in-season nutrient content and yield

LEX25										
Treatment	**V10 SPAD Chlorophyll**		**R1 SPAD Chlorophyll**		**Ear Leaf N (%)**		**Ear Leaf S (%)**		**Yield (bu/ac)**	
Cover Crop										
Barley	55.0	a	59.7	a	2.27	a	0.163	a	180	a
Mix	55.0	a	59.4	a	2.44	ab	0.163	a	175	a
None	54.5	a	58.0	a	2.51	b	0.165	a	167	a
Sulfur										
0	55.2	a	59.2	a	2.43	a	0.161	a	175	a
30	54.4	a	58.9	a	2.38	a	0.166	a	174	a
Nitrogen										
130	54.6	a	58.3	a	2.33	a	0.161	a	175	a
220	55.1	a	59.8	b	2.48	b	0.166	b	173	a

Table 3. GLN25 in-season nutrient content and yield

GLN25										
Treatment	**V10 SPAD Chlorophyll**		**R1 SPAD Chlorophyll**		**Ear Leaf N (%)**		**Ear Leaf S (%)**		**Yield (bu/ac)**	
Cover Crop										
Barley	47.4	a	53	a	2.41	b	0.162	b	113	a
Mix	46.9	a	50.8	a	2.06	a	0.145	a	110	a
None	48.2	a	52.8	a	2.19	ab	0.149	a	117	a
Sulfur										
0	47.1	a	52.3	a	2.21	a	0.146	a	111	a
30	47.9	a	52.1	a	2.23	a	0.158	b	116	a
Nitrogen										
130	46.6	a	51.1	a	2.11	a	0.145	a	108	a
220	48.4	b	53.3	b	2.33	b	0.159	b	119	b

Figure 1. Ear Leaf Nitrogen and Sulfur at LEX25

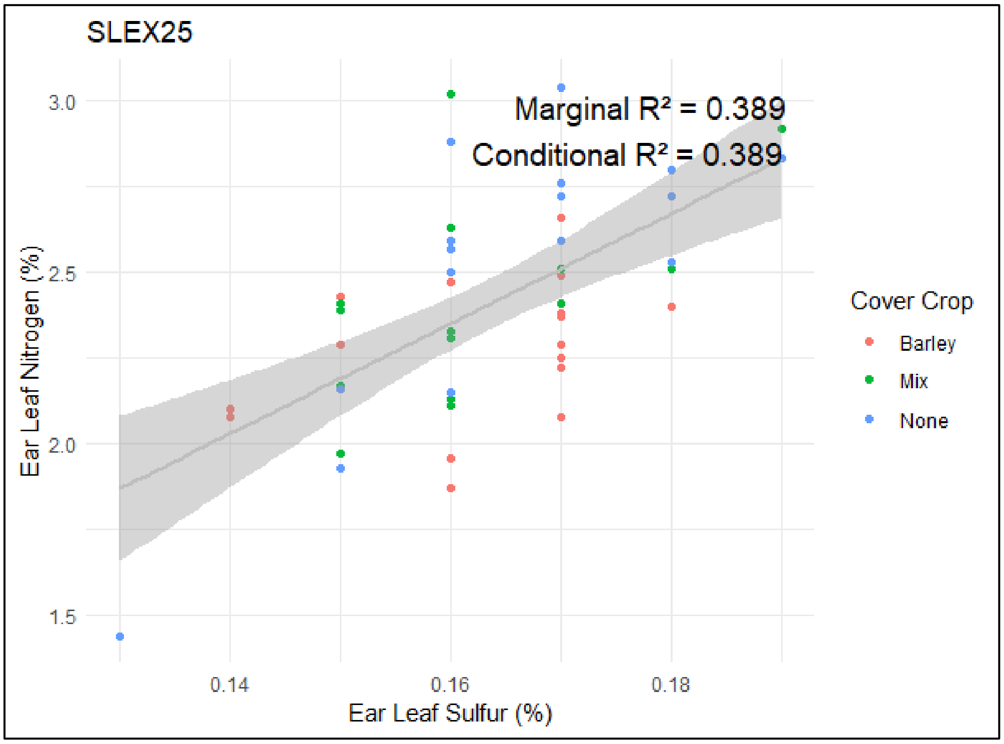

Figure 2. Ear Leaf Nitrogen and Sulfur at GLN25