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Grain and Forage Center of Excellence

CORN SCIENCE RESEARCH REPORT 2019

UNIVERSITY OF KENTUCKY

2019 CORN RESEARCH REPORT

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Successfully Establishing Corn in Cover Crops: Year 2

2019 Research Report to the Kentucky Corn Promotion Council

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KEY POINTS

- This study suggests farmers do not need a corn seeding rate adjustment when following a rye cover crop or including an in-furrow starter to maximize corn yield.
- This study suggests a split application of N can lower the amount of N required by corn to maximize yield following rye.
- Despite significant early-season corn stress and higher levels of corn seedling disease observed following rye, the in-furrow fertilizer, fungicide, or combination did not improve corn yield at any location.

INTRODUCTION

Kentucky corn growers continue to show interest in incorporating a cereal rye cover crop to limit soil erosion, nutrient leaching and runoff, reduce resistant weed populations, and improve soil organic matter and water retention. However, despite observed benefits, many growers are concerned about the potential for reduced corn grain yield losses following a rye cover crop caused by stand loss, corn N stress, and disease incidence, suggesting optimal corn management may need to be adjusted when following a rye cover crop to avoid potential yield losses.

OBJECTIVE

Study 1: Evaluate the effect of a rye cover crop system on corn optimal seeding rate and response to an in-furrow starter combination containing fertilizer (10-34-0 N-P-K) and fungicide (pyraclostrobin + *Bacillus amyloliquefaciens*; Xanthion).

Study 2: Evaluate the effect of a rye cover crop system on corn optimal N fertilizer rate and timing.

Study 3: Evaluate the effect of rye cover crop termination timing, in-furrow fertilizer, in-furrow fungicide, and in-furrow + fungicide on corn emergence, seedling disease, and grain yield.

METHODS AND PROCEDURES

Study 1: Winter rye cover crop 'Aroostook' was fall seeded at 60 lbs. seed per acre. Rye was terminated 14-21 days prior to planting of white corn hybrid 'P1618WAM' (116-d). Individual plots measured 10 ft. x 30 ft. and included 3 factors.

1. Factor 1 compared rye cover crop no cover crop.
2. Factor 2 compared corn seeding rates (20,000, 26,000, 32,000, 38,000, and 44,000 seeds per acre).
3. Factor 3 compared in-furrow starter combination of fertilizer (10-34-0 N-P-K) and fungicide (pyraclostrobin + *Bacillus amyloliquefaciens*; Xanthion) to no in-furrow starter.

Study 2: Winter rye cover crop 'Aroostook' was fall seeded at a rate of 60 lbs. of seed per acre. Rye was terminated 14-21 days prior to planting of white corn hybrid 'P1618WAM' (116-d). Individual plots measured 10 ft. x 30 ft. and included 3 factors:

1. Factor 1 compared plots with rye cover crop to plots without a rye cover crop.
2. Factor 2 was N timing which involved 30 lbs N per acre fertilizer applied in a 2x2 starter at plating (32-0-0 UAN) and remaining N surface-banded either 1 day prior to planting (Pre-plant) or sidedress (V6 growth stage) (Split).
3. Factor 3 compared N fertilizer rates of (0, 30, 90, 150, 210, and 270 lbs. N per acre).

Study 3: Winter rye cover crop 'Aroostook' was fall seeded at a rate of 60 lbs. of seed per acre. and white corn hybrid 'P1618WAM' (116-d) was planted following specific rye terimination timings. Individual plots measured 10 ft. x 30 ft. and included 2 factors:

1. Factor 1 compared two rye cover crop termination timings (14-21 days prior to corn planting and 1 day following corn planting).
2. Factor 2 compared in-furrow starter fertilizer (10-34-0 N-P-K) alone, in-furrow fungicide (pyraclostrobin + *Bacillus amyloliquefaciens*; Xanthion) alone, and an in-furrow combination of fertilizer + fungicide.

All three studies were conducted at three locations in KY. Lexington location was no-till, irrigated, following soybean, Glendale location was no-till, rainfed, following soybean, and Princeton location was no-till, rainfed, following corn.

Year 1 and 2 Results

Table 1. Description of rye cover crop total biomass produced, total carbon and nitrogen uptake, and biomass carbon to nitrogen ratio, Lexington, Glendale, Princeton, KY (2018-19).

Site-year	Cover Crop Planting	Total Biomass	Total C	Total N	C:N Ratio
		lbs per acre	lbs C per acre	lbs N per acre	C:N
Lexington 2018	Late	432	196	13.3	15:1
Lexington 2019	Early	2143	886	45.9	20:1
Glendale 2019	Early	2548	965	49.0	20:1
Princeton 2019	Late	360	161	10.7	15:1

Study 1: Rye cover crop and in-furrow starter impacts on corn emergence, optimal seeding rate and grain yield.

A rye cover crop did not significantly reduce corn grain yield in any site-year (Table 2) despite biomass production upwards of 2500 lbs per acre (Table 1). Despite application following labelled instructions and rates, inclusion of an in-furrow starter combination of both fertilizer and fungicide significantly reduced plant stand at 3 of 4 site-years in 2018 and 2019, which suggests potential incompatibility between the tank-mixed products. However in-furrow starter did not significantly reduce corn yield at any location. At Princeton in 2019 an in-furrow starter application significantly improved corn height and yield only when following a rye cover crop (Table 3). The Princeton location included a corn-corn rotation, had cool average temperatures (45° F) and rainfall one day after planting, and had confirmed corn seedling disease of both *Fusarium* and *Rhizoctonia*. In addition, early-season soil moisture was higher following a rye cover crop. This suggests disease levels were potentially higher in the corn-corn system and following a rye cover crop which induced the greater response to the in-furrow starter compared to the other study site-years presented.

In addition to corn emergence and grain yield across all seeding rates included in this study, we also examined the influence of an in-furrow starter and rye cover crop on the seeding rate required to maximize corn yield (Figure 1). Across all four site-years of this study we did not observe a significant impact of a rye cover crop or an in-furrow starter on the seeding rate of corn required to maximize yield. This data suggets farmers do not need a corn seeding rate adjustment when following a rye cover crop or including an in-furrow starter to maximize corn yield.

Table 2. In-furrow starter (fertilizer + fungicide) significantly reduced corn stand, but not grain yield, Lexington and Glendale, KY (2018-19)

Treatment	Plant Stand (1,000 plants/acre†)			Corn Grain Yield (bu/acre)		
	Lex '18	Lex '19	Glen '19	Lex '18	Lex '19	Glen '19
No Cover Crop	26.2 a	25.9 a	26.3 a	215.0 a	227.8 a	212 a
Rye Cover Crop	26.5 a	26.9 a	25.9 a	213.5 a	224.6 a	206 a
In-Furrow Starter	25.7 b	26.0 b	25.0 b	215.0 a	224.6 a	209 a
No IF Starter	27.0 a	26.9 a	27.2 a	213.5 a	229.4 a	209 a

*Column values followed by the same letter are not significantly different at α=0.1

† Plant stand means averaged across seeding rates.

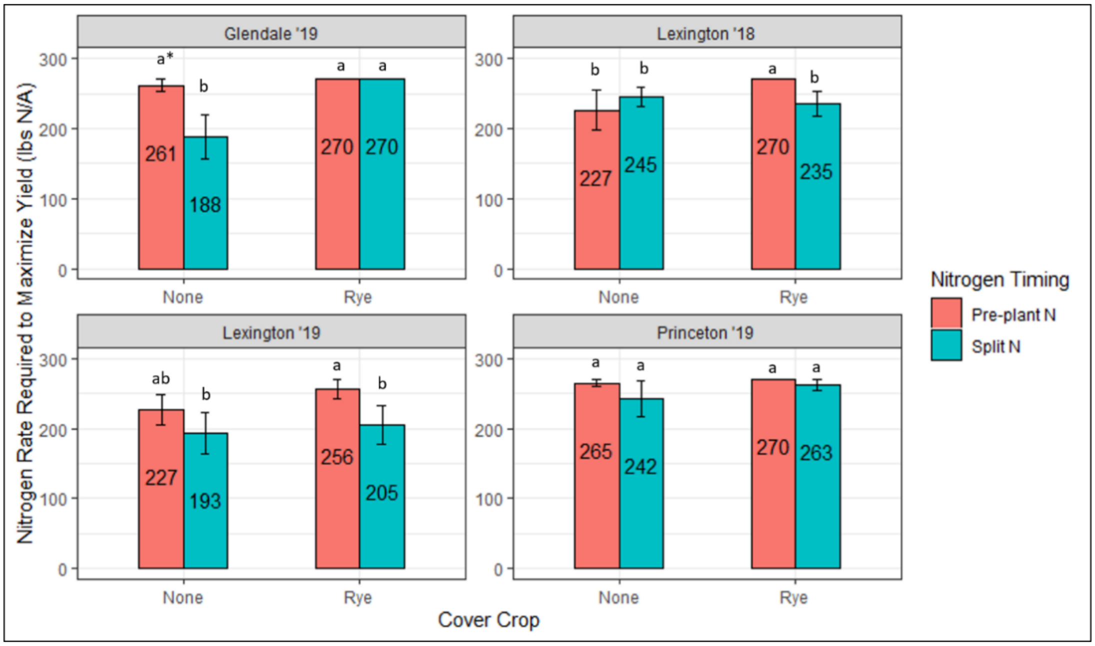
Table 3. When following a rye cover crop, in-furrow starter (fertilizer + fungicide) significantly improved corn height and grain yield, Princeton, KY (2019).

Cover	In-Furrow	Plant Stand†	Plant Height at V7	Grain Yield
		plants/acre	Inches	Bu/acre
Rye	Yes	23,800 a	19.1 a	150 b*
Rye	No	23,700 a	17.8 b	143 c
None	Yes	24,300 a	19.7 a	153 ab
None	No	24,100 a	19.1 a	156 a

*Column values followed by the same letter are not significantly different at α=0.1

† Plant stand means averaged across seeding rates.

Figure 1. Rye cover crop and in-furrow starter (fertilizer + fungicide) did not significantly change the amount of corn seeds per acre required to maximize yield, Lexington, Glendale, Princeton, KY (2018-19).



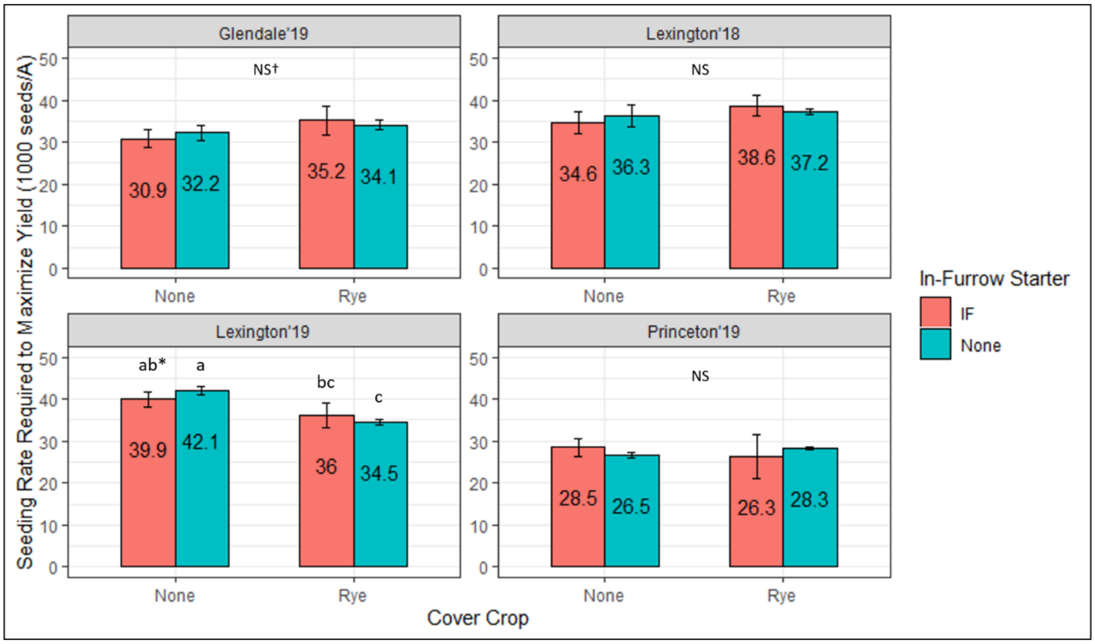
***Bars followed by the same letter within each site-year are not significantly different from each other at α=0.1**

Study 2: Rye cover crop and N fertilizer timing impacts on corn optimum N rate.

In this study we examined the influence of a rye cover crop and nitrogen fertilizer application timing on the nitrogen rate of corn required to maximize grain yield (Figure 2). When following a rye cover crop and when nitrogen was applied in a pre-plant application, the nitrogen rate required to maximize yield average 267 lbs N per acre. In addition, three site-years required 270 lbs N per acre to maximize yield which is the highest N rate applied in this study, suggesting the corn would still respond to N beyond 270 lbs N. When nitrogen was split following a rye cover crop, the N rate required to maximize yield averaged 243 lbs N per acre, which suggests a split application of N can lower the amount of N required by corn to maximize yield following rye. The high N fertilizer rates required to maximize corn yield were likely a function of above-average spring rainfall and below-average summer rainfall at corn tasseling through harvest in 2019. Spring rainfall likely limited corn root growth plus the combination of summer dry soil conditions likely resulted in the plants inability to obtain sufficient N at tasseling which is reflected by the high N rates required to maximize yield. Furthermore, the Lexington location in 2019 was irrigated and required the lowest amount of N to maximize corn yield.

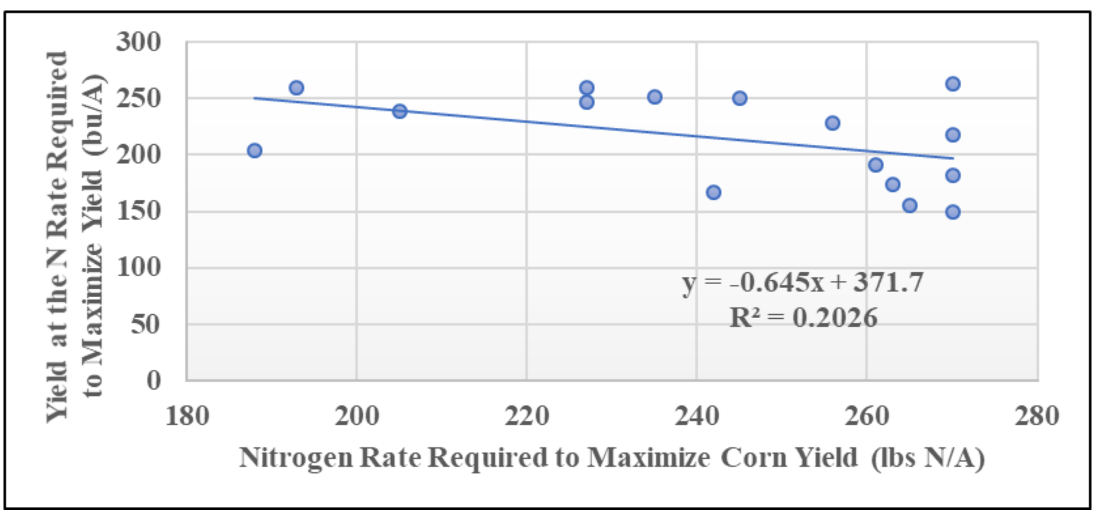
We also plotted the N fertilizer rates required by corn to maximize yield compared to the maximum yields produced within each site-year of this study (Figure 3). Figure 3 shows that as the N rate required to maximize corn yield increases, maximum grain yield decreases. This suggests applying high nitrogen rates does not always equate to the highest corn yield produced.

Figure 2. Split application of nitrogen fertilizer required less nitrogen fertilizer per acre to maximize corn yield when following a rye cover crop, Lexington, Glendale, Princeton, KY (2018-19).



*Bars followed by the same letter within each site-year are not significantly different from each other at α=0.1

Figure 3. High nitrogen fertilizer rates required to maximize corn yield did not result in the highest corn yields produced, Lexington, Glendale, Princeton, KY (2018-19).



Study 3: Rye cover crop termination timing and IF starter impacts on corn grain yield.

When corn was planted into a green rye cover crop that was terminated one day following corn planting, grain yield was significantly reduced at all three locations in 2019, whereas when corn followed rye terminated 14-21 days prior to corn planting, yield was not reduced (Table 4). Corn following this late terminated rye had significant stress caused by slugs, seedling disease, bird damage, and significant shading caused by the rye biomass levels upwards of 4000 lbs per acre produced. These results confirm significant challenges and yield reductions to corn following late-terminated rye and the benefits of terminating rye 14-21 days prior to corn planting. Despite significant early-season corn stress and higher levels of corn seedling disease observed following rye, the in-furrow fertilizer, fungicide, or combination did not improve corn yield at any location. However, severity of corn root disease was decreased with in-furrow fungicide, yet was likely not significant enough to improve corn yield (data not shown). At the Lexington location in 2019 the combination of in-furrow fertilizer + fungicide significantly reduced plant stand and corn grain yield compared to when the products were applied alone. This result further confirms the potential product incompatibility between the tank-mixed fertilizer and fungicide observed in Study 1.

Table 3. Waiting to terminate a rye cover crop until one day following corn planting significantly reduced yield and in-furrow starter provided either a negative or no corn yield benefit, Lexington, Glendale, Princeton, KY (2019).

Treatment	Corn Grain Yield (bu/acre)		
	Lexington '19	Glendale '19	Princeton '19
No Cover Crop	275.9 a*	240.6 a	169.2 a
Termination 14-d Prior to Corn Planting	265.2 a	245.9 a	160.7 ab
Termination 1-d After Corn Planting	165.2 b	205.4 b	154.7 b
No In-Furrow	241.3 a	234.2 a	162.1 a
In-Furrow Fertilizer (10-34-0)	239.0 a	232.7 a	162.0 a
In-Furrow Fungicide (Xanthion)	234.4 a	228.1 a	159.5 a
In-Furrow Fertilizer + Fungicide	223.0 b	227.6 a	162.5 a

*Column values followed by the same letter are not significantly different at α=0.1

FUTURE RESEARCH

Future 2020 growing season research will include the three studies presented and will again be conducted at the same three locations (Lexington, Glendale, and Princeton). Research in 2020 will complete the extensive dataset which will be used to provide valuable information and answer many specific grower questions regarding the successful establishment of corn following a rye cover crop across Kentucky.

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Corn Starter Impacts Early Season Plant and Soil Properties

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ABSTRACT

Starter fertilizers are used by producers to help overcome wet and cool soils often encountered with early planted corn. Early planted corn in no-tilled fields and limited drainage typically have the greatest chance of response from starter fertilizers. Starter fertilizers can range from a mixture of UAN, ammonium polyphosphate (APP), and other fertilizers to low salt (LS) formulations containing N, P, K and various micronutrients. Some that promote LS starter fertilizer products claim that UAN and/or APP contain salts at levels that will inhibit seed germination, growth and ultimately yield, even at low use rates. This study was conducted to determine the influence of starter fertilizer combinations and rates on corn emergence, growth, electrical conductivity, grain moisture, and grain yield. Corn (AgriGold AG6472) was planted on 6 June, 2019 with a four row Precision™ planter. Starter fertilizer was applied in-furrow at planting with a Surefire injection pump system. Treatments included UAN, APP, and a LS starter at 2.5 and 5.0 gallons per acre (gpa), 5.0 gpa mixture of UAN and APP, and an untreated control. All response variables were collected from the middle two rows of each plot. The 5 gpa APP treatment was significantly taller than the control treatment at all three sample dates. Plant height for the LS treatment at either rate was only greater than the 5 gpa UAN treatment at the early sample date. Differences in plant height diminished at later sample dates. Generally, treatments containing UAN resulted in higher electrical conductivity (EC) values than treatments without UAN in the formulation at the early sample date. The 5 gpa UAN treatment resulted in higher EC values than all other treatment except the 5 gpa LS treatment at the last sample date. No differences were observed for tissue nutrient content, grain moisture, test weight, or yield. Treatment costs ranged from \$3.88 to \$36.50 per acre. Although some differences in plant height and EC were observed, yield was not significantly influenced in this experiment. Deer damage in the plots introduced yield variability between replications. The LS starters do not appear to provide any benefit above the APP and UAN/APP mixtures used in this experiment.

INTRODUCTION

Starter fertilizers are utilized by farmers to help overcome harsh, early season conditions like cold, wet soils. Starters provide nutrients to the new seedling until the root system develops. Typically starter fertilizers are used for corn production but not soybean since soybeans are usually planted later in the season when the soil is warmer and less likely to benefit from the starter application. Starter fertilizers are applied at planting in a 2x2 or in-furrow placement. The 2x2 placement method applies the fertilizer two inches to the side and two inches below the seed depth with the planter. In-furrow placement applies the fertilizer in the row and in contact with the seed. A concern with starter fertilizer applications is due to salt injury. Salt injury can be caused by osmotic effects, high levels of biuret or high concentration of ammonia produced by certain nitrogen (N) fertilizers. Osmotic effects of fertilizers are described as fertilizer "pulling" water away from the seed. Biuret and ammonia can reach levels high enough to inhibit seed germination and/or growth. Further, potassium (K) fertilizers typically have higher salt content than phosphorus (P) or N fertilizers.

Higher starter rates can be used with 2x2 placement than in-furrow placement because of the greater distance the fertilizer is placed from the seed. Starter fertilizer rates should not exceed 100 lb of nitrogen (N) plus potash (K_2O) per acre for 2x2 placement. When using the in-furrow placement, less than 15 lbs of N and K_2O is recommended (Ritchey and McGrath, 2019). Lower rates are used in-furrow because of the close proximity to the seed that can reduce germination due to the salt content of the starter fertilizer. Using a high salt fertilizer at too high of a rate can inhibit seed germination. Starter fertilizers should contain low salt (LS) formulations, low rates of fertilizer, or a combination of low salt content and low rates to reduce the risk of seedling injury. Plants show the greatest response from P in starter, followed by N. Little benefit has been observed in Kentucky from K in starter.

OBJECTIVE

Determine if starter fertilizer formulation or rate influences corn emergence, growth, harvest moisture, grain yield, or soil electrical conductivity.

MATERIALS AND METHODS

Corn (AgriGold AG6472) was planted on 6 June, 2019 with a four row Precision™ planter. The starter fertilizer was applied in-furrow at planting with a Surefire injection pump system using metered hoses to apply the desired rates of fertilizer (Table 1). Nitrogen, phosphorus and potassium fertilizer was broadcast applied with a gandy drop spreader at appropriate rates for the given soil test values according to University of Kentucky Cooperative Extension recommendations (AGR-1). The fertilizer applied included 200 lbs of N as urea (46-0-0), 71 lbs of K_2O/A (0-0-60), and 102 lbs of P_2O_5/A (0-45-0). Stand counts, corn height, and electrical conductivity (EC) were measured on 13 June, 17 June, and 1 July. Stand counts and corn heights were collected on 10 ft of the middle two rows for each plot. Electrical conductivity was collected with a Spectrum Field Scout 110 EC meter to a depth of two inches five times for each treatment in the middle row between corn plants. Tissue samples were collected on 8 July 2019 for plant nutrient content. Ten leaves from the uppermost mature leaf (collared leaf) from each plot were collected (Schwab et al., 2007) and submitted to *Waters Agricultural Laboratories* for analysis. Ten feet of the middle two rows of each plot were harvested for yield determination and reported at 15.5% moisture. Grain moisture was determined for each plot with a Dickey-John 2100 grain analysis computer (Dickey-John, Minneapolis, MN). All data was analyzed with SAS version 9.4.

RESULTS

The 5 gpa APP treatment had significantly taller plant heights at all three sample dates than the control treatment (Figure 1). The 5 gpa APP treatment was taller than the control, 5 gpa UAN treatment, and 5 gpa LS treatment at the 1 July sample date, but only taller than the control at the 11 July sample date. Plant height was not negatively influenced by APP relative to other treatments in this study. The LS treatment at either rate was statistically greater than the 5 gpa UAN treatment at the 21 June, but no other treatment. The 2.5 gpa LS treatment had statistically greater plant heights than the control, both UAN treatments, and 5.0 gpa LS treatments at the 1 July sample date. A similar trend was observed at the 11 July sample date (Figure 1). These results indicate that although the LS starter has no negative impact on growth, adequate nutrition was achieved with the lower rate of starter and any product that contained more than UAN alone.

Generally, treatments containing UAN resulted in a higher EC than treatments without UAN in the formulation for the 19 June sample date. Electrical conductivity did not differ between treatments at the second sample date (Figure 2). However, EC increased due to leaching of the surface broadcast application of 0-0-60 fertilizer after 2.7 inches of rain. After an additional 1.8 inches of rain, more leaching of the fertilizer salts below the 2 inch sample depth caused EC to decrease for the last sample date. UAN 5.0 gpa was the only treatment that was statistically different than the rest in the last sampling date (Figure 2). Nutrient content of tissue samples were not statistically different due to treatments with all nutrients, except magnesium and calcium. No reason is known for these results.

Grain moisture ranged from 16.2 to 17%, but statistical differences were not observed for the study (Table 2). It is hypothesized that grain must be allowed to further dry prior to harvest if difference in grain moisture would be observed. Grain test weight did not differ significantly between products and ranged from 57.9 to 58.9%. No significant differences were observed for yield but there was a tremendous amount of variability between replications. This variation was thought to be due to deer damage caused by random feeding within the plots. Yields for the treatments ranged from 159 in the untreated check to 183 bu/A with the UAN 2x and the LS treatments. This does suggest that some yield benefit from the starter may be possible, but not present in this study.

The LS starter was the only product used in this test that contained K fertilizer (Table 1). The LS starter cost substantially more than the UAN or APP, but did not contain appreciably more nutrients than the other products. The salt index was greatest for the UAN, followed by APP compared to the LS starter. Products with APP can produce ammonia which can be detrimental to seed germination and early season growth. No negative effects were observed at the rates used for this study. The price of nutrients contained in the various starters was greatest for the LS starter and was the least economical based on the results thus far of this study.

SUMMARY

Overall, starter that contained some P resulted in a greater corn plant height than N alone or the control. The P appeared to have a greater impact on plant height than N or K. Plant heights were similar for the LS 2.5 gpa rate and APP 2.5 gpa rate, but LS cost $12.27/A more than the APP. Starter fertilizer did not influence stand counts at any date. In the end, using 32-0-0 and 10-34-0 showed similar benefits for a much lower cost for all growth components, with the exception of grain yield. Grain yield, although not significantly different, did appear to show a potential benefit from all products above the untreated check. This research need to be repeated to gain a better appreciation if a true yield benefit was present or if this was just an artifact of the data as influenced by deer damage. Based on the results from one year of data, the economic and agronomic advantage would lend itself to utilizing APP, UAN or the UAN/APP combination to provide a substantial savings over the commercial LS fertilizer.

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Table 1. Corn starter fertilizer treatments and rates.

Treatment	Treatment #	Rate (GPA)	lb N/A	lb P_20_5/A	lb K_2O/A	Salt Index	$/A
No Starter	1	Untreated	0	0	0	0	0
UAN	2	2.5 gal/A	8.9	0	0	71	3.88
UAN 2X	3	5 gal/A	17.8	0	0	71	7.76
APP	4	2.5 gal/A	2.9	9.9	0	20	5.98
APP 2X	5	5 gal/A	5.8	19.8	0	20	11.96
UAN/APP	6	2.5/2.5gal/A	11.8	9.9	0	46	9.86
LS Starter	7	2.5 gal/A	2.5	6.8	0.9	17	18.25
LS Starter 2X	8	5 gal/A	5.0	13.6	1.8	17	36.50

Table 2. Corn grain moisture, test weight and grain yield.

Treatment	Rate (GPA)	Grain Moisture (%)	Test Weight (lb/bu)	Yield (Bu/A)
No Starter	Untreated	17.0	57.9	159
UAN	2.5 gal/A	16.6	58.0	181
UAN 2X	5 gal/A	16.8	57.9	183
APP	2.5 gal/A	16.5	58.4	174
APP 2X	5 gal/A	16.8	58.9	172
UAN/APP	2.5/2.5gal/A	16.2	58.3	160
LS Starter	2.5 gal/A	16.7	58.5	183
LS Starter 2X	5 gal/A	16.2	58.3	175
Pr>F		0.8933	0.5560	0.4471

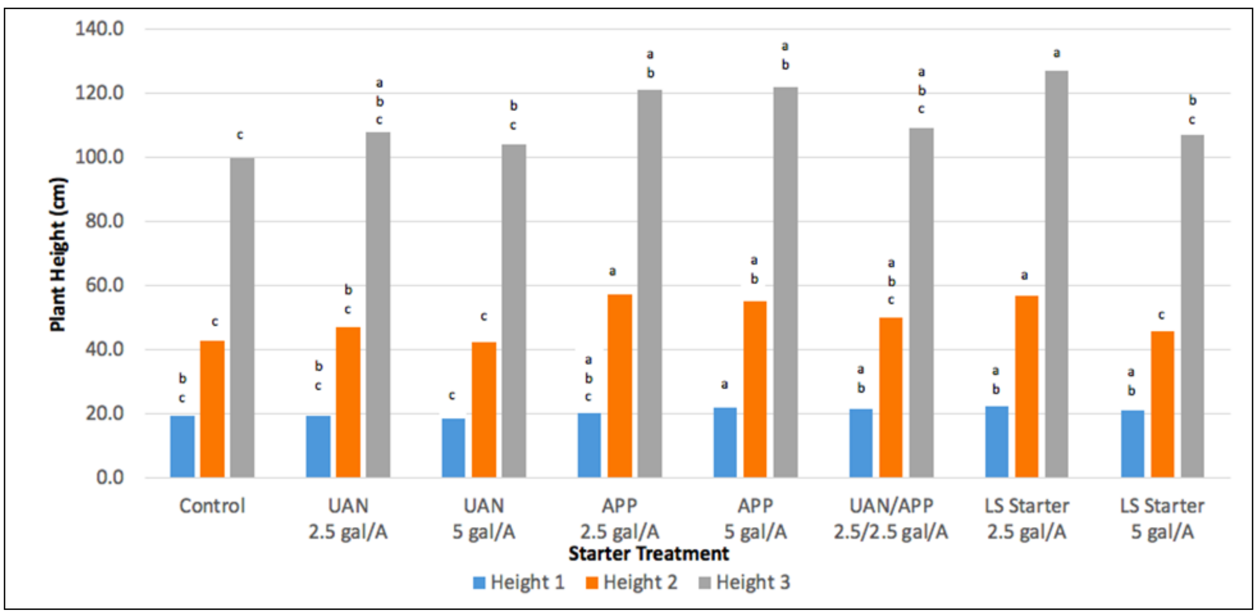

Figure 1. Plant height as influenced by starter formulation and rate. Plant heights collected 21 June (blue), 1 July (orange), and 11 July (gray) 2019. Values within a height for a particular sample date followed by the same letter are not different at the 0.1 level of probability.

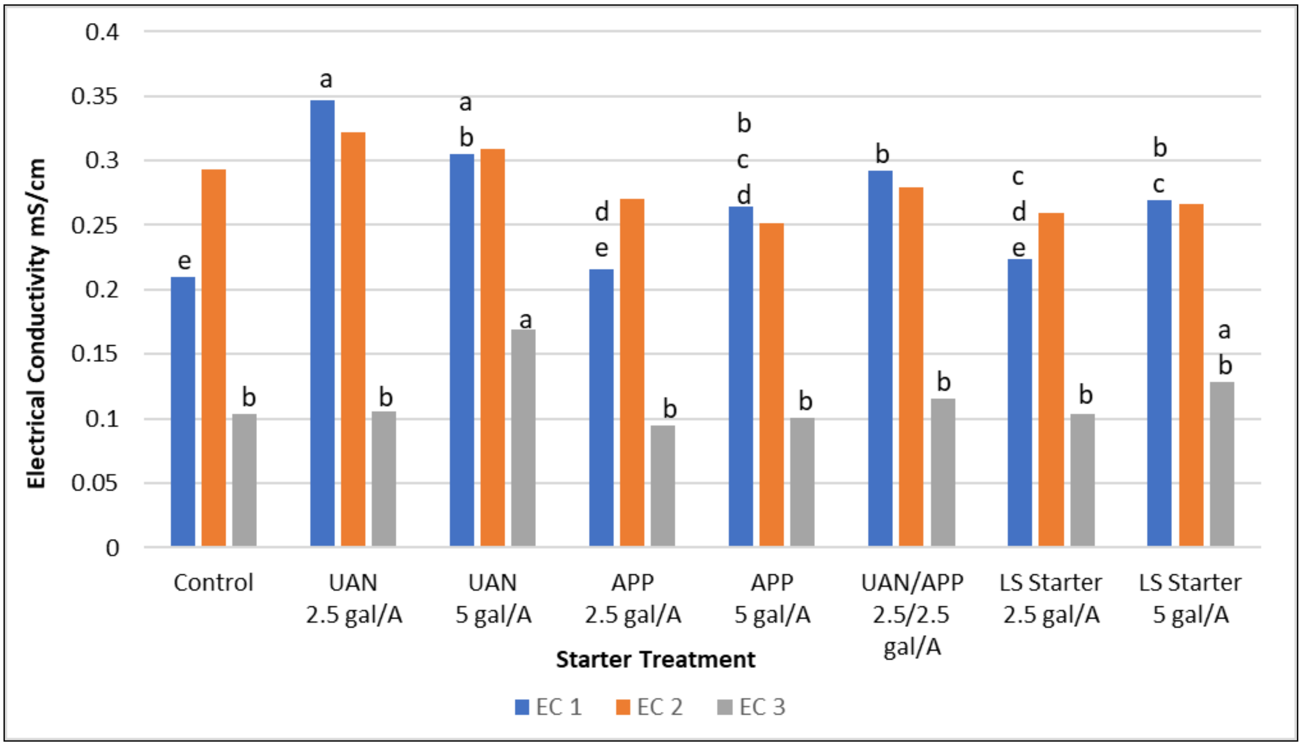

Figure 2. Electrical conductivity (EC) as influenced by starter formulation and rate. EC collected 19 June (blue), 1 July (orange) , and 11 July (gray). Values within EC sample date followed by the same letter are not different at the 0.1 level of probability.

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Effect of In-Furrow Fungicides on Corn Seedling Diseases and Yield

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INTRODUCTION

In-furrow fungicide use in corn has increased in recent years, with these products promoted to increase plant populations, plant vigor, and yield. Previous research in the Midwest has indicated that newly available fungicides and biofungicides may provide a yield benefit in certain fields, particularly when corn is planted early. However, very few replicated field research trials have been conducted in Kentucky, and additional research is needed to help us understand under what environmental conditions in-furrow fungicides will provide a benefit. The objectives of this research were to examine how planting date influences the efficacy of in-furrow fungicide and biofungicide products and measure effects on seedling disease control, plant population and yield.

MATERIALS AND METHODS

Research plots were established at the University of Kentucky Research and Education Center in Princeton, KY in 2018. Plots were planted at 3 planting dates: April 20, May 2, and May 25. Six treatments (Table 1) were replicated four times in a randomized complete block design. Plots were planted with a small-plot planter at a target population of 32,000 seeds/acre on 30-in. row spacing, and 30-ft in length.

Table 1. Treatments, active ingredients, and rates of in-furrow products used in the trial established at the University of Kentucky Research and Education Center in Princeton, KY, 2018.

Treatment #	Fungicide treatment	Active ingredients	Rate (fl oz/A)
1	Non-treated control		--
2	Xanthion	Pyraclostrobin + *Bacillus amyloliquefaciens* MB1600	0.6 + 3
3	Manticor	Pyraclostrobin + Bifenthrin	9.5
4	Ethos	*Bacillus amyloliquefaciens* D747	6.8
5	Headline	Pyraclostrobin	3
6	Tepera	Fluoxastrobin	4.2

Plant populations were assessed twice, at 14 days after planting, and 28 days after planting by counting each plant in the center 10 ft. of the two inner plot rows, and converted to plants per acre. Plants assessed for population counts were also visually rated for seedling disease by observing damping-off, stunting, or other symptoms of seedling disease. Yield, grain moisture and test weight were collected from the inner two rows of the plot and adjusted to 15.5% grain moisture (Table 2). Data were analyzed using mixed models and treatment means separated using least square means.

Table 2. Planting and harvest dates for experiment to examine effect of in-furrow fungicides on plant stand, disease severity and yield at the University of Kentucky Research and Education Center in Princeton, KY, 2018.

	Plant date	Harvest date
Early planting	April 20	September 13
Mid planting	May 2	September 13
Late planting	May 25	September 19

RESULTS

The first planting date target was originally late March, but cool, wet weather delayed planting until mid-April. Although planting was delayed, soil conditions were still cool and wet, and favorable for disease development. Of the factors tested (planting date and fungicide treatment), only planting date significantly impacted plant population at 14 and 28 days after planting (DAP; Figure 1). Plant population was significantly higher at both 14 and 28 DAP in trials established in May. These differences were not attributed to disease development, as no seedling blights were observed in the trial. The field available for research may not have had a strong history of seedling disease, and this may have impacted results.

Despite higher populations, planting date did not impact yield, and in-furrow fungicide treatment had no statistically significant effect on plant population or yield in this experiment (Figure 2). Although no statistical differences were observed, yield was numerically higher for several in-furrow treatments in the April 20 planting date. Yields were not numerically different at later planting dates.

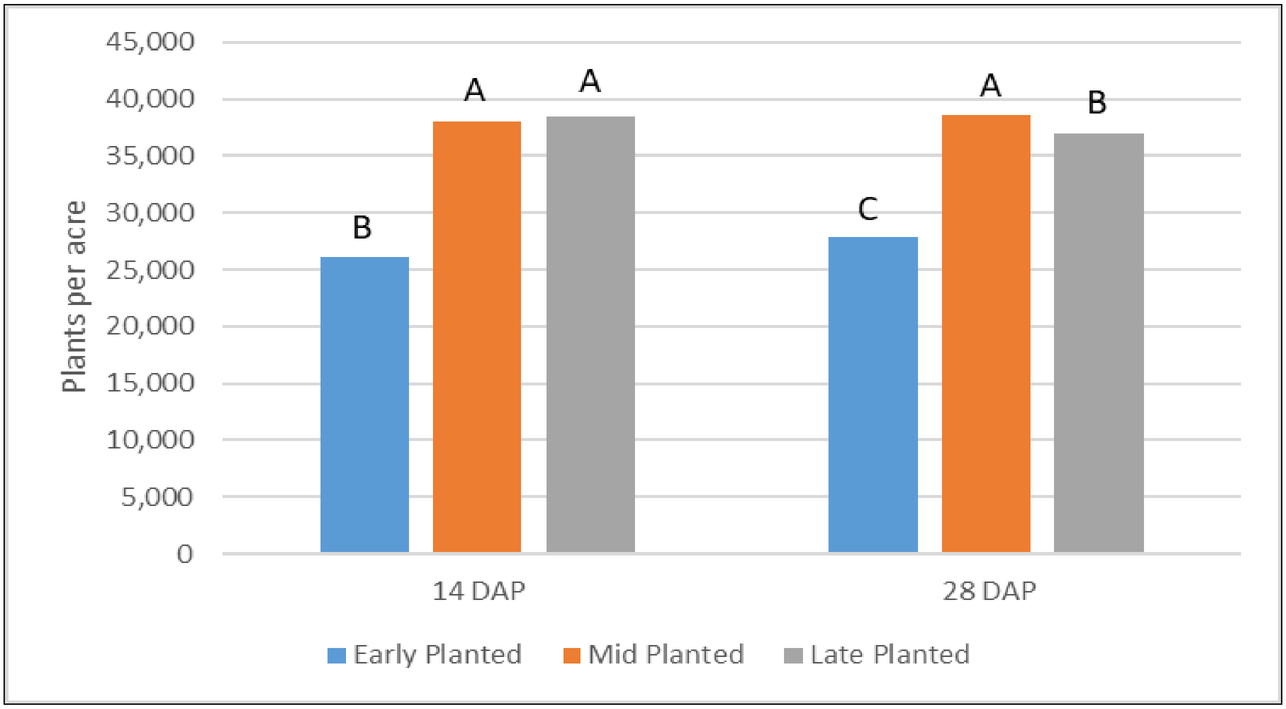

Figure 1. Impact of planting date on plant population in plants per acre 14 and 28 days after planting (DAP). Columns with different letters indicates that values are significantly different within date at the *P* = 0.05 level.

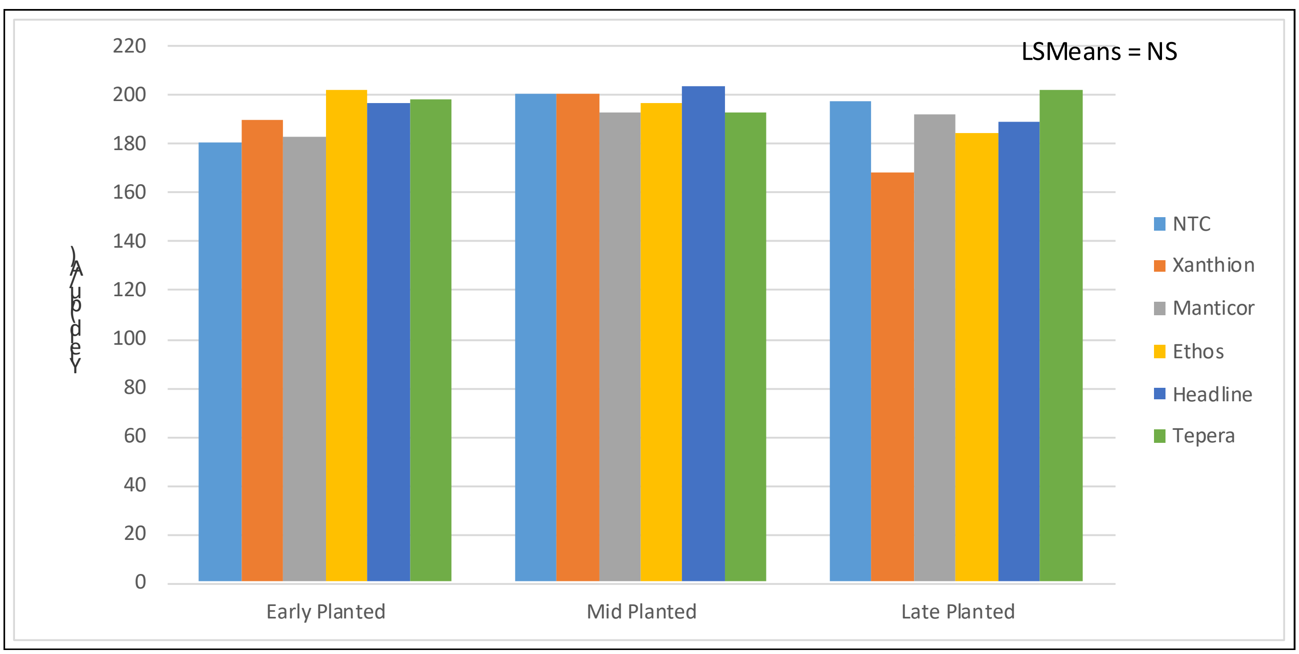

Figure 2. Impact of planting date and in-furrow fungicide treatment on yield. NTC = non-treated control. Neither planting date or fungicide treatment significantly impacted yield at the *P* = 0.05 level.

CONCLUSIONS

- In-furrow fungicides did not improve plant population at three planting dates (early, mid, late) at the UKREC research location in 2018

- Early (April) planted trials had lower plant population than trials planted in May, however this did not result in lower yield
- Farmers who are planting at optimum timings or later may not need in-furrow fungicides
- Although more research is needed, yield response from in-furrow treatments is more likely to occur when corn is planted early into cool, wet conditions compared with later planting timings.

ACKNOWLEDGEMENTS

We gratefully acknowledge the Kentucky Corn Promotion Council for funding this research, and the UKREC Farm Crew, Josh Duckworth, and Carl Bradley for assistance in establishing and maintaining these trials.

Impact of Foliar Fungicide Timing on Standability and Yield in Corn

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INTRODUCTION

Foliar fungicides are a common input in corn production, but they are an added expense, and farmers frequently ask questions about how to optimize fungicide use in corn. Foliar diseases like gray leaf spot and southern rust frequently appear after tasseling and into grain fill, prompting farmers and agribusiness personnel to ask if these late symptoms are causing yield loss, and if late fungicide applications are warranted for disease management and to improve standability. Many farmers are interested in improving stalk quality to prevent lodging and increase the length of time that corn can be harvested without stalk breakage. Understanding the relationship between fungicide timing and the influence of foliar disease on stalk quality and standability will help us more fully understand how to maximize profitability of fungicide use in corn. Research funded by the Kentucky Corn Growers Association was established in 2018 and 2019 to determine the effect of hybrid stalk strength and fungicide timing on lodging (standability) and yield in corn.

MATERIALS AND METHODS

Two hybrids were selected to test the impact of stalk strength on standability. Hybrid P1555CHR had a rating of 8 on a 1-9 scale where 9 is the best (high stalk strength), and P1257AM had a rating of 5 on the same scale (medium stalk strength). In each year, plots were arranged in a split-plot design with four replications per treatment, and planted at a target population of 32,000 seeds/acre on 30-in. row spacing, and 30-ft length. Fungicide treatment timing was randomly arranged within each hybrid tested. Fungicide treatments consisted of Trivapro at 13.7 fl oz/A applied using a hand-held backpack sprayer at one of the following growth stages in each hybrid: tasseling (VT), blister (R2), milk (R3) and dough (R4). Percent foliar disease severity on the ear leaf was rated for 5 plants per plot at R4, and stalk strength assessments were conducted at maturity by pushing 10 plants per plot at 30 degrees from center. Plants that snapped or did not spring back were considered lodged, and the total % lodged plants per plot was averaged for each treatment. Yield, grain moisture and test weight were collected from the inner two rows of the plot and adjusted to 15.5% grain moisture. 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

Environmental conditions each year varied, and therefore data from each year was analyzed separately. In 2018, fungicide timing significantly affected disease severity. Gray leaf spot was observed at low to moderate levels. All fungicide timings reduced disease compared to the non-treated control, with the lowest levels of disease observed when fungicides were sprayed at VT (Figure 1). Hybrid did not affect disease severity.

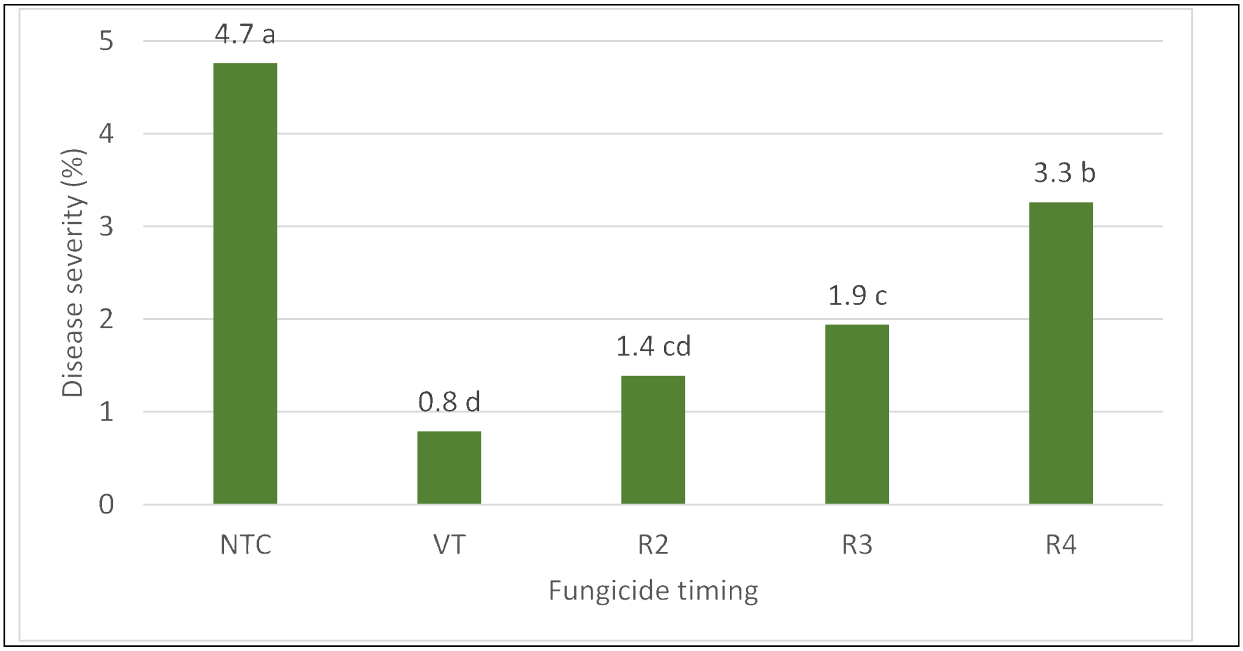

Figure 1. Effect of fungicide timing on gray leaf spot severity (%) across hybrids in 2018. Values followed by different letters indicate values are significantly different at the *P* = 0.05 level. NTC = non-treated control.

Fungicide timing and hybrid significantly affected lodging. Fungicide applied at VT had the lowest percent lodging compared to other fungicide timings (Figure 2). Hybrid P1555CHR with a high stalk strength rating had less lodging than P1257AM (medium stalk strength; Table 1).

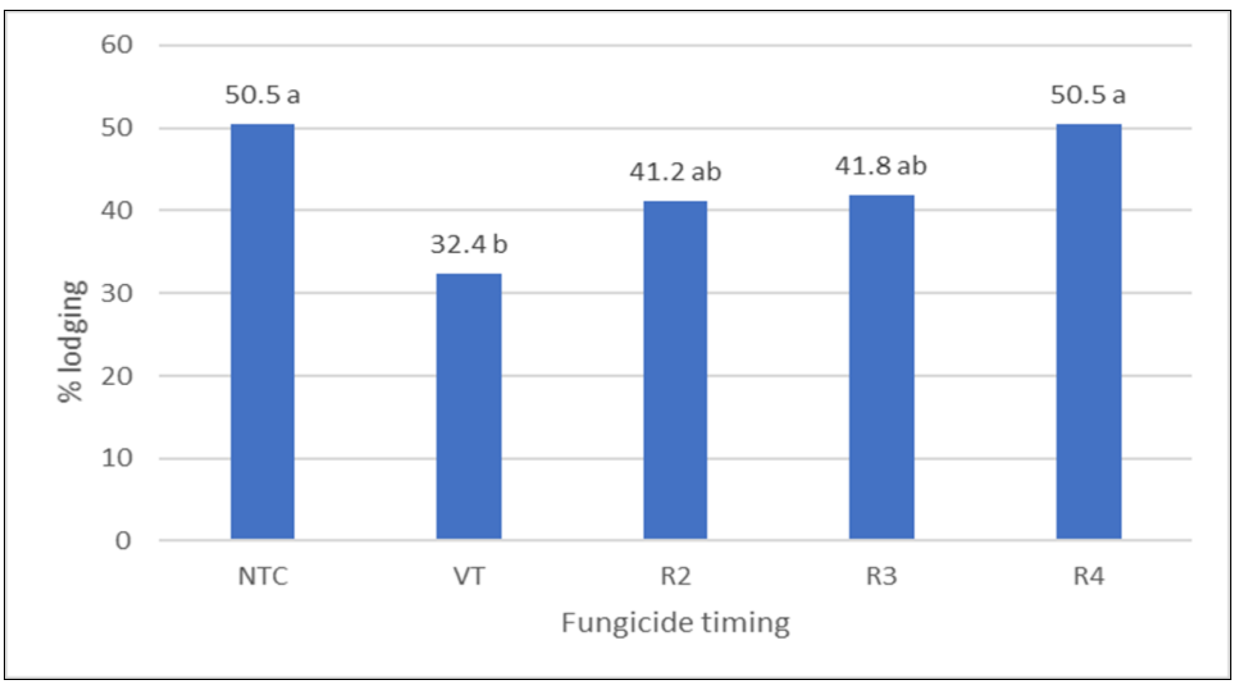

Figure 2. Effect of fungicide timing on percent (%) lodging across hybrids in 2018. Values followed by different letters indicates that values are significantly different at the *P* = 0.05 level. NTC = non-treated control.

Table 1. Impact of hybrid on percent lodging in 2018. Hybrid stalk strength ratings on a 1-9 scale with 9 being best follow hybrid name.

Hybrid	% Disease severity
P1257AM (5)	54.5 a[a]
P1555CHR (8)	41.0 b

[a] Values followed by different letters indicates that values are significantly different at the *P* = 0.05 level.

Although disease severity was influenced by fungicide timing, fungicide timing had no effect on yield. This is likely because disease severity was not high enough in 2018 to reduce yield in this trial, with less than 5% disease severity in the non-treated control. Hybrid stalk strength also did not impact yield.

In 2019, neither fungicide timing or hybrid impacted disease severity or yield. The dry conditions through August and September limited disease development, and foliar disease levels were very low. The only significant effects observed were the effect of hybrid on lodging, with the hybrid with higher stalk strength rating exhibiting lower lodging (Table 2). Fungicide timing did not impact lodging in 2019.

Table 2. Impact of hybrid on percent lodging in 2019. Hybrid stalk strength ratings on a 1-9 scale with 9 being best follow hybrid name.

Hybrid	% Disease severity
P1257AM (5)	79.9 a[a]
P1555CHR (8)	63.4 b

[a] Values followed by different letters indicates that values are significantly different at the *P* = 0.05 level.

CONCLUSIONS

- Choosing hybrids with good stalk strength ratings reduces the impact of lodging
- Fungicide applied at tasseling (VT) resulted in the greatest reduction in foliar disease and lodging in 2018, but fungicide timing didn't affect lodging in 2019
- Fungicide applications at R4 did not reduce lodging (standability) compared to a non-treated control, meaning late-season applications are not needed to improve standability
- There are still some questions about consistency and economic value of using foliar fungicides to improve standability, but if foliar fungicides are applied at VT/R1 for foliar disease control, there is potential for improved standability in some years.

ACKNOWLEDGEMENTS

We gratefully acknowledge the Kentucky Corn Promotion Council for funding this research, and the UKREC Farm Crew, Jesse Gray, and Shawn Wood for assistance in establishing and maintaining these trials.

Evaluating Corn Response to Late-Season N Application in Conventional Tillage and No-Tillage Systems

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BACKGROUND

Nitrogen fertilizer applications to corn are typically made early in the season to supply adequate N for rapid growth between the five-leaf stage and silking. However, applying a large dose of N early in the season can lead to losses prior to crop uptake. Moreover, much of the N applied early-season is depleted by the time corn enters reproductive growth. As a result, the crop is entirely reliant on soil N mineralization for the ~70 lb N/acre taken up during pollination and grain fill.

Recent evidence suggests that newer hybrids take up more N from the soil post-silking than older hybrids, suggesting that a late application of N fertilizer may be necessary to exploit the full yield potential of modern varieties. Previous studies have shown that delaying the major N fertilizer application to late-vegetative growth stages can decrease yield due to early-season N stress. However, recent research conducted in in Indiana indicates that a 'late-split' application, with the majority of N fertilizer applied early in the season and approximately 40 lb N/acre applied at the V12 growth stage, can increase corn N accumulation and N recovery efficiency relative to a single early-season application.

Nitrogen mineralized from soil organic matter often makes up half or more of total corn N uptake, and it is the primary source of mineral N available for crop uptake during reproductive growth. Long-term no-tillage management generally increases total N stocks and mineralizable N. For example, a long-term tillage comparison study in Kentucky has shown that, relative to conventional tillage, no-till leads to greater soil N concentrations and greater corn yields when zero N is applied.

We hypothesized that a late split application of N fertilizer (V3/V12 growth stages) would result in greater corn yield than a single early application (V3 growth stage) at the same rate, but the effect would depend on the tillage system. We expected that a soil under long-term conventional tillage would be more responsive to N fertilization timing than a soil under long-term no-till because the no-till system would provide greater N mineralization.

METHODS

The long-term tillage x N rate trial at University of Kentucky's Spindletop Research Farm includes two tillage treatments (no-till vs. moldboard plowing) crossed with four N rates (0, 75, 150, 300 lb N/acre). Corn is grown every year with cereal rye as a cover crop. In 2018 and 2019, we split the plots within this long-term study into two timing treatments: a single N application at the V3 growth stage, and a split-application with 50 lb N/acre applied at the V12 growth stage and the remaining applied at the V3 growth stage. In addition to crop yield, we measured corn N uptake at silking and maturity to quantify how much N was taken up from the soil and how much was remobilized from vegetative biomass after silking. We also studied the impact of tillage system on the total N stock and rate of soil N mineralization in the 150 lb N/acre treatment to understand mechanisms underlying the crop response. Lastly, we tested the performance of two in-season tools that may be used to predict crop response to late-season application: soil inorganic N content at the V5 growth stage and leaf chlorophyll content using a SPAD meter at the V9 growth stage. We present the highlights of our results in this report.

RESULTS

The soil N stock in the surface 8 inches was 30% higher in the no-till than plowed system (3780 vs. 2840 lb N/acre in the 150 lb N/acre treatment). The no-till system mineralized approximately 50 lb N/acre more than the plowed system during the 2018 corn growing season (Figure 1). These results show that the build-up of soil organic matter in the no-till system over ~50 years has led to a greater soil N-supplying capacity.

Corn yields were greater in the no-till system than the plowed system in the 75 lb N/acre rate in 2018 and across all N fertilizer rate and timing treatments in 2019 (Figure 2). The greater benefit of no-till in 2019 may have been due to the drier conditions – precipitation in 2019 was below average in the summer whereas precipitation in 2018 was above average in the summer. Other research has shown that no-till offers a greater advantage in dry conditions.

The late-split N fertilizer treatment (i.e., withholding 50 lb N/acre until the V12 stage of corn) decreased corn yield relative to the early timing treatment at the 75 lb N/acre rate in 2018 (Figure 3). This negative effect of the late-split treatment on yield was consistent between tillage systems. We believe that this negative effect was due to early-season N stress that could not be reversed by the late application when only 75 lb N/acre was applied. Apart from this treatment in 2018, N fertilization had minimal effect on corn yield.

SUMMARY

Long-term no-till resulted in greater soil N stocks, N mineralization, and corn yields relative to moldboard plowing. Although the no-till system mineralized more N, the response to late N application was similar between systems. The higher yields (and thus greater N demand) in the no-till system may have caused this system to be equally dependent on fertilizer N inputs as the plowed system. Late-split N had minimal impact on yield when corn received 150 or 300 lb N/acre.

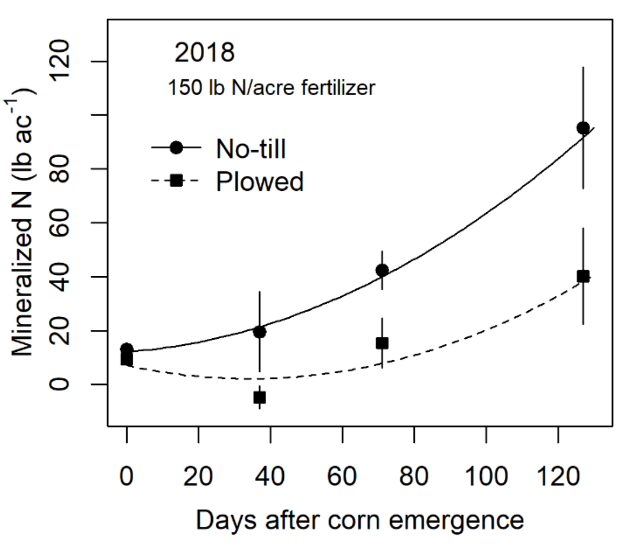

Figure 1. Nitrogen mineralized in the surface 8 inches for two tillage systems during the 2018 corn growing season. Error bars are ± one SE.

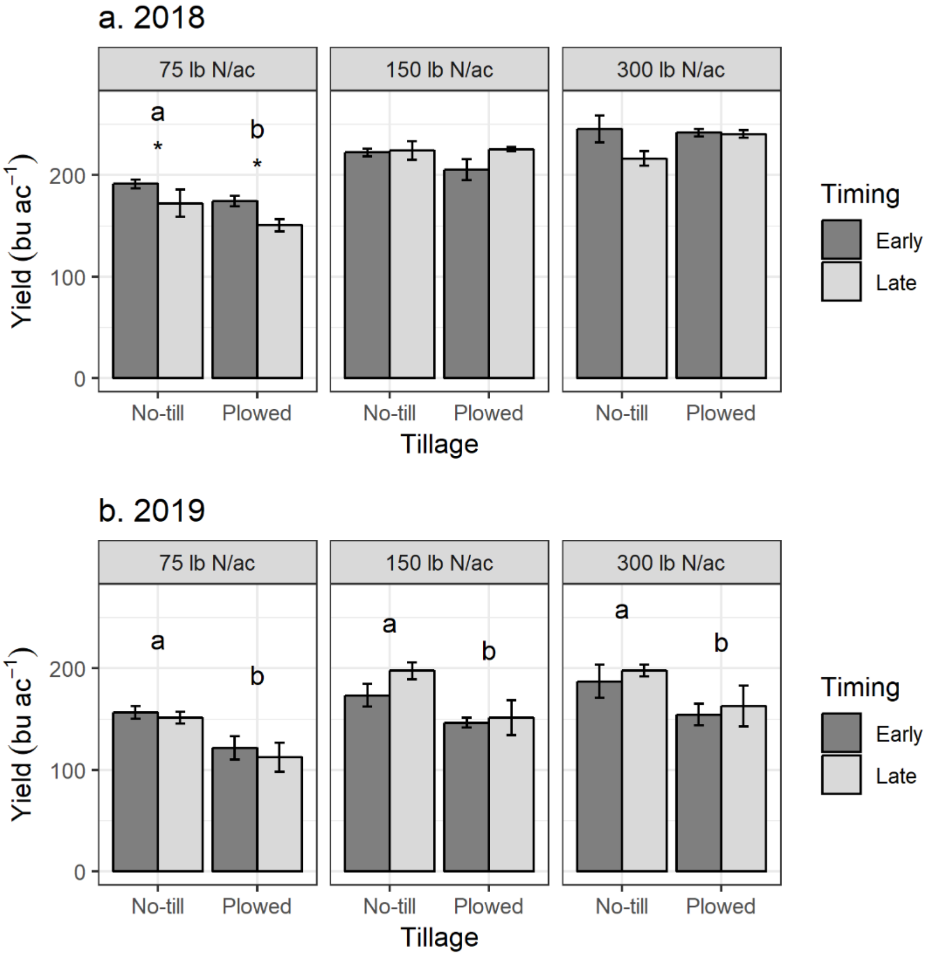

Figure 2. Corn grain yield in response to N fertilization timing for two tillage systems and three N fertilizer rates in 2018 (top) and 2019 (bottom). Error bars are ± one SE. Significant differences between tillage treatments are indicated by different letters. Significant differences between N timing treatments are indicated by an asterisk.

Irrigation Response of Different Corn Hybrid Maturities in Kentucky

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INTRODUCTION AND GOALS

Corn production in Kentucky is mostly under rainfed conditions, with only 3% grown under irrigation in 2018. As a result, water stress during early reproductive stages can severely reduce grain yield depending on the year and location. Providing supplemental water through irrigation could reduce this yield limitation but is an economic investment that also increase fixed management and input costs. More information on the expected increase in grain yield when adopting irrigation becomes essential to make informed decisions that can have a positive impact on the farm net economic returns and for a sustainable use of resources.

Crop management options can have a significant impact on the crop yield potential and the amount and timing of corn water requirements. One management factor that can influence water use is the choice of corn hybrid maturity. Previous research suggests that short-season hybrids may provide an adaptation strategy to water-limited environments by reducing the risk of water-stress and increasing yield stability. In contrast, full-season hybrid maturities that have a longer growing cycle could have a greater yield potential and be better adapted to irrigated conditions in Kentucky.

Information on the timing, severity, and duration of water stress, and the yield gain expected when transforming to irrigation is essential for producers in KY to make informed decisions. In addition, evaluating this response for a range of corn hybrid maturities may help identify best management recommendations that maximize productivity under both irrigated and rainfed conditions.

The objectives of this study were: 1) to estimate the expected timing, intensity, and duration of water deficit at two locations in KY, and 2) to quantify the yield response to irrigation in hybrids with a range in corn relative maturity (CRM) from 102 to 120 days.

MATERIALS AND METHODS

Field experiments were conducted in two locations in 2017, and one location in 2018. In 2017, research plots were planted at the UK North Spindletop Research Farm in Lexington (38.12° N, 84.49° W) and at the UK Research Education Center in Princeton (37.09° N, 87.85° W). During 2018, trials were planted only in Lexington. The factors evaluated were irrigation management (rainfed vs. irrigated), and hybrid maturity. Six different corn hybrids were included in 2017 and eight hybrids in 2018, ranging from 102 to 120 CRM. Yield by hybrid and irrigation treatment was regressed against CRM, and an analysis of covariance was used to test the effect of irrigation on the slopes and intercept of the regressions at each location. Daily weather data obtained from the UK Ag Weather Center for the 1988-2018 period was used to estimate a daily cumulative water deficit from the balance of net reference evapotranspiration and effective precipitation.

RESULTS

Water deficit calculated from historical weather data is expected to occur from June to September (Figure 1, top). The number of days with water stress (cumulative water stress >50) peaked in August at both locations (Figure 2, bottom). On average, the number of days with water stress from May to September were 85 and 101 days in Lexington and Princeton, respectively. Field experiments conducted in Lexington were subject to a greater water deficit in 2017 than in 2018 (Figure 1, top left). As a result, total irrigation applied in Lexington was 130 mm and 88 mm in 2017 and 2018, respectively. In Princeton, the average water deficit exceeded the 50 mm threshold between June and October (Figure 1, top right), and the total irrigation applied was 140 mm.

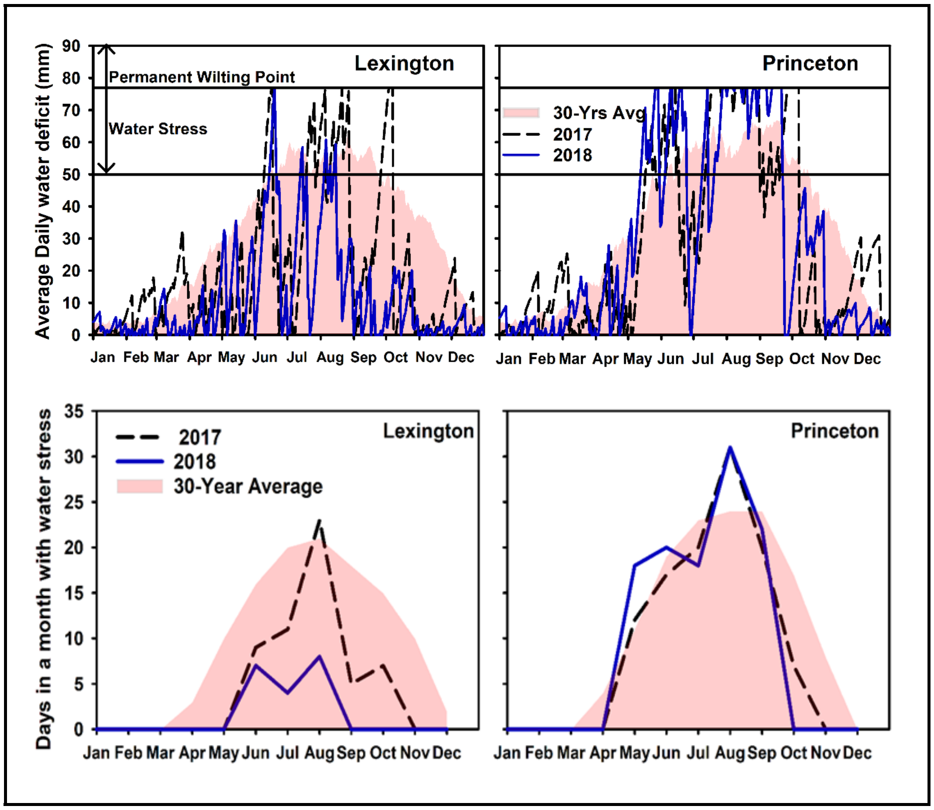

Figure 1. Expected cumulative water deficit (top) and number of days in a month with water stress (bottom) estimated from 30-yr of historical weather data (1988-2018) and for 2017 and 2018 in Lexington and Princeton, KY. A threshold of 50 mm water deficit was used to identify water stress based on 65% water depletion in a soil with a 0.13 m^3 m^{-3} of total crop available water and a rooting depth of 23.6 inches.

Field trials showed a positive yield response to irrigation in 2017 (6 and 28 % yield increase in Lexington and Princeton, respectively), but no response to irrigation in 2018 in Lexington. There was a linear relationship between yield and CRM, indicating that yields increased with later maturities in all locations under both irrigated and rainfed conditions (Figure 2). The yield increase ranged from 143 to 195 kg ha^{-1} and per unit increase in CRM in Lexington (Table 1). Based on these results, yield differences from CRM 102 to 112 hybrids in Lexington could range for instance from 1,430 kg ha^{-1} to 1,950 kg ha^{-1}. The slope of the regression or yield increase by CRM was not affected by the irrigation treatment during both growing seasons in Lexington (Table 1). In Princeton 2017, there was yield increase of 205 Kg ha^{-1} by unit increase in CRM under irrigation, but this response was reduced to 67 kg ha^{-1} CRM^{-1} under rainfed conditions (Table 1).

Table 1. Estimate of the slope from the regression of yield with Corn Relative Maturity (CRM), and the yield at CRM=110 by location and treatment (Rainfed vs. Irrigated). Different letters indicate significant differences within a location and year (α<0.05).

Location	Year	Treatment	Yield change per unit increase in CRM (kg ha^{-1} CRM^{-1})	Estimated yield for CRM = 110 (Mg ha^{-1})
Lexington	2017	Rainfed	147 a	16,268 b
		Irrigated	188 a	17,213 a
	2018	Rainfed	195 a	17,746 a
		Irrigated	143 a	12,186 a
Princeton	2017	Rainfed	67 b	15,366 b
		Irrigated	205 a	15.4 a

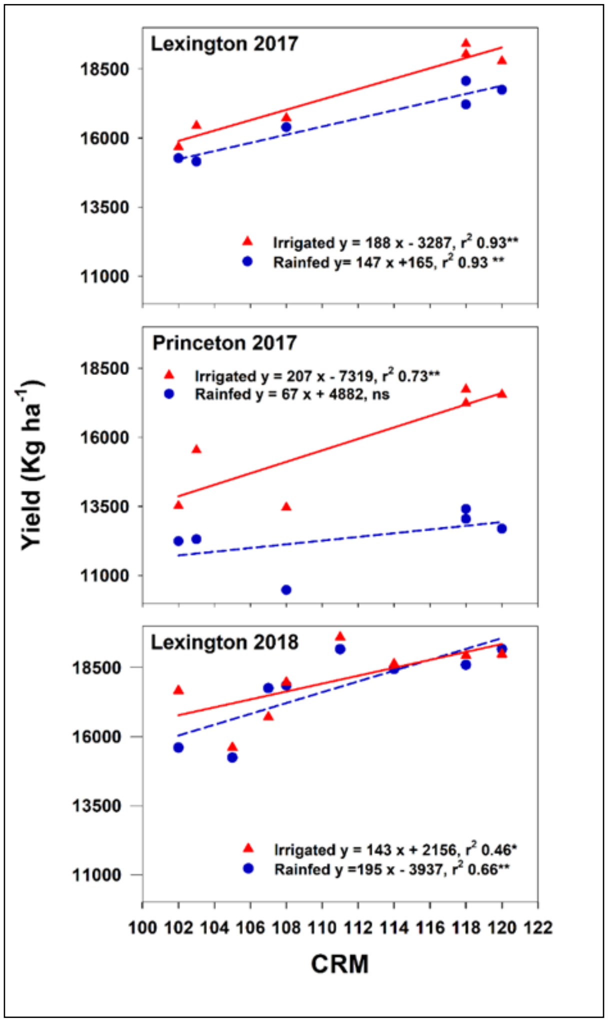

Figure 2. Yield of each hybrid regressed against corn relative maturity (CRM) by location and irrigation treatment.

CONCLUSIONS

The analysis of historical weather data indicated that from May to September we may expect 57 and 67% of days with a cumulative water deficit above 50 mm, with the highest frequency occurring in August. Further studies taking into account different potential root depths for different soils as well as planting date and canopy development to partitioning into soil evaporation and leaf transpiration would provide more accurate estimates of water deficit. The response to irrigation ranged from no response, to a 6 – 28 % yield increase depending on the year and location. Yield increased in all cases with hybrid maturity for CRM ranging from 102 to 120, but this response was greater under conditions of no water stress.

ACKNOWLEDGEMENTS

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Determining Yield and Profitability of Different Corn Irrigation Strategies

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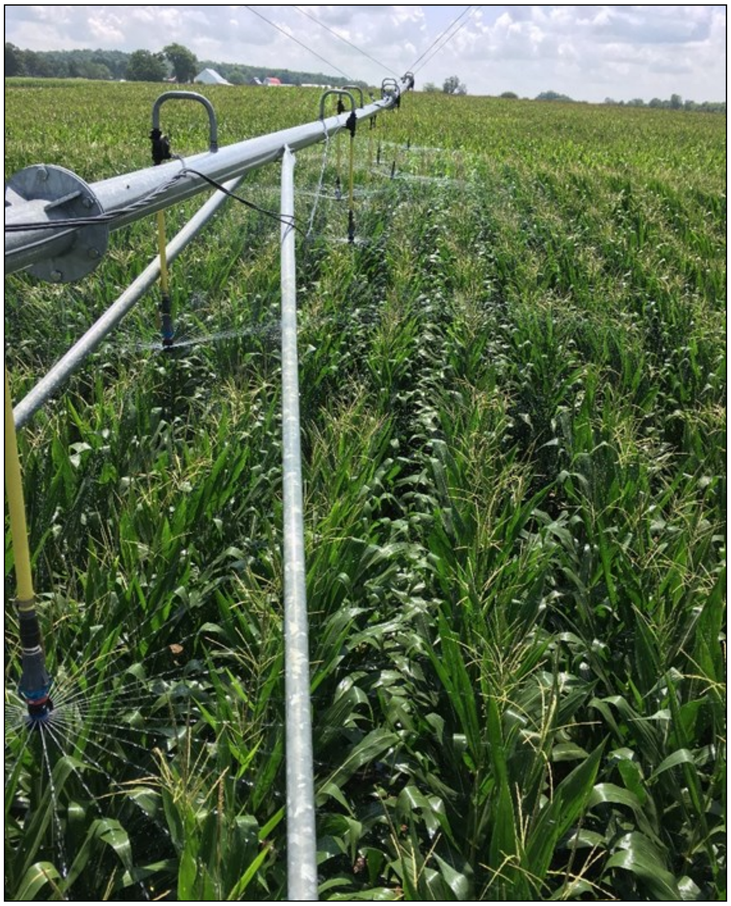

The number of pivot irrigation systems in Kentucky has increased since the 2012 drought. In general, most producers with pivot irrigation systems have developed irrigation strategies specific for their needs with the main driving factor that you should never "get behind" with irrigation applications.

Unfortunately, most of the University of Kentucky's Cooperative Extension Service recommendations for irrigation management rely on information developed in other states. The goal for this project is to create corn irrigation recommendations that are based upon research conducted within Kentucky.

Figure 1. Corn crop being irrigated in July 2019 at University of Kentucky Research and Education, Princeton.

The objective was to determine the differences in grain yield among eight irrigation treatments:

- Non-irrigated control
- Sensor-based treatment
  - During vegetative growth stages
    - Irrigation will be initiated when soil moisture exceeds 80 kPa for the average of two Watermark sensors, one at a depth of 1' and another at 2'
  - During reproductive growth stages
    - Irrigation will be initiated when soil moisture exceeds 80 kPa for the average of Watermark sensors at three depths: 1', 2', and 3'

- Six checkbook irrigation treatments with three initiation and two termination timings
  1. V6 / R5.75 (3/4 milk line)
  2. V12 / R5.75 (3/4 milk line)
  3. R1 / R5.75 (3/4 milk line)
  4. V6 / R6 (black layer)
  5. V12 / R6 (black layer)
  6. R1 / R6 (black layer)

The total water (precipitation + irrigation) per week that was targeted for the checkbook treatments was based upon the needs of the corn crop, which differ among growth stage:

V6 to V7: 1.5" per week
V8 to V11: 1.75" per week
V12 to V16: 2.0" per week
V17 to R2: 2.3" per week
R3 to R4: 1.75" per week
R5 to R6: 1.25" per week

Corn (Pioneer® 1197AM) was planted on April 29, 2019. The seeding rate was 44,000 seeds per acre. A total of 200 lbs of N (46-0-0) was applied on May 13, 2019. For all six checkbook irrigation treatments, 0.6" irrigation was applied on July 3, 19, 24, 29 and Aug 1 and 0.4" was applied on July 20 and 31. For the three checkbook treatments that received irrigation until the R6 growth stage, 0.6" was also applied on Aug 14 and 20. Most center-pivot systems apply 0.33" of water per revolution. Modern center pivots can apply higher rates. The rates used in the study reflect some of those higher rates. Grain was harvested on September 18, 2019. Yield was adjusted to 15.5% grain moisture.

From planting until VT (tasseling) growth stage, there was considerable precipitation, which was about 1.0" more than the 30-year average. Therefore, irrigation during the vegetative growth stages for the checkbook irrigation treatments were not applied. In addition, irrigation was not applied to the sensor-based treatments because the soil moisture, as measured with Watermark sensors, never exceeded 80 kPa for the entire growing season (Figure 2). This resulted in only three irrigation treatments in 2019:

1. Non-irrigated control (including plots initially identified as Sensor-based treatments)
2. R1 to R5.75
3. R1 to R6

Figure 1. Soil moisture, as measured with Watermark sensors, from June 8 to September 7 at Princeton, KY, in 2019. R1 to R5.75 is the irrigation treatment that started at R1 growth stage and ended at R5.75 growth stage. R1 to R6 was the irrigation treatment that started at R1 growth stage and ended at R6 growth stage.

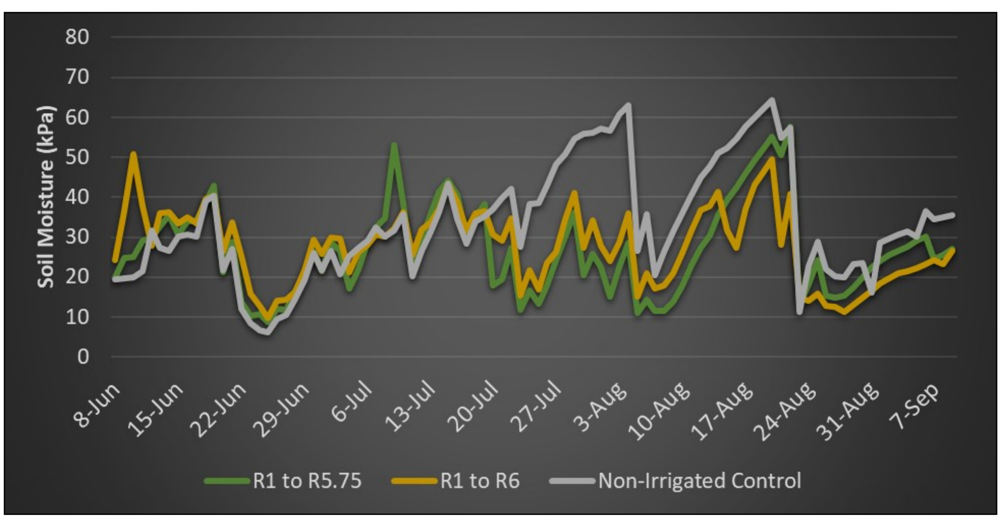

Table 1. Grain yield, number of irrigation events, total irrigation water applied and additional revenue for an irrigated corn study at Princeton, KY, in 2019.

Irrigation Treatment	Yield (bu acre^{-1})	Irrigation Events (number)	Irrigation Water Applied (inches)	Additional Revenue† (per acre)
Non-Irrigated Control‡	256	-	-	-
R1 to R5.75	270	7	3.8	$47.74
R1 to R6	276	9	5.0	$68.20
P-value	0.3536			

†Based upon cash price of $3.41 per bushel.

‡Non-irrigated control treatment includes plots that were initially assigned as Watermark sensor-based plots. R1 to R5.75 is the irrigation treatment that started at R1 growth stage and ended at R5.75 growth stage. R1 to R6 was the irrigation treatment that started at R1 growth stage and ended at R6 growth stage.

Although grain yield ranged from 256 to 276 bushels per acre, statistical differences (P=0.0306) were not found among the three irrigation treatments (Table 1). However, there was considerable revenue generated when the corn crop was irrigated. For the irrigation treatment that started at R1 and ended at R5.75, an additional $48 per acre was generated, when compared to the non-irrigated control. For the R1 to R6 irrigation treatment, an additional $68 per acre in revenue was generated (Table 1). Currently, the cost of operating an irrigation system has not been estimated by the University of Kentucky. However, these estimates are currently being developed, which will allow the determination of profitability of the irrigation treatments.

Corn canopy temperature was also measured in this study. The goal was to determine whether canopy temperature could be utilized by producers to help determine when irrigation should be initiated. Canopy temperature was measured with two methods: an inexpensive FLIR® thermal camera for all replications and Apogee® stationary infrared radiometers for one replication. The FLIR® camera was used to determine canopy temperature beginning at noon on nine sunny days (Figure 2) while the Apogee® stationary radiometers continuously measured canopy temperature every 5 minutes from July 1 to Aug 26. FLIR® thermal images were measured on July 11, 17, and 18 and August 5, 7, 9, 12, 13, and 18.

Differences in canopy temperature were detected among the irrigation treatments. When the FLIR® canopy temperature data was averaged across all nine days, the non-irrigated control had the hottest maximum canopy temperature, which was 99°F (Table 2). In addition, the R1/R5.75 treatment had the coolest minimum temperature, which averaged 73°F (Table 2). However, the average canopy temperature of the entire FLIR image was 87°F for the non-irrigated control and the two irrigation treatments (Table 2).

Additional data are still being processed. Canopy temperature of the top (adaxial) part of the leaves, as measured with the FLIR® camera, is being used to determine if differences exist among the irrigation treatments. In addition, the stationary infrared radiometer data is being used to compare the canopy temperature differences between the two methods and to better identify the time of day that the canopy temperature should be determined to assist with irrigation scheduling.

Figure 2. Thermal image captured by the FLIR® thermal camera to estimate corn canopy temperature of the three irrigation treatments, Princeton, KY in 2019.

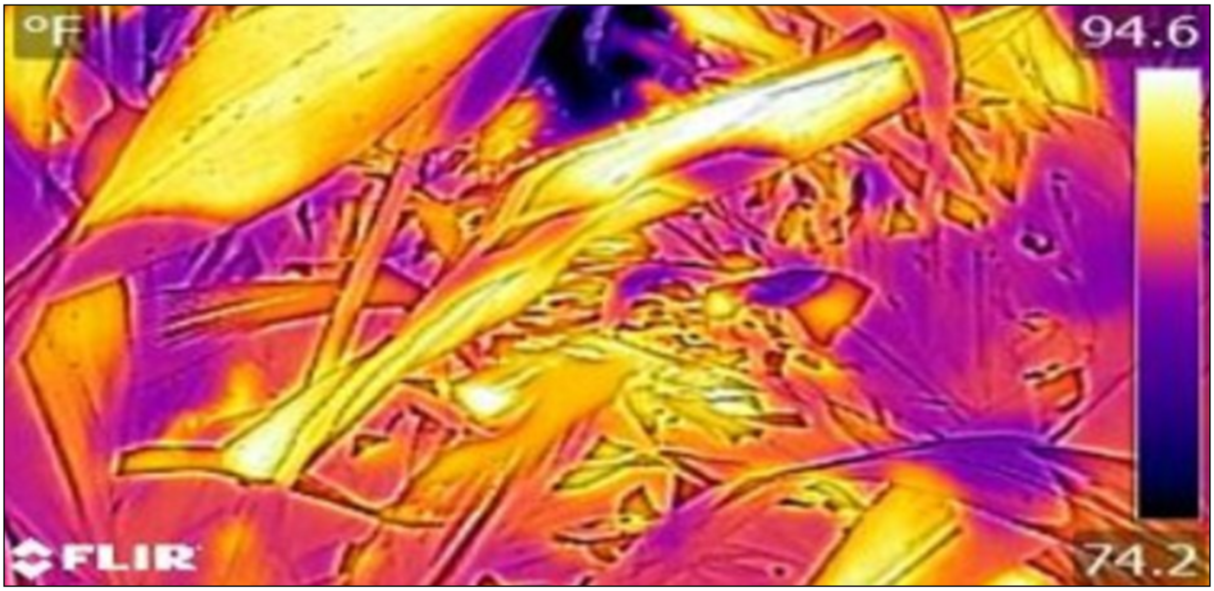

Table 2. The average, minimum, and maximum corn canopy temperature as measured by a FLIR® thermal camera beginning at noon and averaged across nine sunny days (July 11, 17, and 18 and August 5, 7, 9, 12, 13, and 18) at Princeton, KY in 2019.

Irrigation Treatment	Canopy Temperature (°F)		
	Average	Minimum	Maximum
Non-Irrigated Control†	87	75 a‡	99 a
R1 to R5.75	87	73 b	97 a
R1 to R6	87	74 b	95 b
P-value	0.5806	0.0182	0.0005

†Non-irrigated control treatment includes plots that were initially assigned as Watermark sensor-based plots. R1 to R5.75 is the irrigation treatment that started at R1 growth stage and ended at R5.75 growth stage. R1 to R6 was the irrigation treatment that started at R1 growth stage and ended at R6 growth stage.

‡Means within a column followed by different letters are significantly different (P<0.05).

Based upon this first year of data, it appears that the different irrigation treatments can produce very different revenue per acre. It also suggests that corn canopy temperature may provide useful information that can assist with irrigation scheduling. Additional work is needed to better understand the profitability of different irrigation treatments and to identify additional resources that can assist with irrigation scheduling decisions.

ACKNOWLEDGEMENTS

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Management of Caterpillars in Conventional Corn in Western and Eastern Kentucky

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INTRODUCTION

Several caterpillar species are of economic importance for conventional field corn grown in Kentucky. Some of these species are more abundant in certain regions of the state. For instance, the European corn borer (ECB), *Ostrinia nubilabis*, (Crambidae) is more frequently found in central and eastern Kentucky than in the western region, whereas the opposite occurs with the southwestern corn borer (SWCB) *Diatraea grandiosella* (Crambidae). On the other hand, the corn ear worm (CEW), *Helicoverpa zea* (Noctuidae) is well spread across all Kentucky. By mid-July in 2018, there was an outbreak of ECB in central Kentucky (Figure1). This occurrence affected corn fields that did not carry GMO traits. These corn fields were grown for the distillery industry or specialized food-based niche markets. The ECB has two generations per year in Kentucky (Bruck and Lewis 1999) and the outbreak reported above coincided with the second-generation ECB (Bessin, 2004).

FIGURE 1. Damages caused by European corn borer to conventional corn in central KY in 2018 (Photo credit: R.T. Villanueva).

This study aims (1) to study the differences of caterpillar attack on corn planted early and late using conventional and GMO corn (*Bt*-corn) in two locations (Lexington-central KY and Princeton-western KY), and (2) evaluate management effects based on insecticide applications using IPM threshold, and scheduled sprays on yields of conventional and *Bt*-corn.

MATERIALS AND METHODS

In this study, conventional corn and GMO corn were planted at the University of Kentucky's Research and Education Center in western Kentucky, Princeton, Caldwell Co. and the Spindletop Research Farm in central Kentucky, Lexington, Fayette Co. The planting time, tactic utilized, spray dates, plot dimensions, and planting density applied to corn plots in Lexington and Princeton KY in 2018 are listed in Table 1. Warrior II with Zeon Technology (*Lambda-cyhalothrin*, 22.8% a.i.) was the insecticide used at the rate of 1.5 fl. oz/A at 25 GPA in Lexington and Warrior with Zeon Technology (*Lambda-cyhalothrin*, 11.4% a.i.) was the insecticide used at the rate of 3.8 fl. oz/A at 20 GPA in Princeton.

TABLE 1. Planting time, tactic utilized, spray dates, plot dimensions and planting density employed for corn studies conducted in Lexington and Princeton KY in 2019.

LEXINGTON		PRINCETON	
Planting time	Tactic	Planting time	Tactic
EARLY (4/29/19)	Non-Bt	EARLY (4/30/19)	Non-Bt
	IPM threshold*		IPM threshold*♦
	Scheduled sprays▼		Scheduled sprays**
	Bt Corn		Bt Corn
LATE (5/22/19)	Non-Bt	LATE (5/30/19)	Non-Bt
	IPM threshold		IPM threshold**♦
	Scheduled sprays▼		Scheduled sprays**
	Bt Corn		Bt Corn
• Sprays: 14-Jun* and 11-Jul▼ • 4 rows, 30 ft long, • 30 in between rows • 29,600 seeds/A		• Sprays: 14-Jun* 21-Jul**and 31-Jul♦ • 4 rows, 30 ft long, • 30 in between rows • 30,000 seeds/A	

Percentages of plant emergence, and damages by caterpillars were tallied every 15 days. On 12 August, 2019, 5 ears were collected to evaluate the presence of CEW in Princeton and by the end of season the following evaluations were conducted: **Yield:** Hand harvest of **17.4 ft** of row, ears shelled, and moisture corrected to 15.5%, **Corn borers:** 10 sequential stalks were split and the length of tunnels and number of galleries recorded, **Corn Earworm:** All ears which were hand harvested and inspected for earworm damage to the cob tips.

RESULTS AND DISCUSSION

Plant emergences were satisfactory for the two locations. Tallies conducted in Princeton for the presence of CEW caterpillars in ears are presented on Figure 2. Significantly (p<0.001) fewer CEW caterpillars were found in the early planted plot compared with the late planting. Also, significantly fewer CEW caterpillars were found in the *Bt* corn compared with the other three treatments (Figure 2). In Lexington damages from CEW were not observed.

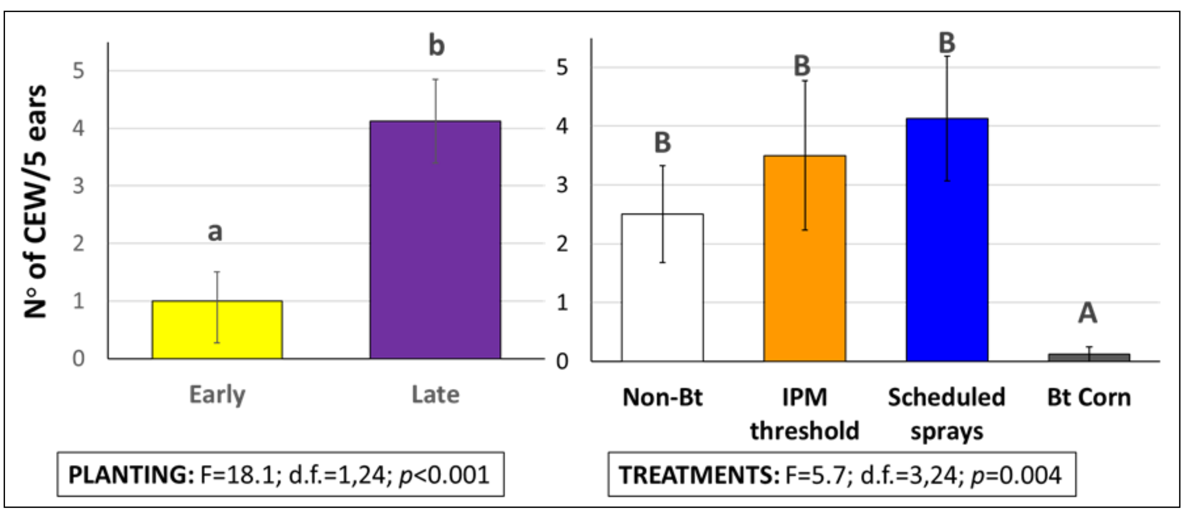

FIGURE 2. Mean (±SEM) corn earworm caterpillars found in corn ears on 12 August 2019 on early vs. late planting (left), and among different treatments (right) utilized in this study in Princeton. Different letter between early and late planting indicates significant differences (p<0.05) after an ANOVA. To find differences among treatments the ANOVA was followed by comparisons of treatment means using Fisher's LSD test.

Yields for the early and late planting corn in Lexington and Princeton are shown on Figure 3. In both locations significant differences were observed between the two planting periods. In Lexington, significantly higher yield was obtained in the early planting compared with the late planting however in Princeton the opposite occurred, early planting yield < late planting yield.

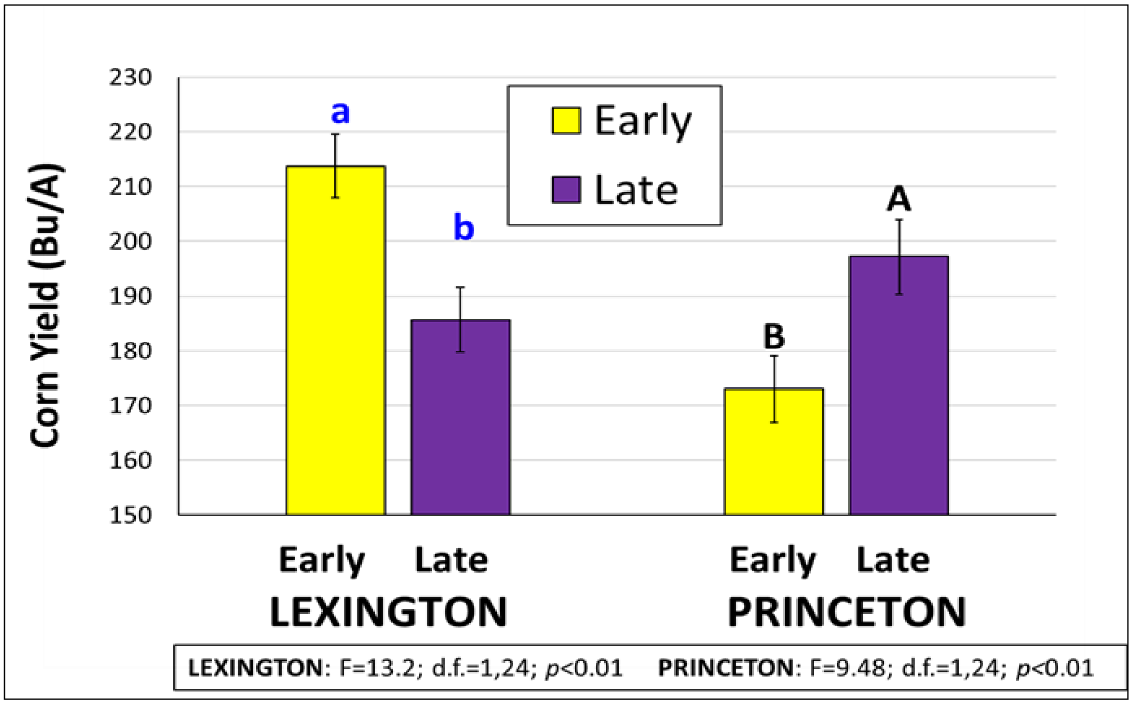

FIGURE 3. Mean (±SEM) corn yields (Bu/A) on Lexington and Princeton between early and late planting. Different letter in each location indicates significant differences (p<0.05) between early and late planting after an ANOVA.

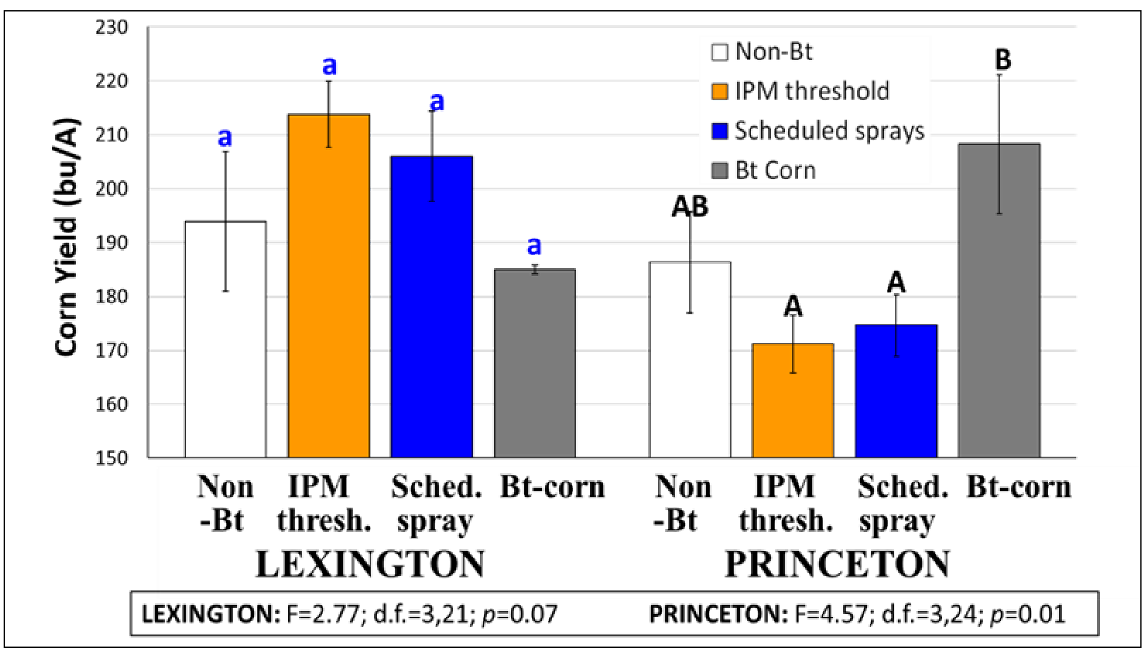

FIGURE 4. Mean (±SEM) corn yields among different treatments in Lexington and Princeton. Different letter among treatments in each location indicates significant differences (p<0.05) after an ANOVA, followed by Fisher's LSD test to compare means among different treatments.

Yields for the four treatments in Lexington and Princeton are shown on Figure 4. Significant differences ($p \geq 0.05$) among the treatments were not found in Lexington, whereas in Princeton the *Bt*-corn reached the highest yield, which significantly ($p<0.05$) differed from the IPM and Scheduled sprays treatment yields. In addition, the results for the corresponding treatments were not analogous. For instance, the highest and lowest yield in Lexington were on the IPM-threshold and *Bt*-corn treatments, respectively. Whereas in Princeton the opposite occurred for the same treatments. The lowest and highest yield in were on the IPM-threshold and *Bt*-corn treatments, respectively ($p<0.05$, after Fisher's LSD test).

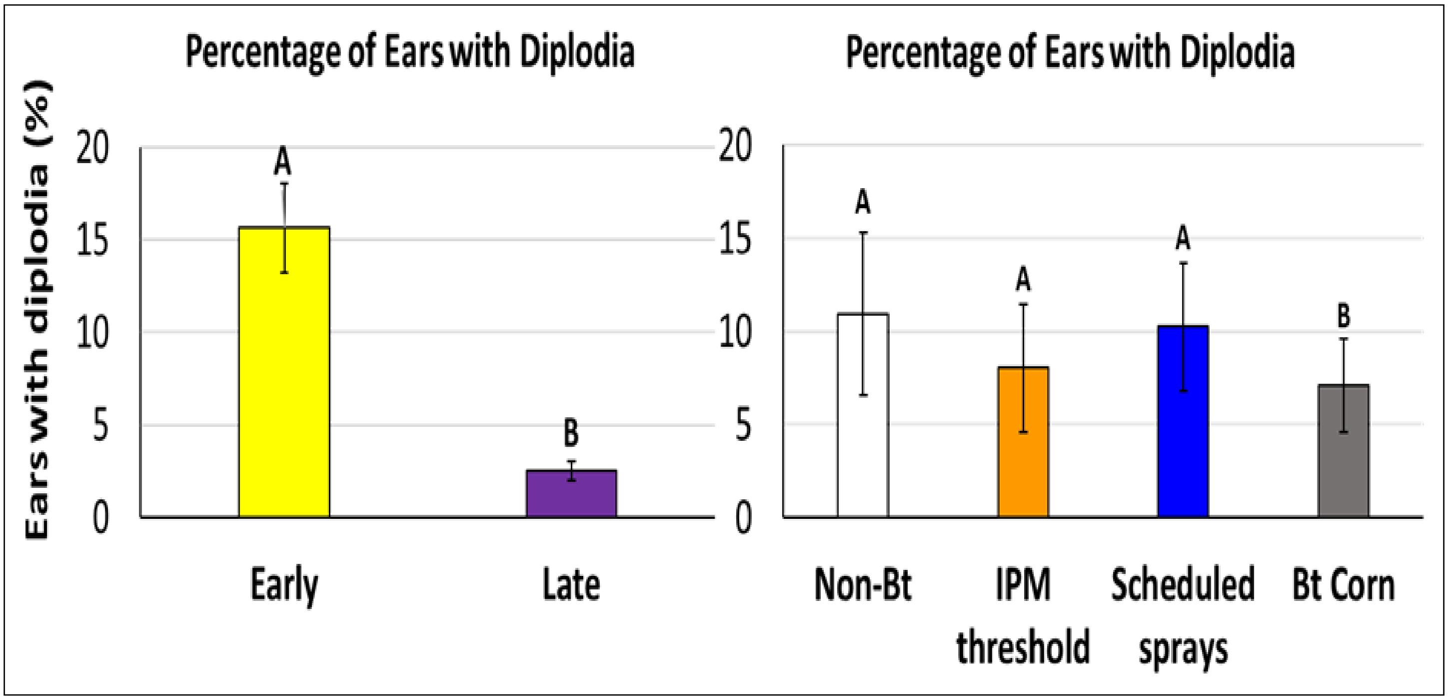

FIGURE 5. Mean percentages (±SEM) of ear with diplodia ear rot (*Stenocarpella maydis*) found in corn ears harvested in Princeton. Different letter between (left) early and late planting indicates significant differences ($p<0.05$) after an ANOVA. To find differences (right) among treatments the ANOVA was followed by comparisons of treatment means using Fisher's LSD test.

The result found in Lexington on early planting and higher yields correspond with previous studies that shown similar trends (Johnson et al.2001) The Princeton results may be explained by two factors. Firstly, the presence of Diplodia ear rot, a disease caused by two fungi, principally by *Stenocarpella maydis,* and in minor degree by *S. macrospora.* in the early planting ears (>15.6% of ears were infested) (Figures 5 and 6), and the late planting had only 2.5% infestations. Among treatments the Bt-corn has the lowest percentages of Diplodia ear rot in Princeton, which agrees with the highest yields obtained in BT-corn (Figures 3 and 5). It was reported that Diplodia ear rot reduces yield, grain quality, and grain fill. Secondly, the pest pressure was higher in Princeton compared to Lexington. In Lexington damages by CEW were scarce to nil. Furthermore, stinkbugs were present during the early development of the plants, and Japanese beetles and June bugs were present during silking and pollination in Princeton. These emerging pests in field corn need to be considered in future studies. In both locations, Bt-corn provided complete control of corn borers. In Lexington insecticide treatments reduced corn borer injury, however, there were no significant differences in yield. In Princeton, insecticide applications did not provide effective control of borers, the presence of frequent rains in July and August interfered with the timely application of insecticides and may have reduced the effectiveness of the insecticide application.

FIGURE 6. Corn showing contrasting differences between healthy and infected ears with Diplodia ear rot in field corn planted early in Princeton in 2019 (Photo credit: R.T. Villanueva).

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Testing Heirloom Corn in Central Kentucky

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Figure 1. Ears of a modern yellow hybrid, modern white hybrid and several heirlooms.

Several heirloom or open-pollinated lines of corn were compared with a modern yellow and a modern white hybrid near Lexington, KY. The soil was a Bluegrass-Maury slit loam, no-till, planted to soybeans the year before. The study was irrigated as needed. Herbicides were applied early postemergence before corn was 11 inches tall. Hand-hoeing was used after corn emergence.

All corn was planted May 14, 2019 into rows spaced 30 inches apart. The heirloom corn types were seeded at 15,000 seeds per acre and the modern hybrids were seeded at 30,000 seeds per acre. Each plot of corn was four rows wide. Each heirloom corn or modern hybrid was planted into four separate plots that were randomized in complete blocks. The middle two rows of each heirloom or hybrid were harvested on October 2, 2019. The average yield for all four plots of each heirloom and hybrid was calculated and those values were compared with statistics to identify differences.

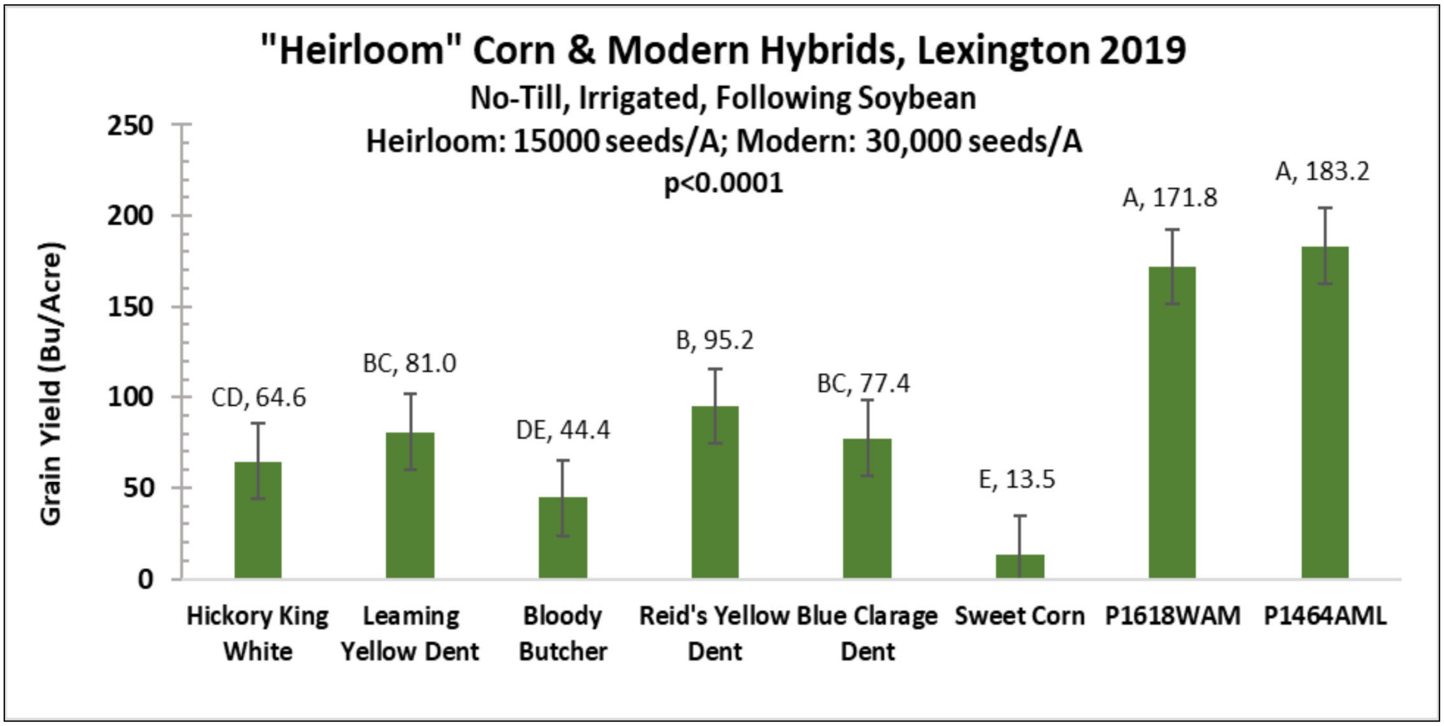

Figure 2: Yields of heirloom open-pollinated corn and two modern hybrids, P1618WAM (white) and P1464AML (yellow).

Heirloom corn lines ranged from 44.4 bushels per acre for Bloody Butcher to 95.2 bushels per acre for Reid's Yellow Dent. Reid's Leaming Yellow Dent ranked second among the heirlooms with 81 bushels per acre and Blue Clarage Dent yielded 71.4 bushels per acre. Hickory King yielded 64.6 bushels per acre. These yields were far below the modern hybrids, which averaged 177.5 bushels per acre. The average yield of the three heirloom dent corns was 84.3 bushels per acre. The heirlooms yielded less than half of the modern hybrids.

Farmers and distillers should consider these yield differences when determining value for the heirloom grain.

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2019 Fragipan Remediation Report

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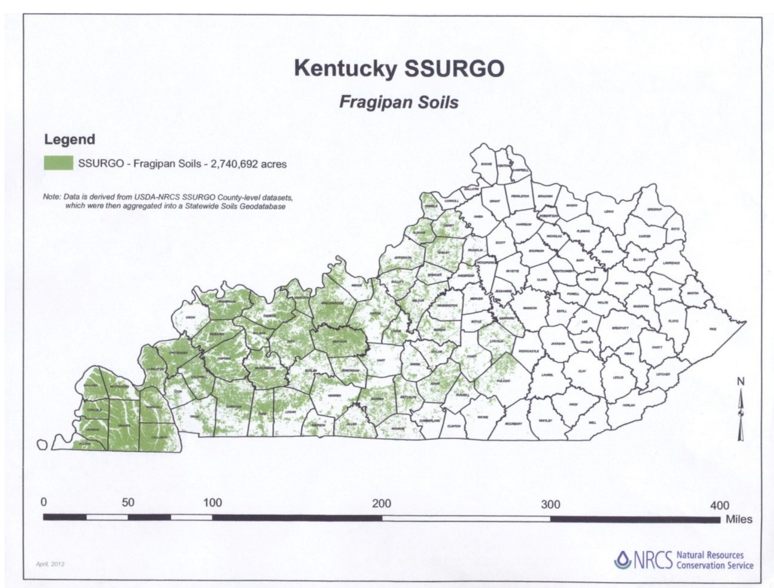
The fragipan is a naturally occurring soil horizon that virtually stops water movement and root growth through the soil. Its depth averages about 20-24 inches in the soil types in which it occurs. The layer is due to the cementation of the soil particles with a silicate rich amorphous aluminosilicate binding agent. The fragipan is present in about 2.7 million acres of Kentucky soils and about 50 million acres in the U.S. Fragipan soils reduce yields of crops for 2 reasons: 1) limited water holding capacity due to limited soil depth 2) water saturated soil conditions during wet periods.

The fragipan itself is a silt loam soil that has been cemented. If the cementation is dissolved, the released soil particles can begin functioning as a productive soil again. The goal of this project is to try to dissolve the cementation and make a deeper soil that will hold more water for summer growing crops and reduce waterlogging in the winter which would make the soil better suited for winter crops and better support trafficking at this time of the year.



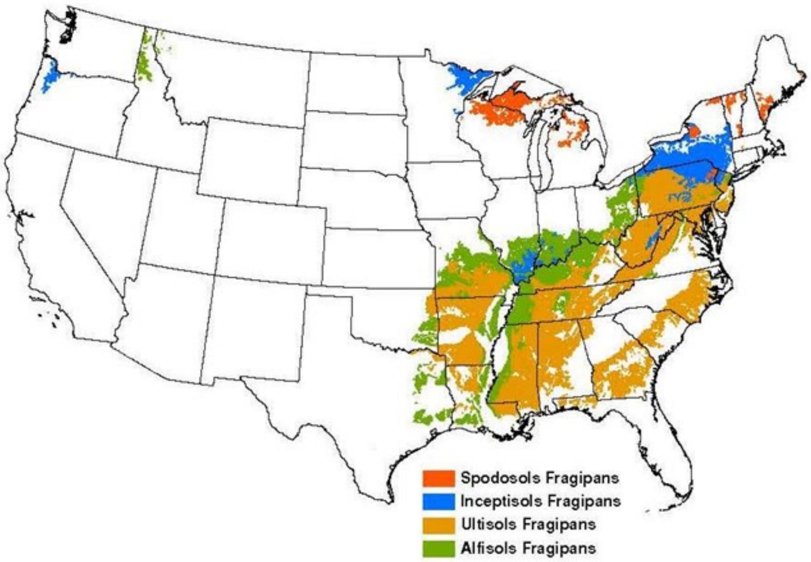


Fig. 2. Distribution of soil mapping units with soils containing fragipans in the US (derived from National Survey Laboratory STATSGO database).

The approach to investigation of a remedy to the fragipan has three phases.

- Laboratory research and evaluation
- Greenhouse research and evaluation
- Field research and evaluation

The research on the fragipan by the research team is having excellent success. Of the many plants, compounds and combinations tested, there are two plants, 4 compounds and another material that have been found to be effective in breaking apart the fragipan. They are annual ryegrass, potassium chloride, potassium sulfate, sodium fluoride, sodium nitrate and possibly leonardite humate.

Annual ryegrass has been chosen as the central focus of the greenhouse and field research due its notable advantages and the compelling proof of its effectiveness. Annual ryegrass roots contain exudates that have a degrading effect on the cement of the fragipan. The deep root penetration also increases soil porosity and may facilitate the leaching of the 4 or 5 other effective compounds down to the fragipan. We are presently looking for varieties of annual ryegrass that are more effective in breaking down the fragipan.

Through research findings in the laboratory, greenhouse and the field, we have gained enough confidence in the ryegrass treatment as a fragipan remedy and its yield increase potential, that we are cooperating with a few farmers across the state to establish on-farm trials. When annual ryegrass was grown 6 times in a rotation with soybeans in the greenhouse, the depth of the newly formed productive soil increased about 7 inches. We have also found 3 fields in Kentucky, 2 in Indiana and 1 in Illinois that had a history of at least 5 years of annual ryegrass over a 10 year period. The annual ryegrass increased soil depth by as much as 14 inches and as little as 3 inches. The average depth increase for growing annual ryegrass across all of these fields is about one inch for each year annual ryegrass is grown. However there is a wide range.

The altered fragipan (lower profile) after annual ryegrass is grown 6 times in an annual ryegrass/soybean rotation. The upper profile is the control.

We are finding lower bulk density and increased porosity as well as an enrichment in some organic compounds in the fragipan horizons undergoing degradation in the greenhouse where ryegrass is present when compared to the control. We are also finding compounds which are suspected to be the compounds which are exudates released from the ryegrass roots which induce the fragipan degradation. At present time, we are trying to scientifically verify and identify the exudates. It will greatly aid in this effort and may lead us to a quicker and more effective method to remediate the fragipan.

Yield Responses to Changing the Fragipan

As the cementing agent in the fragipan is dissolved, the freed soil particles begin to act as a productive soil making the soil deeper. This should increase the yields of these soils as the depth increases.

Six years of research completed in the 1970's and 80's in Kentucky and Tennessee, indicate that for each inch of soil above the fragipan, corn yields are increased an average of 2 to 2.3 bushels/ac (2 to 2.5%) and soybean 1.1 bushels/ac (4%). The yield increase varied greatly from year to year as the many things that affect yield, changed from year to year. The yield change ranged from a plus 5 bu/ac for each added inch to a one-year negative of 2 bu/ac.

The yield comparisons that we presently have from field trials with and without annual ryegrass on fragipan soils are of rather short duration (3 to 6 years). It appears that little or no yield gain is common in the first two years. Yield gains after this become more consistent and significant. In 2018, yield comparisons from seven field trials are seen in Table 1.

The only long-term data demonstrating the ability of annual ryegrass to degrade fragipans was collected from a field owned by Ralph (Junior) Upton in Hamilton County Illinois. Annual ryegrass was grown as a cover crop alone or in a mixture for 15 years on a fragipan soil type (Hickory silt loam). Corn yields in the field with the ryegrass cover crop were compared to the yearly average corn yields for Hamilton County (Figure below). The trend line indicates that yields on his fragipan soil with ryegrass cover crops begin 15 to 20 bu/ac below the county average and after 15 years was 40 plus bu/ac. above the county average. This sloping, somewhat eroded field was compared to all the soils and different management practices in that county. This data demonstrates that the long-term use of an annual ryegrass cover crop positively influences fragipan soils and can increase yields over a long period of time. This is the only long-term data we are aware of at this time. This data is encouraging and suggests the extra effort for this practice is justified.

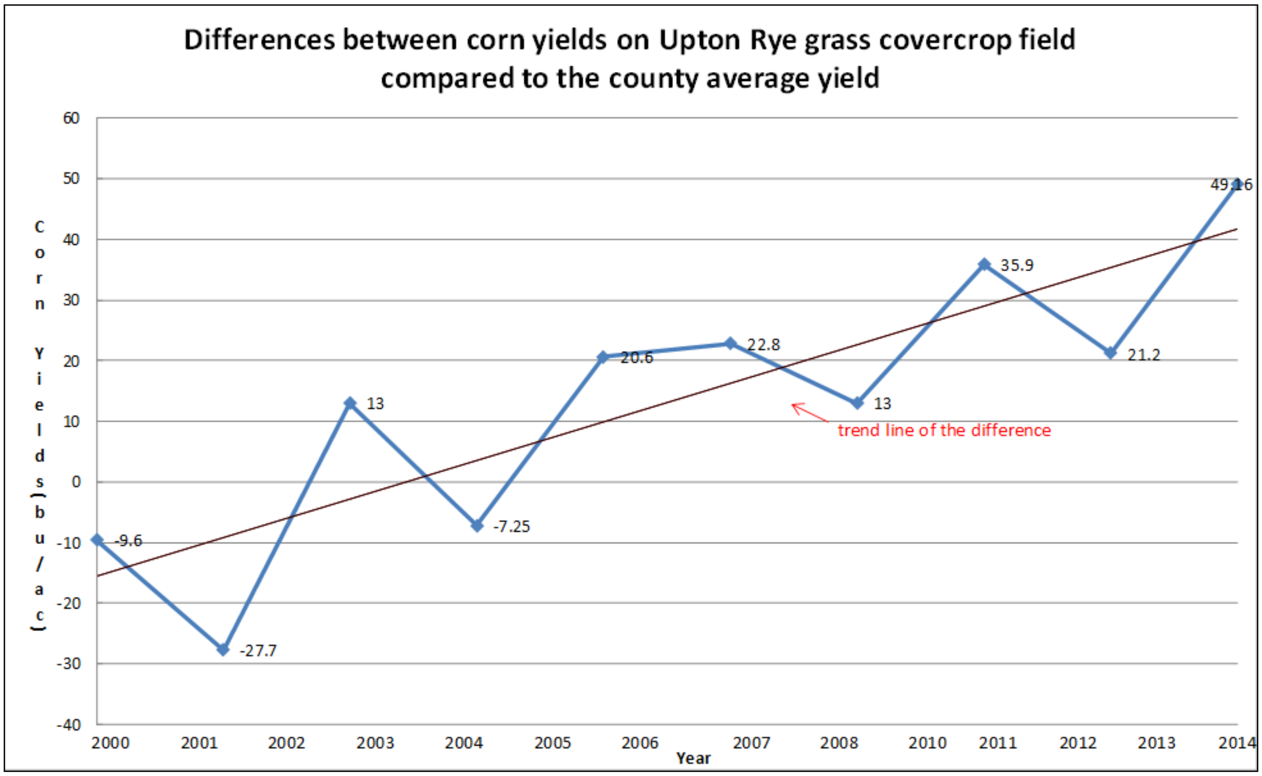


Table 1. Yield Differences Found When Using Annual Ryegrass as a Cover Crop on Fragipan Soils - 2018 Yields				
Location	**ARG* Years**	**Yield (bu/ac) ARG/Residue**	**Increase %**	**Conditions**
UKREC**	3	189/175	8.0	No-Till
UKREC**	3	175/165	3.9	No-Till
UKREC**	3	200/194	3.1	No-Till
UKREC**	3	50/47	6.8	No-Till
UKREC**	6	47/45	3.5	No-Till
Caldwell***	3	78/69	13.0	No-Till
Carlisle***	4	161/130	23.8	No-Till Drought
AVG 8.9				
*Annual Ryegrass ** Research Trials at Princeton *** On Farm Trials				

Degrading the Fragipan in Greenhouse Experiments

Complete intact soil profiles in transparent plastic tubes were used in the greenhouse experiments (Figure below). Different plants were grown in them and the most promising treatments were applied to the surface soil as they would be in the field.

Complete soil profiles in transparent tubes allow for visual verification of different treatments added to break apart the fragipan.

The top of the fragipan was marked on the tube when the core was taken. Rooting patterns and any changes to the fragipan from those roots or applied treatments were observed. Annual ryegrass roots reached the fragipan (18 to 24 inches) about 5 to 6 weeks after planting. Top growth of the annual ryegrass was about 4 to 5 inches tall at this time. Extensive rooting reached the fragipan in about 2 to 2.5 months.

The more often annual ryegrass was grown the more the fragipan was degraded and the degradation became more extensive and deeper. Some chemicals proven in the laboratory to degrade the fragipan were added to the soil in the ARG/soybean rotation. Some appear to accelerate the degradation of the fragipan when added to the soil surface during each cycle (Table 2). These combinations are now being tested in field trials.

Table 2. Effect of Different Treatments on Fragipan Degradation in 3 inch Cores in the Greenhouse		
Treatment	**Growth Cycles**	**Depth of Fragipan Degradation (inches)**
AGR*/Soybeans	6/6	3.25
ARG*/Soybeans Plus Sodium Nitrate	6/5	10.7
ARG*/Soybeans Plus Potassium Chloride	6/5	5.7
ARG*/Soybeans Plus Sodium Fluoride	6/5	3.25
Fescue	60+ years	1.25
*Annual Ryegrass		

With these limited results, it appears that it might be possible to increase yields of corn and soybeans by 25% on the fragipan soils by using an annual ryegrass cover crop. We also expect to improve the yields of wheat. A 25% increase would result in $500,000,000 in increased returns to Kentucky producers per year or $5,000,000,000 over a 10 year period on the 1.5 million acres of cropable fragipan soils in Kentucky. There is 2.7 million acres of total fragipan soils in Kentucky. Kentucky has only a small portion of the fragipan soils in the U.S. There is about 50 million acres of fragipan soils in the U.S.

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