College of Agriculture, Food and Environment

2020 Corn Science Research Report

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2020 CORN SCIENCE RESEARCH REPORT

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2019-2020 Fragipan Remediation

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The research on the fragipan has made excellent progress. There are two plants, potentially 4 compounds and possibly other materials that have been found to be effective in breaking apart the fragipan. They are annual ryegrass, festulolium, potassium chloride, potassium sulfate, sodium fluoride, sodium nitrate and possibly leonardite humate.

Annual ryegrass was chosen as the central focus of the greenhouse and field research due to its notable advantages. Annual ryegrass roots apparently contain exudates that have a degrading effect on the fragipan. The deep root penetration degrades the fragipan and it also increases soil porosity and enrichment of organic compounds in the fragipan undergoing degradation.

The average yield increase in 2019 of corn and soybeans from six field trials ranged from 0.5% to 20% for an annual ryegrass cover crop compared to no-tillage alone. The average yearly increase of corn grown after an annual ryegrass cover crop on a fragipan soil in southern Illinois is 3.7 bushel per acre per year over a 15-year period. The increase is accumulative resulting in an increase of 55 bushels per acre the 15th year.

It appears that it might be possible to increase yields of corn and soybeans by 25% on the fragipan soils over many years 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. This does not include any increase that would be realized in forage production from the deeper soil.

Long-term breeding has altered corn root traits

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BACKGROUND

Corn grain yields rose rapidly with the introduction of hybrid corn and in the decades of breeding since. These yield increases are attributed to both improved genetics and agronomic practices. Modern corn plants have more vertical leaves, a longer grain-filling period, improved lodging resistance, and other traits that have enabled higher yields and higher plant populations. However, little is known about changes to corn root systems.

Plant root traits affect water and nutrient capture and uptake efficiency, plant stability, and ultimately yields. Large, deep root systems are expected to result in greater water and nitrogen capture and reduced lodging. Plant roots also contribute most of the plant litter that persists in the soil as soil organic matter, which has important benefits to soil functioning and health. Given these roles of roots, tracking their changes is necessary for understanding crop performance and long-term soil health.

We hypothesized that breeding has altered corn root traits over time. Due to selection pressures for high-density plantings in nutrient and water-rich settings, we expected that newer hybrids would have smaller, shallower root systems with fewer fine roots, which would lead to less plant carbon inputs to the soil on a per plant basis.

Figure 1. Replicate 3 prior to harvesting, illustrating the growth rack set-up.

METHODS

This research was conducted in the University of Kentucky Research Greenhouse. The study used twelve corn hybrids from a panel spanning from 1936 to 2014. The hybrids were broken into four eras based on breeding practices- double cross, single cross, genetically modified, and modern elite.

The greenhouse portion of the experiment lasted from June 2020 to November 2020. Plants were grown in 5ft tall plastic-lined PVC pipes filled with a sand-based medium (Figure 1). Each replicate contained one plant of each variety in the panel and was grown for 28 days from emergence, which corresponded to the V7-V8 growth stage. Five replicates were grown in total.

At the end of the 28 days, the shoots were removed from the plants and the plastic liners were pulled out to remove the root system from the pots intact. Shoots were measured for leaf area, then dried and weighed. Roots were cleaned, imaged, divided into depth sections, and dried. The dry weight was taken, and other root traits were quantified from the images taken using GiARoots- a root analysis program.

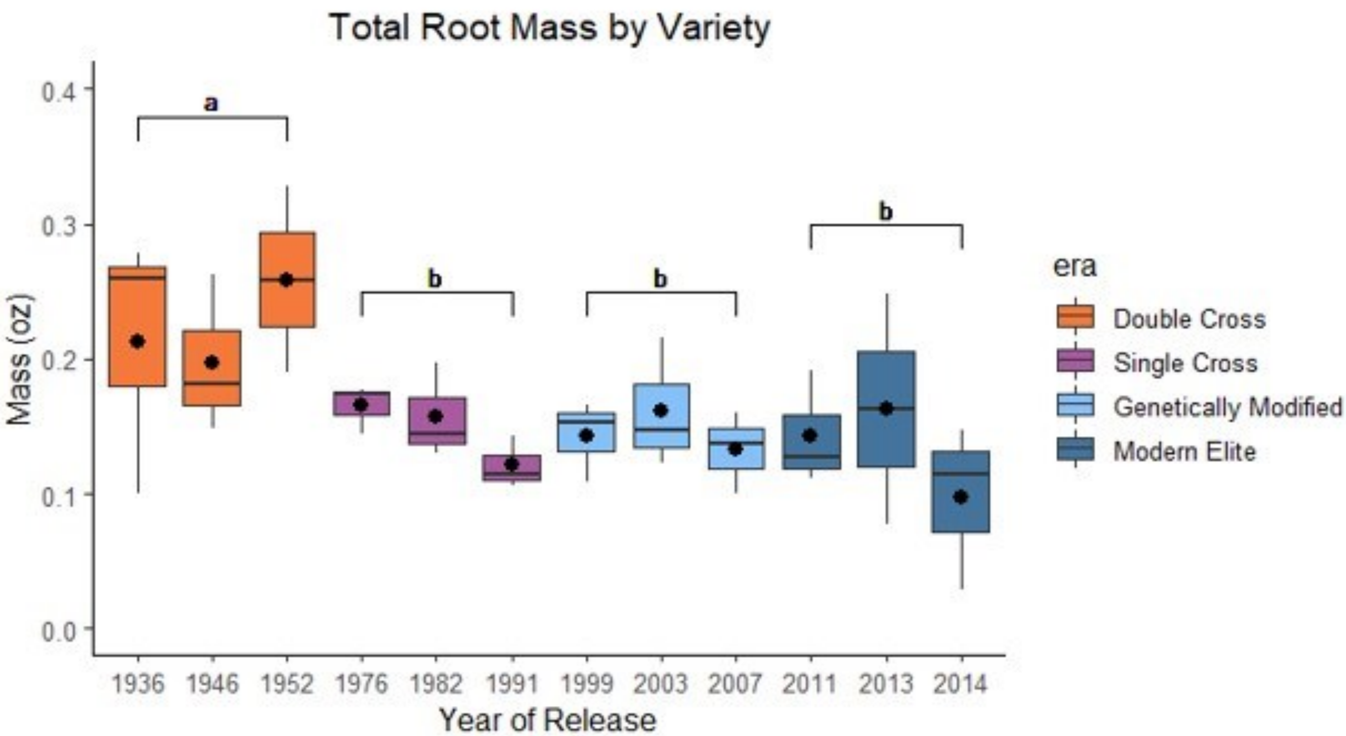

Figure 2. Total root length (top) and total root mass (bottom) for each variety, grouped and analyzed by era. Brackets indicate which varieties are within the same era. Significant differences between eras are indicated by different letters.

RESULTS

The results given here are preliminary results based on data from the first three replicates. As such, a less stringent p-value of 0.1 was used to assess significance.

Total root length and total root mass were greater for the double cross era than for the other three eras (Figure 2). For length, double cross, single cross, genetically modified, and modern elite root systems averaged 800, 525, 487 and 445 ft, respectively. For mass, they averaged 0.22, 0.15, 0.15, and 0.13 oz.

Analysis of the cumulative root length by depth indicated that among the eras, there was a significant difference in the maximum depth of the roots. The shape of the curves and estimated depth of maximum rooting ('dMax') values indicates that the double cross era hybrids had deeper roots than those from the other three eras (Figure 3).

Analysis of the cumulative root mass showed that there were significant differences in both how deep root mass was deposited, and how evenly it was distributed in the profile. The depth of 50% of roots ('d50') and dMax values and the shape of the curves again indicate that the double cross era had a deeper and more even distribution of mass (Figure 3).

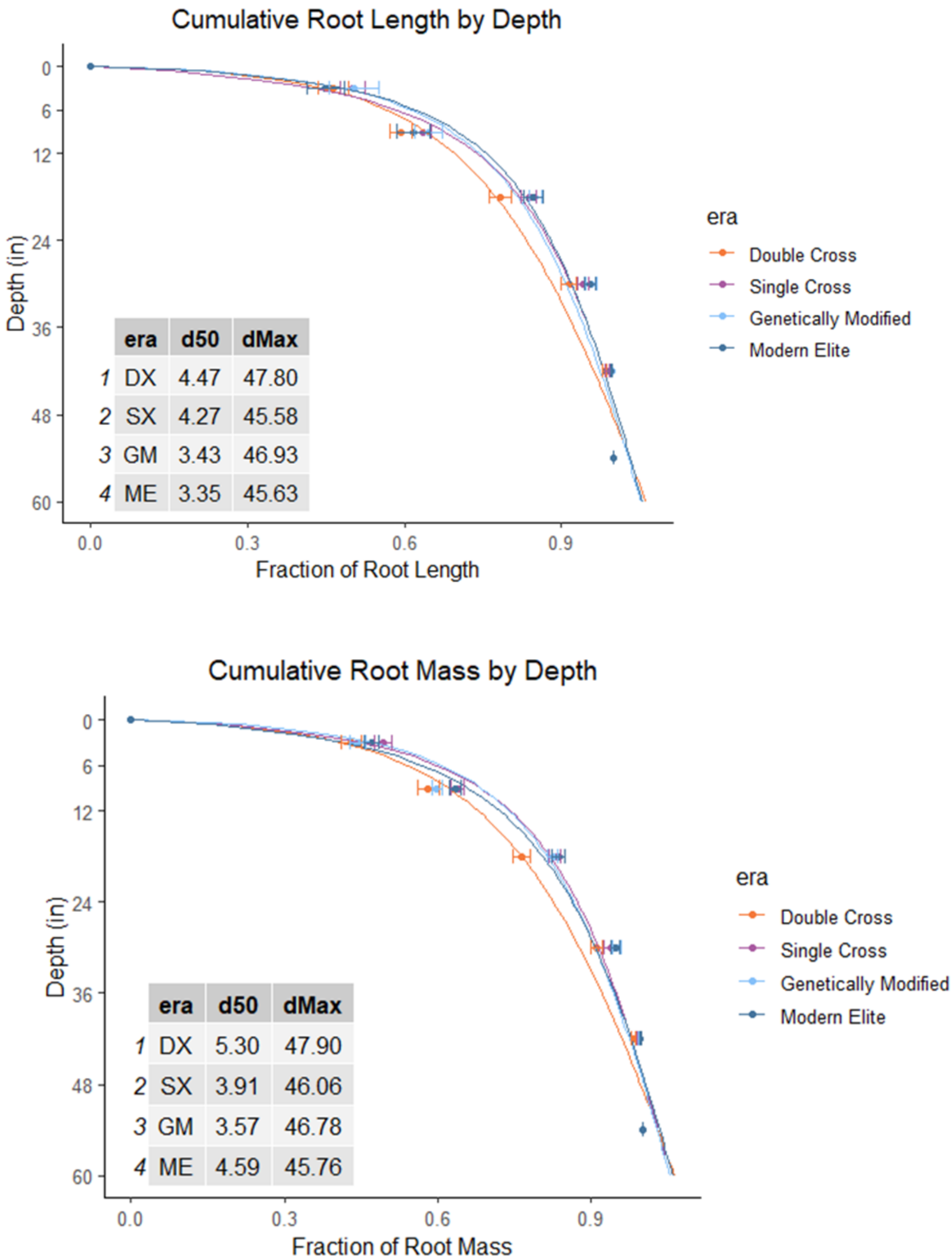

Figure 3. Cumulative root length (top) and cumulative root mass (bottom) for each era. The d50 and dMax values in the tables indicate the depths at which 50% and 100% of the length or mass had accumulated, respectively. Error bars are ± one SE. Significant differences (p-value < .1) in the d50 and dMax are indicated with an asterisk.

Analysis of the relative proportions of fine roots to coarse roots is ongoing. However, qualitative assessment indicates that newer varieties do exhibit less branching and less lateral root development, so further analysis is warranted (Figure 4).

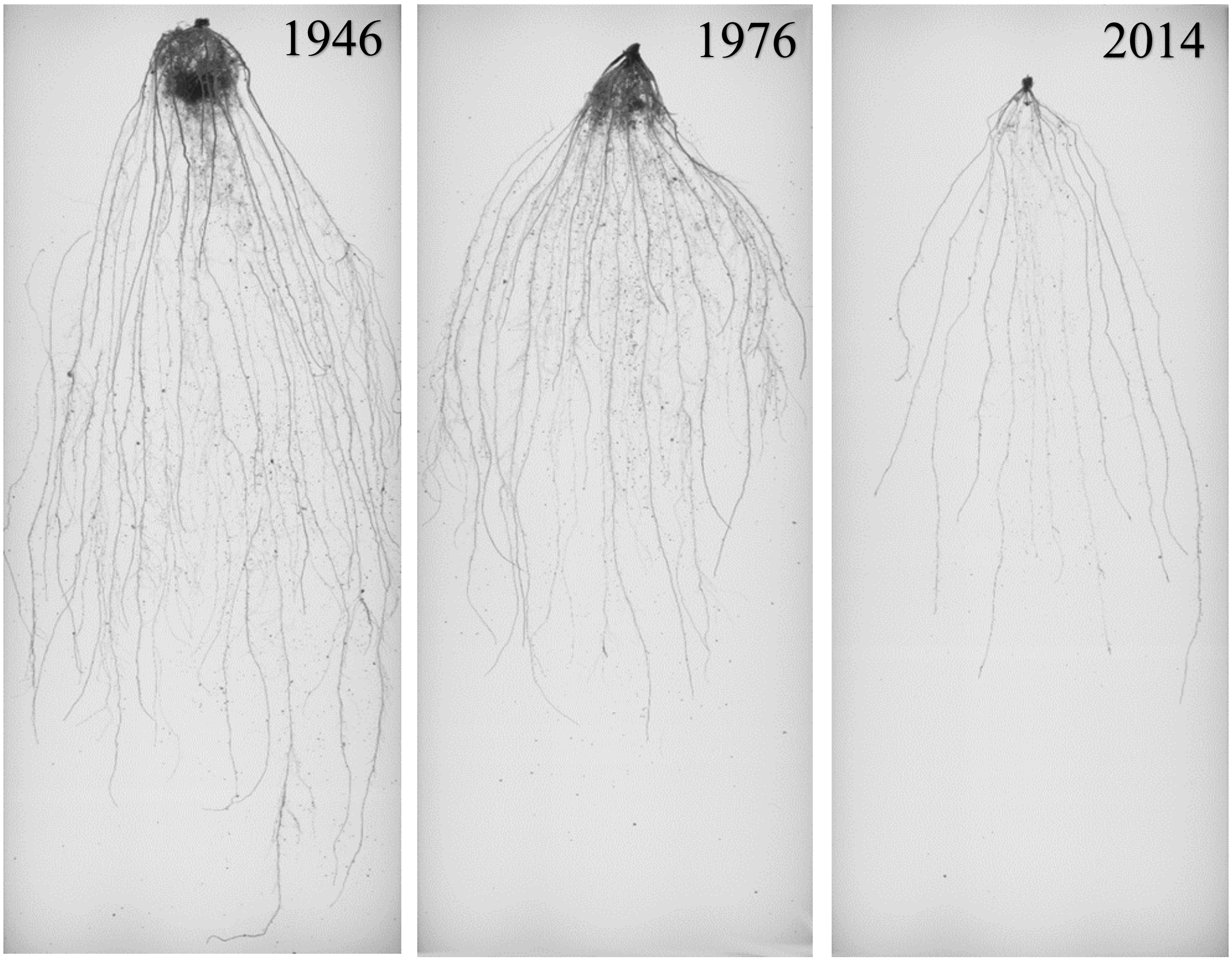

Figure 4. Examples of whole root systems from 28 days after VE for three of the eras. Double cross (1946), single cross (1976), and modern elite (2014).

SUMMARY

Hybrid selection appears to have resulted in root systems that are shorter, less massive, shallower, and have a greater proportion of their length and mass in the upper soil profile. This shift appears to have happened in the transition between double cross and single cross breeding. The smaller root systems of modern corn plants may contribute to a greater tolerance for high populations and greater allocation of energy to grain production. However, the smaller root systems also give less carbon back to the soil on a per-plant basis. Further study is required to assess how modern planting densities may compensate for these changes.

ACKNOWLEDGMENTS

We gratefully acknowledge support from the United States Department of Agriculture National Institute of Food and Agriculture (NC1195 multi-State project and Grant # 2019-67019-29401). We would also like to acknowledge the help of Joe Kupper, Travis Banet, Walter Rhodus, Lucas Canisares, Osei Jordan, and all others who made this work possible.

Understanding subfield variation in corn nitrogen fertilizer needs

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We proposed an experiment to examine the interactive effects of cover crop practices and landscape topography on the profit maximizing nitrogen rate for corn. We wanted to determine how corn yield and reliance on nitrogen inputs vary by landscape position and how this spatial variability is affected by a cover crop. Using the funds provided by the Kentucky Corn Growers Association, we established field trials in the 2019 and 2020 growing seasons at two locations: an on-farm collaboration in Hardin County KY, and the University of Kentucky Spindletop research farm in Fayette County. In the falls of 2018 and 2019, we established three cover crop treatments, a cereal rye monoculture, a cereal rye/crimson clover mixture, and a winter fallow. Following cover crop termination the subsequent spring, four nitrogen rate were applied, which ranged from 0-240 pounds N per acre. Nitrogen was applied as a split application, with 37 pounds applied at planting as a 2X2, and the remainder surface applied at the V5 stage. Once reaching maturity, the corn was harvested, either by hand or using a 2-row plot combine, depending on location.

Figure 1A illustrates the response of corn to landscape position across nitrogen rates and cover crop treatments at the three experimental sites for which data has been collected and processed. We observed a significant effect of landscape position at all experimental locations, with the depression consistently yielding significantly higher than the slope and the summit. We did not observe a significant cover crop effect at any of our experimental sites when looking across nitrogen rates and landscape positions (Figure 1B).

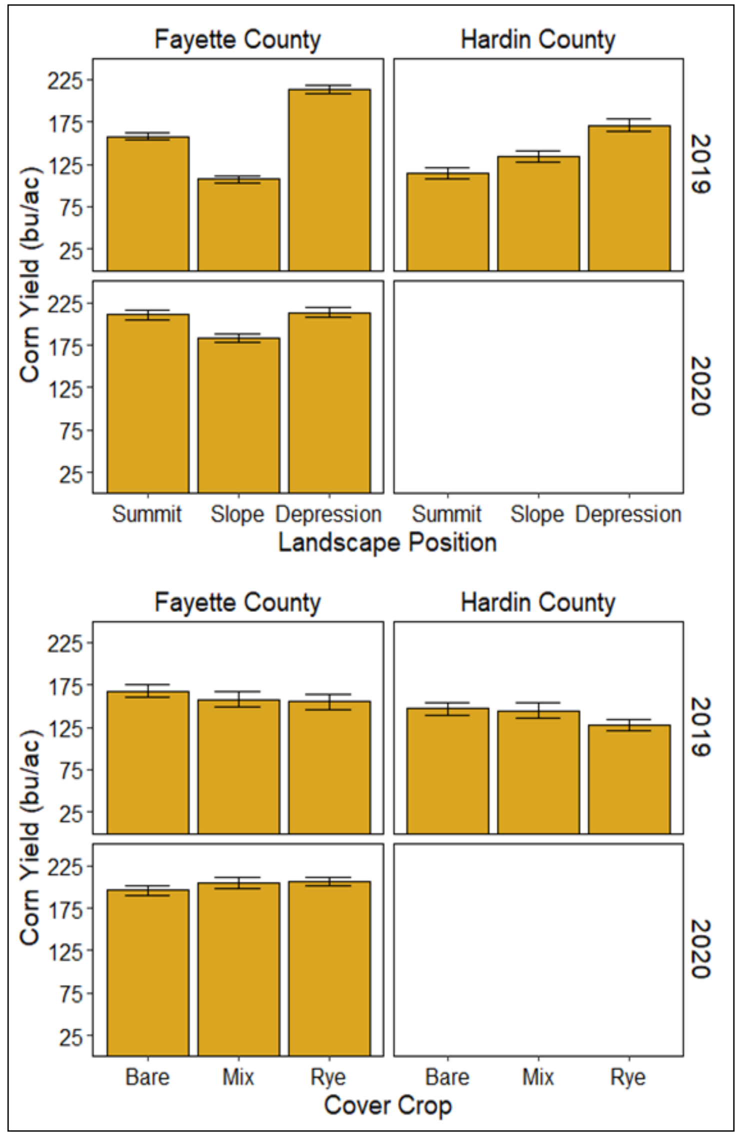

Figure 1. Average corn yields at our 4 site years at different landscape positions (A) and following different cover crops (B). Error bars indicate +/- 1 SE.

When we examine the variability in yields between cover cropped and non-cover cropped plots, we see somewhat increased variability across landscape positions when the corn follows a cover crop (CV = 26 % and 32% for the bare plots and the cover cropped plots, respectively). That variability is further observed when we examine topographic attributes across these fields, such as the slope. Figure 2 shows the yield reduction with increasing slope for corn following different cover crop treatments. Our data from the field trials in KY show that yield decreases with increasing slope, and this effect is more pronounced following a cover crop. This finding suggests that a cover crop may increase spatial variability in corn yield.

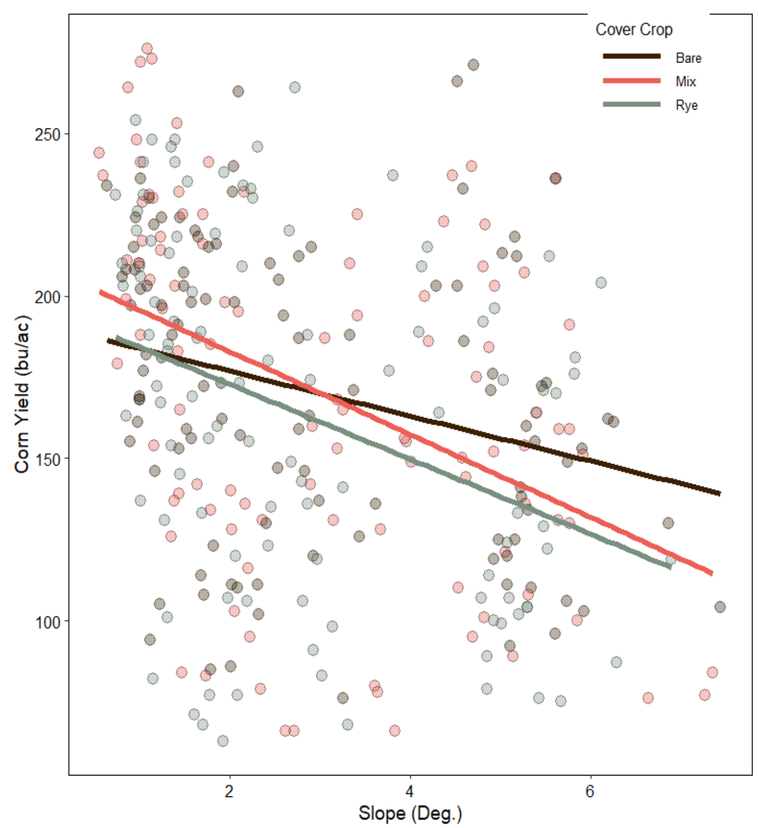

Figure 2. Relationship between yield and slope. Within increasing slope, we observe different rates of corn yield decline between cover crop and fallow treatments at high nitrogen application levels.

Two of the three site-years (Hardin County 2019 and Fayette 2020) responded to nitrogen and the results are summarized in Table 1. Yield with zero nitrogen was lowest on the summit and greatest in the depression. The yield with optimum nitrogen was similar among the three positions. The delta yield, a measure of crop response to nitrogen fertilization, was greatest on the summit and lowest in the depression. The nitrogen rate required to reach maximum yield was 160 or 240 lb N/acre and did consistently differ between landscape positions or cover crop treatments. The variability in crop response to N among landscape positions was slightly higher with the cover crop.

Table 1. Average yield and delta yield for corn following a cover crop (mixture and rye treatments averaged) or winter fallow at different landscape position for site years that responded to nitrogen application. Delta yield is the difference in corn yield between the optimum N treatment and the zero N treatment. CV reflects the variation in delta yield values among landscape positions (higher values indicates greater variation).

	Summit		Slope		Depression	
	Cover	Bare	Cover	Bare	Cover	Bare
Yield at 0 N	132	139	153	150	188	179
Yield at Optimum N	181	196	168	192	218	192
Delta Yield	48	57	14	42	30	13
CV of Delta Yield following fallow	0.55					
CV of Delta Yield following cover	0.59					

In summary, we found that corn yield was lower on upslope than downslope landscape positions and that cover crops slightly increased this spatial variability. Despite lower corn growth on upslope positions, N fertilizer requirements were similar among landscape positions, perhaps because the upslope positions with lower yields also supplied less N from the soil.

ACKNOWLEDGEMENTS

We gratefully acknowledge support from the Kentucky Corn Growers Association, the University of Kentucky College of Agriculture, Food, and Environment, the Sustainable Agriculture Research and Education Graduate Student Grant (#2018-38640-28417), and the United States Department of Agriculture National Institute of Food and Agriculture (NC1195 multi-State project and Grant # 2020-67013-30860). We also thank Richard Preston, Laura Harris, Gene Hahn, Josh McGrath, James Dollarhide, Dan Quinn, Osei Jordan, Danielle Doering, and Katie Jacobs for their continued assistance in the field and the lab.

Impact of pre-tassel in-canopy fungicide applications on corn yield

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INTRODUCTION

Foliar diseases such as gray leaf spot (caused by *Cercospora zeae-maydis*) are annually occurring in Kentucky, and fungicide application is often needed to prevent yield loss. Kentucky farmers are increasingly asking how to use ground-applied fungicides in corn to control foliar disease and optimize yield, rather than relying on aerial fungicide applications. Benefits to ground application include ability to control timing and product choice more than may be possible with contracted aerial applications. Farmers are also asking questions about spraying fungicides with different nozzle technologies including drop nozzles or 360 undercover nozzles. These nozzles target the mid-canopy (ear leaf +/- 1-2 leaves) and are promoted to provide improved disease control and yield benefits compared to standard over-tassel application methods. However, there is no replicated research that looks at the impact of in-canopy fungicide applications in corn to know if the extra investment in this technology is warranted. Additionally, these in-canopy applications are typically targeting a late vegetative/pre-tassel growth stage of corn (V12-V14) rather than the standard tasseling/silking timing (VT/R1), and there is little research that examines the efficacy of late vegetative stage applications to know if this is an effective and economical fungicide timing.

RESEARCH OBJECTIVES

- Determine how fungicide applications occurring at V12-V14 control foliar disease and standability compared to tasseling fungicide applications at the University of Kentucky Research and Education Center.
- Compare efficacy of in-canopy nozzle technology to over-tassel applications.

MATERIALS AND METHODS

The research trial was planted on May 12, 2020 at the University of Kentucky Research and Education Center in Princeton, KY in a randomized complete block design with four replications per treatment. The trial was planted at a target population of 32,000 seeds/acre on 30-in. row spacing. Plots were 30 ft in length. Fungicide treatment and nozzle type were randomly assigned to experimental plots. Fungicide treatment consisted of Trivapro at 13.7 fl oz/A applied using a Lee Agra high clearance sprayer at the twelve leaf collar growth stage (V12), tasseling/silking (VT/R1), or a two pass application of V12 + VT. Applications at each timing were applied with standard overhead flat fan nozzles (TJ8002XR) or overhead flat fan nozzles + 360 undercover nozzles positioned at ear leaf height. 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 on October 5, 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

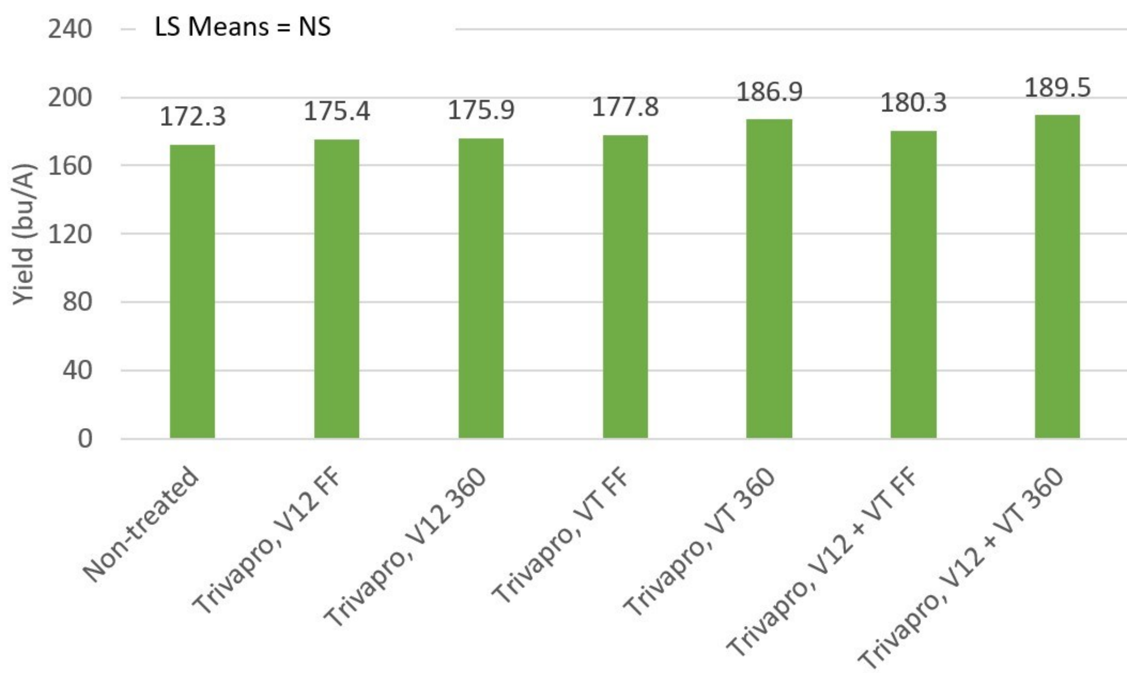
The trial location was dry in June and early July, leading to slow disease development. Gray leaf spot was observed at low to moderate levels. All fungicide timings and nozzle types reduced disease compared to the non-treated control (Table 1).

Table 1. Impact of fungicide timing and nozzle placement on gray leaf spot severity and lodging. Values followed by different letters indicates that values are significantly different at the *P* = 0.05 level.

Treatment	Nozzle	Timing	Gray leaf spot severity (%) at R4	Lodging (%) at harvest
Non-treated	--	--	7.7 a	6.9 ab
Trivapro	Flat fan	V12	1.42 bc	7.7 a
Trivapro	Flat fan + 360 undercover	V12	2.4 b	8.7 ab
Trivapro	Flat fan	VT	0.92 bc	6.2 b
Trivapro	Flat fan + 360 undercover	VT	0.41 bc	5.46 b
Trivapro	Flat fan	V12 + VT	0.04 c	6.2 b
Trivapro	Flat fan + 360 undercover	V12 + VT	0.04 c	2.96 c
P > F			<0.0001	0.0016

Although gray leaf spot severity was reduced in all fungicide treatments, there was no significant impact of treatment on yield (Figure 1). Although yields were not statistically different, fungicide applied with the 360 undercover nozzle at VT or V12 + VT resulted in ~ 9 bushel per acre yield gain in each treatment.

Figure 1. Impact of fungicide timing and nozzle placement on yield. LS Means = NS indicates that yields were not significantly different at the $P = 0.05$ level.



CONCLUSIONS

- Fungicide applications at V12 and VT reduced gray leaf spot compared to the non-treated control.
- Fungicide applied at V12 + VT and with flat fan + 360 undercover nozzle reduced lodging compared to other treatments, but it is unlikely to be a profitable treatment based on yield response.
- Research and economic analyses are ongoing to determine consistency and economic value of fungicide application timing and fungicide delivery system.

ACKNOWLEDGEMENTS

We gratefully acknowledge the Kentucky Corn Growers Association for funding this research, and the UKREC Farm Crew, Julie Hancock, Jesse Gray, and Shawn Wood for assistance in establishing and maintaining the trial.

Evaluation of Glyphosate Alternatives for Johnsongrass Control in Corn

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INTRODUCTION

Johnsongrass (*Sorghum halpense*) has traditionally been a major pest in Kentucky row crops but can be especially difficult to control in corn. Although, the introduction of glyphosate resistant corn (Roundup Ready) and the ability to apply glyphosate in corn has made management of Johnsongrass relatively simple for the last 20 years. The availability of glyphosate for control of Johnsongrass in corn is in constant threat due to a number of factors including glyphosate-resistance, potential reductions in glyphosate use, and the increased demand for non-gmo corn. The threat of glyphosate resistance in Johnsongrass is likely the largest threat to glyphosates future use for Johnsongrass control in corn. Glyphosate-resistant Johnsongrass has been confirmed in Arkansas and Mississippi and with the heavy reliance on glyphosate for control of Johnsongrass in corn and soybean it is reasonable to assume glyphosate-resistance is likely to occur in Kentucky.

Johnsongrass is a rhizomatous perennial weed making it difficult if not impossible to control with preemergence herbicides, especially if the population has been allowed to produce an extensive rhizome network. There are options for postemergence including nicosulfuron, rimsulfuron, tembotrione, and glufosinate (glufosinate-resistant corn hybrids), but none are as effective as glyphosate and can struggle to control rhizomatous Johnsongrass. The recent introduction of Enlist corn offers the option of quizalofop for postemergence control of Johnsongrass in corn.

OBJECTIVE

Evaluate non-glyphosate herbicide options for control of Johnsongrass in corn including quizalofop in Enlist Corn.

MATERIAL AND METHODS

A small plot research trial was established at the University of Kentucky Research and Education Center (UKREC) in Princeton, KY on a field with a heavy infestation of rhizomatic and seedling johnsongrass. An Enlist corn hybrid (herbicide tolerance to glyphosate, glufosinate, 2,4-D, and quizalofop) was planted at 32,000 seeds per acre on May 4, 2020. Prior to planting a burndown of Liberty and Bicep II Magnum was applied to control any existing vegetation and provide residual control of broadleaf weeds and annual grasses.

Experimental treatments were laid out in a randomized complete block with four replications. Experimental plots measured 10 ft in width or 4 corn rows by 30 ft in length. Herbicide treatments consisted of ALS-inhibiting chemistries, HPPD-inhibitors, Liberty, Asssure II, and glyphosate for comparison. All treatments were applied when Johnsongrass plants reached six inches in height, with a subset of treatment also being applied to 12-inch johnsongrass when allowed by the label. A complete list of treatments, herbicide rates, site of action groups, and application timing can be found in Table 1.

Evaluations of visual Johnsongrass control was taken 14 days after application.

RESULTS

Control of 6-inch Johnsongrass 14 days after application ranged from 47 to 98 percent control (Figure 1). The greatest level of control of non-glyphosate products was achieved with Steadfast Q, which had similar control to all other products except for Armezon and Liberty. In comparison to glyphosate, all products evaluated had equivalent control, except for Liberty.

Control of 12-inch Johnsongrass 14 days after application ranged from 38 to 98 percent control (Figure 2). The greatest control was achieved with applications of Roundup PowerMax and Assure II, both of which provided greater control than Accent Q and Steadfast Q (Figure 2).

Further evaluations beyond 14 days after application revealed that levels of control could not be differentiated between products. This is likely due to regrowth and new emergence of Johnsongrass at that time. In an overall evaluation of this trial, a follow up or second postemergence application was warranted. Although, the options for follow up application would have been limited, due to corn growth stages being well beyond the growth stage limit of many of the products evaluated in this research.

In summary, there are several herbicide products available for control of Johnsongrass in the absence of glyphosate. Products containing ALS-inhibiting herbicides nicosulfuron and/or rimsulfuron provided the most consistent control of 6-inch Johnsongrass, while Assure II in an Enlist corn Hybrid provided equivalent control to glyphosate on 12-inch Johnsongrass. Further research evaluating season long control of Johnsongrass with a herbicide program approach, including directed drop applications, is warranted and planned for 2021.

Table 1. Herbicides, site of action group, application rate, and application timing for treatments evaluated for Johnsongrass control.

Herbicide *active ingredient*	**Site of Action (SOA Group #)**	**Application Rate** *a.i. rate*	**Herbicide Timing**
Roundup PowerMax *glyphosate*	EPSP-synthase inhibitor (9)	44 fl oz/a *1.55 lb/a*	6- and 12-inch Johnsongrass
Liberty *glufosinate*	Glutamine synthetase inhibitor (10)	32 fl oz/a *0.59 lb/a*	6-inch Johnsongrass
Accent Q *nicosulfuron*	ALS-inhibitor (2)	0.9 oz/a *0.0307 lb/a*	6- and 12-inch Johnsongrass
Resolve *rimsulfuron*	ALS-inhibitor (2)	1.25 oz/a *0.0195 lb/a*	6-inch Johnsongrass
Steadfast Q *nicosulfuron + rimsulfuron*	ALS-inhibitor (2)	1.5 oz/a *0.0353 lb/a*	6- and 12-inch Johnsongrass
Spirit *Prosulfuron + Primisulfuron*	ALS-inhibitor (2)	1 oz/a *0.0356 lb/a*	6-inch Johnsongrass
Laudis *tembotrione*	HPPD-inhibitor (27)	3 fl oz/a *0.082 lb/a*	6-inch Johnsongrass
Capreno *tembotrione + thiencarbazone*	HPPD-inhibitor (27) + ALS-inhibitor (2)	3 fl oz/a *0.081 lb/a*	6-inch Johnsongrass
Armezon *topramezone*	HPPD-inhibitor (27)	1 fl oz/a *0.0219 lb/a*	6-inch Johnsongrass
Assure II *quizalofop*	ACCase-inhibitor (1)	8 fl oz/a *0.055 lb/a*	6- and 12-inch Johnsongrass

Figure 1. Visual Johnsongrass control 14 days after application to 6-inch tall Johnsongrass.

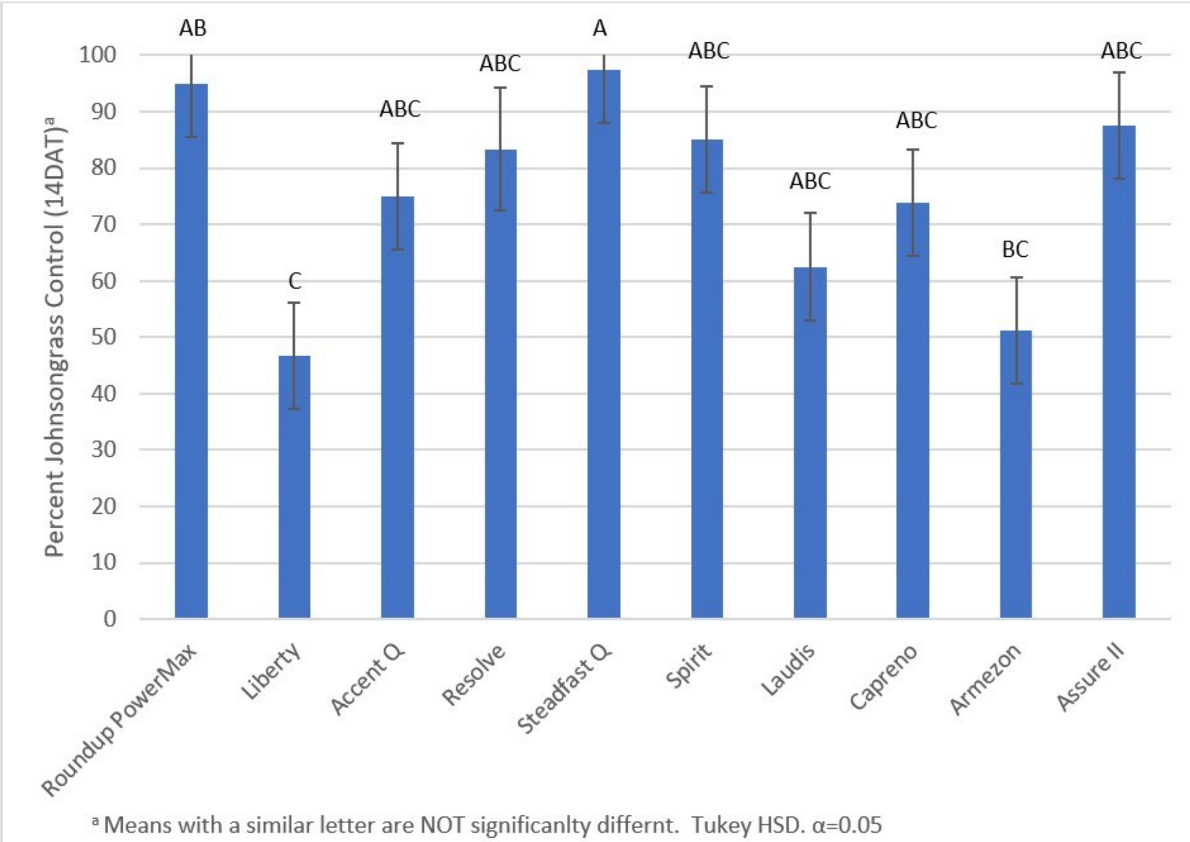
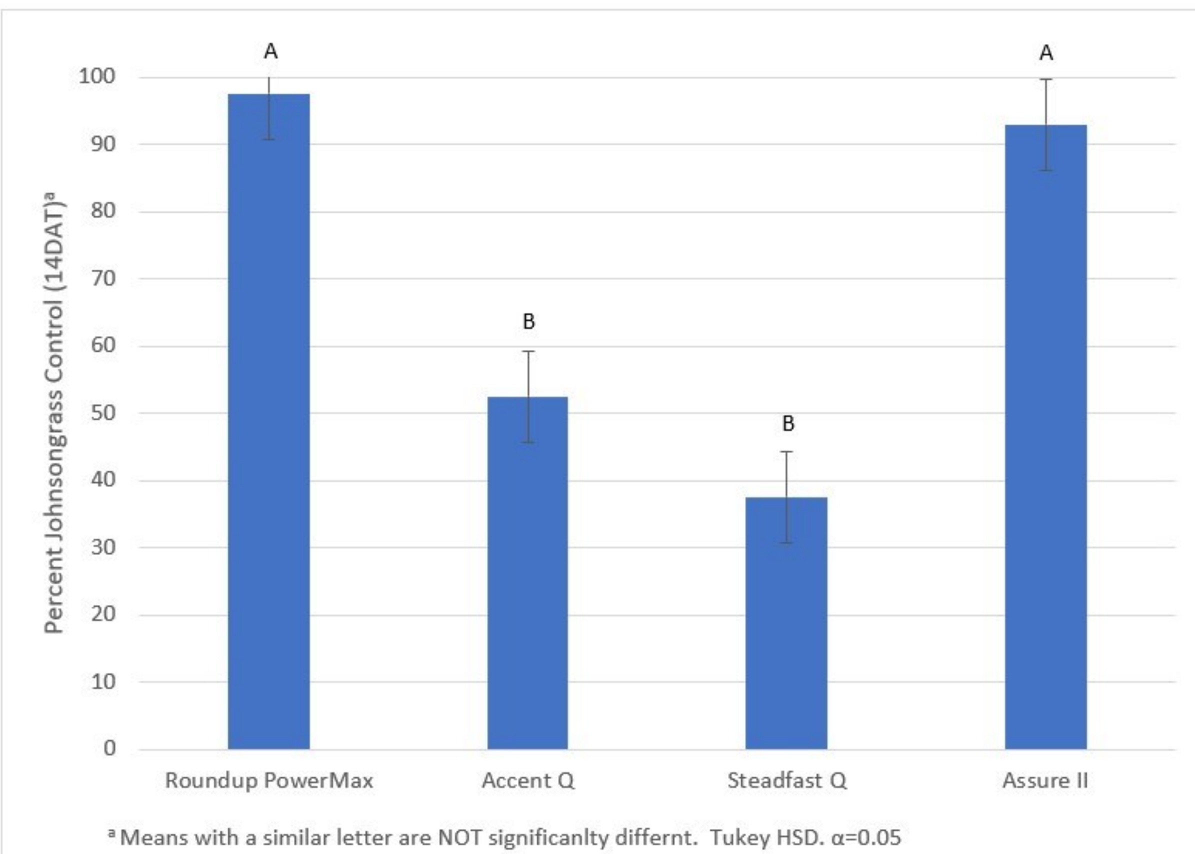


Figure 2. Visual Johnsongrass control 14 days after application to 12-inch tall Johnsongrass.



Successfully Establishing Corn in Cover Crops

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KEY POINTS

- A higher seeding rate may be required following a rye cover crop to limit stand and yield loss. An in-furrow starter containing both fertilizer and fungicide did not improve corn plant stand and yield following a rye cover crop.
- Split-applied N fertilizer can potentially lower the amount of N required by corn to maximize yield following a rye cover crop.
- In-furrow fertilizer and fungicide do not improve corn plant stand and yield following a late-terminated rye cover crop.

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. Therefore, 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; Headline).

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 in-furrow fertilizer, in-furrow fungicide, and in-furrow + fungicide on corn emergence and grain yield following different rye cover crop termination timings.

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 to 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; Headline) 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 planting (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 termination 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.

FINAL RESULTS

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

Across 2018, 19 and 20 a rye cover crop significantly reduced corn grain yield at two of three locations (Lexington and Princeton). In addition, despite an application following labelled instructions and rates, inclusion of an in-furrow starter combination of both fertilizer and fungicide significantly reduced plant stand at two of three locations, which suggests potential incompatibility between the tank-mixed products. However in-furrow starter did not significantly reduce corn yield at any location.

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. We did not observe a significant impact of a rye cover crop on optimum seeding rate of corn at two of three locations (Glendale and Princeton). However, at Lexington, the location that averaged the highest amount of rye cover crop biomass across locations and years (1902 lbs per acre), a greater corn seeding rate may be required to improve corn stand and yield following a rye cover crop (Figure 1). Additionally, we did not observe any impact of an in-furrow starter containing both fertilizer and fungicide on the optimum seeding rate of corn. This data suggets farmers do not need an in-furrow starter of fertilizer + fungicide when following a rye cover crop to maximize corn yield. However, a higher corn seeding rate may be required following a rye cover based on overall biomass production.

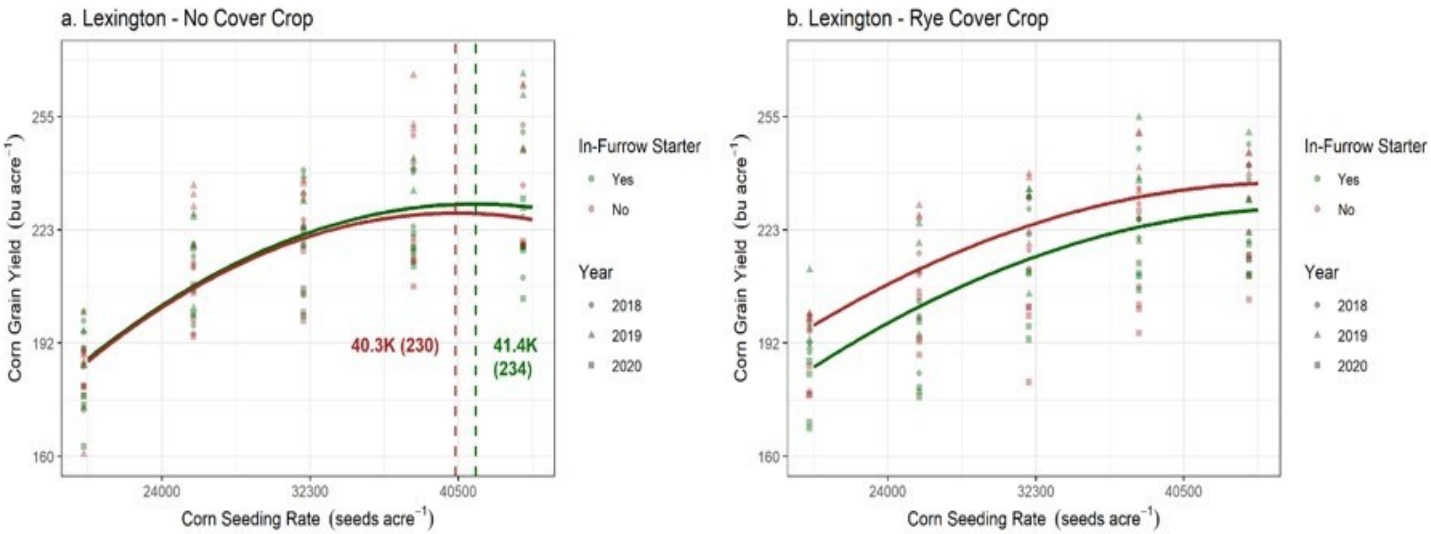

Figure 1. Corn grain yield response to in-furrow starter (IF), and corn seeding rate following no cover crop (a) or following a rye cover crop (b) combined across years. Lexington, KY (2018-20). Vertical lines and numbers illustrate the seeding rate required by corn to maximize grain yield (AOSR) for each respective IF starter and cover crop treatment, and numbers within parentheses illustrate the corn grain yield at the respective AOSR.

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 averaged 232 lbs N per acre and maximum corn yield produced was 201 bushels per acre. When nitrogen was split following a rye cover crop, the N rate required to maximize yield averaged 194 lbs N per acre and the maximum corn yield produced was 214 bushels per acre. Overall, across locations and years our results suggest a split application of N can lower the amount of N required by corn to maximize yield following rye. Overall, regardless of a rye cover crop, a split application of N fertilizer reduced the N rate required by corn to maximize yield by 18% and improved corn yield by 5%.

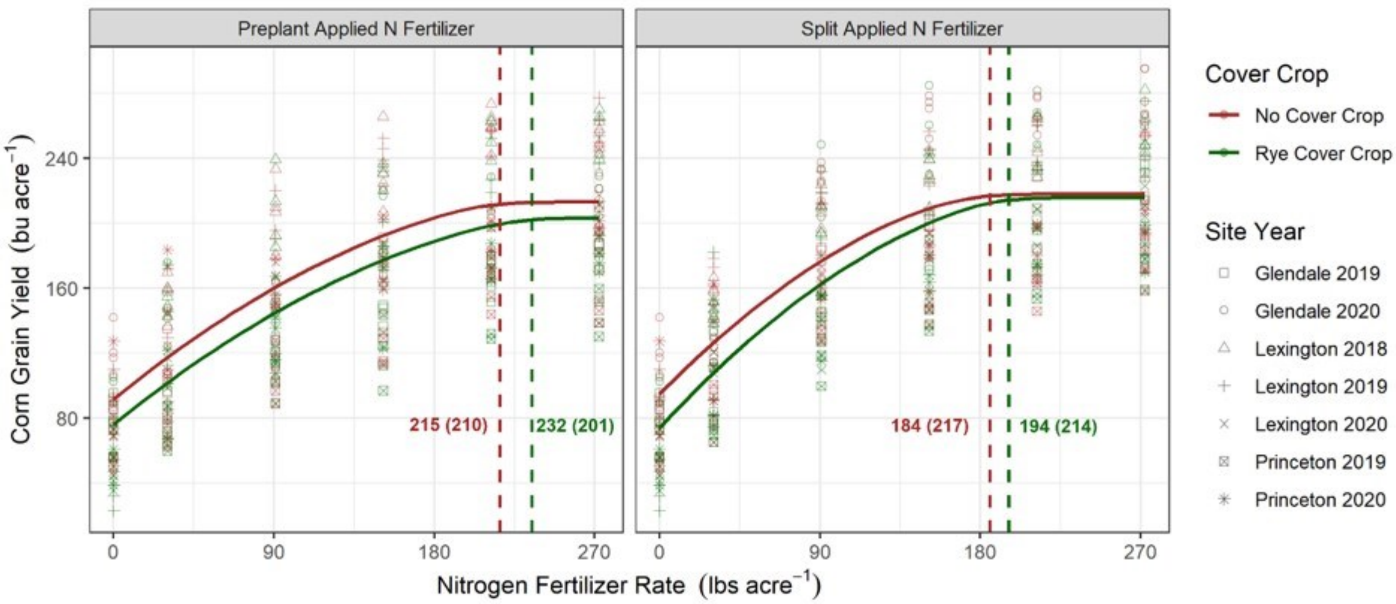

Figure 2. Corn grain yield response to rye cover crop, nitrogen (N) fertilizer application timing, and N fertilizer rate, across sites and years. Glendale, Lexington, and Princeton, KY (2019-2020). Vertical lines and numbers illustrate the nitrogen rate required by corn to maximize grain yield (AONR) for each respective N timing and cover crop treatment, and numbers within parentheses illustrate the corn grain yield at the respective AONR.

Study 3: Rye cover crop termination timing and In-Furrow 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 across both 2019 and 2020, whereas when corn followed rye terminated 14-21 days prior to corn planting, yield was reduced at one of three locations (Table 1). Corn following this late terminated rye had significant stress and stand loss caused by slugs, 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 observed following rye, the in-furrow fertilizer, fungicide, or combination did not improve corn yield at any location. Corn seedling disease was assessed in both 2019 and 2020, however both incidence and severity was low in both years. The overall lack of seedling disease and low rate of N fertilizer (5 lbs N per acre) due to an in-furrow starter application were likely insufficient to contribute to improved corn stand and yield following a late-terminated rye cover crop.

Table 1. Waiting to terminate a rye cover crop until one day following corn planting significantly reduced yield and in-furrow starter provided no corn yield benefit, Glendale, Lexington, Princeton, KY (2019-20).

Treatment	**Corn Grain Yield (bu/acre)**		
	Glendale	Lexington	Princeton
No Cover Crop	255.9 a*	245.6 a	181.4 a
Termination 14-d Prior to Corn Planting	253.8 a	233.6 a	162.2 b
Termination 1-d After Corn Planting	218.9 b	186.1 b	166.2 b
No In-Furrow	248.3 a	226.5 a	170.3 a
In-Furrow Fertilizer (10-34-0)	243.3 a	222.6 a	171.5 a
In-Furrow Fungicide (Headline)	240.7 a	223.8 a	169.3 a
In-Furrow Fertilizer + Fungicide	239.3 b	214.2 a	168.6 a

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

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