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Wheat Science Research Report

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MANAGEMENT OF FUSARIUM HEAD BLIGHT OF WHEAT WITH FUNGICIDES AND VARIETIES

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INTRODUCTION (objective)

Fusarium head blight (FHB) (caused by *Fusarium graminearum*) is one of the most destructive diseases of wheat in Kentucky. The objective of this research was to evaluate different fungicide products for FHB management across different wheat varieties.

METHODS & MATERIALS

A field trial was conducted at the University of Kentucky Research and Education Center (UKREC) in Princeton, KY to evaluate the effect of different foliar fungicide treatments across different wheat varieties for management of FHB. On October 10, 2023, five different wheat varieties ('AgriMaxx 513', 'Dynagro 9172', 'Pembroke 21', 'Pioneer 26R59', and 'Pioneer 26R36' were planted at approximately 1.5 million seeds/A. Each plot was 5 ft wide (8 rows spaced 7.5 inches apart) and 15 ft long. Plots were planted no-till into corn stubble and were arranged in a randomized complete block design with 3 replications (blocks). Across each wheat variety, the following treatments were applied at Feekes growth stage 10.51 (anthesis), which occurred on April 22, 2024. The fungicide treatments included a non-treated control; Folicur (tebuconazole) at 4 fl oz/A; Miravis Ace (pydiflumetofen + propiconazole) at 13.7 fl oz/A; Caramba (metconazole) at 13.5 fl oz/A; Prosaro (prothioconazole + tebuconazole) at 6.5 fl oz/A; Prosaro Pro (prothioconazole + tebuconazole + fluopyram) at 10.3 fl oz/A; Sphaerex (metconazole + prothioconazole) at 7.3 fl oz/A; and Double Nickel LC (*Bacillus amyloliquefaciens* strain D747) at 192 fl oz/A. All treatments were applied with a backpack sprayer equipped with Twinjet 60 8002 nozzles calibrated to deliver 20 gal/A. To help ensure FHB disease pressure, plots were mist-irrigated 3 times daily for a duration of 15 minutes each from the boot stage through soft dough stage, and plots were inoculated with a spore suspension of *Fusarium graminearum* (40,000 spores/ml) the day following fungicide application. Yield, grain moisture, and test weight were obtained at harvest. Data were statistically analyzed using the General Linear Models procedure using SAS software (version 9.4). When treatments were found to be statistically significant ($P \leq 0.05$), means were compared for differences using Fisher's least significant difference (LSD) test with an alpha = 0.05. University of Kentucky Cooperative Extension recommendations were followed for nutrient and weed management.

RESULTS & DISCUSSION

In addition to the mist-irrigation that was applied just prior to heading and through grain fill, frequent rainfall occurred beginning approximately 10 days after beginning anthesis (Feekes growth stage 10.51). This rainfall allowed for late infections of the Fusarium head blight fungus, which resulted in relatively high deoxynivalenol (DON) values in the grain collected at harvest. When comparing the non-treated control treatments for each variety, DON values ranged from 2.8 to 5.2 ppm, where ‘Pioneer 26R36’ and ‘Pioneer 26R59’ had the greatest DON values, which were not significantly different than ‘Dynagro 9172’ (Table 1). ‘Pembroke 21’ and ‘AgriMaxx 513’ had the lowest DON values, which were not significantly different than ‘Dynagro 9172’. Within each variety, the effect of specific fungicides on reducing DON values differed. Within ‘AgriMaxx 513’, Miravis Ace, Caramba, and Spherex all significantly reduced DON values compared to the non-treated control. Within ‘Dynagro 9172’, Miravis Ace and Caramba significantly reduced DON values compared to the non-treated control. Within ‘Pembroke 21’, only Prosaro Pro significantly reduced DON values compared to the non-treated control. Within ‘Pioneer 26R36’, all treatments, except Folicur, significantly reduced DON values compared to the non-treated control. Within ‘Pioneer 26R59’, Miravis Ace, Caramba, Prosaro, and Prosaro Pro significantly reduced DON compared to the non-treated control.

Compared to the non-treated control, grain moisture was significantly increased with Miravis Ace in 2 varieties, with Sphaerex in 1 variety, and with Prosaro in 1 variety. A significant increase in test weight relative to the non-treated control was observed with Folicur in 1 variety, Miravis Ace in 5 varieties, with Caramba in 2 varieties, with Prosaro in 3 varieties, with Prosaro Pro in 4 varieties, with Sphaerex in 1 variety, and with Double Nickel in 1 variety. Within varieties, the only increase in protein relative to the non-treated control occurred when Double Nickel LC was applied to ‘AgriMaxx 513’. Only Miravis Ace provided a significant increase in yield relative to the non-treated control, which was observed in 3 varieties.

ACKNOWLEDGEMENTS

This research was funded by the Kentucky Small Grain Growers Association.

TABLES

Table 1. Effect of different fungicide treatments applied at feekes growth stage 10.51 on grain moisture, test weight, yield, protein, and deoxynivalenol (don) on five different wheat varieties at Princeton, KY in 2024.

Variety	Treatment	Rate (fl oz/A)	Grain moisture (%)	Test weight (lb/bu)	Yield (bu/A)	Protein (%)	DON (PPM)
AgriMaxx 513	Nontreated	.	18.9	48.6	59.5	13.3	2.9
	Folicur	4	19.1	50.3	64.3	13.6	2.0
	Miravis Ace	13.7	19.1	51.6	73.4	13.6	1.3
	Caramba	13.5	18.9	51.0	60.3	13.7	1.3
	Prosaro	6.5	19.0	50.9	47.1	13.4	1.9
	Prosaro Pro	10.3	19.0	50.9	62.1	13.6	1.9
	Sphaerex	7.3	18.8	50.9	57.2	13.8	1.1
	D. Nickel	192	18.7	49.6	63.4	13.9	2.7

(Table 1 continued on next page)

_Variety	Treatment	Rate (fl oz/A)	Grain moisture (%)	Test weight (lb/bu)	Yield (bu/A)	Protein (%)	DON (PPM)
Dynagro 9172	Nontreated	.	18.6	48.8	54.2	13.0	4.0
	Folicur	4	18.6	49.2	63.0	13.1	4.2
	Miravis Ace	13.7	19.6	50.9	75.4	12.8	2.7
	Caramba	13.5	18.6	49.4	57.5	12.8	2.6
	Prosaro	6.5	18.8	49.4	52.7	13.4	3.0
	Prosaro Pro	10.3	18.8	50.1	63.0	13.2	3.1
	Sphaerex	7.3	19.1	49.6	60.2	13.0	3.0
	D. Nickel	192	18.8	47.5	52.5	13.0	3.3
Pembroke 21	Nontreated	.	19.2	50.9	55.4	13.6	2.8
	Folicur	4	19.1	51.0	62.5	13.0	1.9
	Miravis Ace	13.7	19.5	52.4	67.4	13.5	1.7
	Caramba	13.5	19.2	51.4	61.2	13.0	1.8
	Prosaro	6.5	19.2	52.5	61.6	13.3	1.7
	Prosaro Pro	10.3	19.2	52.3	62.2	13.4	1.4
	Sphaerex	7.3	19.2	52.0	56.8	13.7	1.6
	D. Nickel	192	19.0	51.3	53.8	13.9	2.2
Pioneer 26R36	Nontreated	.	18.7	51.5	67.5	13.3	5.2
	Folicur	4	18.7	50.8	75.1	12.9	4.6
	Miravis Ace	13.7	19.0	52.9	75.4	13.2	1.5
	Caramba	13.5	18.6	51.7	68.0	12.9	2.6
	Prosaro	6.5	18.3	51.8	66.9	13.7	2.7
	Prosaro Pro	10.3	18.6	52.0	73.3	13.0	2.8
	Sphaerex	7.3	18.3	52.1	63.9	13.6	2.1
	D. Nickel	192	18.7	51.0	67.7	13.1	3.2
Pioneer 26R59	Nontreated	.	18.9	46.8	56.0	13.1	4.2
	Folicur	4	19.2	46.6	56.7	12.8	3.4
	Miravis Ace	13.7	19.7	49.5	62.5	13.0	2.6
	Caramba	13.5	19.1	48.1	58.4	12.9	2.7
	Prosaro	6.5	19.4	48.3	53.6	13.0	2.4
	Prosaro Pro	10.3	19.1	48.8	57.9	13.4	2.5
	Sphaerex	7.3	19.2	47.8	59.4	13.0	2.9
	D. Nickel	192	18.9	46.6	59.5	13.1	4.3
		LSD 0.05*	**0.5**	**1.2**	**9.4**	**0.6**	**1.3**

***Fisher's least significant difference with alpha = 0.05.**

METRIBUZIN SAFETY IN WHEAT DEPENDS ON VARIETY PLANTED AND APPLICATION RATE

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INTRODUCTION

Metribuzin is a photosystem-II inhibiting herbicide that has a wide applicability on a number of weed species. Metribuzin is especially useful for managing Italian ryegrass and will also help manage broad leaf weeds that are resistant to synthetic auxin herbicides, such as dicamba or 2,4-D. However, safety of metribuzin used postemergence on wheat varies with variety. Occasionally, weather conditions such as cold temperatures or clouds have led to widespread damage on winter wheat where metribuzin was applied.

OBJECTIVE

To mitigate crop damage from metribuzin in winter wheat systems, a greenhouse study was conducted to determine the metribuzin tolerance of 75 wheat varieties commonly grown in Kentucky.

MATERIALS AND METHODS

To remove the impact of weather conditions on the damage done to wheat, metribuzin was applied to the 75 cultivars in controlled greenhouse conditions using a spray chamber to apply accurate doses uniformly. All 75 wheat varieties from the 2024 University of Kentucky variety testing program were sprayed with metribuzin at the 3-leaf stage with 100g ha^{-1}, 400g ha^{-1}, 1600 ha^{-1}, and 6400g ha^{-1} of metribuzin, in addition to an untreated control. 21 days after the metribuzin was applied to the wheat, visual injury ratings were recorded where “1” was no discoloration or damage, “2” was mild discoloration on the leaves, “3” was severe discoloration on the leaves, “4” was that the growing point was wilted but there was still some green in the leaves, “5” was that the plant was completely dead. Once visual rating was completed, each plant (including controls) was cut down to the growing point so that regrowth could be measured. 14 days after each plant was cut down the growing point, the regrowth was cut and weighed (fresh). Three replications of each genotype at each dose were recorded. Additionally, a field trial was performed spraying the plants at the tillering stage with 1471g ha^{-1} to determine if the greenhouse study was correlated with response under field growing conditions.

RESULTS AND DISCUSSION

Using the raw data from injury ratings and biomass of the regrowth, reliability (H^2), treatment/genotype mean estimates (BLUEs) and other statistics were calculated (Table 1). Clearly, the best dose to differentiate the tolerance of varieties to metribuzin was 400g ha^{-1} in this trial. The reliability of varieties for injury rating and regrowth in % of the untreated control (PCRG) was the highest at 400g ha^{-1} with estimates of 0.821 for the injury rating and 0.782 for PCRG. As expected, the average injury ratings increased and PCRG decreased as the dose was increased. However, at the 400g ha^{-1}, there was different responses among varieties (Table 2).

At 400g ha^{-1} there was a high correlation between injury ratings and PCRG (s=0.72, Figure 1) indicating that visual ratings which are much easier to measure could be used to predict how well wheat varieties will recover (regrow) after metribuzin applications. Between the two methods of assessment many of the top/worst tolerating lines were identical. Producers interested in applying metribuzin to their wheat would be better off selecting Dyna-Gro 9172, USG 3352, or USG 3463 as the variety in their fields, as these varieties were identified as the most tolerant varieties by both measures (Table 2). Conversely, producers applying metribuzin would likely have issues with crop damage if they chose to grow GROWMARK FS 606, AgriMAXX EXP 2314, AgriMAXX 545, Dyna-Gro 9231, USG 3884, X14-1049-27-10-1 or X14-1049-27-10-1, as these varieties were identified as the least tolerant using both measures.

CONCLUSION

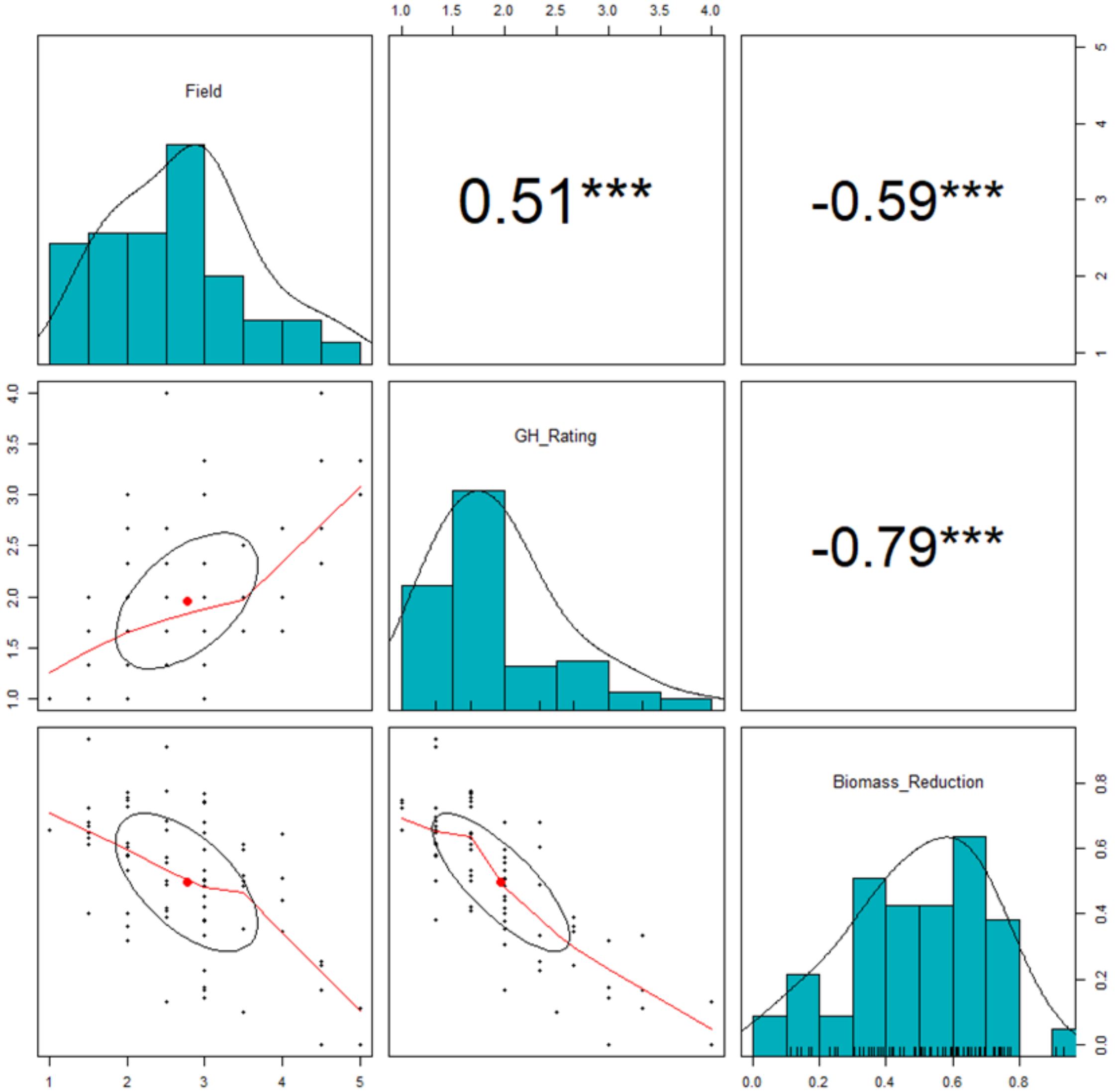

Figure 1. Distributions and correlations of the BLUEs for trial 1 of wheat varieties response to metribuzin. Spearman correlation is on the upper diagonal. Scatter plots with a line corresponding to a smoothing spline are below the diagonal. Rating is the injury rating from 1 to 5 where 5 is the most severe damage. PCRG is the percent of the control for regrowth. For Ratings and PCRG the “g” is grams per hectare applied.

Clearly, the choice of variety and dose impact the ability of wheat to tolerate a metribuzin treatment. At 400g ha^{1} some varieties of wheat are nearly undamaged while other varieties are completely dead. With a high reliability associated with variety at 400g ha^{1} it is apparent that metribuzin tolerance in wheat is genetically controlled and that selection for more metribuzin tolerant wheat varieties is possible. However, the environment also impacts the ability of wheat plants to tolerate metribuzin which was not possible to test in this experiment. In the future, we will work to develop markers for metribuzin tolerance to assist local wheat breeders in the development of metribuzin tolerant lines.

ACKNOWLEDGEMENTS

We would like to acknowledge the Kentucky Small Grain Growers Board for in-part funding this research.

TABLES

	Injury Rating (1-5)				Regrowth in % of Untreated Control			
Dose per hectare	**H^2 (Cullis)**	**Mean**	**BLUE Min**	**BLUE Max**	**H^2 (Cullis)**	**Mean**	**BLUE Min**	**BLUE Max**
GH 100g	0.624	1.31	1	2.33	0	95	64	180
GH 400g	0.821	1.96	1	4	0.782	50	0	93
GH 1600g	0.739	4.39	3	5	0	1	0	33
Field 1471g	0.916	2.8	1	5				

Table 1. Descriptive metrics from Metribuzin trial on wheat in the greenhouse during March 2024. N = 75, BLUE is the best linear unbiased estimates and H^2 (Cullis) is the broad sense heritability estimated using the Cullis et al. 2006 method. BLUEs are basically the treatment mean for each genotype at each dose. BLUEs are very similar to the mean response of a wheat variety.

Injury Ratings		PCRG	
Most Tolerant	**Least Tolerant**	**Most Tolerant**	**Least Tolerant**
CROPLAN CP8045	AgriMAXX 545	AgriMAXX 516	AgriMAXX 545
Dyna-Gro 9151	AgriMAXX EXP 2314	AgriMAXX EXP 2312	AgriMAXX EXP 2314
Dyna-Gro 9172	Dyna-Gro 9231	Dyna-Gro 9172	AgriMAXX EXP 2405
Go Wheat 4059S	Dyna-Gro 9542	Dyna-Gro 9422	CROPLAN CP8224
Go Wheat 6056	GROWMARK FS 597	KWS529	Dyna-Gro 9231
GROWMARK FS 745	GROWMARK FS 606	PEMBROKE 2021	GROWMARK FS 606
GROWMARK FS WX24A	USG 3574	USG 3329	USG 3884
KWS525	USG 3884	USG 3352	X14-1049-27-10-1
USG 3352	X14-1049-27-10-1	USG 3463	X14-1107-95-18-5
USG 3463	X14-1107-95-18-5	X14-1009-84-4-3	X14-1128-23-12-5

Table 2. Ten most and least tolerant varieties to 400g ha^{-1} metribuzin assessed with both injury ratings and percent of control for the regrowth (PCRG).

EVALUATION OF FOLIAR-APPLIED NANO-FERTILIZERS FOR ENHANCED NITROGEN USE EFFICIENCY OF WHEAT

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OBJECTIVE

The goal of this study is to assess the N use efficiency and environmental impacts of foliar N application with and without nanocarriers. Our specific objectives are to:

Determine the effect of foliar UAN and urea applications relative to soil applications on wheat yield, N uptake, and N use efficiency at a low and recommended N rate.

Compare the wheat yield, N uptake, and N use efficiency of foliar-applied UAN and urea with nanocarriers to foliar-applied UAN and urea without nanocarriers at a low and recommended N rate.

Quantify N losses, including nitrate leaching, nitrous oxide emissions, and ammonia volatilization for the different N sources and delivery methods at the recommended N rate.

METHODS & MATERIALS

During the 2023-2024 wheat growing season at Spindletop Farm in Lexington, we evaluated two common nitrogen fertilizer sources – urea and urea ammonium nitrate (UAN) applied to the soil and to the foliage. The N fertilizer source and application methods included in our study are listed below (Table 1). We applied these treatments at three rates – 0, 50, and 100 lb N/acre. The applications were split applied with 30% at Feekes 3, 30% at Feekes 5/6, and 30% at Feekes 8. The study design was a randomized complete block design in which the combinations of N rate, source, and application method were randomized within each of four replicate blocks. The plots were 5 ft wide by 15 ft long. However, for the plots receiving the experimental nanocarrier for urea, the applications were made over the central 3 ft by 10 ft of the plot due to limited supply of the material, while the remainder of the plot received the same N rate as granular urea.

The field study was conducted in a field that had been harvested as high moisture grain. Muriate of potash was applied on October 10, 2023 at 100 lb K_2O/acre according to soil test results. On October 18, 2023, Pembroke 2021 wheat was planted at 120 lb seed/acre and a depth of 1.5 inches. Nitrogen fertilizer applications were made on March 7 (Feekes 3), March 28 (Feekes 6), and April 13 (Feekes 8). We used UAN with 28% N and urea solutions with 2% N. Liquid applications were done using a CO_2 backpack sprayer while granular urea was applied to the soil by hand. Silwet L-77 was included with urea solutions to aid in leaf penetration of fertilizer. The wheat also received an application of Harmony Extra for weed control on March 14, 2024 and Caramba for disease control at anthesis on May 2, 2024. Following wheat harvest, double crop soybeans (AG42XF4) were planted on June 26, 2024 at 200,000 seeds/acre on 15 inch rows.

Soil samples for inorganic N were collected at 0-4, 4-8, and 8-16 inches just prior to planting on October 17, 2023, at the time of greening up on February 26, 2024, at the time of heading on April 29, 2024, and after harvest on June 24-25, 2024. Passive lysimeters were installed at a depth of 1.25 ft prior to wheat planting to capture leachable nitrate. The lysimeters will be removed and analyzed following harvest of double crop soybeans in fall of 2024. In addition, we measured nitrous oxide emissions throughout the entire growing season of wheat and double crop soybeans. The preparation of lysimeters and greenhouse gas sampling equipment took more time than expected, and we were not able to install equipment to measure ammonia volatilization. All of the measurements of N losses were collected in the plots receiving 100 lb N/acre. In addition, photos were taken of each plot every two weeks to assess potential leaf damage due to N applications. Wheat biomass samples were collected from a 1 m2 area within each plot at full maturity. The grains, chaff, and straw were weighed and are being prepared for N analysis to determine N uptake and N use efficiency.

RESULTS AND DISCUSSION

To date, we have completed data collection for grain yield and wheat aboveground biomass as well as nitrous oxide emissions for the wheat growing season. We present yield and nitrous oxide results below (Figures 1-3). The aboveground biomass results show the same treatment effects as the yield results, so we have not included graphs of those results. We have also viewed the wheat photos and determined that leaf damage was not an issue for any applications during the 2023-2024 season. The plant N uptake, soil inorganic N, and nitrate leaching measurements are still in progress.

Regarding our first objective, we determined that foliar application had no effect on wheat grain yield relative to soil application (Figure 1). In addition, wheat yielded similarly with UAN or urea. Considering the traditional fertilizer treatments (i.e., excluding the nanocarriers), the only significant factor affecting yield was N rate, with 100 lb N/acre resulting in the highest yields (Figure 1).

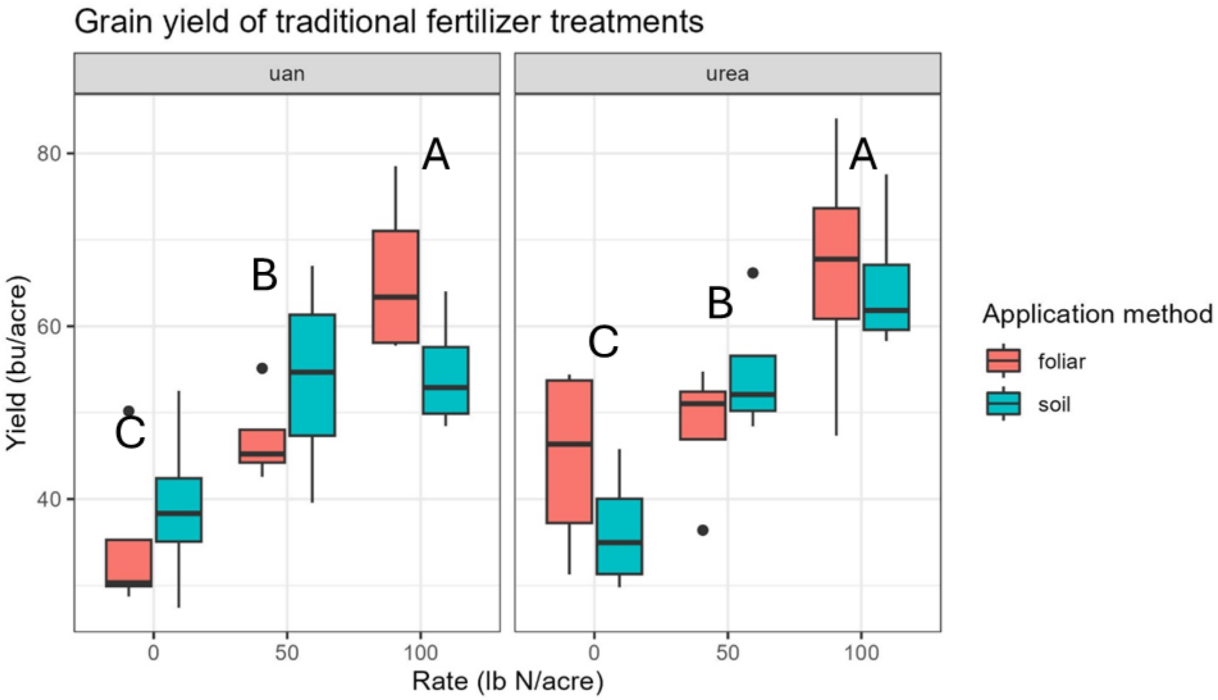

Figure 1. Boxplots showing wheat yield response to N rate and application method for each source UAN – left; urea – right) in Lexington, KY 2023-2024. The different capital letters indicate differences among N rates averaged across the application methods for each of the N sources ($p<0.05$).

We also wanted to compare the wheat yield of foliar-applied UAN and urea with nanocarriers to foliar-applied UAN and urea without nanocarriers at different N rates. For this objective, we found that the wheat responded positively to N rate for all treatments but not the nanocarrier controls (Figure 2). However, the nanocarriers with N ('uan-nano' and 'urea-nano') were not significantly different from the traditional fertilizers ('uan' and 'urea') (Figure 2, right plot). The nanocarrier controls, which consisted of the nanocarriers without any N loaded on them, all yielded low and like the 0 lb N/acre treatments (Figure 2, left plot), indicating that the nanocarriers on their own did not impact wheat yield.

In terms of the environmental impact of our treatments, we observed significantly lower nitrous oxide emissions for all of the foliar applications ('Urea Foliar', 'UAN Foliar', 'Urea Nanocarrier', 'UAN nanocarrier') as compared to the soil applications (Figure 3).

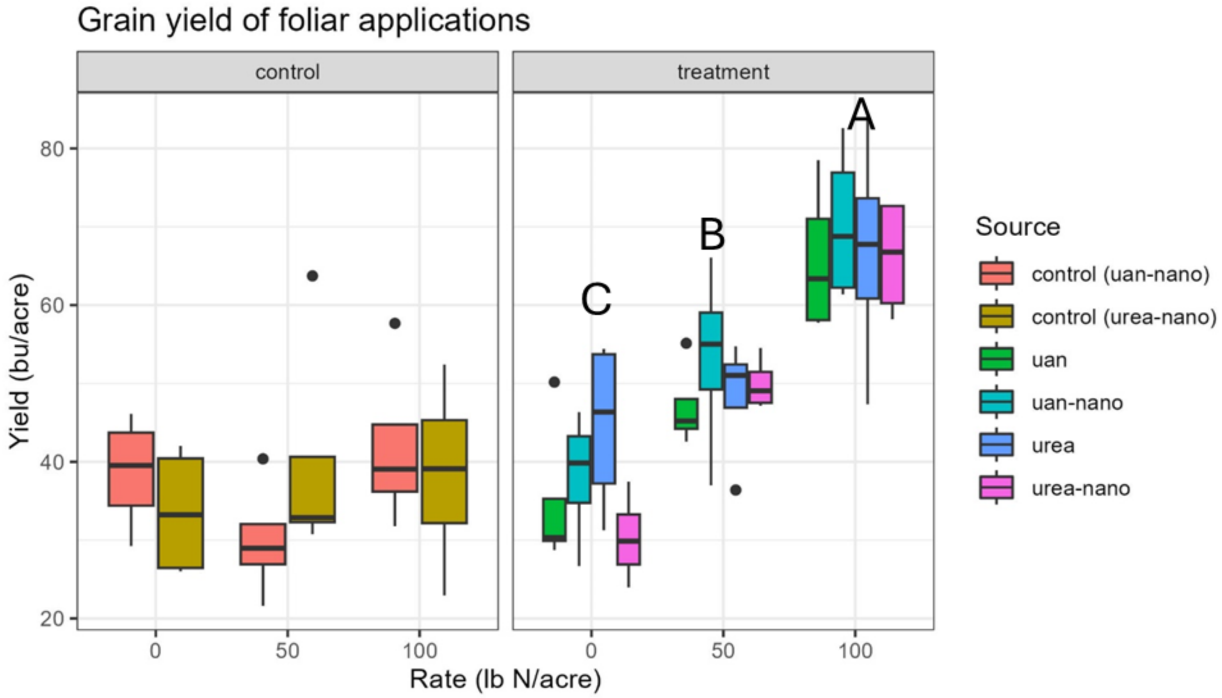

Figure 2. Boxplots showing wheat yield response to N rate and source for the foliar application method in Lexington, KY 2023-2024. The controls shown on the left plot consist of nanocarriers that did not include N but were applied at rates that provided the same amount of nanoparticles as the nanocarrier treatments that contained N. The different capital letters in the right plot indicate differences among N rates averaged across the N sources ($p<0.05$).

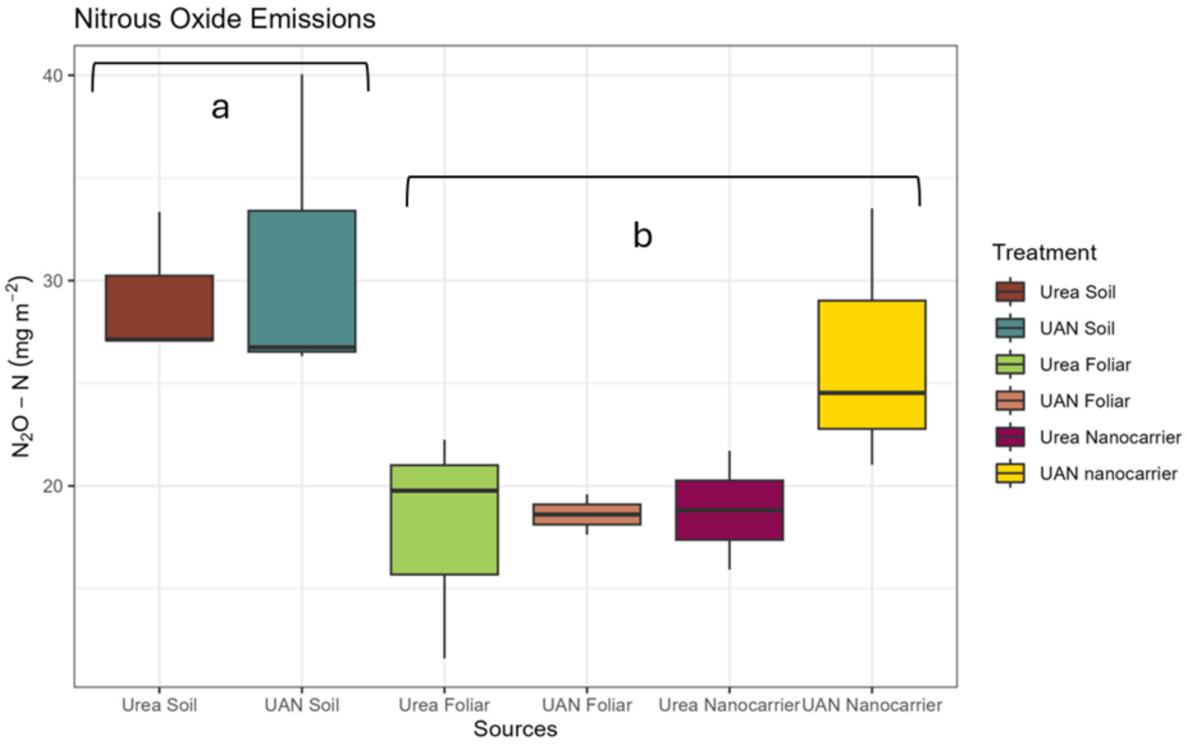

Figure 3. Boxplots showing cumulative nitrous oxide emissions for each fertilizer treatment applied at 100 lb N/ acre during the wheat growing season in 2023-2024. Different lowercase letters indicate significant differences between the bracketed treatments.

CONCLUSION

Overall, our results from the first year of this research indicate that the source, application method, and use of nanocarriers has negligible impact on the productivity of wheat. However, we were intrigued to find a significant effect of application method on the nitrous oxide emissions. We believe that the lower emissions associated with foliar applications can be attributed to the reduced interaction of fertilizer N with soil microbes, which are responsible for producing this gas. To our knowledge, we are the first to evaluate the effects of foliar application on nitrous oxide emissions in wheat. Although the absolute amount of N lost as nitrous oxide is small from an agronomic perspective, it is environmentally consequential because nitrous oxide is such a powerful greenhouse gas. Further research is needed, but our preliminary findings suggest that a relatively easy change - applying UAN to the foliage rather than soil – could improve environmental quality without negative effects on wheat yield.

ACKNOWLEDGEMENTS

We would like to thank the Kentucky Small Grain Growers’ Association for their funding support of this project. Funding for the field study was also provided by the National Science Foundation grant number: 1122905-464772. We thank Laura Harris and John Connolly for their help with implementing the field study.

EVALUATION OF HERBICIDE RESIDUAL TIMINGS FOR CONTROL OF ITALIAN RYEGRASS IN KENTUCKY WINTER WHEAT

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INTRODUCTION (objective)

Italian ryegrass (annual ryegrass) continues to be problematic in Kentucky wheat acres and has shown rapid increases in infestations across the state. This weed species has proved to be the most problematic weed for Kentucky wheat growers with our previous research identifying multiple populations of glyphosate-resistant, pinoxaden (Axial XL), and pinoxaden plus fenoxaprop (Axial Bold) resistant annual ryegrass in Kentucky wheat fields.

In the absence of a post-emergence herbicide option many Kentucky wheat growers have utilized pyroxasulfone based residual herbicides for control of ryegrass. While these preemergence herbicides have proven to be effective for suppressing fall emerging ryegrass plants, we have witnessed more ryegrass emergence in the spring months when fall applied residuals have dissipated. The previous mild Kentucky winters have likely contributed to this trend of increased spring ryegrass emergence, but also has accelerated residual herbicide degradation. Research was initiated in 2023 to further examine how to maximize residual herbicide for both fall and spring emerging populations of Italian ryegrass in Kentucky wheat. The research objective was to investigate the use of residual herbicides and residual application timing for control of Italian ryegrass in wheat.

METHODS & MATERIALS

Two research trials were established in the fall of 2023, one at the UKREC in Princeton and a second on a grower field in Simpson County with a known Italian ryegrass infestation. The UKREC has an established field with a pinoxaden -sensitive ryegrass population, while the Simpson County field had a suspected pinoxaden-resistant ryegrass population. Herbicide treatment programs were implemented that include Fierce EZ and Anthem Flex applied as single fall application and multi-pass applications in the fall and early winter/early spring while staying within current label restrictions. For example, Anthem Flex was applied PRE only at the maximum rate of 3.5 fl oz/a and was compared to Anthem Flex applied Pre at 3 fl oz followed by a post application of 1.5 fl oz in either early winter (Dec) or early spring (Feb). The post applications were applied with and without 2oz Metribuzin 75DF to continue to evaluate the utility of postemergence metribuzin applications. Additionally, all residual treatments were split with and without an application of Axial Bold in the spring. A full list of treatments, planting dates, and application dates can be found in Tables 1 and 2 for the UKREC and Simpson locations, respectively.

Trials were laid out in a randomized complete block design with four replications. Individual plots measured 30 ft in length by 5 ft in width. All herbicide applications were applied using CO2 pressurized backpack sprayers calibrated for 15 gallons per acre for all residual applications and 10 gallons per acre for the Axial Bold applications.

Visual ratings were collected in March 2024 prior to Axial Bold applications and again prior to wheat harvest at both locations. Additionally, ryegrass seed head panicle density per half meter square was collected prior to harvest. All data was analyzed in SAS using PROC GLIMMIX.

RESULTS & DISCUSSION

Italian ryegrass visual control ranged from 66 to 97% control on March 20,2024 following residual applications at the UKREC location (Table 3). All treatments receiving Anthem Flex resulted in 95 to 97 % control regardless of timing of application or use of Metribuzin 75DF. Conversely, Fierce EZ resulted in reduced Italian ryegrass control when splitting the residual application as compared to the single fall application of Fierce EZ or any of the applications of Anthem Flex. Italian ryegrass control at Simpson County on March 18, 2024, ranged from 82 to 100% (Table 4). In contrast to the UREC site the Simpson County site did not have any statistical differences between residual herbicide packages.

Ryegrass control at the end of the growing season ranged from 38 to 100% control at the UKREC location on Jun 6, 2024 (Table 5). Treatments receiving applications of Anthem Flex resulted in the greatest control with 96 to 100% control. Anthem Flex treatments did not differ in control regardless of timing of application, the inclusion of Metribuzin 75DF, or the inclusion of an Axial Bold application in the herbicide program. Similar to the spring visual control, control at the end of the season was reduced with the split application of Fierce EZ as compared to the single fall application of Fierce EZ or the split Fierce EZ application with the inclusion of Metribuzin 75DF. Fierce treatments receiving a spring application of Axial Bold all resulted in 100% control of ryegrass, indicating the great utility of Axial Bold on a sensitive ryegrass population. The ryegrass seed head counts at UKREC had a similar trend to the end out the season visual control ratings with seed head counts ranging from 0 to 248 seed heads per m^2 (Table 6). The highest seed head counts occurred in the Fierce EZ split treatment without Metribuzin 75DF or a spring application of Axial Bold with 130 seed heads per m^2. Despite having a greater seed head count than all other herbicide treatments, the split Fierce EZ treatment did reduce seed head counts as compared to the untreated.

End of season visual ratings and seed head counts (data not shown) at the Simpson County site resulted in a lack of differences between treatments (Table 7). Despite the lack in statistical differences, numerical differences at Simpson County are similar to those found at the UKREC with the split applications of Fierce EZ resulting in lower control than the other treatments. The inclusion of Axial Bold as a spring application did not have an influence at the Simpson County location, in contrast to the UKREC location, pointing to a likely higher tolerance of the ryegrass population to pinoxaden and fenoxaprop.

CONCLUSION

At the Caldwell County (UKREC) location, statistical differences in treatment effectiveness were observed, while no significant differences were noted at the Simpson County site. The lack of differences at Simpson County is attributed to inconsistent ryegrass densities typical in on-farm research. Both total pre-emergent (PRE) and split applications of Anthem Flex did not differ in ryegrass control at either location. However, using Axial Bold after Anthem Flex led to complete ryegrass control at UKREC, while its application following all residuals in Simpson County did not enhance control. Split applications of Fierce EZ were less effective than a single 14 day pre plant (DPP) application of Fierce EZ at UKREC, necessitating the addition of metribuzin during the POST application to manage any emerged ryegrass. Although not statistically significant, results from Fierce EZ in Simpson County displayed a similar trend to those observed at UKREC.

The differences in how Anthem Flex and Fierce EZ performed can be linked to the differences in total pyroxasulfone being applied between the two products. Anthem Flex allows for a season maximum cumulative rate of 4.5 fl oz/a or 0.13 lb pyroxasulfone while the Fierce EZ label has a maximum cumulative rate of 6 fl oz/a or 0.08 lb pyroxasulfone. The greater amounts of pyroxasulfone in Anthem Flex were observed in this research. Further research on the spilt rates of Fierce EZ is warranted to understand the correct balance of the reduced pyroxasulfone offered by this product.

Based on the first year results we would recommend the following for ryegrass control in wheat. Anthem Flex can be applied either all at planting or split between planting and post-emergence, with split applications potentially needing to occur in December or early February for maximum control. For split applications of Fierce EZ, the inclusion of metribuzin in the post-application applied in December would be necessary. The use of Axial Bold to clean up any escapes in the spring is still warranted for many populations in Kentucky. Further evaluation of the application rate for split Fierce EZ is required, although current label restrictions limit its potential use.

ACKNOWLEDGEMENTS

This research was supported by the Kentucky Small Grain Growers Association. Thank you for your continued support of this research.

TABLES

Table 1. Residual herbicide treatments applied at the University of Kentucky Research and Education Center (UKREC) and dates of herbicide applications. The UKREC trial was planted on November 6, 2023, with emergence occurring on November 15, 2023. All listed treatments were split with half receiving an Axial Bold application on March 20, 2024, and half receiving no spring post herbicide application.

Herbicide	Rate	Application Timing
Anthem Flex	3.5 fl oz/A	Preemergence – Nov 7, 2023
Anthem Flex fb Anthem Flex	3 fl oz/A fb 1.5 fl oz/A	Preemergence – Nov 7, 2023 fb Post – Feb 20, 2024
Anthem Flex fb Anthem Flex + 75DF Metribuzin	3 fl oz/A fb 1.5 fl oz/A + 2 oz/A	Preemergence – Nov 7, 2023 fb Post – Feb 20, 2024
Fierce EZ	6 fl oz/A	14 DPP – Oct 17, 2023
Fierce EZ fb Fierce EZ	3 fl oz/A fb 3 fl oz/A	14 DPP –Oct 17, 2023 fb Post – Feb 20, 2024
Fierce EZ fb Fierce EZ + 75 DF metribuzin	3 fl oz/A fb 3 fl oz/A + 2 oz/A	14 DPP –Oct 17, 2023 fb Post – Feb 20, 2024

Table 2. Residual herbicide treatments applied at Simpson County and dates of herbicide applications. The trial was planted on November 1, 2023. All listed treatments were split with half receiving an Axial Bold application on March 20, 2024, and half receiving no spring post herbicide application.

Herbicide	Rate	Application Timing
Anthem Flex	3.5 fl oz/A	Preemergence – Nov 2, 2023
Anthem Flex fb Anthem Flex	3 fl oz/A fb 1.5 fl oz/A	Preemergence – Nov 2, 2023 fb Post – Feb 20, 2024
Anthem Flex fb Anthem Flex + 75DF Metribuzin	3 fl oz/A fb 1.5 fl oz/A + 2 oz/A	Preemergence – Nov 2, 2023 fb Post – Feb 20, 2024
Fierce EZ	6 fl oz/A	14 DPP – Oct 3, 2023
Fierce EZ fb Fierce EZ	3 fl oz/A fb 3 fl oz/A	14 DPP –Oct 3, 2023 fb Post – Dec 6, 2023
Fierce EZ fb Fierce EZ + 75 DF metribuzin	3 fl oz/A fb 3 fl oz/A + 2 oz/A	14 DPP –Oct 3, 2023 fb Post – Dec 6, 2023

Table 3. Influence of residual herbicide timing and rates on visual ryegrass control at University of Kentucky Research and Education Center (UKREC) on March 20, 2024.

Herbicide	Rate	% Visual Ryegrass Control – March 20, 2024[a]
Anthem Flex	3.5 fl oz/A	97 A
Anthem Flex fb Anthem Flex	3 fl oz/A fb 1.5 fl oz/A	97 A
Anthem Flex fb Anthem Flex + 75DF Metribuzin	3 fl oz/A fb 1.5 fl oz/A + 2 oz/A	95 AB
Fierce EZ	6 fl oz/A	90 AB
Fierce EZ fb Fierce EZ	3 fl oz/A fb 3 fl oz/A	66 C
Fierce EZ fb Fierce EZ + 75 DF metribuzin	3 fl oz/A fb 3 fl oz/A + 2 oz/A	80 BC

[a] Means followed by the same letter are NOT statistically different. Tukey HSD α = 0.05

Table 4. Influence of residual herbicide timing and rates on visual ryegrass control at Simpson County on March 18, 2024.

Herbicide	Rate	% Visual Ryegrass Control – March 18, 2024[a]
Anthem Flex	3.5 fl oz/A	100 A
Anthem Flex fb Anthem Flex	3 fl oz/A fb 1.5 fl oz/A	99 A
Anthem Flex fb Anthem Flex + 75DF Metribuzin	3 fl oz/A fb 1.5 fl oz/A + 2 oz/A	94 A
Fierce EZ	6 fl oz/A	94 A
Fierce EZ fb Fierce EZ	3 fl oz/A fb 3 fl oz/A	84 A
Fierce EZ fb Fierce EZ + 75 DF metribuzin	3 fl oz/A fb 3 fl oz/A + 2 oz/A	82 A

[a] Means followed by the same letter are NOT statistically different. Tukey HSD α = 0.05

Table 5. Influence of herbicide programs on visual ryegrass control at University of Kentucky Research and Education Center (UKREC) on June 6, 2024.

Herbicide	Rate	% Visual Ryegrass Control – June 6, 2024[a] No Axial Bold	% Visual Ryegrass Control – June 6, 2024[a] Axial Bold
Anthem Flex	3.5 fl oz/A	96 A	100 A
Anthem Flex fb Anthem Flex	3 fl oz/A fb 1.5 fl oz/A	97 A	100 A
Anthem Flex fb Anthem Flex + 75DF Metribuzin	3 fl oz/A fb 1.5 fl oz/A + 2 oz/A	98 A	100 A
Fierce EZ	6 fl oz/A	76 A	100 A
Fierce EZ fb Fierce EZ	3 fl oz/A fb 3 fl oz/A	38 B	100 A
Fierce EZ fb Fierce EZ + 75 DF metribuzin	3 fl oz/A fb 3 fl oz/A + 2 oz/A	75 A	100 A

[a] Means followed by the same letter are NOT statistically different. Tukey HSD α = 0.05

Table 6. Influence of herbicide programs on ryegrass seed head density at University of Kentucky Research and Education Center (UKREC) on June 3, 2024.

Herbicide	Rate	Ryegrass Seed Heads per 0.5m^2– June 3, 2024[a]	
		No Axial Bold	Axial Bold
Anthem Flex	3.5 fl oz/A	4 C	0 C
Anthem Flex fb Anthem Flex	3 fl oz/A fb 1.5 fl oz/A	5 C	0 C
Anthem Flex fb Anthem Flex + 75DF Metribuzin	3 fl oz/A fb 1.5 fl oz/A + 2 oz/A	2 C	0 C
Fierce EZ	6 fl oz/A	43 C	0 C
Fierce EZ fb Fierce EZ	3 fl oz/A fb 3 fl oz/A	130 B	0 C
Fierce EZ fb Fierce EZ + 75 DF metribuzin	3 fl oz/A fb 3 fl oz/A + 2 oz/A	39 C	0 C
Untreated		248 A	

[a] Means followed by the same letter are NOT statistically different. Tukey HSD α = 0.05

Table 7. Influence of herbicide programs on visual ryegrass control at Simpson County on May 29, 2024

Herbicide	Rate	% Visual Ryegrass Control – May 29, 2024[a] No Axial Bold	Axial Bold
Anthem Flex	3.5 fl oz/A	95 A	94 A
Anthem Flex fb Anthem Flex	3 fl oz/A fb 1.5 fl oz/A	87 A	94 A
Anthem Flex fb Anthem Flex + 75DF Metribuzin	3 fl oz/A fb 1.5 fl oz/A + 2 oz/A	68 A	93 A
Fierce EZ	6 fl oz/A	68 A	94 A
Fierce EZ fb Fierce EZ	3 fl oz/A fb 3 fl oz/A	75 A	72 A
Fierce EZ fb Fierce EZ + 75 DF metribuzin	3 fl oz/A fb 3 fl oz/A + 2 oz/A	75 A	78 A

[a] Means followed by the same letter are NOT statistically different. Tukey HSD α = 0.05

EVALUATION OF WHEAT VARIETIES FOR METRIBUZIN TOLERANCE

Bill Bruening and Samuel Revolinski
University of Kentucky

INTRODUCTION

Metribuzin is an older chemistry herbicide that is becoming an important tool in controlling Italian Ryegrass and Annual Bluegrass, as well as a number of broadleaf weed species in wheat production, due to increasing resistance to other herbicides in weeds. Wheat varieties do, however differ in tolerance to Metribuzin. With the exception of the University of Kentucky, no other public institution has evaluated soft red winter wheat varietal differences in postemergence Metribuzin tolerance in the past decade. Because new varieties are continually being released, regular evaluation is needed and Kentucky growers benefit from this information being available for commercially available varieties. With the support of the Kentucky Small Grain Growers Association, Metribuzin tolerance among wheat varieties was re-evaluated in the 2023-24 growing season.

METHODOLOGY

During the 2023-24 growing season, 76 wheat varieties were rated for postemergence Metribuzin tolerance as part of the University of Kentucky Wheat Variety Trials. Metribuzin tolerance was evaluated in

Differences in Metribuzin injury among wheat varieties (half the test plot was sprayed).

both field and greenhouse trials. The field screening was conducted at Princeton, KY on two replicated plots (4 x 12 ft.) for each variety, where half the plot was sprayed. To insure damage levels were sufficient to make ratings, 21 ounces (which is twice the maximum labeled rate) of Metribuzin 75 DF was applied per acre at Feekes 4. The greenhouse screening test applied 7.6 ounces per acre on 3 replicated pots at the 3-leaf stage in a spray chamber. An injury rating scale of 1 to 5 was used to indicate if varieties were tolerant (1) or susceptible (5) to Metribuzin injury. Due to moderate correlation of field and greenhouse results, results presented are the average injury ratings from the field and greenhouse tests.

RESULTS AND DISCUSSION

The rates of Metribuzin applied to these trials was much higher than would normally be applied by growers. In the field trial, 21 ounces Metribuzin 75DF was applied per acre whereas the labeled rate is 4 to 10 ounces per acre at Feekes 4. Likewise, the greenhouse trial applied 7.6 ounces per acre compared with the labeled rate of 1 to 4 ounces at the 3-Leaf stage. The recommended labeled rate varies depending on soil organic matter content and soil texture. In both field and greenhouse trials, crop injury was achieved and the averaged ratings ranged from 1.0 to 4.3 (Table 1) where 1.0 has no injury and 5.0 is plant death.

These results should help growers assess potential for crop injury for a given variety when using the herbicide Metribuzin. Likewise, seed companies can use this data to access the potential for injury and make variety specific recommendations on the use of Metribuzin for their clients. Most growers will apply 3-4 oz per acre at the 2-Leaf to 2-Tiller stage. Injury can occur at this rate, particularly under cold and cloudy conditions where phytotoxicity is increased as a result of slower metabolism of Metribuzin. Metribuzin is a selective triazinone herbicide and its use in wheat is expected to dramatically increase as weeds develop resistance to other herbicides, such as glyphosate , ALS and ACCase chemistries. Varietal tolerance to this herbicide will be a very important factor for growers needing this type of herbicide. Always follow herbicide label instructions.

Table 1. 2024 Kentucky Wheat Variety Postemergence Metribuzin Tolerance.

- Variety	Metribuzin Tolerance		- Variety	Metribuzin Tolerance
AgriMAXX 503	2.0		KWS397	3.4
AgriMAXX 505	2.1		KWS490	1.6
AgriMAXX 513	2.3		KWS500	1.9
AgriMAXX 516	1.8		KWS501	1.4
AgriMAXX 525	2.5		KWS525	1.0
AgriMAXX 535	1.8		KWS527	1.4
AgriMAXX 545	3.0		KWS529	2.3
AgriMAXX EXP 2312	2.3		KWS542	2.8
AgriMAXX EXP 2314	3.0		KWS543	1.7
AgriMAXX EXP 2405	2.7		PEMBROKE 2014	2.3
CROPLAN CP8045	1.7		PEMBROKE 2016	2.6
CROPLAN CP8081	1.8		PEMBROKE 2021	1.8
CROPLAN CP8224	3.0		Revere Reagan	2.7
Dyna-Gro 9120	2.3		Revere Valor	2.2
Dyna-Gro 9151	1.4		Revere Washington	2.1
Dyna-Gro 9172	1.9		Revere Grant	2.5
Dyna-Gro 9231	1.4		Revere Anthem	2.7
Dyna-Gro 9290	3.3		Truman	3.0
Dyna-Gro 9393	3.6		USG 3329	1.9
Dyna-Gro 9422	2.8		USG 3352	1.5
Dyna-Gro 9533	2.1		USG 3354	2.3
Dyna-Gro 9542	2.5		USG 3463	1.5
Dyna-Gro 9551	3.2		USG 3472	1.8
Dyna-Gro 9553	2.7		USG 3574	2.5
Dyna-Gro 9570	2.4		USG 3884	4.0
Go Wheat 4059S	2.2		VT Pitman	3.0
Go Wheat 6056	1.7		X11-0039-1-17-5	2.8
Go Wheat Exp 1	1.8		X14-1009-84-4-3	1.8
GROWMARK FS 597	3.3		X14-1031-103-4-1	1.9
GROWMARK FS 600	2.6		X14-1035-67-7-1	2.6
GROWMARK FS 606	3.9		X14-1049-27-10-1	4.2
GROWMARK FS 617	2.3		X14-1107-95-18-5	4.3
GROWMARK FS 624	2.8		X14-1128-23-12-5	2.5
GROWMARK FS 743	2.3		X15-1004-24-4-5-1	2.5
GROWMARK FS 745	1.3		X15-1019-48-8-3	2.9
GROWMARK FS WX24A	2.2		X16-1021-131-19-1-1	2.5
GROWMARK FS WX24B	1.6		X16-1021-13-13-3-5	2.3
GROWMARK FS WX24C	1.4		X16-3013-1-12-5	2.8
			Average	2.4

Metribuzin tolerance (injury) ratings: 1 = no injury; 5 = severe injury.

UNDERSTANDING RYE DISEASE MANAGEMENT 2023-2024

Chad Lee and Carl Bradley
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INTRODUCTION (Objective)

Rye as a grain crop has a potential local market with distilleries. Farmers grew rye in Kentucky until about the 1920’s. Rye in Kentucky is highly susceptible to Fusarium head blight (FHB, or Head Scab). We propose to continue testing the effect of fungicide timings on various rye hybrids and populations on grain yield and grain quality.

Studies were initiated at Princeton and Lexington where rye hybrids were planted in October. The Lexington site had poor stands and was replanted in November. Studies were managed for weeds and insects according to crop scouting. Fungicide treatments included a fungicide at flag leaf, a fungicide at anthesis (flowering) and a combination of fungicides at flag leaf and anthesis all compared to a untreated control. Disease assessments were conducted by Dr. Bradley. Yields were determined with small plot combines. Yields were adjusted to 14% moisture and 56 lb/bushel test weight.

Rye yields at Princeton ranged from 52.0 to 90.6 bushels per acre (Table 1), which are excellent yields for the 2024 season. Disease ratings were lower for fungicides applied at anthesis or the combination of flag leaf and anthesis. Fungicide applied at flag leaf only usually had no effect different from the untreated control. Rye yields were highest for the fungicides applied at flag leaf and anthesis for Serafino, Tayo and H2003. Yields of those three hybrids for fungicide applied at anthesis only were not significantly different from the fungicides applied at flag leaf and anthesis. Fungicide had no effect on yield for Recepter, which was the lowest-yielding hybrid in the trial.

Rye at the Lexington location was a disaster, with yields barely registering on the combine. No disease was present, either. Rye during seed fill in Lexington experienced 15 consecutive days above 88 F and 13 days above 90 F with no measured rainfall. Seed development was extremely poor in Lexington. Rye at Princeton was physiologically mature when those temperatures hit Kentucky. The later planting date in Lexington pushed the rye into later development and the timing of that extremely hot and dry weather essentially terminated seed development. The hot, dry weather also kept disease pressure extremely low. The rye at Lexington was examined but no ratings were taken.

SUMMARY

This study confirms that rye needs a fungicide at anthesis to protect against FHB. Applying fungicides at both flag leaf and anthesis resulted in yields that were not significantly different from rye treated with fungicide at anthesis only. Rye at Lexington demonstrated once again that rye for grain needs to be planted in late September or early October.

ACKNOWLEDGEMENTS

We would like to thank the Kentucky Small Grain Growers’ Association for their funding support of this project.

Table 1. Rye response to fungicide timings at Princeton, 2024.

Rye Hybrid	**Fungicide Treatments†**	**FHB severity (%)**	**FHB incidence (%)**	**FHB index (0-100)**	**Leaf disease severity (%)**	**Grain Moisture (%)**	**Test weight (lb/bu)**	**Yield (bu/A)‡**
Serafino	Untreated	33.4	91.3	30.7	28.1	17.2	44.5	59.7
Serafino	Flag leaf	24.6	95.0	23.1	23.2	17.3	45.1	63.2
Serafino	Anthesis	**10.4**	**56.3**	**6.0**	**10.4**	17.2	**47.9**	**78.6**
Serafino	Flag leaf + Anthesis	**8.8β**	**62.5**	**5.6**	**10.0**	17.2	**48.1**	**79.0**
Tayo	Untreated	35.7	97.5	34.7	26.0	16.9	42.3	44.6
Tayo	Flag leaf	26.5	92.5	24.7	20.5	17.0	42.6	45.8
Tayo	Anthesis	**13.1**	**61.3**	**8.2**	**11.8**	17.0	**45.7**	**63.6**
Tayo	Flag leaf + Anthesis	**10.7**	**57.5**	**6.7**	**8.7**	17.1	**46.7**	**69.5**
H2003	Untreated	28.7	86.3	24.8	23.6	17.1	44.8	75.6
H2003	Flag leaf	15.9	63.8	12.1	14.5	17.2	45.8	**82.9**
H2003	Anthesis	**8.0**	**52.5**	**4.5**	**10.3**	17.2	**46.9**	**90.0**
H2003	Flag leaf + Anthesis	**8.3**	**33.8**	**2.4**	**7.1**	17.2	**47.2**	**90.6**
Recepter	Untreated	36.6	97.5	35.7	28.8	16.9	44.6	52.8
Recepter	Flag leaf	27.9	96.3	27.0	28.1	16.8	44.7	52.0
Recepter	Anthesis	**12.2**	**65.0**	**7.8**	**17.3**	16.9	**47.2**	61.9
Recepter	Flag leaf + Anthesis	**11.9**	**68.8**	**8.0**	**12.2**	16.9	**46.8**	59.3
	P > F	**0.0001**	**0.0001**	**0.0001**	**0.0001**	**0.0088**	**0.0001**	**0.0001**
	LSD 0.05	**7.8**	**20.9**	**7.7**	**9.1**	**0.3**	**1.1**	**10.2**
	CV %	**28.1**	**19.9**	**32.8**	**36.6**	**1.1**	**1.7**	**10.7**

† Fungicide treatments included Tilt at 4 fl oz/acre at flag leaf stage and Mirivas Ace at Miravis Ace at 13.5 fl oz/acre at anthesis (flowering).

‡ Yields are adjusted to 14% grain moisture and 56 lb/bu test weight.

β Smaller values for disease ratings are preferred while larger values for test weight and yield are preferred. Within a hybrid, the lowest value for disease ratings is in bold and shaded. Other values similar to that value are in bold. For test weight and yield, the highest value in a hybrid is bold and shaded. Other values similar to the highest value are in bold.

Table 2. Rye response to fungicide timings at Lexington, 2024

Hybrid	Fungicide Treatments†	Tillers (per 0.5 m of row)	Test Weight (lb/bu)	Grain Moisture (%)	Yield (bu/A)‡
Serafino	Flag Leaf	43	43.6 -	6.9 -	1.09 -
Serafino	Flag Leaf + Anthesis	65	66.0 -	7.4 -	0.42 -
Serafino	Anthesis	51	43.6 -	7.8 -	1.18 -
Serafino	Untreated Control	54	44.0 -	5.7 -	0.80 -
Tayo	Flag Leaf	42	65.2 -	8.8 -	7.56 -
Tayo	Flag Leaf + Anthesis	47	43.8 -	6.8 -	0.59 -
Tayo	Anthesis	38	43.6 -	7.2 -	1.07 -
Tayo	Untreated Control	31	65.5 -	8.9 -	4.22 -
	LSD P=.05	33.6	53.22	7.44	7.136
	Standard Deviation	19.2	30.39	4.25	4.075
	CV	41.31	58.53	57.2	192.46

† Fungicide treatments included Tilt at 4 fl oz/acre at flag leaf stage and Mirivas Ace at Miravis Ace at 13.5 fl oz/acre at anthesis (flowering).

‡ Yields are adjusted to 14% grain moisture and 56 lb/bu test weight. Rye during seed fill in Lexington experienced 15 consecutive days above 88 F and 13 days above 90 F with no measured rainfall. Seed development was extremely poor in Lexington.

WINTER OAT BREEDING FOR KENTUCKY
PROGRESS REPORT FOR 2023-2024

Lauren Brzozowski and Carrie Knott
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INTRODUCTION (OBJECTIVE)

Winter oats (*Avena sativa*) could increase diversity in Kentucky grain rotations. However, there is limited cultivation of winter oats in Kentucky, totaling approximately 536 acres in 2017 USDA Agricultural Census. This may be due to several factors. First, winter oats are known to be among the least cold tolerant of small grains. Second, there has not been plant breeding to date for adapted oat varieties for Kentucky climates and grain rotations (e.g., maturation date aligning with typical double crop rotation). Thus, the goal of this project is to address these major barriers to winter oat in production in Kentucky by improving our understanding of winter survival in oats, breeding new oat varieties, and assessing how oats fit into a double crop rotation. This project addresses KySGGA priorities of breeding new small grain varieties, where oats can be an option to reduce winter fallow and increase rotational diversity. Our objectives were:

Objective 1. Use variety trial data to assess the effects of winter severity on oat yield

Objective 2. Winter oat breeding

Objective 3. Evaluate viability of winter oats in a no-till double crop system

MATERIALS AND METHODS

Objective 1. Use variety trial data to assess the effects of winter severity on oat yield.
Winter survival is generally poorer in oats than wheat or rye, but the relationship between winter temperatures and winter oat survival and yield is not well established. To address this question, we collected oat performance data from state variety trials (managed by Bill Bruening, and supported by KySGGA) spanning from 2011-2023, and weather data from NASA Power. We then examined the relationship between metrics of winter weather severity and winter oat performance.

Objective 2. Winter oat breeding.
My winter oat breeding program follows a structure typical for small grains: cross-pollinations between parents, followed by advancement by family until breeding line derivation as F4:5 lines, and continuing with plot-level trials at the F5 stage for at least three years. This breeding program is new; I began this program when I started at University of Kentucky in August 2022. As such, the current material in the advanced stages of testing is advanced breeding material from North Carolina State University (Dr. Paul Murphy). I have used that material as well as other lines from the Noble Foundation and other breeding programs to generate new Kentucky-bred material. I have also selected within early generations of populations provided from other public winter oat breeding programs to develop breeding lines adapted to Kentucky.

The breeding program is focused on improving winter stress resilience, yield and test weight while maintaining maturity timelines similar to wheat. At all stages of the breeding cycle, winter survival, winter stress and heading date are measured. For plots, yield, test weight, lodging, plant height and relevant disease severity is measured. For advanced lines in state-wide yield trials, basic quality traits like percent protein, oil and starch are evaluated by NIR. Lines with a pending variety release are evaluated for advanced quality and milling traits at a testing lab.

Crossing is conducted at a University of Kentucky greenhouse (Lexington, KY), early generation evaluations are conducted at University of Kentucky North Farm (Lexington, KY), and yield trials are evaluated at North Farm, as well as University of Kentucky research farms in Versailles, KY and Princeton, KY, and on Walnut Grove Farms in Schochoh, KY.

Objective 3. *Evaluate viability of winter oats in a no-till double crop system*.
We sought to test how oats compare to wheat in terms of subsequent soybean yield for a double crop rotation. At both North Farm and Princeton, we planted four varieties each of oats and wheat in 4 x 15 ft plots replicated four times in a randomized complete block design, for a total of 32 plots per location. We planned to harvest the small grains in June 2024, follow with a single variety of soybeans, and then assess soybean yield and quality to determine if there are advantages (or disadvantages) to double cropping with oats as compared to wheat. Unfortunately, the winter oats in the double crop trial did not survive in Princeton (the trial was in a low field; oats in an adjacent field had >95% winter survival), and both the wheat and oats suffered from severe lodging in Lexington, and this trial was not completed.

RESULTS & DISCUSSION

Objective 1. *Use variety trial data to assess the effects of winter severity on oat yield*.
We used historical state variety trial data (2011-2023) to examine the relationship between winter temperatures and oat performance. This work was conducted by a graduate student, and we found a negative correlation between the number of days below freezing and oat winter survival (winter survival was higher with fewer days below freezing during the growing season; **Figure 1**). However, this relationship did not extend to yield. Yield was not always higher in these warmer years (**Figure 2**). This has spurred further work to elucidate how timing of specific winter stresses affects yields.

Figure 1. Mean and standard error of oat winter survival in the state variety trials from 2011-2023. Color indicates the number of days below freezing in the growing season, with blue indicating more days below freezing (colder) and red indicating fewer days below freezing (warmer).

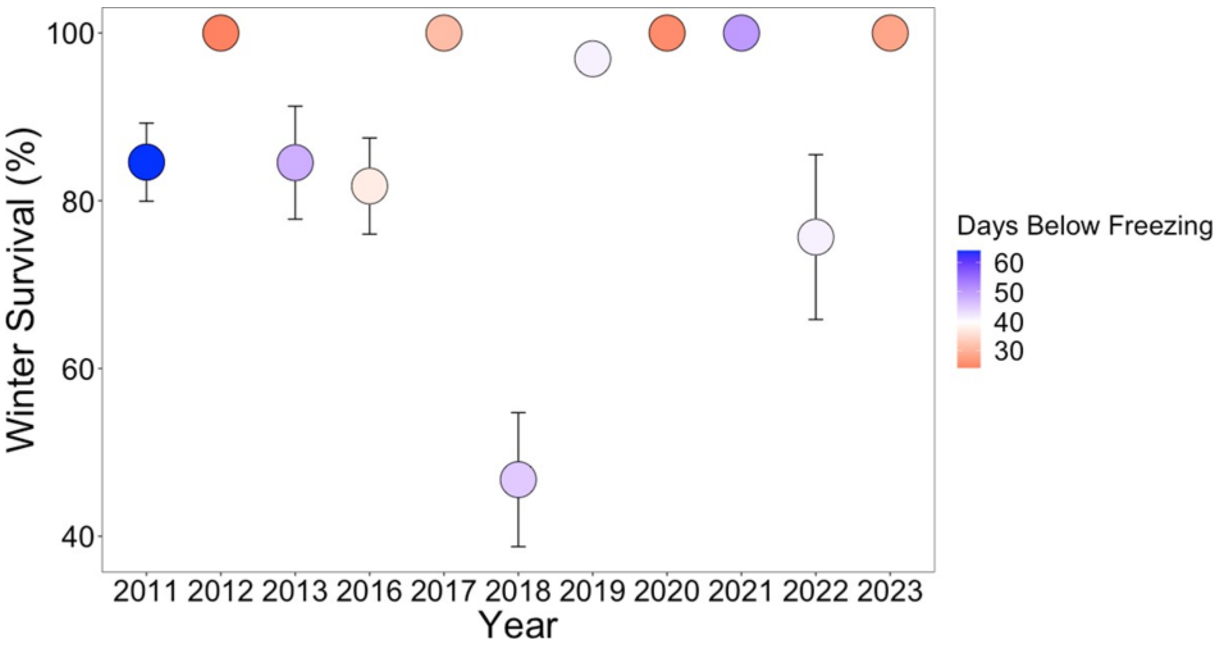
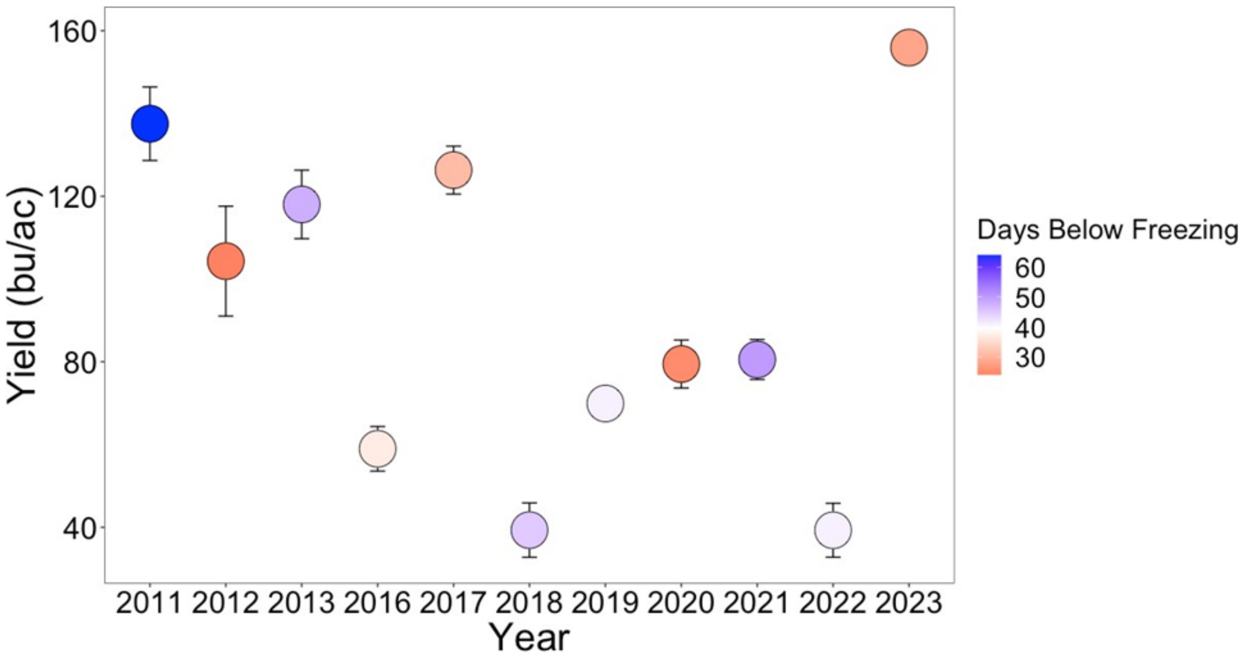


Figure 2. Mean and standard error of oat yield (32 lb bu/ac) in the state variety trials from 2011-2023. Color indicates the number of days below freezing in the growing season, with blue indicating more days below freezing (colder) and red indicating fewer days below freezing (warmer).



Objective 2. *Winter oat breeding*.

The winter oat breeding program has successfully generated new breeding lines and advanced promising lines through the breeding pipeline, up to entry of advanced lines in the state yield trials this upcoming year (2024-2025).

The breeding program has made new cross pollinations each year: 30 crosses in the 2022- 23 season, and 50 in the 2023-24 season, with the goal to have 50-80 annually hereafter. In the 2024-25 season, the F2s and F3s are UK breeding lines developed from KySGGA support in 2023- 2024.

We have also made selections within early generation material (F2 and F3 families) generously provided by other public winter oat breeding programs. This early generation material was selected for winter hardiness in Kentucky for the past two years and F4:5 breeding lines were derived in 2024. In the 2024-25 season, there will be >1000 F4:5 headrows to be evaluated. Concurrently, F5 seed harvested from F4 plots is grown in replicated plots in three environments for early yield estimation (early yield trial, EYT). In the 2024-25 season, there will be 40 entries in the EYT.

Finally, advanced lines from North Carolina State University have now been evaluated in at least two locations for two years. The advanced lines were evaluated at North Farm (**Tables 1**) and Walnut Grove Farms (**Table 2**) in 2023, and at North Farm (**Tables 3**), Woodford (**Table 4**) and Schochoh (**Table 5**; not harvested due to flooding, lodging) Princeton (**Table 6**) in 2024. Overall, these lines are on par with or had better winter survival than current commercial checks (Gerard 224, Gerard 227, Horizon 201, Horizon 578), with higher yield and test weights. The goal with these advanced lines is to select new winter oat varieties for Kentucky. Eight of these top lines will be evaluated again in the advanced yield trial (AYT) of the breeding program and have seed increases in 2024-25; these lines are indicated with a (*) in **Tables 1-5**. In addition, five of these lines will be entered into the state variety trials. Ultimately, I hope to co-release one of these lines as a new variety with NCSU.

Next steps

- To build upon our results about winter oat survival, we will conduct a study to test the effect of planting date on oat winter survival. The damage inflicted by cold temperatures depends in part on plant developmental stage, and so using a planting date gradient will allow us to capture different developmental stages at key moments of winter stresses (e.g., major freeze events). This will allow for evaluation of varieties that experience winter stresses at different developmental stages. We expect that this work will provide a clearer picture of oat resilience to winter stress and provide useful planting date information.
- The breeding program will continue to develop new breeding lines as described above.
- The double crop trial will continue.

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TABLES

The tables summarize mean trait values adjusted for spatial variation for each line in the advanced trial. The commercial checks Gerard 224, Gerard 227, Horizon 201, Horizon 578 are listed at the top of the table, followed by the eight lines advancing to the advanced yield trials which are also indicated with a (*). Each table is a separate location, year.

Table 1. Oat advanced trial – 2023, Lexington, KY

Genotype	Winter Survival (%)	Height (cm)	Heading Date	Lodging (%)	Yield (bu/ac)	Test Weight (lbs)
Gerard 224	59.4	109.6	123.8	11	153.6	37
Gerard 227	69.6	119.8	126.2	47.9	158.1	38.7
Horizon 201	74.4	127.9	121.1	50.1	153.3	34.7
Horizon 578	72.5	113.9	125.1	62.5	167.5	37.6
NC20-4402*	75.1	127	124.6	25.3	227.2	37.3
NC20-4452*	73	119.8	128	15.9	133.2	37.2
NC20-4526*	61.4	117.9	122.4	42.2	136.7	39.6
NC20-4551*	72.9	123.9	125.6	66.6	153.4	40.9
NC21-6492*	80	115.9	123.1	39.4	174.5	38.1
NC21-6497*	79.5	115.7	123.8	52.7	176.3	38.5
NC21-6502*	71.9	118.6	126.9	9.2	180.3	37.6
NC21-6511*	64.4	132	123.1	12.7	172.5	35.8
NC12-3753	71.1	120.4	123.7	58.2	114.4	39.2
NC12-3922	77	117.1	123.1	13.3	156.4	39.6
NC17-6440	73.9	113.6	121.6	22.8	159.7	39.3
NC17-6550	78.8	115.8	126.6	51.3	151.4	40.6
NC19-3362	74.5	122.5	128.9	21.5	139.8	38
NC19-3542	66.5	116	126.7	52.1	134.6	37
NC20-4352	71.7	101.4	125.7	9.1	142.7	34.7

(Table 1 continues on next page)

NC20-4441	76.2	127.4	125.8	26.6	155.6	39.2
NC20-4621	64.5	135.6	130.1	37.4	164.9	39
NC20-4700	77.6	116	126.1	-4.6	155.7	37
NC20-4702	68.5	128	128.4	30.1	111.4	41.1
NC20-4795	70.8	133.7	126.2	26.5	171.7	35.5
NC21-6328	71.7	122.5	117.1	1.8	144.5	41.5
NC21-6429	75.1	116.8	126.6	52.8	142.4	37.9
NC21-6436	66.1	103.2	125.1	-12.2	83.7	33.5
NC21-6463	76.8	139.1	127.3	98.1	134.2	37.2
NC21-6475	75.6	129.6	119.2	130.2	158.6	39.1
NC21-6505	71.7	117.3	122.6	28.3	188.5	39.1
NC21-6515	73.1	107	124.8	48.7	128.9	36.4
NC21-6520	59.4	124.8	124.8	46.8	109	37.9
NC21-6521	77.9	117.6	124.4	48.5	153.4	37.4
NC21-6569	74.8	114.4	118.6	98.7	120.3	38.7
NC21-6576	76.9	116.8	120.1	95.6	154.5	39
NC21-6587	74.2	112.5	121.3	12.5	101.5	35.9
NC21-6592	68.8	114.9	119.4	98.5	109.6	39.3
NC21-6609	79.8	104.5	124.4	-10.2	181	35.8
NC21-6610	68.1	98.1	126.6	32.2	170.1	36.3

Table 2. Oat advanced trial – 2023, Schochoh, KY

Genotype	Heading Date	Yield (bu/ac)	Test Weight (lbs)
Gerard 224	114	165.8	36.9
Gerard 227	114.6	145.9	35.9
Horizon 201	116.7	128.3	34.6
Horizon 578	112.7	165.6	38.3
NC20-4402*	116.1	150.6	37.7
NC20-4452*	114.3	183.6	38.3
NC20-4526*	114.2	128.1	36.6
NC20-4551*	116.9	179.8	38.6
NC21-6492*	111.8	179.1	38.1
NC21-6497*	111.3	182	37.8
NC21-6502*	110.9	143	36.6
NC21-6511*	110.5	161.4	37.3
NC12-3753	111.6	138.9	37.9
NC12-3922	112.2	168.2	38.2
NC17-6440	112	157.8	37.7
NC17-6550	116.5	155	38.5
NC19-3362	119.3	152.8	35.6
NC19-3542	113	167.9	35.9
NC20-4352	113.7	149.2	37.3
NC20-4441	113.7	149.1	37.2
NC20-4621	123.9	176.8	38.5
NC20-4700	112.8	169.5	34.7
NC20-4702	116.4	159.1	39.9
NC20-4795	114.9	141.6	35.8
NC21-6328	110.6	124.2	38.8
NC21-6429	116.5	141.1	38.4
NC21-6436	111.9	116.6	38.9
NC21-6463	121.3	122.7	36.8
NC21-6475	112.3	118.8	39
NC21-6505	111.7	155.8	36.2
NC21-6515	113.3	130.3	38
NC21-6520	118.3	164.2	37.9
NC21-6521	117	158.1	38.1
NC21-6569	112.5	162.3	37.9
NC21-6576	111.9	130.7	36.9
NC21-6587	112.8	101.7	37.9
NC21-6592	111	139.2	37.1
NC21-6609	112.3	168.3	37
NC21-6610	113	175.3	35.9

Table 3. Oat advanced trial – 2024, Lexington, KY

Genotype	Winter Stress (1-9)	Winter Survival (%)	Height (cm)	Heading Date	Lodging (%)	Yield (bu/ac)	Test Weight (lbs)
Gerard 224	2	96.5	95.8	115.4	-8.4	128.4	34.9
Gerard 227	2	94.9	99.8	116	35.3	102.9	32.9
Horizon 201	2.2	90	114.6	117	21.8	119.5	32.7
Horizon 578	1.8	91	94.1	117.2	6.1	100.9	34.1
NC20-4402*	2.3	90.8	116.1	116.4	3.4	115.1	34.9
NC20-4452*	2.1	92	92.5	117.8	7.7	114.4	34.9
NC20-4526*	2.4	96.6	97.8	116.8	0.1	116.2	36.1
NC20-4551*	1.9	94.2	105.4	118.6	44.1	96.2	36.8
NC21-6492*	1.7	90.3	92.6	117.6	5.2	115.1	35.3
NC21-6497*	1.6	91.2	90.8	116.7	1.6	116.6	34.8
NC21-6502*	3	91.8	96.9	117.1	7.9	91.1	34.6
NC21-6511*	1.7	93.3	101.5	116.4	21.6	90.3	35.1
NC12-3753	1.5	92.2	107.1	116.1	4.4	107.3	36
NC12-3922	2	94.9	91.9	116.6	0.6	108.1	34.5
NC17-6440	2	93.6	94.9	116.9	26.5	106.1	32.9
NC17-6550	2	95.9	98.8	117.4	51.1	83.2	35.6
NC19-3362	3.1	92.6	101.5	120.4	5.9	117.2	32.8
NC19-3542	4.6	94	88.4	117.4	39.1	81.8	33.1
NC20-4352	1.9	96.3	88.2	118.8	-5	81.7	31.4
NC20-4441	2.1	92.6	97.1	116.6	32.9	85	35.3
NC20-4621	2.6	93.9	110.6	119.6	52.9	88.1	35.1
NC20-4700	2.6	87.9	93.4	116.8	5.9	117.3	32.7
NC20-4702	1.5	95	NA	119.6	87.8	45.6	35.8
NC20-4795	2.6	91.2	115.4	116.7	22.7	102.7	33
NC21-6328	2.4	89.4	100.9	111.5	5.9	106.3	38.8
NC21-6429	1.9	79.7	110.4	116.9	82.5	65.5	34.2
NC21-6436	3.6	87.1	76.8	116.3	5.3	71.5	36.1
NC21-6463	2.1	85	113.5	120.2	74.1	49.1	33.6
NC21-6475	2.1	94.6	110.5	116.4	79.7	78.3	37.4
NC21-6505	2.6	90.2	94.7	113.5	1.5	106.1	35.3
NC21-6515	2.5	91.6	83.7	118.5	52.7	56.7	33.9
NC21-6520	1.9	91.9	118.5	118.6	87.9	47.8	35.1
NC21-6521	2	90.4	106.4	118.4	94.4	93.8	34.4
NC21-6569	2.6	97.2	92	113.9	53	62.7	34.3
NC21-6576	2.3	93.5	87.7	112	70.6	85.9	34.7
NC21-6587	2.1	94.5	90.4	115.6	8.8	92.9	35.1
NC21-6592	2	91.7	104.9	115.3	88.4	72.2	36.4
NC21-6609	2.4	90.7	91.3	117.2	24.4	107.1	32.7
NC21-6610	1.9	96.2	91.4	116.9	4.2	112.8	32.9

Table 4. Oat advanced trial – 2024, Versailles, KY

Genotype	Winter Survival (%)	Height (cm)	Heading Date	Lodging (%)	Yield (bu/ac)	Test Weight (lbs)
Gerard 227	97.3	102.2	123	91.6	61	35.5
Horizon 201	94.5	112.3	122.6	99	71.8	35.8
Horizon 578	94.5	107.6	123	95.6	125.2	36.4
NC20-4402*	93.6	106.7	123	64.4	125.7	36.2
NC20-4551*	101	106.6	123.9	91.3	100.8	36.7
NC21-6492*	95.3	108.2	122.5	96.5	132.7	35.9
NC21-6497*	94.3	108.4	123	59.8	124	37
NC21-6502*	95.3	102.6	125	75.8	143.3	37.5
NC21-6511*	95.2	108.9	122.5	98.9	143.5	37.3
NC12-3922	90.7	105.9	122	70.6	129.8	37.2
NC17-6440	95.3	100	124	98.3	81.9	34.9
NC17-6550	99.3	100.3	123.1	95.2	64.7	38.5
NC20-4441	95.6	109.4	123.9	96.5	99.5	34.9
NC21-6328	92.6	102.6	119	92.2	107.4	39.9
NC21-6475	92.5	118.2	122	104	68.4	36.4
NC21-6505	91.1	111.8	125.5	90.8	137.9	38.1
NC21-6576	96.1	99.6	121	94.2	74.4	38
NC21-6592	95.5	102.7	122.5	88.8	80.5	39.5
NC21-6609	91.8	94.7	124.4	88.7	77.4	37.2
NC21-6610	94.8	97.2	124	99.7	75.2	35.4

Table 5. Oat advanced trial – 2024, Schochoh, KY

Genotype	Winter Stress (1-9)	Winter Survival (%)	Height (cm)	Heading Date	Lodging (%)
Gerard 224	1.7	100.2	NA	115.7	-3.9
Gerard 227	1.5	100	125.4	115.7	26.1
Horizon 201	2.8	100.1	138.4	116.5	23.7
Horizon 578	1.4	99.8	118.1	116.3	13.9
NC20-4402*	1.6	100.1	137.2	116.2	15.8
NC20-4452*	1.3	99.9	NA	118.3	14
NC20-4526*	1.3	100.1	130.2	116.4	38.2
NC20-4551*	0.1	99.9	132.1	119.4	25
NC21-6492*	1.6	100.1	119.1	114.9	9.3
NC21-6497*	0.9	100.1	NA	114.7	15.4
NC21-6502*	1.7	99.9	119.4	117.2	-2.4
NC21-6511*	2.1	99.8	119.4	112.9	22.8
NC12-3753	1.2	96.7	NA	113.3	17.1
NC12-3922	1.4	100	116.6	115.5	5.9
NC17-6440	1.3	100.1	119.4	117.2	9.7
NC17-6550	1.4	100	116.8	116	24.6
NC19-3362	1.3	100.1	116.8	121.4	24.2
NC19-3542	1.7	100	111.8	117.3	3.1
NC20-4352	1.3	100.1	112.9	119.9	1.3
NC20-4441	1	100.1	124.5	117.2	42.1
NC20-4621	2.4	100	145.1	120.8	1.6
NC20-4700	1.7	99.9	NA	117	29.4
NC20-4702	1.3	100.1	125.5	120.1	9.2
NC20-4795	2	100.1	127	115.4	30.1
NC21-6328	3.1	99.8	111.8	113.1	23.7
NC21-6429	1.7	99.9	NA	119.4	15.8
NC21-6436	1.1	100	104.1	113.2	30.4
NC21-6463	1.6	100	137.2	117.6	23.8
NC21-6475	1.6	100	142.2	113.3	26.7
NC21-6505	2.3	100.1	128.3	117.1	-13.5
NC21-6515	1.1	99.9	111.8	116	22.4
NC21-6520	1.6	100.1	NA	117.4	15.2
NC21-6521	1.7	99.9	114.8	118.4	15.4
NC21-6569	1.7	99.9	NA	114.1	16.7
NC21-6576	1.7	99.9	NA	114.5	19.8
NC21-6587	2.4	100	119.4	115.3	45
NC21-6592	2.1	99.9	119.4	112.9	20.2
NC21-6609	1.9	100.1	116.8	114.6	52.2
NC21-6610	2.7	100	111.8	114.3	20.1

Table 6. Oat advanced trial – 2024, Princeton, KY

Genotype	Winter Stress (1-9)	Winter Survival (%)	Height (cm)	Heading Date	Lodging (%)	Yield (bu/ac)	Test Weight (lbs)
Gerard 224	1.4	94.9	106.5	116.4	38.8	77.3	33.9
Gerard 227	1.4	94.5	112.3	116.2	42.9	80.5	32.5
Horizon 201	2.3	93.6	119.4	114.5	57.9	59.6	31.9
Horizon 578	1.5	96.3	107.3	116.4	28.6	76.1	34.9
NC20-4402*	1.5	95.8	120.5	116.6	58.6	72.9	33.5
NC20-4452*	1	95.6	110.2	117.6	28.6	81.8	33.8
NC20-4526*	1	94.8	106.4	114.2	72.3	78.2	35
NC20-4551*	0.9	95.1	116.6	118.3	28	75.9	35.6
NC21-6492*	0.9	97.6	101.6	115.3	8	87.8	34.8
NC21-6497*	2	95.1	101.3	116	6.2	81.8	35.5
NC21-6502*	1.6	97.1	105.5	115.2	0.2	77	33.2
NC21-6511*	1.9	97.6	110.3	112.4	13.8	75.2	34.3
NC12-3753	0.9	93.5	112.4	114.6	48.6	75.6	34.3
NC12-3922	2	92.5	109.8	117	26.2	71.9	35
NC17-6440	1.5	95.3	100.1	112.2	72.3	69.4	34.1
NC17-6550	2.1	94.8	115.7	117.5	71.7	55.1	34.6
NC19-3362	1.9	93	114.2	119.9	72.8	64.5	30.5
NC19-3542	1.6	93.1	141.8	117.6	51.6	81.3	32.2
NC20-4352	1.6	91.7	100.5	118.5	1.7	65.9	32.2
NC20-4441	1.9	95.6	114	116.3	39.3	67.2	34
NC20-4621	2.9	92.4	122.7	118.4	36.3	88.8	32.8
NC20-4700	2	94.2	107.2	116.4	11.7	71.4	32.7
NC20-4702	1.1	94.4	117.1	118.7	57.7	54.2	36
NC20-4795	2	93.2	124.7	115.1	21.1	70.7	31.9
NC21-6328	1.5	92.4	114.6	110.2	49.8	63.8	37.1
NC21-6429	2.6	85.5	113.5	118.1	64.1	42.3	32.2
NC21-6436	1	95.7	97.7	113.8	23	61.9	34.1
NC21-6463	2.5	94.5	120.6	117.1	90.7	51.5	29
NC21-6475	2	94.4	116.5	112.6	43.2	49.9	35.6
NC21-6505	2.4	90.1	109.3	116.3	8	71.7	34.3
NC21-6515	1	97.9	96.1	115.8	58	70.5	34.2
NC21-6520	1.1	94.2	116.4	116.2	57.7	56.6	35.1
NC21-6521	1	97	120.5	116.1	59	55.6	34.8
NC21-6569	1	97.2	101.6	112.7	32.3	58	35.7
NC21-6576	1.4	98.2	98.2	113.6	53.6	66.5	34.6
NC21-6587	2.1	95.5	100	112.6	59.1	52.7	33.7
NC21-6592	1	94.6	108.7	112.4	91.7	99.7	35.6
NC21-6609	1.9	94.7	98.9	115.3	8	68	35.3
NC21-6610	2	95.1	102.4	115.2	32.3	86.9	34.5

IMPROVING BREEDING EFFICIENCY OF LOCALLY-ADAPTED CEREAL RYE VARIETIES PROGRESS REPORT FOR 2023-2024

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INTRODUCTION (objective)

Breeding for regionally adapted cereal rye varieties for Kentucky supports regional industries, like distillers, and sustainable agriculture practices through diversity in crop rotations and cover crop seed production. This work has augmented ongoing breeding efforts of the University of Kentucky to develop rye open-pollinated varieties. Specifically, we have continued breeding efforts and are developing tools to improve efficiency throughout the breeding cycle. This work addresses the KYSGGA goals of reducing winter fallow and developing new small grain varieties. Our objectives were:

Objective 1. Breeding for larger seeds and improved agronomic performance.

Objective 2. Developing new stocks and tools to breed dwarfing varieties.

Objective 3. Testing approaches for isolation.

Objective 4. Developing methodologies and estimating heritability of grain fill.

MATERIALS AND METHODS

Objective 1. Breeding for larger seeds and improved agronomic performance.

Dr. Phillips conducts rye breeding at the University of Kentucky through selection of half-sib families, polycrosses and recurrent selection populations. Selection is conducted at the University of Kentucky research farm, North Farm, in Lexington KY. In this past year, Dr. Phillips selected plants with largest seed size towards increased yield and to meet the needs of local distillers. Dr. Phillips also selected in four populations, including one population made by blending largest seed from 15 diploid populations, and an early, shorter population (KYSC1806C0), in addition to the two proposed populations. These populations were evaluated in yield plots.

Objective 2. Developing new stocks and tools to breed dwarfing varieties.

Kentucky growers have expressed that inconsistent yields and large amounts of straw are key challenges in rye production. Reducing plant height may alleviate issues with lodging and straw residue that can complicate harvest and no-till planting of soybeans following harvest. We sought to establish molecular markers that could be used to screen for rye with reduced height. We began by reviewing the scientific literature for known dwarfing genes, established lab protocols, and then tested if the largest effect dwarfing gene, *Ddw1*, was present in UKY rye germplasm.

Objective 3. Testing approaches for isolation.

The need for isolation distances to maintain rye breeding lines limits the amount of germplasm that can be screened. We tested if coleoptile color could be used as an easy-to-screen indicator of pollen contamination. Rye coleoptiles are purple or green, where purple is dominant to green. We first sought to understand the genetics of coleoptile color, with the goal of moving to field trials. Ultimately, lab work showed found that the genetic inheritance of coleoptile color was too complex for use as an indicator phenotype for pollen contamination, and so this work was not brought to field scale.

Objective 4. Developing methodologies and estimating heritability of grain fill.

Kernel weight reduction negatively influences grain yield. Rye kernel weight is reduced under high temperature and drought conditions, thus rye with shorter grain filling period would increase yield stability in Kentucky. We sought to understand the heritability of grain fill so that this trait could be included in breeding programs. We proposed to measure grain maturity by color (loss of green color) and grain fill period on a large sample of rye accessions, where this research would be conducted by Dr. Szuleta in Schochoh, KY. We unfortunately were not able to complete this objective after Dr. Szuleta relocated, and thus no results are reported.

RESULTS & DISCUSSION

Objective 1. Breeding for larger seeds and improved agronomic performance.

University of Kentucky rye breeding lines have been evaluated in multiple yield trials. A survey of selected populations showed that the Kentucky breeding lines have yields on par with some open pollinated commercial checks and are earlier to head (**Tables 1-2**).

In addition, a few of the top breeding lines were evaluated in a variety trial managed by Dr. Szuleta, where KYSC1701 C1 SP1 was shown to be especially promising, and thus seed will be increased for yield trials next year (**Table 3**).

Objective 2. Developing new stocks and tools to breed dwarfing varieties.

We identified *Ddw1* as our first target for developing molecular tools. We refer to alternate form of a gene as alleles. In triticale, the dominant allele is reported to result in a 30% reduction in plant height. A molecular marker was developed for triticale, where alleles have different sized bands in the assay (Figure 1; from Litvinov et al, 2020).

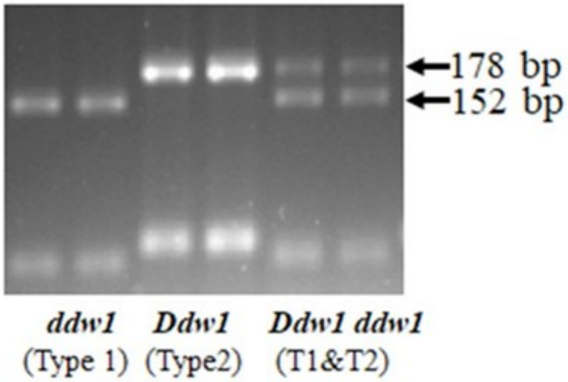

Figure 1. Demonstration of molecular marker for *Ddw1* in triticale; the dominant allele is larger after cutting with a restriction enzyme (178 bp) than the recessive allele (152 bp) and thus can be visualized by gel electrophoresis.

We tested these protocols to determine if this marker would work in rye in addition to triticale, and were successfully able to evaluate the *Ddw1* marker in our lab (**Figure 2**).

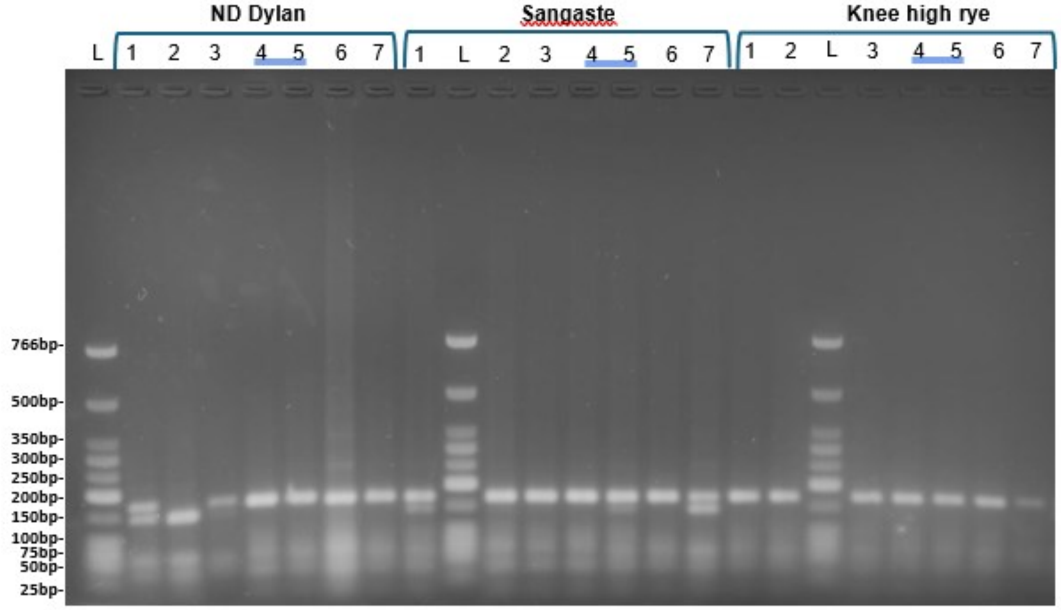

Figure 2. Gel imag from the *Ddw1* marker screened in different rye populations in our lab. Different sizes of DNA fragments indicate that we can evaluate both the dominant and recessive allele.

We then assessed the frequency of the different alleles in rye varieties: we expected that the taller rye varieties would have higher frequencies of the dominant (short) *Ddw1* allele, but did not know how common it would be across accessions. We found most rye varieties had a high frequency of homozygous dominant (short) alleles (DD), although some varieties like Danko, Sangaste and Aroostook also harbored heterozygotes and homozygous recessive (short) alleles (dd) (**Table 4**). These results show that the dominant (short) allele of *Ddw1* is already common in some of our Kentucky germplasm, but that the Kentucky breeding material may be further improved by selection to reduce frequency of the allele in populations.

Next Steps

- We are continuing breeding efforts for new open-pollinated rye varieties, including increased selection for reduced height, as well as increasing seed from promising lines for variety release.
- We will continue our work with the dwarfing markers by assessing the degree to which these markers reduce plant height in Kentucky varieties (e.g., if the effect is as large as is reported for triticale), selecting for the dwarfing alleles in Kentucky breeding lines to eliminate sources of tall alleles, and testing additional dwarfing markers like *Ddw3*, *Ddw4*, and *Ddw9*. The long term goal is to have a suite of molecular markers that can be used for screening for height.
- Due to the high levels of Fusarium head blight observed this year, we will screen breeding lines and varieties in the FHB nursery.
- We will continue multi-location rye variety trials
- Three promising OP lines will be increased in 1–2-acre plots for larger on-farm evaluation in 2025-2026.

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TABLES

Table 1. Results from 2023 selection yield trials in Lexington and Versailles. Yield is in 56 lb bu/ac, test weight in lbs, and heading date is reported as days after April 1

Genotype†	**Lexington**			**Versailles**		
	Yield	**TW**	**HD**	**Yield**	**TW**	**HD**
CHECK_F1_Serafino	97.5	53.2	32	88.5	51.6	32
CHECK_F1_TayoF1	102.7	53.0	32	80.1	52.2	32
CHECK_OPV_AVENTINO	68.7	51.6	29	64.6	51.1	29
CHECK_OPV_ND_DYLAN	67.1	51.3	30	51.3	50.4	30
KYSC1503_C2	54.8	51.2	15	49.4	50.9	15
KYSC1705_C2	67.3	52.0	18	52.4	50.0	16
KYSC1706_C2	55.2	49.5	25	55.8	47.7	23
KYSC1707_C2	59.1	51.8	16	55.2	50.7	17
KYSC1710_C2	58.7	51.8	22	47.6	50.2	22
KYSC1802_C2	42.3	47.1	24	70.2	50.8	22
KYSC1807_C2	55.6	51.4	16	44.9	46.2	16
KYSC1811_C2	85.8	51.3	24	53.2	50.0	26
KYSC1812_C2	62.3	51.6	18	58.9	51.2	16

† F1 signifies a hybrid variety; OPV signifies an open pollinated variety; C2 signifies 2 cycles of selection for larger kernels.

Table 2. Results from 2024 selection yield trials in Lexington and Versailles. Yield is in 56 lb bu/ac, test weight in lbs, and heading date is reported as days after April 1.

Genotype†	**Lexington**			**Versailles**		
	Yield	**TW**	**HD**	**Yield**	**TW**	**HD**
CHECK_F1_Serafino	68.1	55.1	33	86.5	58.2	31
CHECK_F1_TayoF1	49.6	51.8	33	84.9	56.2	31
CHECK_OPV_AVENTINO	21.7	41.2	31	43.4	56.5	29
CHECK_OPV_ND_DYLAN	28.9	50.8	32	31.3	47.2	29
KYSC1503_C2	40	51.1	22	19.5	31.3	22
KYSC1705_C2	36.6	46	26	29.7	42.2	24
KYSC1706_C2	21.1	33.5	28	28.9	41.8	26
KYSC1707_C2	34.4	50.3	26	36	47.5	23
KYSC1710_C2	36.2	51.1	28	34.6	46.7	26
KYSC1802_C2	33.4	47.4	29	39.6	50.4	26
KYSC1807_C2	42.2	47.9	24	25.8	37.6	22
KYSC1811_C2	22.3	33.4	31	39.4	54.7	27
KYSC1812_C2	33.7	48.3	27	25.1	38	22

† F1 signifies a hybrid variety; OPV signifies an open pollinated variety; C2 signifies 2 cycles of selection for larger kernels.

Table 3. Results from 2024 variety trial in Lexington, Ky

Variety	Yield (bu/acre)
KWS Serafino	69.5
KYSC1707	63.9
SH05	61.7
SH06	59.0
KYSC1705	58.8
Aventino	58.7
KYSC1701 C1 SP1	56.3
KYSC1503 C3	55.8
KYSC1710 C1 SP1	54.8
KYSC1806 C0	52.1
KWS Tayo	51.8
SH03	50.9
SH07	50.7
Danko C0	48.8
Aroostook C0	46.3
ND Dylan	44.0
Balbo (2114C0)	44.0
AC Hazlet	40.2

Table 4. Results of *Ddw1* allele frequency in six rye populations. The number of scoreable markers are shown, as well as the percent that were scoreable of the total run. Then the percent of individuals with the DD, Dd, or dd genotypes are shown.

Variety	**Scoreable markers (*n*)**	**Scoreable (%)**	**DD (%)**	**Dd (%)**	**dd (%)**
Knee high rye	74	100	100.0	0.0	0.0
Sangaste	76	86.8	86.8	10.5	2.6
Aroostook	76	96.1	96.1	3.9	0.0
Danko	93	83.9	83.9	14.0	2.2
ND Dylan	96	99	99.0	1.0	0.0
KYSC1710C1Sp1	64	96.9	96.9	3.1	0.0