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# WHEAT SCIENCE RESEARCH REPORT

Grain and Forage Center of Excellence

*Martin-Gatton College of Agriculture, Food and Environment*

# Contents

# WINTER COVER CROP EFFECTS ON SOIL HEALTH IN SLOPING CROPLAND

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## OBJECTIVE

Healthy soils are critical for high and stable productivity of wheat and other crops grown in Kentucky. Growing cover crops is one way to improve soil health. However, research findings about cover crop impacts on soil health and sustainability are derived mainly from flat research plots that are not representative of the rolling cropland that is common in Kentucky. These existing datasets may overlook the disproportionate benefits that cover crops can provide on sloping land. The objective of this study is to determine the effects of cereal rye and mixed cereal rye-crimson clover cover crops on soil organic C and N and other soil health indicators at three different landscape positions. We expected to find that cover crops would have greater benefits for soil health on sloping land than flat land.

## METHODS & MATERIALS

The winter cover crop effects on soil health were investigated using an existing field study at University of Kentucky's Spindletop Farm. The study includes two fields that rotate between corn and soybeans. The study was established in the first field in 2018 and in the second field in 2019. Each field includes three landscape positions – top of hill (summit), side of hill (backslope), and bottom of hill (toeslope). At each of those positions, three winter cover crop treatments – cereal rye, cereal rye-crimson clover mixture, and winter fallow were established. The project involves routine sampling for soil moisture, soil inorganic nitrogen (N), cover crop biomass and N uptake, corn N uptake, and crop yields. Cover crop biomass and crop yield data from this study are summarized in Tables 1 and 2.

On April 19, 2021 just before cover crop termination, soil samples were taken at 0-10 and 10-20 cm (0-4 and 4-8 inches) in the first field. The second field was sampled in the same way on April 28, 2022. The samples were air-dried, sieved through a 2 mm screen, and analyzed for soil C, total N, potential respiration, potential N mineralization, and wet aggregate stability. Soil C and N were measured using the dry combustion method. We subtracted the inorganic C from total C to determine organic C; however, inorganic C results from the second field are still in process. Potential respiration was measured using a soil incubation in which 100 g (first field) or 20 g (second field) of air-dried soil were brought to 60% water-holding capacity and carbon dioxide concentrations were measured in the incubation jars after 0, 24, 48, and 72 hours of incubation. We calculated potential respiration as the average daily rate of $CO_2$-C production over the three-day period per kg of dry soil. Potential N mineralization was measured using a soil incubation in which 8 g of air-dried soil were brought to 60% water- holding capacity and inorganic N was measured after 0 and 7 days of incubation. The difference in inorganic N between these two timepoints was divided by 7 days to determine the average rate of N mineralization per day. Wet aggregate stability was determined as the portion of 1-2 mm aggregates that remained on a 0.250 mm sieve following three minutes of oscillation in water and correction for sand content. For statistical analysis, we evaluated the interactive effects of cover crop and landscape position using analysis of variance and considered p values $\leq 0.05$ to be significant.

## RESULTS

Soil organic C and N are key components of soil organic matter. In the first field, we found that the backslope position had significantly greater soil organic C and total N than the toeslope and summit positions for the 0-10 cm depth (Figure 1). The landscape position effect was not observed for 10-20 cm. Although we did not detect statistical differences among cover crop treatments, it is possible to observe a trend toward higher soil organic C for the rye and mixture treatments than the fallow treatment that was most pronounced in the surface soil on the backslope (Figure 1). In the second field, we found no significant effects of landscape position or cover crop for the soil surface (Figure 2). However, for the depth of 10-20 cm we found that the backslope had significantly greater total N than the toeslope, while the summit was not different than the backslope or toeslope in total N concentration (Figure 2).

Potential soil respiration is an indicator of microbial activity and fast-turnover soil organic matter. For the first field, in the surface 0-10 cm, potential soil respiration was greater on the toeslope than the backslope position, while the summit had an intermediate potential respiration rate (Figure 3). In addition, potential soil respiration was 15% greater with a mixture or rye cover crop than winter fallow. The effect of cover crop use was similar across landscape positions. The 10-20 cm had generally lower potential respiration than the 0-10 cm layer. While the toeslope and summit had higher soil potential respiration than the backslope at 10-20 cm, there was no cover crop effect at that depth (Figure 3). In the second field, in terms of landscape position effects, the backslope had greater potential soil respiration than the summit and toeslope positions in the 0-10 cm increment (Figure 4). In terms of cover crop, we found that the rye resulted in 34% more potential soil respiration than the mix and fallow treatments in the surface soil (Figure 4). Considering the depth of 10-20 cm, the backslope position produced greater potential soil respiration than the summit. Besides that, there were no differences in view of cover crop effects for 10-20 cm (Figure 4).

Potential N mineralization is an indicator of the soil's ability to supply plant-available N. For the first field, in the surface 0-10 cm, potential N mineralization was greater with a rye cover crop than winter fallow on the toeslope position. However, the cover crop effect on the toeslope was reversed in the 10-20 cm depth, where the cover crop mixture led to significantly lower potential N mineralization than fallow (Figure 5). The rye cover crop increased variation in potential N mineralization among landscape positions at 10-20 cm, with significantly greater N mineralization on the summit and toeslope than on the backslope in the rye cover crop treatment (Figure 5). Potential N mineralization was overall higher in the second field, but no effects of landscape position or cover crop were observed (Figure 6).

Soil aggregate stability is an indicator of soil structure and tilth. For the first field, all three landscape positions had very high percentages of water-stable aggregates, and the cover crop treatments tended to increase the aggregate stability, though the effect was not statistically significant (Figure 7). Due to the lack of treatment effects at the soil surface, we decided not to measure aggregate stability on the second depth. For the second field, soil aggregate stability was also high and a significant statistical effect of cover crops was found, in which rye and mix led to 3% greater aggregate stability than the fallow treatment for each landscape position (Figure 8).

## DISCUSSION

The mixture and rye cover crops increased potential respiration in the top 10 cm across all landscape positions relative to the winter fallow treatment in the first field (Figure 3), but in the second field only the rye cover crop showed a pronounced difference compared with the fallow treatment (Figure 4). These results suggest that the cover crop treatments contributed to enhancing the fast-turnover, easily decomposable soil organic matter that is responsible for feeding the soil microbial community. However, in this relatively small study, the rye cover crop was more consistent in increasing the potential respiration than the mixture treatment. This was surprising because the rye and mixture cover crops produced similar cover crop biomass (Tables 1 and 2). Perhaps the cereal rye cover crop depleted inorganic N to a greater extent than the mixture, causing a 'N mining' response in which microbes increased their rate of decomposition to make N more available.

The greater potential mineralization of the cover crop treatments may be an early indication of soil organic C buildup. Indeed, the soil organic C and N concentrations showed a similar trend in response to cover crop treatments as the potential respiration in the surface depth of each field (Figures 1-4), even though cover crop effects on soil organic C and N were not significant. Soil organic C often takes five years or more to show statistically significant changes, while potential respiration can change more quickly because it represents a fast-turnover fraction of soil organic matter. It is also important to highlight that soil organic C and N concentrations varied much more between landscape positions than among cover crop treatments, emphasizing that natural variability in soil organic matter can outweigh management impacts.

It was observed that the backslope position in the first field had the lowest potential respiration despite having the highest soil organic C concentration (Figures 1 and 3). In contrast, the backslope position had the highest potential respiration among landscape positions in the second field (Figure 4), aligning with the slightly higher total N found at that position in field #2 (Figure 2). The higher organic C and total N concentrations on the backslope in both fields may reflect the relatively shallow soil profiles on the backslope, resulting in a limited mass of soil in which to store organic inputs, and thus enrichment of organic matter in that shallow soil. The potential respiration reflects only the easily decomposable forms of organic matter, such as cash crop and cover crop residues. In the first field, the backslope position is the least productive position in terms of crop yield and thus has the lowest crop residues and lowest potential respiration despite its high soil organic C concentration (Table 1). However, in the second field, the backslope is more similar to the other positions in terms of productivity and residue inputs (Table 2), which may explain why the potential soil respiration generally aligned with the total N concentrations.

Easily decomposable organic matter is thought to contribute to nutrient release. However, the effect of cover crops on potential N mineralization was less consistent than their effect on potential respiration. The rye cover crop increased potential N mineralization in the top 10 cm on the toeslope of the first field, but the mixture cover crop decreased potential N mineralization in the 10-20 cm layer on the toeslope. Considering the second field, no significant effects of cover crop or landscape position were detected at either depth. In this study, the C:N ratio of aboveground cover crop biomass ranges from 25 to 35, meaning that the residues contain about as much N as the microbes need to decompose the residue. With a moderate C:N ratio, the cover crop residues are not expected to release N quickly. Since the soil was sampled immediately after cover crop termination, it is possible that the cover crop residue had not decomposed enough to cause significant N mineralization. The C:N ratio of cover crop roots ranges from 35 to 60, and it is possible that the high abundance of roots at 10-20 cm depth led to N immobilization on the toeslope position of field #1 with the cover crop mixture.

The easily decomposable organic matter is also thought to promote aggregate stabilization. While it was not found that the cover crop treatments increased aggregate stability in the first field, we did observe significantly greater wet aggregate stability for the rye and mixture cover crops than the winter fallow in the second field. It is important to note that the aggregate stability was quite high in both fields even in the no cover crop treatment, which suggests that the soils have favorable structure with a possible minimal opportunity for improvement in this property.

## CONCLUSION

This research suggests that cereal rye and cereal rye-crimson clover mixtures were effective in increasing soil potential respiration across landscape positions, with rye providing more consistent benefits across fields. The increased soil potential respiration is an early indication that the cover crops are contributing to buildup of soil organic C. In the first field, it was observed that potential respiration increased with crop yield among the landscape positions, suggesting that cover crops and productive cash crops are beneficial for soil health. The cover crops had inconsistent effects on potential N mineralization. The cover crops were generally beneficial for aggregate stability, with significant impacts observed in one of two fields.

**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 United States Department of Agriculture National Institute of Food and Agriculture Grant Number 2020-67013-30860. We thank Kristine Gauthier for her help performing the soil health measurements and Sam Leuthold, Laura Harris, and Gene Hahn for their help with implementing the field study.

## TABLES

**Table 1.** Average winter biomass production, corn yield, and soybean yield for field #1 of the landscape position project averaged across years. Corn yields are for the plots that received 240 lb N/acre. Winter biomass production for the fallow treatment was derived from winter weeds. Standard errors are shown in parentheses.

| Cover crop | Summit | Backslope | Toeslope |
|---|---|---|---|
| Winter biomass, lb/acre (2019-2021) | | | |
| Fallow | 226 (48) | 413 (94) | 204 (156) |
| Mix | 4110 (470) | 3520 (327) | 3700 (634) |
| Rye | 3710 (305) | 3010 (281) | 3160 (327) |
| Corn yield, bu/acre (2019, 2021) | | | |
| Fallow | 210 (22) | 152 (19) | 239 (19) |
| Mix | 220 (25) | 136 (25) | 237 (16) |
| Rye | 201 (23) | 131 (19) | 212 (20) |
| Soybean yield, bu/acre (2020) | | | |
| Fallow | 55 (0.6) | 39 (2.3) | 61 (2.1) |
| Mix | 55 (1.0) | 38 (1.6) | 62 (0.6) |
| Rye | 52 (3.2) | 40 (1.2) | 59 (1.0) |

**Table 2.** Average winter biomass production, corn yield, and soybean yield for field #2 of the landscape position project averaged across years. Corn yields are for the plots that received 240 lb N/acre. Winter biomass production for the fallow treatment was derived from winter weeds. Standard errors are shown in parentheses.

| Cover crop | Summit | Backslope | Toeslope |
|---|---|---|---|
| Winter biomass, lb/acre (2020-2022) | | | |
| Fallow | 861 (135) | 1050 (220) | 1160 (187) |
| Mix | 3230 (402) | 2870 (462) | 3310 (315) |
| Rye | 3500 (389) | 3200 (350) | 3200 (228) |
| Corn yield, bu/acre (2020, 2022) | | | |
| Fallow | 231 (10) | 219 (18) | 225 (12) |
| Mix | 247 (10) | 183 (17) | 239 (13) |
| Rye | 239 (20) | 211 (16) | 230 (15) |
| Soybean yield, bu/acre (2021) | | | |
| Fallow | 60 (3.7) | 53 (3.0) | 78 (3.1) |
| Mix | 60 (2.7) | 51 (2.7) | 68 (4.7) |
| Rye | 52 (3.1) | 48 (2.4) | 66 (3.7) |

## FIGURES

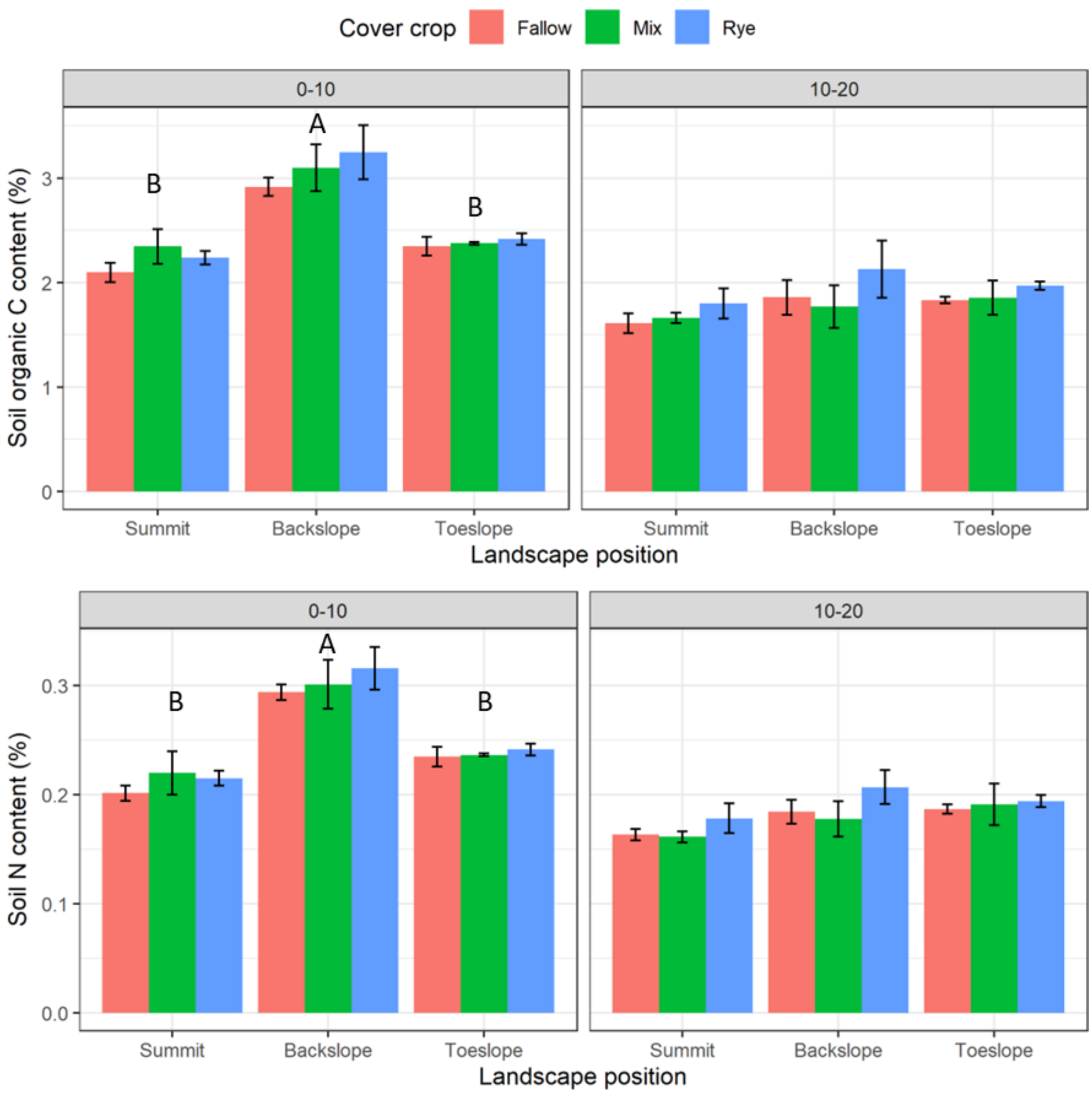


**Figure 1.** Soil organic C concentrations (top) and N concentrations (bottom) for 0-10 cm (left) and 10-20 cm (right) by landscape position measured in spring 2021 following three years of cover crop treatments in a corn-soybean rotation (Field #1). Different capital letters show differences among landscape positions averaged across cover crop treatments. There were no significant effects of cover crop treatment on soil organic C at 0-10 or 10-20 cm, and no significant effect of landscape position at 10-20 cm. Error bars are ± one standard error.

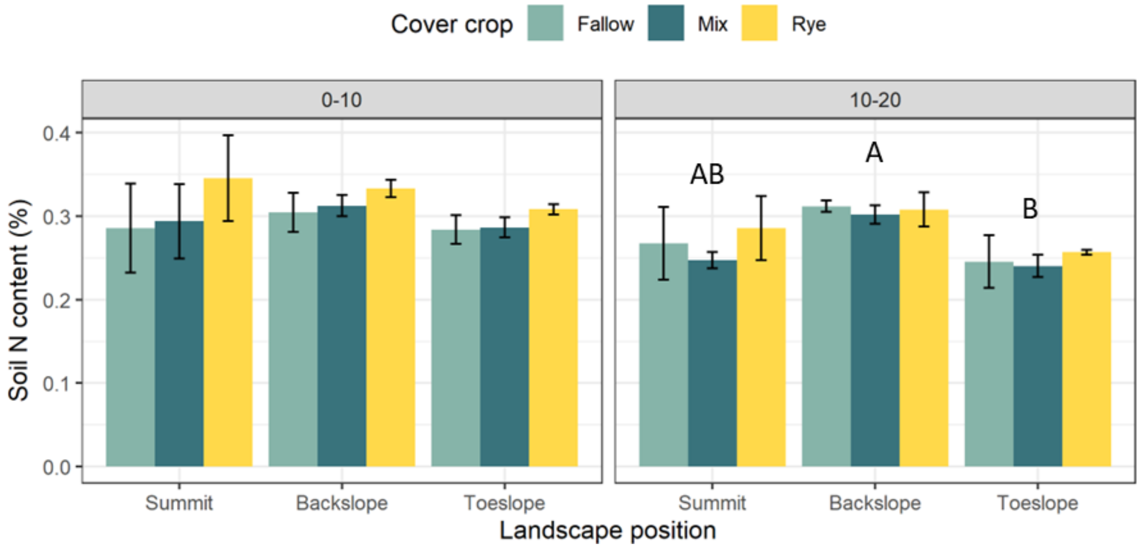


**Figure 2**. Soil total N content for 0-10 cm (left) and 10-20 cm (right) by landscape position measured in spring 2022 following three years of cover crop treatments in a corn-soybean rotation (Field #2). Different capital letters show differences among landscape positions averaged across cover crop treatments. There were no significant effects of landscape positions and cover crop treatment on soil total N at 0-10 cm, while at 10-20 cm there was a significant effect of landscape position but no difference among cover crop treatments within each landscape position. Error bars are ± one standard error.

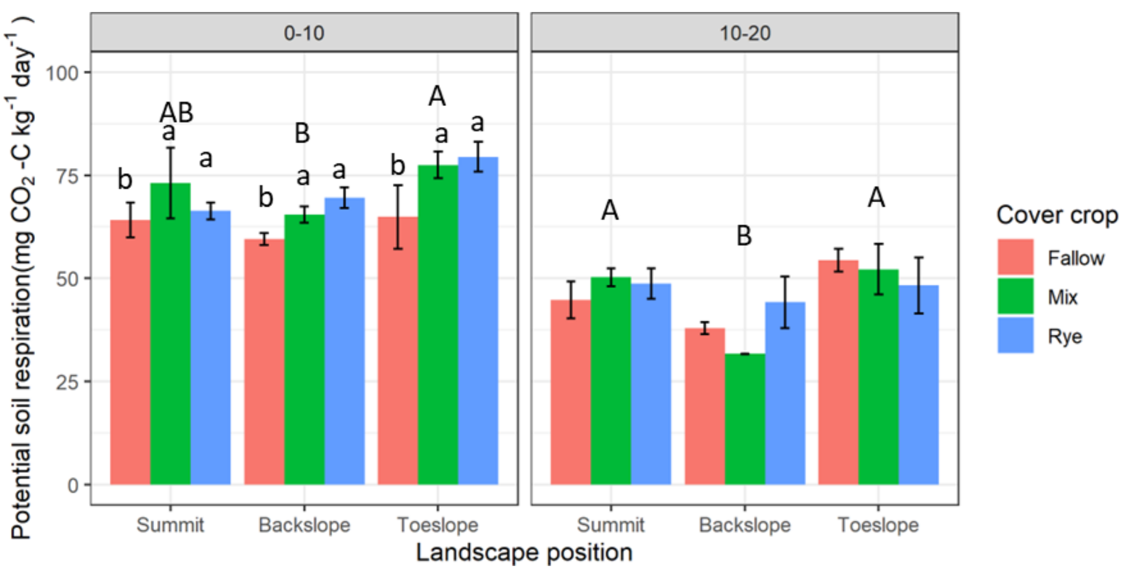


**Figure 3.** Potential soil respiration for 0-10 cm (left) and 10-20 cm (right) by landscape position measured in spring 2021 following three years of cover crop treatments in a corn-soybean rotation (Field #1). Different capital letters show differences among landscape positions averaged across cover crop treatments, while different lowercase letters show differences among cover crop treatments within each landscape position. There were no significant effects of cover crop treatment on potential soil respiration at 10-20 cm. Error bars are ± one standard error.

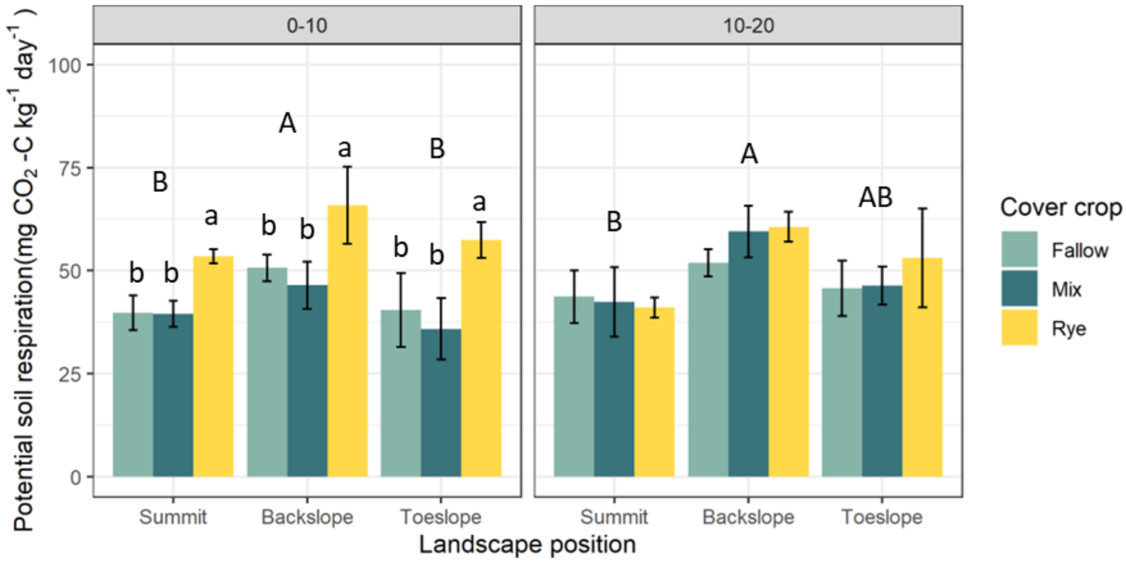


**Figure 4.** Potential soil respiration for 0-10 cm (left) and 10-20 cm (right) by landscape position, measured in spring 2022 following three years of cover crop treatments in a corn-soybean rotation (Field #2). Different capital letters indicate differences among the landscape positions averaged across cover crops, and different lowercase letters show differences among cover crop treatments within each landscape position. There were no significant effects of cover crop treatment on potential soil respiration at 10-20 cm. Error bars are ± one standard error.

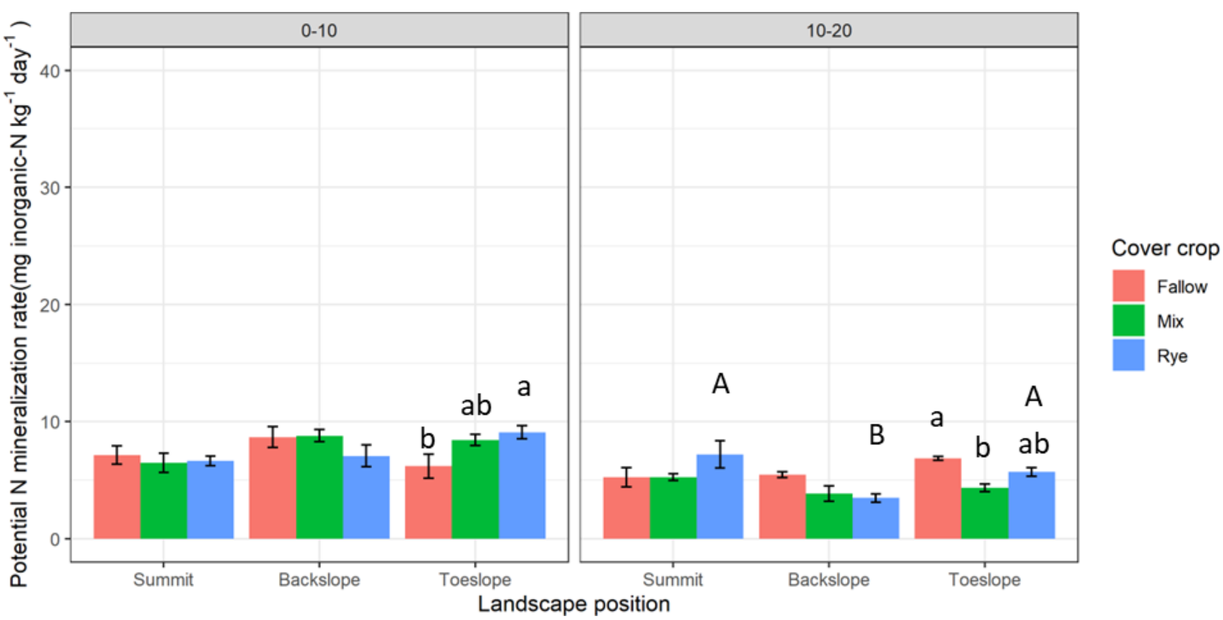


**Figure 5.** Soil potential N mineralization for 0-10 cm (left) and 10-20 cm (right) by landscape position measured in spring 2021 following three years of cover crop treatments in a corn-soybean rotation (Field #1). Different capital letters show differences among landscape positions for a particular cover crop treatment while different lowercase letters show differences among cover crop treatments within a particular landscape position. There was no effect of landscape position on potential N mineralization at 0-10 cm and no effect of cover crop treatment on the summit and backslope position at either depth. Error bars are ± one standard error.

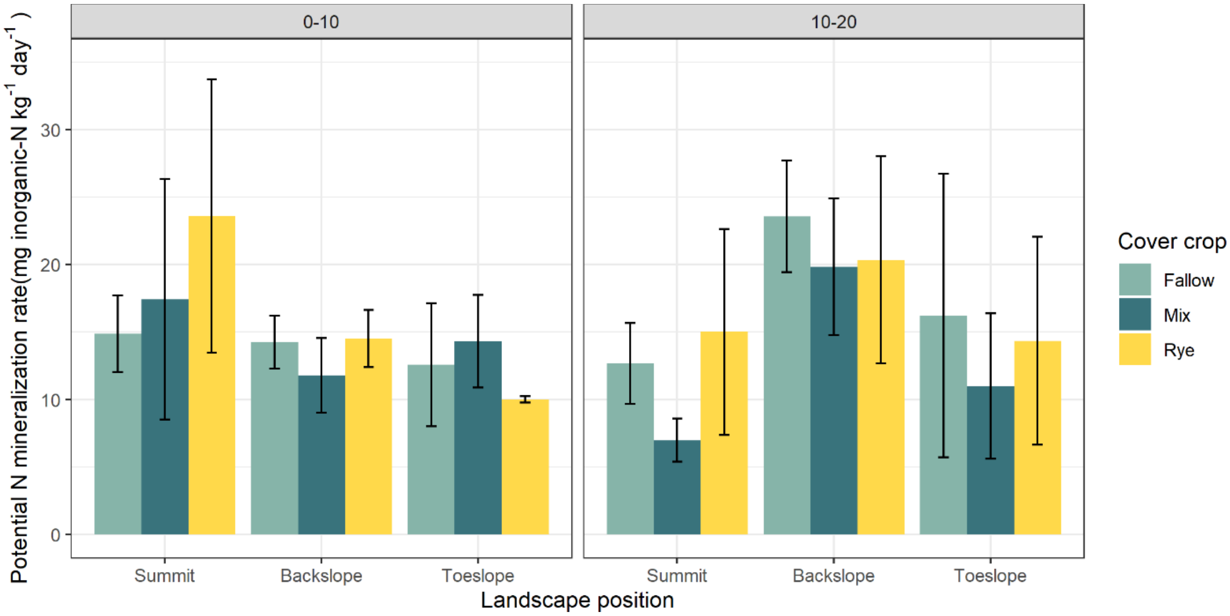


**Figure 6.** Soil potential N mineralization for 0-10 cm (left) and 10-20 cm (right) by landscape position measured in spring 2022 following three years of cover crop treatments in a corn-soybean rotation (Field #2). There were no effects of cover crop or landscape position on potential N mineralization for either depth. Error bars are ± one standard error.

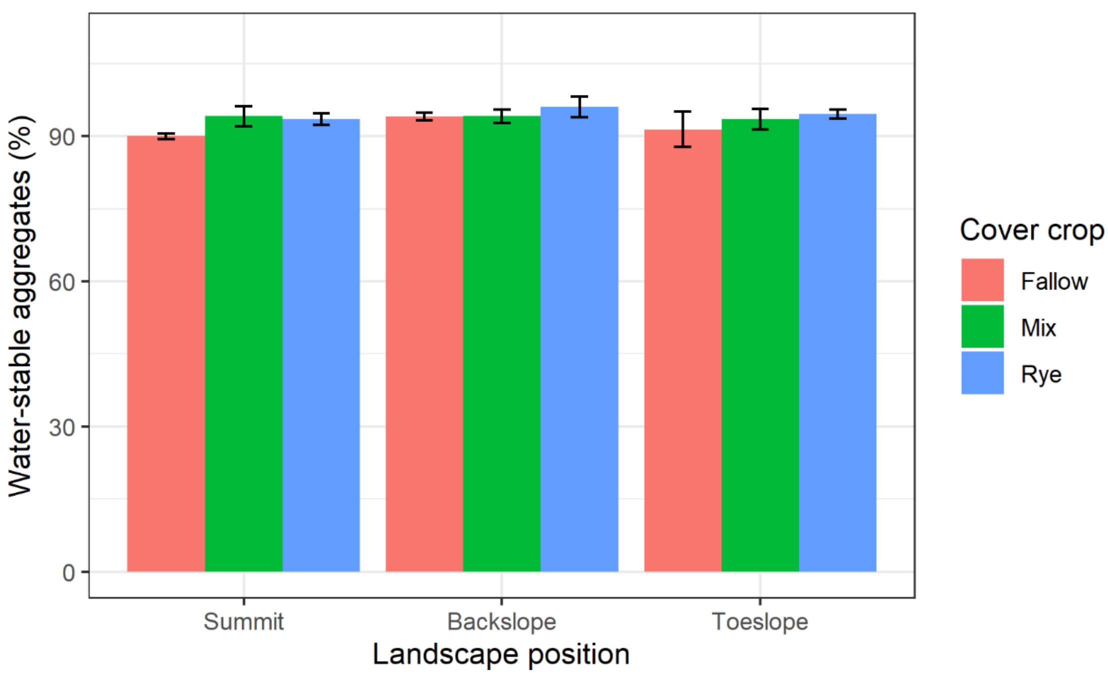


**Figure 7.** Percentage water-stable aggregates for 0-10 cm by landscape position measured in spring 2021 following three years of cover crop treatments in a corn-soybean rotation (Field #1). There were no significant effects of landscape position or cover crop treatment on percentage water-stable aggregates. Error bars are ± one standard error.

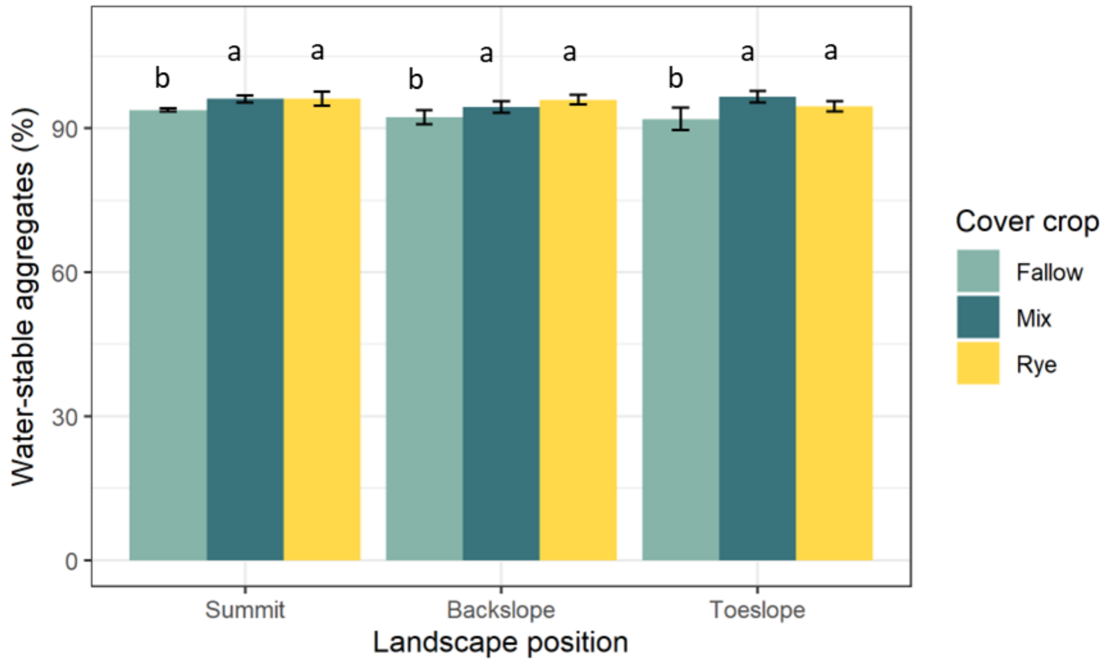


**Figure 8.** Percentage water-stable aggregates for 0-10 cm by landscape position measured in spring 2022 following three years of cover crop treatments in a corn-soybean rotation (Field #2). Different lowercase letters show significant differences among cover crop treatments within each landscape position. Error bars are ± one standard error.

# WHEAT VARIETAL RESPONSE TO A LOW INPUT PRODUCTION ENVIRONMENT

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**INTRODUCTION / OBJECTIVE**

Most of Kentucky's wheat acreage is grown using intensive management practices, which is associated with high production costs. Recent high input costs have caused some growers to consider whether it is economically feasible to grow wheat. Fertilizer, fuel, pesticides and labor costs have dramatically increased in recent years making wheat production profitability dependent on high yields, high commodity prices or both.

Variety selection is a simple and cost effective way to maximize wheat production profitability. Identifying varieties with superior yield performance across all environments is of primary importance, but identifying varieties that have a high percent proportion of yield in a low input environment to that in a high input environment would allow growers to utilize seed genetics to maximize yield potential in a low input management environment.

Some wheat varieties are marketed as high input varieties. Varieties with strong straw strength may be able to handle high levels of nitrogen fertilizer to maximize yield. Additionally, use of specific high yielding varieties that have notable disease issues may require multiple fungicides to achieve maximum yield potential. There is however, little information on wheat seed marketed as low input/management varieties.

Use of fewer pesticide or fertilizer applications/rates reduce environmental costs and financial costs. Wheat serves as an important cover crop and identification of high performing low input varieties may facilitate wheat production using less inputs which may be defined as a sustainable practice.

The objective: to evaluate wheat varietal differences in the percent proportion of grain yields in a low input to a high input production environment**.**

**MATERIALS AND METHODS**

Seventy-six wheat variety / breeding lines were evaluated under both high and low management practice environments. The low input trial had all the herbicide and insecticide applications as the high input trial, but the low input trial did not have a fungicide application and utilized a single nitrogen application of 60 lbs N at Feekes 5 rather than a split 40/60 lbs N applications at Feekes 3 and 5. The low and high input trials were planted side by side at Princeton, KY on 10/9/2022 and harvested on 6/15/2023. Trials were laid out in a randomized complete block design with 4 replication per entry. 15 x 4 ft plots were planted in a conventionally tilled seedbed. Percent proportion of low input to high input grain yields were calculated by dividing the low input yield value by the high input yield value and multiplying by 100 for each variety.

**RESULTS AND DISCUSSION**

The grain yield proportion of low input to high input production environments among varieties ranged from 73.5 to 102.4 % and averaged 87.7 % (Table 1.). The percent proportion values for varieties in Table 1 was conditionally formatted with green having a higher percent proportion and red having a low percent proportion of yield. The wide range in percent proportion values indicate that there are genetic yield potential differences among varieties in high and low input environments.

When comparing the average yield in the high input environment for the top and bottom 15 proportion (%) values, the top 15 proportion average yield was 102.5 bu/a and the bottom 15 was 110.7 bu/a. This suggests that varieties with lower proportion values benefited more than varieties with a high proportion when grown in a high input environment. It could also suggest that varieties with lower yield potential may not be penalized as much in a low input environment. There were however, several examples of varieties with above average high input yield values that also had high proportion values such as AgriMaxx EXP 2302, USG EXP 3354 and Dyna-Gro 9231 which had high proportion values, but also had above average yields (109.0, 108.6, 111.7 bu/a, respectively compared to the average 106.7 bu/a) in the high input environment. These examples could be varieties worth marketing to growers interested in producing wheat with good yield potential using low input or non-intensive management practices. This type of experiment would need to be repeated before identifying varieties that have a higher potential to yield well in low input environments.

Table 1. Wheat varietal grain yield percent proportion of low input to high input environments.

| VARIETY | High Input Yield (bu/a) | Low Input Yield (bu/a) | Percent Proportion | VARIETY | High Input Yield (bu/a) | Low Input Yield (bu/a) | Percent Proportion |
|---|---|---|---|---|---|---|---|
| Dyna-Gro 9120 | 100.0 | 102.5 | 102.4 | PEMBROKE 2021 | 105.9 | 92.5 | 87.4 |
| Croplan CP8022 | 102.9 | 103.5 | 100.5 | Dyna-Gro 9290 | 99.0 | 86.1 | 87.0 |
| X14-1107-182-13-3 | 99.5 | 98.7 | 99.2 | KAS 23X01 | 106.0 | 92.1 | 87.0 |
| AgriMAXX EXP 2302 | 109.0 | 104.4 | 95.8 | AgriMAXX 454 | 114.6 | 99.6 | 86.9 |
| USG EXP 3354 | 108.6 | 103.5 | 95.4 | USG 3472 | 106.0 | 91.9 | 86.7 |
| KWS459 | 101.8 | 95.9 | 94.1 | AgriMAXX 525 | 111.8 | 96.8 | 86.6 |
| X11-0120-12-4-3 | 103.0 | 96.4 | 93.6 | Growmark FS WX23B | 113.6 | 98.2 | 86.4 |
| X14-1209-141-18-3 | 106.7 | 99.3 | 93.1 | Growmark FS 600 | 112.0 | 96.8 | 86.4 |
| Dyna-Gro 9231 | 111.7 | 103.7 | 92.9 | X14-1147-131-6-3 | 108.1 | 93.3 | 86.3 |
| AgriMAXX 514 | 106.0 | 98.2 | 92.6 | PEMBROKE 2014 | 89.8 | 77.5 | 86.3 |
| Growmark FS 597 | 95.0 | 88.0 | 92.6 | X14-1141-172-14-5 | 100.9 | 86.9 | 86.0 |
| X14-1205-147-13-5 | 94.6 | 87.4 | 92.4 | Dyna-Gro 9393 | 107.5 | 92.1 | 85.6 |
| AgriMAXX 511 | 108.0 | 99.6 | 92.2 | KAS 23X02 | 118.1 | 100.9 | 85.5 |
| KWS482 | 103.5 | 94.5 | 91.4 | Growmark FS 603 | 98.1 | 83.6 | 85.2 |
| Truman | 86.5 | 79.1 | 91.4 | AgriMAXX EXP 2301 | 108.5 | 92.3 | 85.1 |
| AgriMAXX 535 | 109.9 | 100.3 | 91.2 | AgriMAXX 513 | 114.2 | 97.1 | 85.0 |
| KWS490 | 107.9 | 98.2 | 91.0 | USG 3463 | 110.3 | 93.7 | 85.0 |
| Dyna-Gro WX23444 | 111.9 | 101.8 | 91.0 | Dyna-Gro 9481 | 102.4 | 86.8 | 84.7 |
| Croplan CPX92394 | 98.5 | 89.5 | 90.8 | KWS453 | 105.8 | 89.5 | 84.6 |
| Dyna-Gro 9151 | 108.1 | 98.1 | 90.8 | Croplan CP8045 | 105.0 | 88.6 | 84.4 |
| USG 3234 | 103.4 | 93.8 | 90.7 | KAS Monroe | 115.8 | 97.7 | 84.3 |
| KWS397 | 99.5 | 90.2 | 90.7 | KWS472 | 111.5 | 93.8 | 84.1 |
| Growmark FS 606 | 103.1 | 93.4 | 90.7 | X14-1031-103-4-1 | 107.1 | 90.0 | 84.1 |
| Go Wheat 6056 | 102.4 | 92.8 | 90.6 | Growmark FS 617 | 106.9 | 89.7 | 83.9 |
| Growmark FS 623 | 106.8 | 96.7 | 90.6 | Croplan CP8081 | 107.0 | 89.7 | 83.9 |
| PEMBROKE 2016 | 94.7 | 85.2 | 90.0 | X11-0039-1-17-5 | 112.2 | 94.1 | 83.8 |
| X14-1147-158-14-5 | 103.2 | 92.5 | 89.6 | KAS Reagan | 113.0 | 93.8 | 83.0 |
| Dyna-Gro 9422 | 113.4 | 101.6 | 89.6 | Dyna-Gro 9172 | 111.3 | 92.2 | 82.8 |
| AgriMAXX 505 | 111.0 | 99.3 | 89.5 | KWS369 | 112.6 | 93.0 | 82.6 |
| KAS Washington | 111.5 | 99.5 | 89.3 | X14-1009-84-4-3 | 119.8 | 97.6 | 81.5 |
| USG EXP 3574 | 106.5 | 95.0 | 89.2 | Growmark FS 624 | 117.6 | 95.0 | 80.8 |
| X14-1049-27-10-1 | 103.9 | 92.4 | 88.9 | Growmark FS WX23A | 106.6 | 86.0 | 80.6 |
| Croplan CP8224 | 115.0 | 102.1 | 88.8 | KWS477 | 108.4 | 87.4 | 80.6 |
| USG 3783 | 105.9 | 93.8 | 88.6 | USG 3352 | 110.5 | 88.5 | 80.1 |
| AgriMAXX 503 | 107.2 | 95.0 | 88.6 | Revere 2169 | 110.0 | 88.0 | 80.0 |
| Go Wheat 4059S | 101.9 | 89.5 | 87.8 | X14-1008-92-13-3 | 111.9 | 86.3 | 77.1 |
| AgriMAXX 531 | 104.5 | 91.6 | 87.6 | KWS495 | 99.4 | 75.1 | 75.6 |
| AgriMAXX 516 | 108.1 | 94.6 | 87.5 | Growmark FS 745 | 113.3 | 83.3 | 73.5 |
| | | | | **Average** | **106.7** | **93.4** | **87.7** |

# WHEAT, TRITICALE AND CEREAL RYE VARIETAL DIFFERENCES IN COVER CROPPING POTENTIAL

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## INTRODUCTION / OBJECTIVE

Winter small grain crops, such as wheat, barley, cereal rye, canola, oats and triticale are an important part of Kentucky's agricultural economy and also serve as winter cover crops. Cover cropping is an essential component of sustainable agricultural practices. Cover crops reduce soil erosion, add organic matter to the soil, provide moisture conserving residues and reduce ground water contamination by utilizing residual fertilizer from the previous crop.

Cereal rye is known for its robust fall growth and is often used specifically for cover cropping. Wheat however, is more commonly used as a cover crop because seed is readily available and it is a primary grain crop in Kentucky. Triticale is a cross between wheat and cereal rye and has good cover cropping potential, but its use is not common.

The objective of this study was to evaluate the cover cropping potential of wheat, triticale and cereal rye varieties in Kentucky.

## MATERIALS AND METHODS

There were 11 cereal rye, 11 triticale and 84 wheat entries planted October 23, 2020, in Lexington, KY. The trials were set up in randomized complete block design with 4 replications. Cover crop potential was an estimate of the amount of biomass accumulated during the fall and winter growing periods and measured on January 22, 2021 using the Canopeo app. Higher levels of winter biomass, provide greater levels of protection from erosion and foster the other fore mentioned benefits of cover cropping.

## RESULTS AND DISCUSSION

In 2021, cereal rye averaged 44% canopy coverage among varieties and ranged from 32–59% (Table 1). The "SH" hybrids had the highest level of canopy coverage. These "SH" lines are facultative lines, which are spring types that also function as winter types. Other hybrid lines tended to have more biomass than the traditional open pollenated cereal rye varieties. The same trends (facultative lines having high levels and open pollenated varieties having lower canopy coverage) were observed in 2020 (data not shown).

Triticale varieties averaged 32% canopy coverage in 2021 and ranged from 20–51% (table 1). This was 12% lower on average than the cereal rye trial. In 2020 however, the triticale averaged 10% greater canopy levels than the cereal rye (data not shown), indicating a seasonal variability response and that triticale also has high cover cropping potential.

Wheat varieties averaged 19% canopy cover in 2021 and ranged from 8-35% (Table 2). This was about half of the average cereal rye canopy coverage.

The results indicate that cereal rye and triticale have superior cover cropping potential over wheat in terms of fall/winter biomass accumulation. Wheat seed is however, widely available and commonly used for cover cropping. The results of the wheat trial indicate that there is a wide range in genetic differences in fall/winter biomass accumulation among varieties. Wheat varieties with high cover crop potential are similar to average cereal rye and triticale varieties. For wheat producers, use of high grain yielding varieties with high cover cropping potential allows growers to benefit from maximizing short term grain production profitability while utilizing sustainable practices for the future.

**Table 1.** 2021 Kentucky Cereal Rye and Triticale Cover Crop Variety Trial.

| Cereal Rye Variety | Cover Crop^ Canopy (%) |
|---|---|
| KWS SH4 ** | 59 |
| KWS SH6 ** | 57 |
| KWS SH3 ** | 56 |
| KWS SH5 ** | 54 |
| KWS Serafino ** | 43 |
| KWS Receptor ** | 43 |
| Aroostook | 39 |
| Aventino | 37 |
| KWS Bono ** | 35 |
| Guardian | 34 |
| Spooner | 32 |
| **AVERAGE** | **44** |

| Triticale Variety | Cover Crop^ Canopy (%) |
|---|---|
| Trical Merlin Max | 51 |
| Trical Gun- ner | 47 |
| Trical Thor | 41 |
| Trical Exp 20T02 | 36 |
| Trical Flex 719 | 33 |
| Trical Surge | 30 |
| Arcia | 28 |
| Trical Gainer 154 | 27 |
| SS1414 | 22 |
| LAX Nitrous | 21 |
| SY TF813 | 20 |
| **AVERAGE** | **32** |

Location: Fayette Co. (Lexington, KY). Planting date: 10-23-2020; Conventional tillage.
^ Winter Cover Crop / Grazing biomass estimate (% Canopy coverage using Canopeo): measured: 1-22-2021.
** Hybrid Cereal Rye

## Table 2. 2021 Kentucky Wheat Variety Cover Crop Trial.

| Wheat Variety | Cover Crop* Canopy (%) | Wheat Variety | Cover Crop* Canopy (%) |
|---|---|---|---|
| X11-0130-13-2-3 | 35 | AgriMAXX 498 | 18 |
| X11-0120-12-4-3 | 31 | AgriMAXX 454 | 18 |
| Liberty 5658 | 31 | AgriPro 100 | 18 |
| X11-0170-52-3-3 | 31 | Dyna-Gro 9692 | 17 |
| X11-0039-1-17-5*** | 31 | USG 3329 | 17 |
| AC-2-17-5-5 | 30 | MI16R0898 | 17 |
| KY06C-1178-16-10-3-34 | 30 | AgriMAXX 505 | 17 |
| X11-0374-104-13-5** | 30 | KAS ADAMS | 17 |
| X12-920-39-9-5 | 29 | USG 3562 | 17 |
| USG 3118 | 28 | USG 3352 | 16 |
| KWS291 | 28 | Dyna-Gro WX20738 | 16 |
| X12-3051-53-17-3 | 27 | GROWMARK FS 623 | 16 |
| 13VTK429-3 | 26 | Dyna-Gro 9120 | 16 |
| X12-3010-4-4-1 | 26 | Dyna-Gro 9172 | 16 |
| AgriMAXX EXP 2009 | 26 | GROWMARK FS WX21B | 16 |
| KWS375 | 26 | Pioneer variety 26R41 | 16 |
| KWS338 | 26 | Dyna-Gro 9941 | 16 |
| AgriMAXX 492 | 25 | PROGENY #BULLET | 16 |
| X11-0357-24-13-5*** | 25 | AgriMAXX 503 | 16 |
| GROWMARK FS 624 | 25 | KAS 20X16 | 15 |
| VA 17W-74 | 25 | Pioneer variety 26R10 | 15 |
| PEMBROKE 2021 | 24 | PROGENY #BLAZE | 15 |
| MI16R0906 | 23 | AgriMAXX 513 | 15 |
| AgriMAXX 514 | 23 | AgriMAXX 516 | 15 |
| GoWheat 2059 | 22 | MI16R0720 | 15 |
| Bess | 22 | AgriMAXX 485 | 14 |
| PEMBROKE 2016 | 22 | Pioneer variety 26R45 | 14 |
| AgriPro 576 | 21 | AgriPro SREXP0119 | 14 |
| Truman | 21 | Dyna-Gro WX20734 | 13 |
| Pioneer variety 26R36 | 21 | Pioneer variety 26R59 | 13 |
| Go Wild Feral Forage | 20 | KAS 19X24 | 13 |
| KAS 20X47 | 20 | AgriPro Viper | 13 |
| GROWMARK FS 600 | 20 | AgriPro Richie | 13 |
| USG 3316 | 20 | USG 3472 | 13 |
| GROWMARK FS 616 | 20 | Dyna-Gro 9002 | 12 |
| LOCAL LW2848 | 20 | Go Wheat 4059S | 12 |
| LOCAL LW2169 | 19 | AgriPro 547 | 11 |
| KWS340 | 19 | PROGENY PGX18-7 | 11 |
| Dyna-Gro 9151 | 19 | Dyna-Gro WX21741 | 10 |
| GROWMARK FS 601 | 19 | AgriPro SREXP0117 | 10 |
| LOCAL LW2068 | 19 | GoWheat 2058 | 10 |
| LOCAL LW2148 | 19 | KAS 20X29 | 8 |
| | | **AVERAGE** | **19** |

Location: Bluegrass Region - Fayette Co.; Planting date: 10-23-2020; Conventional tillage.
* Winter Cover Crop / Grazing biomass estimate (% Canopy coverage using Canopeo): measured: 1-22- 2021.

# EVALUATION OF A SEED CONTROL UNIT FOR MANAGEMENT OF ITALIAN RYEGRASS IN WHEAT

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## OBJECTIVES

Italian ryegrass, also known as annual ryegrass, continues to be a problematic weed in Kentucky soft red winter wheat. The University of Kentucky has confirmed multiple populations of Italian ryegrass with resistance to pinoxaden and fenoxaprop the active ingredients in Axial Bold that is heavily used for postemergence control of ryegrass in wheat. University of Kentucky weed scientists recommend the use of pyroxasulfone as a soil residual at winter wheat planting to relieve the pressure on postemergence herbicides for ryegrass control. While the use of pyroxasulfone has proven to effectively suppress the majority of ryegrass emergence in the fall, the practice does not assure complete control of the problematic weed. In the face of increasing resistance to fenoxaprop and pinoxaden it is vital that new methods of weed control are explored.

Harvest Weed Seed Control is the method of destroying weed seed at the time of crop harvest. These methods are only effective on weeds that mature and produce seed at the same time as the crop they are competing within. There are several forms of Harvest Weed Seed Control, but one of the most successful is the use of cage mills or high impact mills to destroy any weed seed contained in the fine chaff as it exits the combine. These mills only handle the fine chaff and straw chaff is diverted into the straw chopper or spinners as it would in a normal combine operation, thus any weed seed in the straw portion of the chaff would not be destroyed. Although it has been found that the majority of weed seed in most scenarios would be contained in the fine chaff portion. The use of cage mills or high impact mills installed on combines has been effective for ridged ryegrass control in small grains in Australia over the past decade. This research was an expansion upon previous research at the University of Kentucky to understand the utility of a Seed Control Unit (SCU) for reducing Italian ryegrass seed distribution at harvest in Kentucky winter wheat. This research had two primary objectives.

1. Evaluate the ability of a Redekop Seed Control Unit (SCU) to destroy Italian ryegrass seed during wheat harvest in Kentucky.
2. Observe the distribution of Italian ryegrass seed during wheat harvest, including seed loss at the combine header, seed within the grain tank, and seed loss in straw chaff while using a SCU.

## METHODS & MATERIALS

Research was conducted on a grower wheat field with a known population of Italian ryegrass in 2022. A Redekop Seed Control Unit (SCU) was installed on the growers John Deere S780 combine to use for evaluation during wheat harvest. The selected field was treated with a pyroxasulfone residual herbicide at wheat planting to provide suppression of ryegrass emergence,
while the farmer was instructed to not apply Axial Bold to the area of evaluation to allow for ryegrass escapes to mimic an Axial Bold resistant population.

The trial was laid out as a randomized complete block with four replications and two treatments: Seed Control Unit On and Seed Control Unit Off. Each treatment plot was approximately 1 acre in size. The following samples were collected from each plot to provide data for both Objectives:

- Four combine header shatter samples were collected by placing small trays with a cumulative area of one meter squared between wheat rows prior to harvest. The combine header was allowed to harvest over the trays but stopped prior to the front wheels reaching the trays. This allowed for the collection of ryegrass seed that shattered at the combine header.

- Four ground chaff samples were collected by placing three trays with a cumulative area of one meter squared behind the combine while harvesting to collect all chaff exiting the combine.

- Four samples of chaff were collected directly from the combine using sweep nets as the combine harvested. In plots where the SCU was off all fine chaff and straw chaff exited through the combine straw chopper, thus a single sweep net was used for collection. In contrast in the plots with the SCU engaged the fine chaff exits the SCU ejection ports while the straw chaff was ejected out the straw chopper without any interaction with the SCU. In the plots with the SCU engaged two sweep nets were used to collect chaff simultaneously from the straw chopper and the SCU. This collection allows for the evaluation Italian seed loss through the straw fraction of chaff.
- A single grain tank sample was collected at the end of each plot harvest using a chambered grain probe. The total weight and moisture of grain was also collected at the end of each plot as well to allow for calculations of seed per square meter to enable comparison to the other collection points.

All samples were processed using sieves and air column cleaners to separate Italian ryegrass seed from chaff, straw, and grain. Whole ryegrass seed (partial or fragmented seed was excluded) was counted for each sample and converted to Italian ryegrass seed per square meter (for all ground tray samples and grain samples) or seed per Kg of chaff (direct chaff catches).

## RESULTS AND DISCUSSION

**Objective 1.** Whole ryegrass seeds deposited onto the ground during wheat harvest with the chaff was significantly reduced when the SCU was engaged. The number of ryegrass seeds was reduced from 335 seeds per $m^2$ to 60 seed per $m^2$ when the SCU was engaged (Figure 1). Similarly, Italian ryegrass seed contained in chaff collected directly from the combine was decreased when the SCU was engaged. Ryegrass seed within the chaff was reduced from 1460 seeds per kg chaff when the SCU was off as compared to 402 seeds per kg chaff when the SCU was engaged (Figure 2).

**Objective 2.** Ryegrass distribution between the header shatter, grain tank, and chaff was analyzed only in plots with the SCU off to eliminate any interaction with the seed control unit. Equal amounts of ryegrass seed per $m^2$ were found in the chaff, in the header shatter samples, and contained in the grain tank. Although, a greater amount of ryegrass seed entered the combine (combination of seed found in chaff and grain tank) as compared ryegrass seed that shattered at the combine header (Figure 3). Despite that greater portion of ryegrass seed entering the combine than shattering at the combine header, the amount of ryegrass seed shattered at the combine header was still significant. When including plots where the seed control unit was engaged and considering header shatter in combination with seed in the chaff for the total amount of ryegrass seed deposited back onto the field at harvest the benefits of the SCU were negated. The total amount of ryegrass seed being deposited back onto the field was 819 seeds per $m^2$ when the SCU was off which was similar to when the SCU was engaged at 526 seed per $m^2$ (Figure 4). Further evaluation of potential Italian ryegrass seed evasion of the SCU was evaluated by observing seed contained in the straw portion of the chaff when the seed control unit was engaged. Whole ryegrass seed contained in the fine chaff exiting the SCU was 372 seeds per kg of fine chaff as compared to 172 seed per kg of straw chaff exiting the straw chopper, indicating that there was not a significant loss or escape of ryegrass seed through the straw portion of the chaff flow (Figure 5).

## CONCLUSION

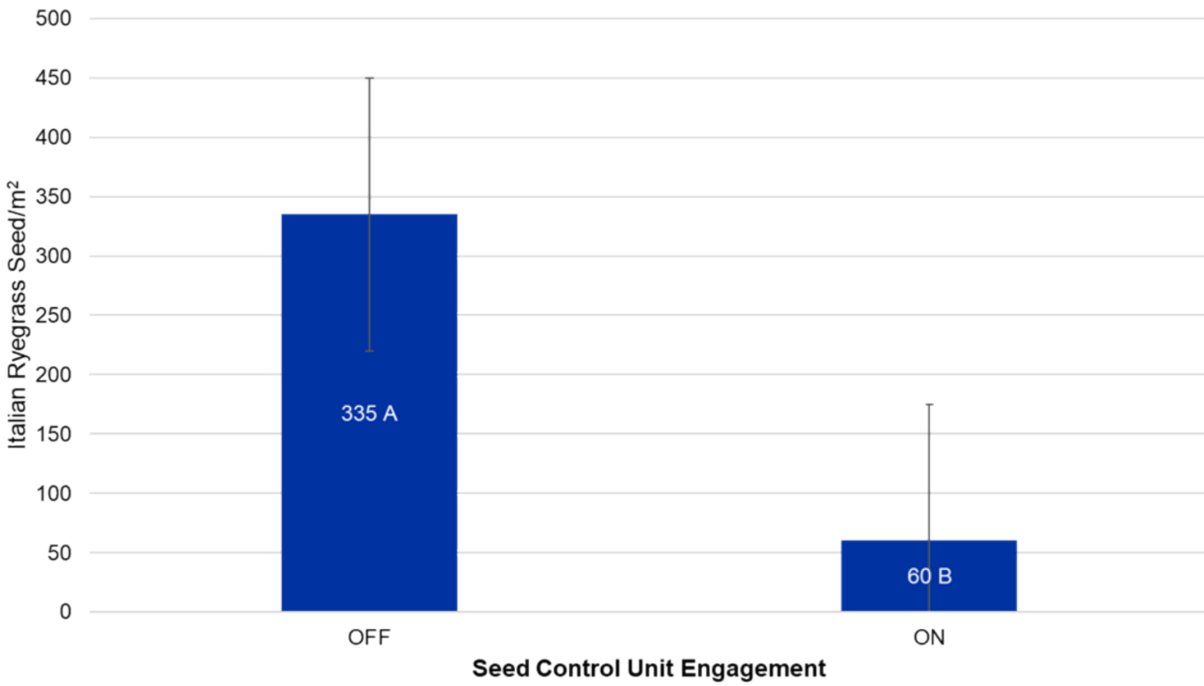
The use of a Seed Control unit did reduce the amount of viable Italian ryegrass seed in the chaff exiting the combine during wheat harvest in 2022. The reduction in ryegrass seed in the chaff was found in both collections on the ground behind the combine as well as collections directly from the combine chaff flow. Despite the ability of the seed control unit to effectively destroy Italian ryegrass seed, the amount of seed found shattering at the combine header negated the effects of the seed control unit. Further collections were made during the 2023 wheat harvest and are being actively evaluated and analyzed. Additionally, further research into reducing Italian ryegrass seed loss due to header shatter is also warranted.

**ACKNOWLEDGEMENTS**

The author would like to thank the Kentucky Small Grain Growers Association and Siemer Milling for providing funding to support this research.

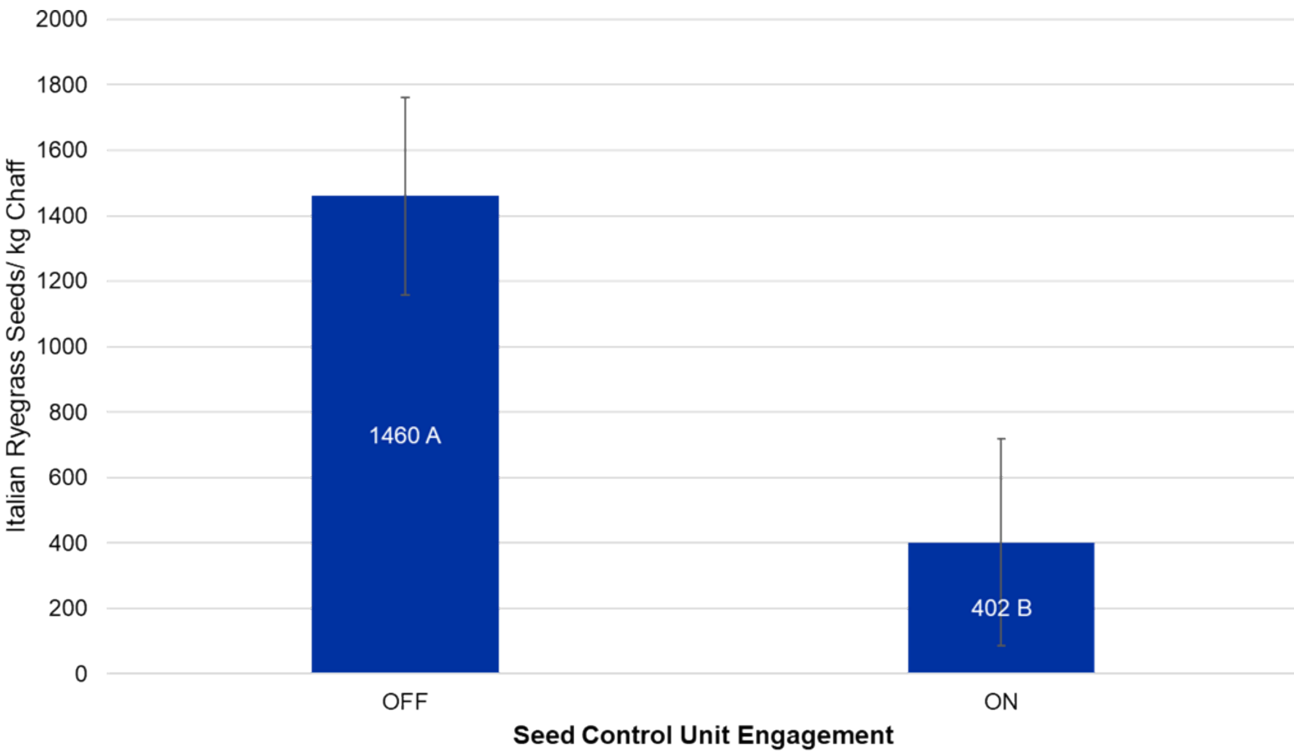
**FIGURES**

**Figure 1**. Italian ryegrass seeds deposited onto the ground with fine and straw chaff during wheat harvest with and without the engagement of a Seed Control Unit.



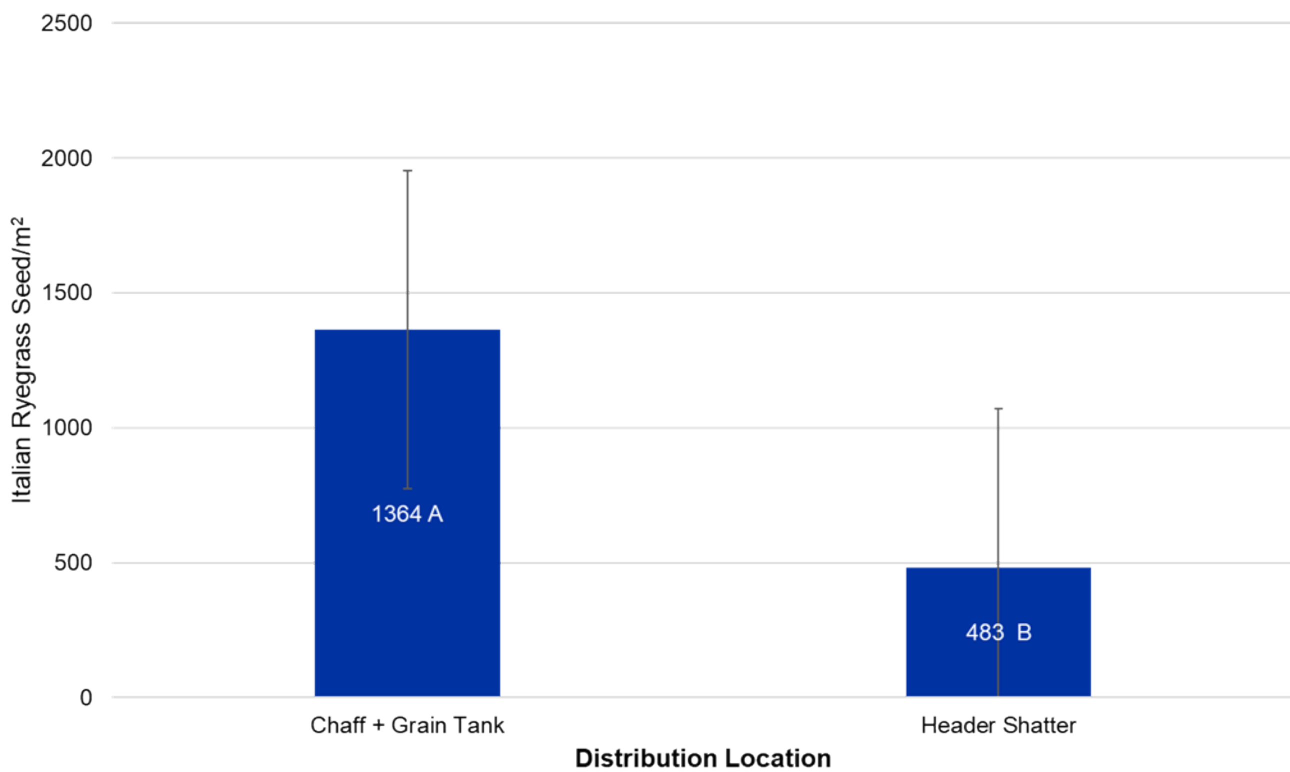

* Means with a different letter are significantly different. Tukey HSD α=0.05

**Figure 2.** Italian ryegrass seeds contained within the composite chaff (fine and straw chaff combined) during wheat harvest with the engagement of a Seed Control Unit.



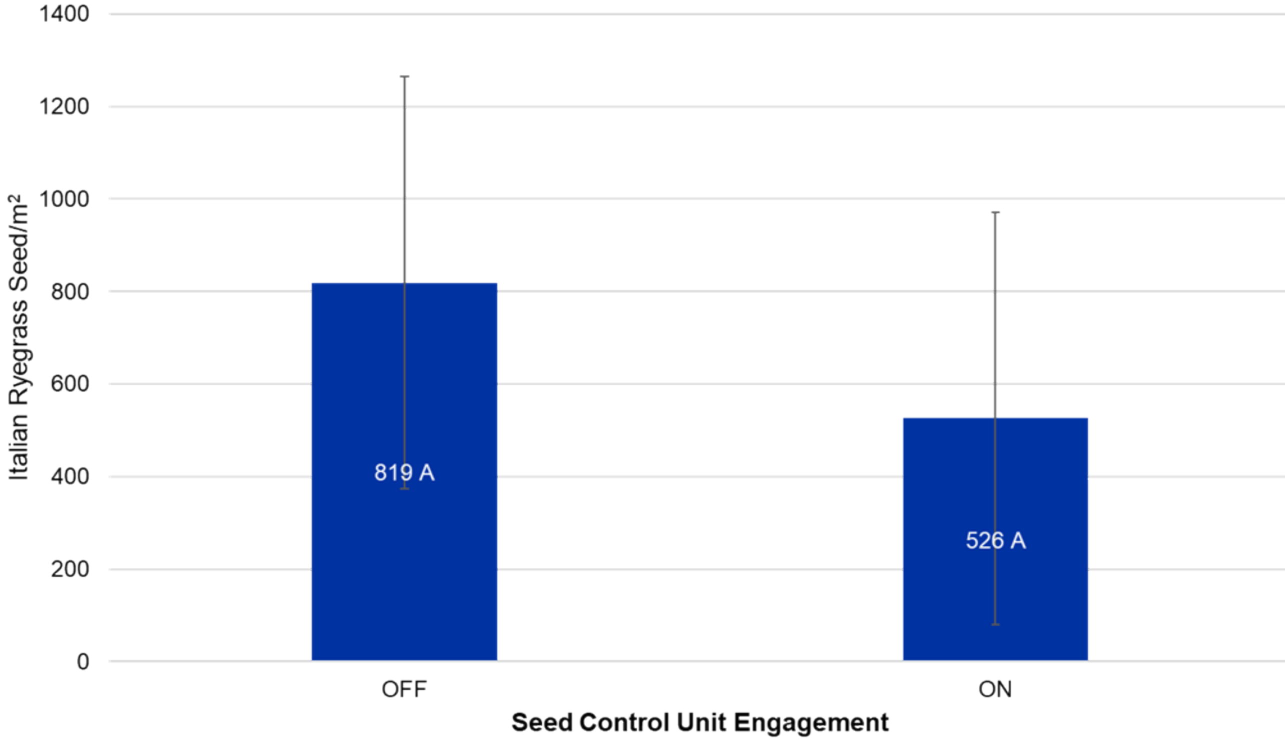

* Means with a different letter are significantly different. Tukey HSD α=0.05

**Figure 3.** Italian ryegrass seed entering the combine at harvest (Chaff +Grain Tank) as compared to seed that shattered at the combine header.



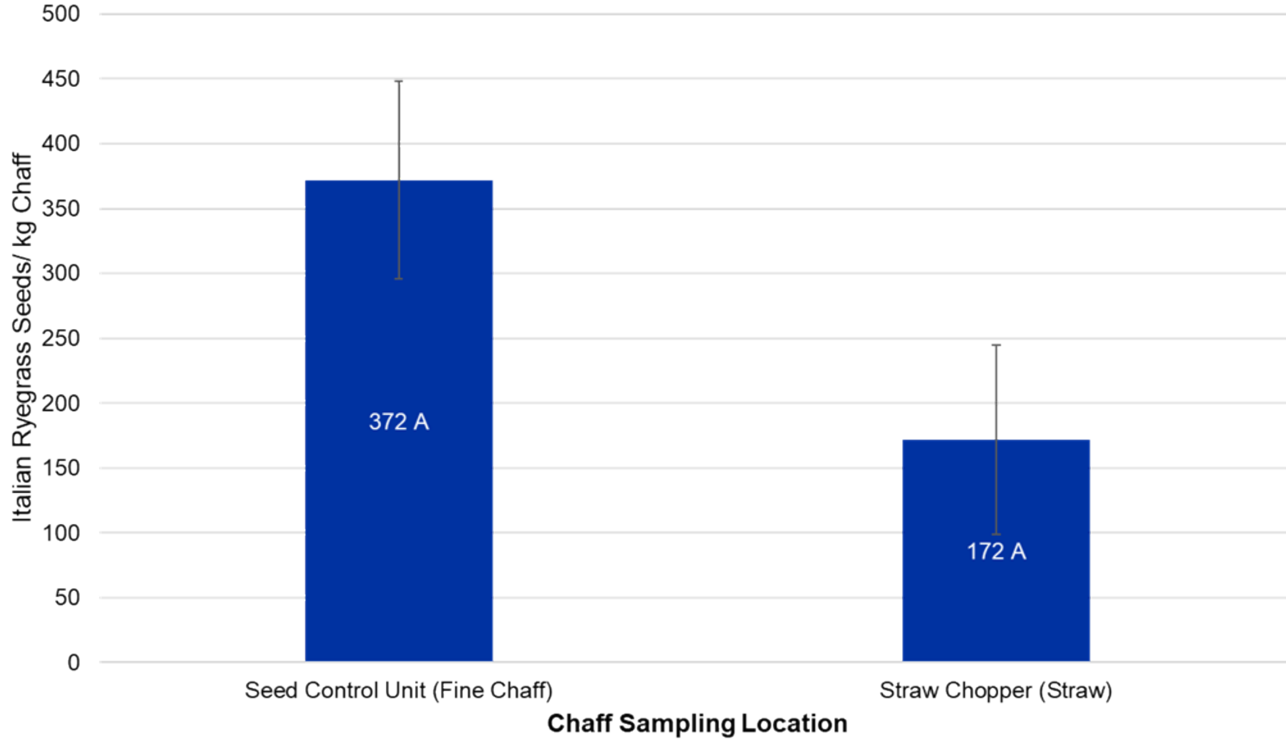

* Means with a different letter are significantly different. Tukey HSD α=0.05

**Figure 4**. Italian ryegrass seed deposited back onto field when considering both seed within chaff and seed shattered at the combine header as influences by Seed Control Unit engagement.




* Means with a different letter are significantly different. Tukey HSD α=0.05

**Figure 5.** Italian ryegrass contained in fine chaff and straw chaff portions of the chaff flow when the Seed Control Unit was engaged. During SCU engagement only the fine chaff passes through the SCU to destroy weed seed, while all straw chaff bypasses the SCU. Thus, any seed found in the chaff would remain viable and be placed back on the field.




* Means with a different letter are significantly different. Tukey HSD α=0.05

# GENOMIC SELECTION IN THE WHEAT BREEDING PROGRAM

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**OBJECTIVE**

Plant breeding is a very expensive area of research, and we are constantly looking for ways to be more efficient and cost effective. Our most expensive activity is the testing of breeding lines in the field at multiple locations to determine whether they should be released as new varieties.

Genomic selection is a new plant breeding tool that offers a way to reduce that cost. The figure below illustrates how genomic selection works.

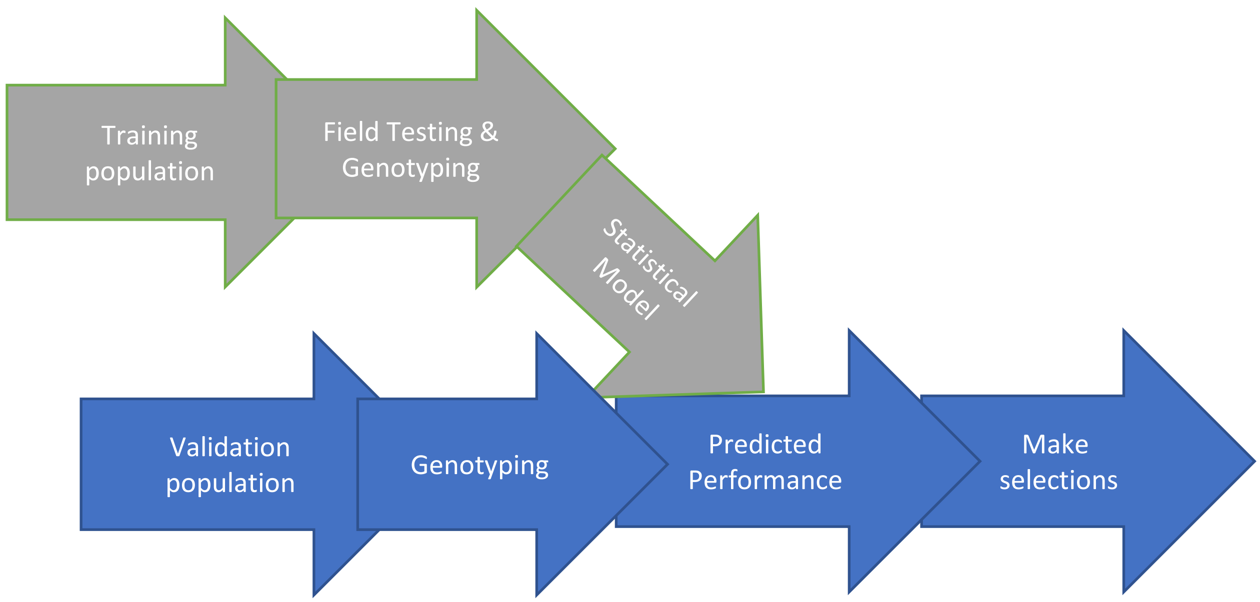


Figure 1. Flow chart of genomic selection in a wheat breeding program.

**METHODS & MATERIALS**

We start off with a Training Population, a collection of lines and varieties that have been widely tested in the field and have also had their genomes sequenced. The Validation Population is a set of breeding lines whose genomes have been sequenced but **which have not yet been tested in the field**. These lines are related to the lines in the training population by pedigree, so they share some of the same genes. We use a statistical model that takes into account these shared genes *and* the performance data of the lines in the Training Population and that model will predict yield, test weight, height, heading date and scab resistance of the lines that have not yet been tested in the field (Table 1). Based on these predictions, we select lines to test in the field. The efficiency payoff comes from the fact that we do NOT test lines in the field that have very low predicted values.

Figure 2. Wheat breeding lines grown in single rows

Table 1. Predicted agronomic and scab traits in breeding lines grown in single rows.

| ENTRY | PREDICTED YIELD (BU/A) | PREDICTED TWT (LB/BU) | PREDICTED HEAD DATE APR.1 = 1 | PREDICTED HEIGHT (IN) | PREDICTED DON (PPM) |
|---|---|---|---|---|---|
| X18-1214-174-1-1 | 94.0 | 58.9 | 30.7 | 40.7 | 8.2 |
| X18-1214-174-6-5 | 90.8 | 59.1 | 30.1 | 39.3 | 6.2 |
| X18-1214-174-2-3 | 89.1 | 57.8 | 30.0 | 37.5 | 5.3 |
| X18-1214-174-6-1 | 94.1 | 59.0 | 31.6 | 40.6 | 8.8 |
| X18-1079-150-15-3 | 94.7 | 58.5 | 33.2 | 39.5 | 9.0 |
| X18-1079-69-7-3 | 87.3 | 58.5 | 30.2 | 35.9 | 5.6 |
| X18-1178-2-18-5 | 92.0 | 57.5 | 31.8 | 37.8 | 8.1 |
| X18-1214-174-16-1 | 90.5 | 58.6 | 31.5 | 37.2 | 7.7 |
| X18-1079-69-2-1 | 90.8 | 58.7 | 28.6 | 38.1 | 9.6 |
| X18-1215-52-5-1 | 89.8 | 58.8 | 30.0 | 39.7 | 7.2 |
| X18-1079-69-6-1 | 90.0 | 58.4 | 27.4 | 37.3 | 9.7 |

## RESULTS AND DISCUSSION

The question that most people ask is how can you be sure that the predictions are accurate? We have tested the accuracy for 6 years prior to committing to genomic selection at the single row stage. The models are not 100% accurate but overall we have found that this method is more accurate than growing the preliminary lines in a single plot at one location and basing a testing decision on that data.

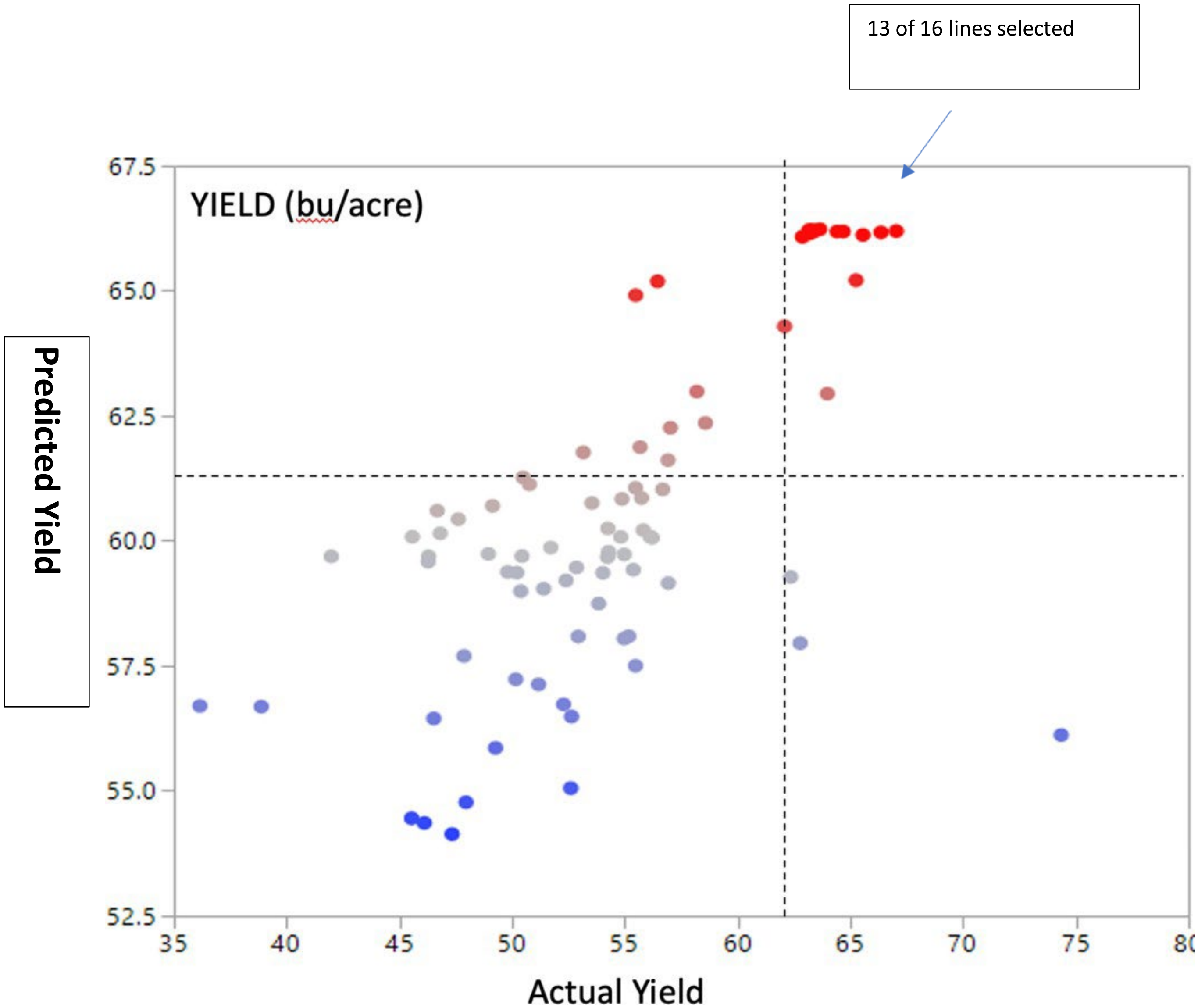


**Figure 3. Actual vs Predicted Yield in a set of wheat breeding lines, Lexington, 2021.**

## CONCLUSION

In Figure 3, the most important take-home is that based on genomic predictions, we would have selected 13 of the 16 lines that we would have selected based on actual performance. We are now 2 years into using this method as a mainstay of the breeding program and the lines we are testing look very promising.

## ACKNOWLEDGEMENTS

I gratefully acknowledge the support of the Kentucky Small Grain Growers Association.

# EFFECT OF FUNGICIDE X WHEAT VARIETY ON FUSARIUM HEAD BLIGHT, DEOXYNIVALENOL CONTAMINATION, AND YIELD

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## OBJECTIVE

The objective of this research was to evaluate different fungicide products for management of Fusarium head blight (FHB) and the associated mycotoxin Deoxynivalenol (DON) and their impact on wheat yield.

## 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 three different wheat varieties for management of FHB and DON, and for their effects on wheat yield. On October 29, 2022, three different wheat varieties (‘AgriMaxx 463’, ‘Pembroke 21’, and ‘Pioneer 26R59’) were planted at approximately 1.5 million seeds/A. Each plot was 60 inches 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 split-plot design with wheat variety being the main plot and fungicide being the subplot. Every treatment was replicated 4 times in different blocks. Treatments included a non-treated control, Miravis Ace (pydiflumetofen + propiconazole) at 13.7 fl oz/A, Prosaro (prothioconazole + tebuconazole) at 6.5 fl oz/A, Prosaro Pro (prothioconazole + tebuconazole + fluopyram) at 10.3 fl oz/A, and Sphaerex (metconazole + prothioconazole) at 7.3 fl oz/A. All treatments were applied with a backpack sprayer equipped with Twinjet 60 8002 nozzles calibrated to deliver 20 gal/A. All plots were inoculated with a suspension of *Fusarium graminearum* spores (60,000 spores/ ml) on May 6, 2023. Plots were rated for FHB incidence and severity on May 25, 2023, and those data were used to calculate an FHB severity index score (0-100 scale) that were statistically analyzed. Weight of harvested grain and moisture were obtained at harvest and were used to calculate yields on a bushel per acre basis using a standard grain moisture of 13.5%. Grain samples from each plot were collected at harvest and sent to the University of Minnesota DON Testing Laboratory (St. Paul, MN) to analyze samples for DON contamination. Data were statistically analyzed 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 AND DISCUSSION

Fusarium head blight (FHB) pressure was moderately low in the trial, with the FHB severity index in the non-treated/inoculated controls in the different wheat varieties ranging from 5.5 to 8.3, with the lowest FHB severiting being observed in ‘AgriMaxx 463’ and greatest in ‘Pioneer 26R59’ (Table 1). Within each variety, all treatments significantly reduced the FHB index relative to respective non-treated control for each variety. In general, DON contamination was relatively low and stayed below the 2 ppm dockage threshold, except in the non-treated control treatment for ‘Pioneer 26R59’. Within each variety, all treatments significantly reduced DON relative to the respective non-treated control for each variety, except for Sphaerex fungicide applied to ‘Pembroke 21’, which had a DON value that was not significantly different than the non-treated control for that variety. Statistically significant differences in yields occurred among varieties, but within varieties, significant differences were not detected across treatments.

The lowest FHB severity index and DON values were achieved when the most resistant varieties were applied with an efficacious fungicide treatment. This is similar to past field research trials that have documented that the integrated management effects of variety resistance and fungicides are the best way to manage FHB and DON. In general, all fungicide products tested resulted in similar management of FHB and DON. Although supply demands can affect the availability of products within different regions, farmers should be able to have access to at least one of the products tested in this research, which should have good efficacy against FHB and DON, based on our research.

**ACKNOWLEDGEMENTS**

This material is based upon work supported by the U.S. Department of Agriculture, under Agreement No. 59-0206-098. This is a cooperative project with the U.S. Wheat & Barley Scab Initiative. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the authors and do not necessarily reflect the view of the U.S. Department of Agriculture.

**TABLES**

Table 1. Effect of different fungicide treatments applied at Feekes 10.51 on Fusarium head blight (FHB) severity index, deoxynivalenol (DON) contamination, and yield on three different wheat varieties at Princeton, KY in 2023.

| Variety | Treatment | Rate (fl oz/A) | FHB severity index (0-100) | DON (ppm) | Yield (bu/A) |
|---|---|---|---|---|---|
| AgriMaxx 463 | Non-treated | . | 5.5 | 1.7 | 88.2 |
| | Miravis Ace | 13.7 | 1.5 | 0.9 | 98.5 |
| | Prosaro | 6.5 | 2.4 | 0.7 | 93.0 |
| | Prosaro Pro | 10.3 | 2.4 | 0.6 | 95.8 |
| | Sphaerex | 7.3 | 2.9 | 1.0 | 90.2 |
| Pembroke 21 | Non-treated | . | 8.3 | 1.2 | 90.5 |
| | Miravis Ace | 13.7 | 1.9 | 0.7 | 95.3 |
| | Prosaro | 6.5 | 4.0 | 0.5 | 94.2 |
| | Prosaro Pro | 10.3 | 1.8 | 0.7 | 91.9 |
| | Sphaerex | 7.3 | 3.5 | 0.8 | 92.4 |
| Pioneer 26R59 | Non-treated | . | 8.4 | 2.4 | 97.1 |
| | Miravis Ace | 13.7 | 2.0 | 0.7 | 105.6 |
| | Prosaro | 6.5 | 4.0 | 0.7 | 107.5 |
| | Prosaro Pro | 10.3 | 2.7 | 1.0 | 106.7 |
| | Sphaerex | 7.3 | 3.7 | 0.9 | 104.4 |
| | | ***P > F*** | **0.0001** | **0.0001** | **0.0436** |
| | | **LSD 0.05** | **1.9** | **0.5** | **14.0** |