Kansas Agricultural Experiment Station Research Reports

Volume 9
Issue 4 *Kansas Field Research*

Article 19

2023

Increasing Winter Wheat Grain Yield by Replicating the Management Adopted in High-Yielding Commercial Fields in Kansas during 2021–2022

L. Ryan
Kansas State University, lpryan@k-state.edu

L. Haag
Kansas State University, lhaag@ksu.edu

J. D. Holman
Kansas State University, jholman@ksu.edu

See next page for additional authors

Recommended Citation

Ryan, L.; Haag, L.; Holman, J. D.; and Lollato, R. P. (2023) "Increasing Winter Wheat Grain Yield by Replicating the Management Adopted in High-Yielding Commercial Fields in Kansas during 2021–2022," *Kansas Agricultural Experiment Station Research Reports*: Vol. 9: Iss. 4. https://doi.org/10.4148/2378-5977.8478

Funding Source
This project was partially supported by award no. A23-0040-001 from the Kansas Wheat Commission.

Authors
L. Ryan, L. Haag, J. D. Holman, and R. P. Lollato

Increasing Winter Wheat Grain Yield by Replicating the Management Adopted in High-Yielding Commercial Fields in Kansas during 2021–2022

L. Ryan, L. Haag, J. Holman, and R.P. Lollato

Summary
Large winter wheat (*Triticum aestivum*) yield gaps between actual yields from farmers and yield potential in the U.S. Great Plains indicate the need to improve recommendations of best management strategies to profitably bridge these gaps. Many studies have compared individual management factors pre-determined by the individual researcher, but we are not aware of studies comparing combination of practices that producers are currently using, which would be more relevant for real-world scenarios. Our objective was to determine the yield gains resulting from management intensification using the combination of practices currently adopted in commercial wheat fields. Four management intensities (i.e., low, average, high, and top) were derived from a survey of 656 commercial wheat fields, and replicated in trials conducted in six western Kansas locations (cultivated after a sorghum-fallow period) and six central Kansas locations (directly no-tilled following soybean) during the 2021–2022 growing season. Management intensities were tested factorially on two adapted varieties which differed between central and western sites. Grain yield in central Kansas ranged from 37.1 bu/a in the low management intensity to 47.3 bu/a in the top intensity, with increases in yield of 14%, 6%, and 5% from the low to average, average to high, and high to top management intensities, respectively. The variety WB4269 outyielded Zenda (44.6 and 41.3 bu/a) across central environments. In western Kansas, there was a significant management effect, where wheat yield increased from the low intensity to the high and top intensities (from 45.9 to 60.1–61.4 bu/a); though WB-Grainfield and KS Dallas varieties had similar yields. Using similar management practices as the high yielding producers in central and western Kansas increased yields from the low- or average-management intensities, while further increases in management intensification sometimes resulted in no yield increases. Variety selection played an important role to increase attained yields in central Kansas but was dependent on location in western Kansas.

Introduction
The adoption of conservative farming practices has led to large (c.a., 55% or more) hard red winter wheat (*Triticum aestivum L.*) yield gaps between actual and potential yields in Kansas and most of the U.S. central Great Plains (Jaenisch et al., 2021; Lollato et al., 2017; Patrignani et al., 2014). While part of this conservative management is justified due to harsh weather (Couëdel et al., 2021; Lollato et al., 2020a; Sciarresi et al., 2019), evidence suggests that the highest yielding growers (i.e., those that competed in state

and national yield contests) were able to narrow this yield gap to less than 15% (Lollato et al., 2019a). Thus, efforts to improve management practices to narrow this yield gap profitably and effectively are warranted to sustainably increase food production.

Among the most important management practices that can potentially narrow the wheat yield gap in this region are fertilization practices (Lollato et al., 2019b, 2021) and foliar fungicides (Cruppe et al., 2017, 2021; Jaenisch et al., 2019, 2022), as quantified by de Oliveira Silva et al. (2020). We note, though, that other practices such as crop rotation and sowing date (Munaro et al., 2020; Simão et al., 2023), seeding rate (Bastos et al., 2020), fungicide and insecticide seed treatments (Pinto et al., 2019), in-furrow fertilizer (Maeoka et al., 2020), and liming (Lollato et al., 2013; 2019c) have also benefited the wheat yields in this region.

Many studies evaluating strategies to narrow the yield gap have treatments originally designed by the researcher him/herself (e.g., de Oliveira Silva et al., 2020; Jaenisch et al., 2019, 2022). While these studies can provide valuable information, they usually do not quantitatively reflect practices currently adopted by growers. To our knowledge, there are no studies where the practices (or combination of practices) tested have been quantitatively determined by practices that producers are already using in commercial fields. Still, we argue that using field experiments to replicate the different management intensities adopted in commercial wheat fields can help identify avenues to increase yields while maintaining treatment parsimony and connection to reality. Thus, our objective was to quantify the gain in wheat grain yield resulting from adopting the same management practices of those adopted by top commercial wheat growers, as compared to the average- and low-yielding fields, using Kansas as a case study.

Procedures

Two experiments were conducted in a number of locations in the state of Kansas, one representing growers in the central region and one in the western region of the state. All central Kansas locations were conducted immediately after the harvest of a previous soybean crop, and included Ashland Bottoms (Belvue silt loam), Belleville (Crete silt loam), Hutchinson (Funmar-Taver loams), Manhattan (Kahola silt loam), Great Bend (Taver loam), and Solomon (Detroit silty clay loam). Western Kansas locations were conducted following a previous sorghum crop and a fallow period after the sorghum crop, and included Belleville (Crete silt loam), Colby (Keith silt loam), Garden City (Satanta silt loam), Hays (Harney silt loam), Leoti (Richfield silt loam), and Norcatur (Holdrege silt loam). Belleville was included in both east and western studies by differing the cropping system evaluated, and this is justified as this is a transitional region. The study was set up in a two-way factorial experiment in a split-plot design with management intensity as the whole plot, and wheat variety as the sub-plot. Management intensities were based on a survey of management practices adopted in 656 wheat fields (Jaenisch et al., 2021). Fields were categorized by grain yield into low (bottom 30% yielding fields), average, high (upper 30% yielding fields), and top (upper 5% yielding fields) categories. The frequency of adoption of different management practices was quantified for each group and replicated as treatments. A listing of management practices used in each treatment is provided in Table 1. Two hard red winter wheat varieties were planted at each location, including Zenda and WB4269 in the central locations, and KS Dallas and WB-Grainfield in the western locations. Central locations were sown following harvest of a preceding soybean crop while western locations followed a period of fallow, as was regionally common according to the survey of adopted practices. We also note that these differences in fallow period (western Kansas) versus continuous cropping (central Kansas) can result in vastly different available water at wheat sowing (Lollato et al., 2016), likely decreasing yield potential in the central locations.

Treatments were established according to Table 1, either by hand spreading fertilizers or by using a CO_2-pressurized backpack sprayer for application of foliar fungicides. Plots were harvested with a Massey Ferguson 8XP small plot, self-propelled combine. Grain weight, test weight, and moisture content were measured at harvest with an on-board HarvestMaster GrainGage system. Grain yield was calculated with an adjustment to 13% moisture content. Statistical analysis was completed using RStudio v. 2022.12.0. Two-way analysis of variance was used with environments as the random effect, which detected the effects of the fixed effects variety, management, and their interaction. Means were separated at the alpha = 0.05 level.

Results

Central Kansas

The main effects of management and variety both influenced grain yield in the central Kansas experiment, however with no significant interaction. The fields with 'Low' management yielded on average 37.1 bu/a across environments and varieties (Table 2). Increasing inputs to average management increased yield by 14.3% to 42.4 bu/a. High management resulted in a grain yield of 45.1 bu/a, an increase of 6.4% compared to the average level. Further increases in inputs to the top intensity significantly increased yield by an additional 4.9% as compared to high management. Half of the central Kansas trials saw increases in yield as management intensified, while the other half did not. Great Bend, Hutchinson, and Solomon had observed yields that were statistically similar across all management intensities. The Ashland Bottoms and Belleville trials had similar effects of treatments, where the increase from low to average and from average to high input levels produced increases in grain yield. Both of these trials did not see further statistical increases in yield at the top input level but did observe numerical increases. The Manhattan location was the only site where the top intensity statistically increased yield, where there was a 10.0% increase.

Across all levels of management intensity, WB4269 produced 8.0% greater grain yield than Zenda (44.6 vs. 41.3 bu/a). WB4269 variety yielded statistically higher than Zenda in two locations (Belleville and Hutchinson) but exhibited higher numerical yields at all locations (Table 2). The differences in yield potential between these varieties may relate to their protein production potential (Lollato et al., 2020b).

Different management practices were changed simultaneously when evaluating management intensification, thus, we cannot differentiate the effect of each practice individually. However, we can discuss the potential contribution of each. For example, seeding rate may be among the most impactful for increasing grain yield in central Kansas due to the previous crop of soybean, which pushed sowing dates to the later side of the window. Higher seeding rates are needed in lower yielding environments (Bastos et al., 2020), which often occur when winter wheat is planted following the summer crop harvest to compensate for later planting dates (Lollato et al., 2019a; Staggenborg et al., 2003). Consistent with findings from Lollato et al. (2019b), optimum nitrogen rates to maximize grain yield are about 100 lb of N/a; two of the three sites that saw input-related yield increases maximized the yield when increasing nitrogen from 80 to 120 lb of N/a. Low disease levels due to dry weather make it unlikely that application of fungicide at jointing played a significant role, a practice that has been found to be dependent on cultivar and environment (Watson et al., 2020). This points to increases in fertility as the driving factor of yield increases at the top intensity level.

Western Kansas

In the western Kansas experiments, there was only a significant effect of management on grain yield. General yield trends showed no significant increases in grain yield were observed between the low and the average management intensities, which ranged from 54.9–56.7 bu/a.

As inputs were increased to the high and top levels of management, grain yield significantly increased to 60.1–61.4 bu/a. Across all locations, increasing management intensity from the High to the Top level did not further increase grain yield. When breaking down the impact of management intensity by location (Table 2), Hays was the only location that had significant effects when management intensity increased between the low and average levels, where a 16.9% increase was observed. Colby and Hays both maximized yield when increasing from average to high input intensity, while Norcatur required the additional inputs at the top level to maximize yield. The Belleville, Garden City, and Leoti locations did not have any significant differences in grain yield between treatments. None of the western locations experienced increases in yield between the high and the top management intensities.

Varieties were not statistically different at yields of 58.2 and 58.3 bu/a. Varietal effects varied by location, with both varieties being favored in different sites (Table 2). WB-Grainfield produced higher yields in Belleville and Colby, and KS Dallas had higher yields in Hays and Norcatur, while no differences were observed in Garden City and Leoti.

Although seeding rate increased between low and average management, there was no collective increase in yield, in part due to wheat being planted at the optimal timing following fallow. This was also observed by Lollato et al. (2019a) where wheat yield was unaffected by increasing the seeding rate when planted at the optimal timing. The result also aligns with the findings of Bastos et al. (2020) where wheat yield was less responsive to seeding rates at high yielding environments. The increase of management intensity to high input levels is where we see the largest overall increase of input levels with the addition of several factors, which resulted in an increase in grain yield compared with the low management. One factor was the addition of sulfur fertilizer, which is documented to increase the plant's ability to respond to nitrogen applications. Fungicide likely had little impact on grain yields this year due to the low disease presence, which has been observed to increase yield in the presence of disease pressure (Cruppe et al., 2021; Jaenisch et al., 2019; Lollato et al, 2019c).

Conclusions

In both central and western Kansas, using similar management practices as the top 30% of producers in these regions increases grain yield, but any further increase in management intensity did not consistently result in yield increases. Variety impacted grain yield in both regions, but the yields often depended on the location.

Acknowledgments

This project was partially supported by award no. A23-0040-001 from the Kansas Wheat Commission.

References

Bastos, L. M., Carciochi, W., Lollato, R. P., Jaenisch, B. R., Rezende, C. R., Schwalbert, R., Vara Prasad, P. V., Zhang, G., Fritz, A. K., Foster, C., Wright, Y., Young, S., Bradley, P., & Ciampitti, I. A. (2020). Winter Wheat Yield Response to Plant Density as a Function of Yield Environment and Tillering Potential: A Review and Field Studies. *Frontiers in Plant Science*, *11,* 54.

Couëdel, A., Edreira, J. I. R., Pisa Lollato, R., Archontoulis, S., Sadras, V., & Grassini, P. (2021). Assessing environment types for maize, soybean, and wheat in the United States as determined by spatio-temporal variation in drought and heat stress. *Agricultural and Forest Meteorology*, *307,* 108513.

Cruppe, G., Edwards, J.T. and Lollato, R.P., 2017. In-season canopy reflectance can aid fungicide and late-season nitrogen decisions on winter wheat. Agronomy Journal, 109(5), pp.2072-2086.

Cruppe, G., DeWolf, E., Jaenisch, B. R., Andersen Onofre, K., Valent, B., Fritz, A. K., & Lollato, R. P. (2021). Experimental and producer-reported data quantify the value of foliar fungicide to winter wheat and its dependency on genotype and environment in the U.S. central Great Plains. *Field Crops Research*, *273*,108300.

de Oliveira Silva, A., Slafer, G. A., Fritz, A. K., & Lollato, R. P. (2020). Physiological Basis of Genotypic Response to Management in Dryland Wheat. *Frontiers in Plant Science*, *10,* 1644.

Jaenisch, B. R., Munaro, L. B., Bastos, L. M., Moraes, M., Lin, X., & Lollato, R. P. (2021). On-farm data-rich analysis explains yield and quantifies yield gaps of winter wheat in the U.S. central Great Plains. *Field Crops Research*, *272*, 108287.

Jaenisch, B. R., Oliveira Silva, A., DeWolf, E., Ruiz-Diaz, D. A., & Lollato, R. P. (2019). Plant Population and Fungicide Economically Reduced Winter Wheat Yield Gap in Kansas. *Agronomy Journal*, *111*(2), 650–665.

Jaenisch, B.R., Munaro, L.B., Jagadish, S.V. and Lollato, R.P., 2022. Modulation of wheat yield components in response to management intensification to reduce yield gaps. Frontiers in plant science, 13, p.567.

Lollato, R.P., Patrignani, A., Ochsner, T.E. and Edwards, J.T., 2016. Prediction of plant available water at sowing for winter wheat in the Southern Great Plains. Agronomy Journal, 108(2), pp.745-757.

Lollato, R.P., Roozeboom, K., Lingenfelser, J.F., da Silva, C.L. and Sassenrath, G., 2020b. Soft winter wheat outyields hard winter wheat in a subhumid environment: Weather drivers, yield plasticity, and rates of yield gain. Crop Science, 60(3), pp.1617-1633.

Lollato, R. P., Bavia, G. P., Perin, V., Knapp, M., Santos, E. A., Patrignani, A., & DeWolf, E. D. (2020a). Climate-risk assessment for winter wheat using long-term weather data. *Agronomy Journal*, *112*(3), 2132–2151.

Lollato, R. P., Edwards, J. T., & Ochsner, T. E. (2017). Meteorological limits to winter wheat productivity in the U.S. southern Great Plains. *Field Crops Research*, *203*, 212–226.

Lollato, R. P., Edwards, J. T., & Zhang, H. (2013). Effect of Alternative Soil Acidity Amelioration Strategies on Soil pH Distribution and Wheat Agronomic Response. *Soil Science Society of America Journal*, *77*(5), 1831–1841.

Lollato, R. P., Figueiredo, B. M., Dhillon, J. S., Arnall, D. B., & Raun, W. R. (2019a). Wheat grain yield and grain-nitrogen relationships as affected by N, P, & K fertilization: A synthesis of long-term experiments. *Field Crops Research*, *236*, 42–57.

Lollato, R. P., Jaenisch, B. R., & Silva, S. R. (2021). Genotype-specific nitrogen uptake dynamics and fertilizer management explain contrasting wheat protein concentration. *Crop Science*, *61*(3), 2048–2066.

Lollato, R. P., Ochsner, T. E., Arnall, D. B., Griffin, T. W., & Edwards, J. T. (2019b). From Field Experiments to Regional Forecasts: Upscaling Wheat Grain and Forage Yield Response to Acidic Soils. *Agronomy Journal*, *111*(1), 287–302.

Lollato, R. P., Ruiz Diaz, D. A., DeWolf, E., Knapp, M., Peterson, D. E., & Fritz, A. K. (2019c). Agronomic Practices for Reducing Wheat Yield Gaps: A Quantitative Appraisal of Progressive Producers. *Crop Science*, *59*(1), 333–350.

Maeoka, R. E., Sadras, V. O., Ciampitti, I. A., Diaz, D. R., Fritz, A. K., & Lollato, R. P. (2020). Changes in the Phenotype of Winter Wheat Varieties Released Between 1920 and 2016 in Response to In-Furrow Fertilizer: Biomass Allocation, Yield, and Grain Protein Concentration. *Frontiers in Plant Science*, *10,* 1786.

Munaro, L. B., Hefley, T. J., DeWolf, E., Haley, S., Fritz, A. K., Zhang, G., Haag, L. A., Schlegel, A. J., Edwards, J. T., Marburger, D., Alderman, P., Jones-Diamond, S. M., Johnson, J., Lingenfelser, J. E., Unêda-Trevisoli, S. H., & Lollato, R. P. (2020). Exploring long-term variety performance trials to improve environment-specific genotype × management recommendations: A case-study for winter wheat. *Field Crops Research*, *255*, 107848.

Patrignani, A., Lollato, R. P., Ochsner, T. E., Godsey, C. B., & Edwards, Jeff. T. (2014). Yield Gap and Production Gap of Rainfed Winter Wheat in the Southern Great Plains. *Agronomy Journal*, *106*(4), 1329–1339.

Pinto, J. G. C. P., Munaro, L. B., Jaenisch, B. R., Nagaoka, A. K., & Lollato, R. P. (2019). Wheat Variety Response to Seed Cleaning and Treatment after Fusarium Head Blight Infection. *Agrosystems, Geosciences & Environment*, *2*(1), 1-8.

Sciarresi, C., Patrignani, A., Soltani, A., Sinclair, T. and Lollato, R.P., 2019. Plant traits to increase winter wheat yield in semiarid and subhumid environments. Agronomy Journal, 111(4), pp.1728-1740.

Simão, L.M., Peterson, D., Roozeboom, K.L., Rice, C.W., Du, J., Lin, X. and Lollato, R.P., Crop rotation and tillage impact yield performance of soybean, sorghum, and wheat. Agronomy Journal.

Staggenborg, S. A., Whitney, D. A., Fjell, D. L., & Shroyer, J. P. (2003). Seeding and Nitrogen Rates Required to Optimize Winter Wheat Yields following Grain Sorghum and Soybean. *Agronomy Journal*, *95*(2), 253–259.

Watson, B. H., Hunger, R. M., & Marburger, D. A. (2020). Economic returns of one versus two fungicide applications in Oklahoma winter wheat. *Crop Science*, *60*(1), 441-453.

Table 1. Combinations of management practices adopted in 656 commercial winter wheat fields based on different yield levels in the central and western environments

	Central Kansas (Sub-Humid) Previous crop: Soybean				Western Kansas (Semi-Arid) Previous crop: Fallow			
Practice	**Low**	**Average**	**High**	**Top**	**Low**	**Average**	**High**	**Top**
Yield goal (bu/a)	35	55	75	95	35	55	80	95
Seeding rate (seeds/a)	1,000,000	1,200,000	1,450,000	1,450,000	750,000	900,000	1,050,000	1,050,000
Nitrogen (lb N/a)	40	80	120	160	40	80	120	180
Phosphorus (lb P/a)	-	20	30	35	-	-	30	30
Sulfur (lb S/a)	-	10	10	20	-	-	10	20
Chloride (lb KCl/a)	-	15	15	15	-	-	-	-
Seed treatment	-	Yes	Yes	Yes	-	-	Yes	Yes
Split N application	-	-	Yes	Yes	-	-	Yes	Yes
Flag leaf fungicide	-	-	Yes	Yes	-	-	Yes	Yes
Jointing fungicide	-	-	-	Yes	-	-	-	Yes
Micronutrients	-	-	-	Yes	-	-	-	Yes

Table 2. Grain yield by management intensity, variety, and location for the central and western Kansas experiments

	Central Kansas grain yield (bu/a)						
Management intensity	**Ashland Bottoms**	**Belleville**	**Great Bend**	**Hutchinson**	**Manhattan**	**Solomon**	**Sites combined**
Low	40.0 c	54.5 c	30.5 a	30.3 a	29.6 d	37.8 a	37.1 d
Average	48.9 b	65.9 b	32.0 a	32.0 a	39.0 c	36.4 a	42.4 c
High	53.1 a	72.3 a	29.0 a	30.6 a	47.2 b	38.3 a	45.1 b
Top	55.7 a	75.3 a	31.1 a	32.7 a	51.9 a	37.3 a	47.3 a
Variety							
WB4269	49.9 a	71.6 a	32.2 a	34.1 a	42.0 a	37.8 a	44.6 a
Zenda	48.9 a	62.5 b	29.1 a	28.6 b	41.9 a	37.1 a	41.3 b

	Western Kansas grain yield (bu/a)						
Management intensity	**Belleville**	**Colby**	**Garden City**	**Hays**	**Leoti**	**Norcatur**	**Sites combined**
Low	80.5 a	38.0 b	52.4 a	48.0 c	56.5 a	54.2 b	54.9 c
Average	75.3 a	38.0 b	57.6 a	56.1 b	58.5 a	54.9 b	56.7 bc
High	76.9 a	50.0 a	51.2 a	62.4 a	60.0 a	60.2 ab	60.1 ab
Top	76.8 a	45.8 a	52.9 a	64.7 a	59.4 a	69.0 a	61.4 a
Variety							
WB Grainfield	81.2 a	45.5 a	53.4 a	55.5 b	58.6 a	55.3 b	58.2 a
KS Dallas	73.6 b	40.4 b	53.6 a	60.2 a	58.6 a	63.9 a	58.3 a

Letters denote significance at the 0.05 probability level.