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Summary

Large winter wheat yield gaps between farmer yields and yield potential in the southern Great Plains indicate the need to improve recommendations of best management strategies to profitably bridge this gap. Many studies have been completed on 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 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 fields, and replicated in trials conducted in four and six locations in western and central Kansas. Management intensities were tested factorially on two adapted varieties. Grain yield in central Kansas ranged from 45.5 bu/a in the Low management intensity to 69.3 bu/a in the High and Top intensities, with the Average management increasing yields by 30% as compared to the Low intensity, and the High management increasing yields 18% from the Average. The variety WB4269 outyielded Zenda (63.2 and 58.7 bu/a) across central environments. In western Kansas, there was a significant variety by management interaction, where wheat yield increased from the Low and Average intensities to the High and Top intensities (72.8–78.9 to 90.7–96.0 bu/a). The WB-Grainfield and KS Dallas varieties produced similar yields in the western environments. Using similar management practices as the producers with high-yield results in central and western Kansas narrowed the yield gap, and further increases in management intensification were not warranted. Variety selection played an important role either by increasing attained yields or by interacting with management practices.

Introduction

The adoption of conservative farming practices has led to large (approximately 55% or more) hard red winter wheat (*Triticum aestivum* L.) yield gaps between actual and potential yields in Kansas and most of the US 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 (Couedel et al., 2021; Lollato et al., 2020; 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., 2019c). 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., 2019a, 2021) and foliar fungicides (Cruppe et al., 2021; Jaenisch et al., 2019), 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), 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; 2019b) have also benefited 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, the practices (or combination of practices) tested in other studies not been quantitatively determined by the 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 current practices. Thus, our objective was to quantify the yield gain for wheat resulting from adopting the same management practices as 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 several locations in Kansas, one representing growers in the central region and one in the western region of the state. Central Kansas locations included two at Ashland Bottoms [Belvue silt loam (1) and Bismarck-grove-Kimo complex (2)]; Belleville (Crete silt loam); Hutchinson (Ost Loam); Manhattan (Kahola silt loam); and Tipton (Harney silt loam). Western Kansas locations included Colby (Keith silt loam); Garden City (Ulysses silt loam); Leoti (Richfield silt loam); and Norcatur (Holdrege silt loam). 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 (top 30% yielding fields), and Top (top 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.

Treatments were established according to Table 1, either by hand-spreading fertilizers or by using a CO₂-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.

2021.09.0. Two-way analysis of variance with environments as the random effect detected the effects of 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 'Low' management yielded on average 45.5 bu/a across environments and varieties. Increasing inputs to average management increased yield by 29.5% to 58.9 bu/a. High management resulted in a grain yield of 69.3 bu/a, an increase of 17.7% compared to the average level. Further increases in inputs did not significantly increase yield as compared to high management. Across all levels of management intensity, WB4269 produced 7.7% greater grain yield than Zenda (63.2 vs. 58.7 bu/a).

The WB4269 variety yielded higher than Zenda in all locations except for Manhattan, where the two varieties had similar yield (Table 2). In all central Kansas locations, increases in management intensity generally increased grain yield. The Ashland Bottoms trials and the Hutchinson trial had similar effects of treatments, where the increase from Low to Average and from Average to High input levels produced increases in grain yield. Manhattan and Tipton trials did not have a significant increase in yield when increasing inputs from Low to Average management. In Manhattan, the High management intensity increased yield by 25.0% compared to the Average treatment. A 26.8% increase in grain yield was observed with the High treatment in Tipton compared to the Low input level. All locations in central Kansas showed no significant differences in grain yield between the High and Top management intensities except for Belleville, where there was a 4.7% increase with the Top treatment.

Of the management practices included in the treatments, seeding rate may have been among the most impactful for increasing grain yield due the previous crop of soybeans. Higher seeding rates are needed in lower yielding environments (Bastos et al., 2020), which often occur when winter wheat is planted following summer crop harvest, to compensate for later planting dates (Lollato et al., 2019c; Staggenborg et al., 2003). Consistent with findings from Lollato et al. (2019a) that optimum nitrogen rates to maximize grain yield are about 100 lb N/a, our study in central Kansas maximized yield when increasing nitrogen from 80 to 120 lb N/a. Fungicide applied at the jointing stage did not increase yield in the Top management, a practice that has been found to be dependent on the cultivar and environment (Watson et al., 2020).

Western Kansas

In the western Kansas experiment, there was a significant management by variety interaction on grain yield. General yield trends showed no significant increases in grain yield between the Low and the Average management intensities, which ranged from 72.8–78.9 bu/a. As inputs were increased to the High and Top levels of management, grain yield significantly increased to 90.7–96.0 bu/a. Increasing management intensity from the High to the Top level did not further increase grain yield. The significant management by variety interaction was brought about by numerical (though not statistical) differences between varieties as function of management, where KS Dallas had lower

numerical yields than WB-Grainfield at the Low and Average treatments, and greater numerical yields at the High and Top treatments.

Both varieties in the western region yielded similarly in all locations except Leoti, where WB-Grainfield yielded 5.1% more than KS Dallas (Table 2). The Garden City and Norcatur trials responded similarly to increases in management intensity, where the only significant increase in yield occurred when increasing intensity from the Average level to High. In Leoti, a 9.6% increase in yield occurred when management increased from Low to Average, and an 8.5% increase when increasing from Average to High management. The Colby location did not have any significant differences in grain yield among treatments. None of the western locations experienced increases in yield between the High and the Top management intensities.

Although seeding rate increased between Low and Average management, there was no observed increase in yield, in part due to being planted at optimal timing following fallow. This was also observed by Lollato et al. (2019c) where yield was unaffected by increasing seeding rate when planted at the optimal timing. It 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 from Average 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. The most beneficial of these factors was the addition of sulfur fertilizer, which is documented to increase the plant's ability to respond to nitrogen applications (Salvagiotti and Miralles, 2008). The addition of fungicide also likely played a role in increasing grain yields, which has been observed with 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 increased grain yield and decreased the yield gap. A further increase in management intensity was not necessary to increase yield in the conditions experienced in 2021. Variety impacted both regions, affecting yield either by increasing yield or by interacting with the management intensity.

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

Management practice	Central Kansas				Western Kansas			
	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
Seed treatment	No	Yes	Yes	Yes	No	No	Yes	Yes
Split N application	No	No	Yes	Yes	No	No	Yes	Yes
Nitrogen (lb N/a)	40	80	120	160	40	80	120	180
Phosphorus (lb P/a)	0	20	30	35	0	0	30	30
Sulfur (lb S/a)	0	10	10	20	0	0	10	20
Chloride (lb KCl/a)	0	15	15	15	0	0	0	0
Micronutrients	No	No	No	Yes	No	No	No	Yes
Jointing fungicide	No	No	No	Yes	No	No	No	Yes
Flag leaf fungicide	No	No	Yes	Yes	No	No	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 1	Ashland Bottoms 2	Belleville	Hutchinson	Manhattan	Tipton	Sites combined
Low	51.7 c*	46.0 c	41.2 d	40.3 c	35.7 b	48.8 b	45.5 c
Average	64.1 b	61.6 b	59.9 c	53.5 b	45.2 b	57.3 ab	58.9 b
High	79.1 a	73.3 a	67.5 b	64.5 a	56.7 a	61.9 a	69.3 a
Top	77.0 a	74.8 a	70.7 a	67.9 a	57.0 a	61.6 a	70.2 a
Variety							
WB4269	70.7 a	65.2 a	63.3 a	58.4 a	49.1 a	60.4 a	61.9 a
Zenda	65.2 b	62.6 b	56.3 b	54.7 b	48.2 a	54.2 b	58.7 b

Western Kansas grain yield (bu/a)					
Management intensity	Colby	Garden City	Leoti	Norcatatur	Sites combined
Low	84.2 a	79.4 b	82.2 c	49.6 b	73.9 b
Average	83.5 a	82.3 b	90.1 b	48.1 b	76.0 b
High	87.7 a	101.6 a	97.8 a	90.1 a	94.3 a
Top	83.0 a	101.9 a	96.8 a	83.6 a	91.3 a
Variety					
WB-Grainfield	66.2 a	92.1 a	94.0 a	66.2 a	84.3 a
KS Dallas	69.5 a	90.5 a	89.4 b	69.5 a	83.4 a

*Letters denote significance at the 0.05 probability level.