INCREASING WINTER WHEAT GRAIN YIELD BY REPLICATING THE MANAGEMENT ADOPTED IN HIGH-YIELDING COMMERCIAL FIELDS

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ABSTRACT

Large winter wheat (*Triticum aestivum*) 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). WB Grainfield and KS Dallas varieties produced similar yields in the western environments. Managing like high yielding producers in central and western Kansas narrowed the yield gap and further increases in management intensification were not warranted, as managing like the top producers shows no significant increase in yield. Variety selection played an important role either by increase attained yields or by interacting with management.

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 US central Great Plains (Jaenisch et al., 2021; Lollato et al., 2017; Patrignani et al., 2014). While part of this conservative management is justified to harsh weather (Couedel et al., 2021; Lollato et al., 2020), 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). While these studies can provide valuable information, they usually do not quantitatively reflect practices currently adopted by growers. To our knowledge, that 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 wheat grain yield gain resulting from adopting the same management practices to those adopted by top commercial wheat growers, as compared to the average- and low-yielding fields using Kansas as a case study.

MATERIALS AND METHODS

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. Central Kansas locations included two at Ashland Bottoms (Belvue silt loam and Bismarckgrove-Kimo complex), 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 are provided in Table 1. Two hard red winter wheat varieties were planted at each location, including Zenda and WestBred WB4269 in the central locations, and KS Dallas and WestBred 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.

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 (lbs N/a)	40	80	120	160	40	80	120	180
Phosphorus (lbs P/a)	0	20	30	35	0	0	30	30
Sulfur (lbs S/a)	0	10	10	20	0	0	10	20
Chloride (lbs 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

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. 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 AND DISCUSSION

The main effects of management and variety both influenced grain yield in the Central Kansas experiment, however with no significant interaction (Figure 1). 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).

Of the management practices included in the treatments, seeding rate may be amongst 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 lbs N/a, our study in central Kansas maximized yield when increasing nitrogen from 80 to 120 lbs N/a. The addition of jointing fungicide did not increase yield in the top management, a practice that has been found to be cultivar and environment dependent (Watson et al., 2020).

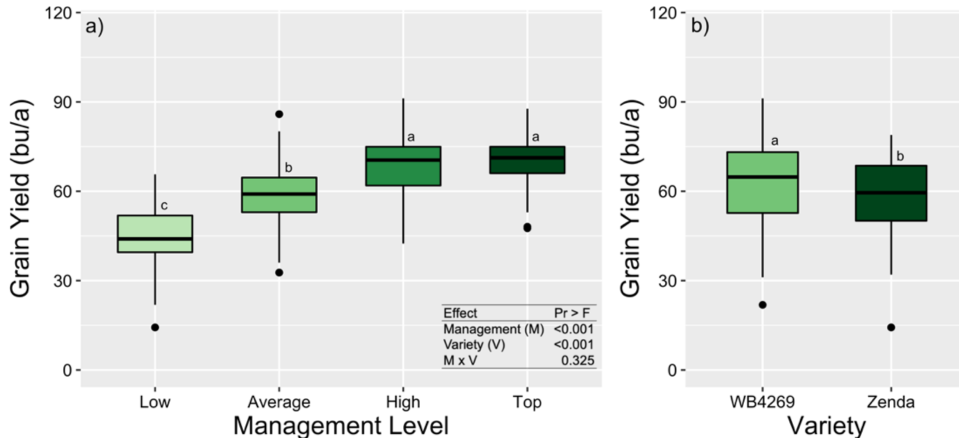

Figure 1. Box plots of wheat grain yield response to (a) management and (b) variety across six experimental locations in central Kansas. Inset table shows significance ANOVA effects. Box-plots followed by the same letter indicate no statistical difference at the 0.05 probability level.

In the western Kansas experiment, there was a significant management by variety interaction on grain yield (Figure 2). General yield trends were that there were no significant increases in grain yield observed between the low and the average management intensities, which ranged from 72.8-78.9 bu/a; and 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 (Figure 2).

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. Of these 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 observed with the presence of disease pressure (Cruppe et al., 2021; Jaenisch et al., 2019; Lollato et al, 2019c).

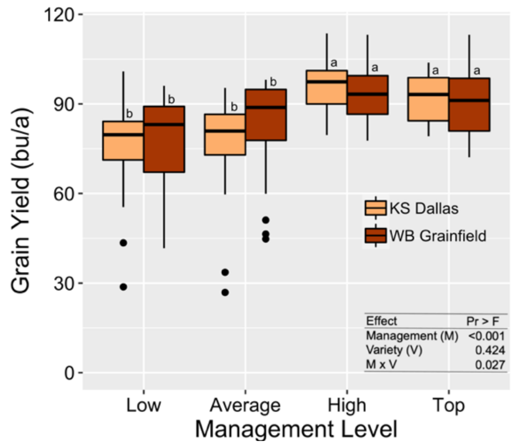

Figure 2. Wheat grain yield response to variety and management interaction across four locations in western Kansas. Inset table shows significance ANOVA effects. Box-plots followed by the same letter indicate no statistical difference at the 0.05 probability level.

CONCLUSIONS

In both central and western Kansas, managing like the top 30% of producers in these regions increases grain yield and decreases the yield gap. A further increase in management intensity is not necessary to increase yield. Variety impacted both regions, affecting yield either by increasing yield or interacting with the management intensity.

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