WINTER WHEAT GROWTH AND GRAIN YIELD RESPONSE TO INDIVIDUAL AGRONOMIC INPUTS

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ABSTRACT

Producers' interested in optimizing wheat (*Triticum aestivum L.*) growth and yields have adopted intensive (i.e. high-input) wheat management systems in Michigan. Additional research is required to evaluate growth, grain yield, and profitability of multiple and individual agronomic inputs. An omission field trial was initiated in Lansing, MI during 2015 to evaluate the response of soft red winter wheat to six agronomic inputs in enhanced (high-input) and traditional (low-input) management systems. The study was arranged in a randomized complete block with four replications. Inputs included: two nitrogen rates (90 lbs. A^{-1} and 108 lbs. A^{-1}), urease inhibitor, nitrification inhibitor, fungicide, plant growth regulator, and foliar micronutrients. Nitrogen, urease inhibitor, and nitrification inhibitor were applied at Feekes 3 (i.e., green-up), plant growth regulator and foliar micronutrients were tank-mixed and applied at Feekes 6 (i.e., first node of stem visible), and fungicide was applied at Feekes 10.5.1 (i.e., flowering). No significant yield and gross profitability responses were observed with the urease inhibitor, nitrification inhibitor, plant growth regulator, or increased nitrogen rate. The addition of the fungicide to the traditional management system significantly increased yield by 10.8 bu A^{-1} and the removal of the foliar micronutrient from the enhanced management system resulted in a yield increase of 9.8 bu A^{-1} and gross profit increase of \$51.36 A^{-1}. Results indicated high-input management systems demonstrated limited potential for increased yield and producer profitability across the weather and environmental conditions encountered in 2016.

INTRODUCTION

The economic importance of winter wheat production to Michigan's agriculture and milling industry has increased producer interest in high or intensive management (Khan and Spilde, 1992; Mohammed et al., 1990). Research in Michigan and other states has shown increased yields can be obtained by using intensive management systems. Intensive management includes the use of agronomic inputs for optimum fertilization, insect, disease, weed control, and reduction of lodging (Oplinger et al., 1985). Therefore it is necessary to evaluate the individual effects of several common inputs on winter wheat. In addition to evaluating inputs for growth and grain yield, each input must be evaluated for profitability and whether or not yield gains from specific inputs are able to withstand commodity price fluctuations. Yield and economic evaluation of different management systems and agronomic inputs may allow winter wheat to be viewed as more of a revenue-generating cash crop and subsequently increase acreage and production across the state of Michigan. Regularly sold inputs of interest to producers include urease inhibitor, nitrification inhibitor, plant growth regulator, fungicide, and nitrogen fertilizer.

To increase grain yield and grain quality, nitrogen (N) availability is necessary throughout the entire growing season and must withstand a variety of environmental conditions (White and Edwards, 2008). Producers in Michigan often use spring top-dress applications of N to maximize wheat profitability and performance (Warncke and Nagelkirk, 2010). When urea or UAN is applied to the soil surface, nitrogen can be lost through volatilization, denitrification, or leaching, therefore inhibiting adequate N uptake and ultimately reducing grain yield and quality (Warncke et al., 2009). The risk of N loss through volatilization can be further minimized by supplying the urea or UAN with a urease inhibitor. One example of a urease inhibitor is N-(n-butyl) phosphoric triamide (NBPT). NBPT urease inhibitor is most effective in soils that have a high potential for volatilization (high pH, coarse textured) (Olson-Rutz et al., 2011).

Nitrogen, when converted from ammonium (NH_4^+) to nitrate (NO_3^-) also has the potential to be lost through leaching or denitrification. These N loss mechanisms reduce the agronomic and economic benefits of using urea based fertilizers (Mohammed et al., 2016). Nitrapyrin is one example of a nitrification inhibitor that when added with urea or UAN can keep nitrate in the ammonium form longer thereby reducing N losses from leaching or denitrification (Trenkel, 2010). Protecting nitrogen from Michigan's erratic and unpredictable spring weather is required to reduce nitrogen losses.

Intensive cereal management programs must have the ability to withstand or minimize plant lodging. Lodging can interfere with water and nutrient uptake of the wheat plant and ultimately reduce grain fill and grain yield. To further increase wheat yield, producers often apply increased N rates. However, this management decision often increases the risk for plant lodging (Knapp and Harms, 1988; Knott et al., 2016). Trinexapac-ethyl (TE) is one example of a plant growth regulators (PGR) used in wheat production in the United States. TE works by inhibiting the formation of active gibberellins, resulting in decreased stem elongation, stronger stem tissues, and ultimately the prevention of lodging (Rademacher, 2000; Matysiak, 2006). Research has observed that TE significantly increases yield when lodging occurs (Nagelkirk, 2012; Brinkman et al., 2014).

Fungicides are regularly applied to control fungal diseases of wheat, prevent yield loss, and maximize economic returns (Wegulo et al., 2012). In many cases the most effective control of disease in wheat is between the appearance of the flag leaf (Feekes growth stage 9) and the milk stage of grain development (Feekes growth stage 10.5.4) (Lorenz and Cothren, 1989). Fusarium head blight (FHB) or scab is one of the most important pathogens affecting wheat in the upper Midwest. FHB results in significant reductions of yield, test weight, and seed quality (McMullen et al., 1997). Research has found that triazole-based fungicides, such as tebuconazole + prothioconazole (Prosaro 421 SC; Bayer CropScience) can significantly reduce FHB severity and significantly increase grain yield and quality when applied directly to the grain head during anthesis (Feekes growth stage 10.5.1) (Paul et al., 2010). Decreased FHB and foliar disease presence in Michigan wheat as a result of fungicide applications could potentially allow for increased production and profitability for producers.

Although micronutrient deficiencies in Michigan wheat are rare, yield losses can be great when deficiencies of these nutrients do occur (Vitosh et al., 1994) Micronutrients are being reduced in the soil due to the increased dependence on synthetic fertilizer, and increased cropping intensity with higher yielding crops (Dewal and Pareek, 2004). In Michigan micronutrient recommendations are based on soil test, soil pH, and crop responsiveness

(Warncke et al., 2009). Foliar micronutrient applications can be used to correct deficiencies that may be present across different soil types and environments in Michigan.

Nitrogen rate has direct implications on wheat grain yield and profitability. Nitrogen rate can directly affect root growth, tillering, and production of chlorophyll (White and Edwards, 2008). However, excessive nitrogen can increase ground water contamination, delay maturity, and increase risk of lodging (Warncke et al., 2009). Despite these concerns producers with varying management regimes may increase N rates to further increase wheat yields (Knapp and Harms, 1988; Knott et al., 2016). Grain yield and economic evaluation of an increased N rate in different management systems would fine-tune producer management decisions.

The objective of this study was to determine the growth, grain yield, and profitability response of winter wheat to several common agronomic inputs, in order to maximize producer investment and fine-tune input management strategies.

MATERIALS AND METHODS

An omission field experiment was initiated on 29 September 2015 to evaluate the response of soft red winter wheat to various agronomic inputs: two nitrogen rates (90 lbs. N A^{-1} and 108 lbs. N A^{-1}), urease inhibitor, nitrification inhibitor, plant growth regulator, fungicide, and foliar micronutrients. The experiment was conducted on a Capac loam soil in Lansing, MI. The soft red winter wheat variety used was Sunburst (Michigan Crop Improvement Assoc., Lansing, MI), planted in 7.5 inch rows to achieve a final plant population of 1.8 million seeds A^{-1}. Field was previously cropped to corn silage and received conventional tillage. Soil properties included 6.4 pH, 27 ppm P, and 94 ppm K.

The omission trial design used (Table 1) was arranged as a randomized complete block with four replications. Two treatment controls are used in an omission trial. One control contains all of the inputs applied (enhanced treatment), and the other control contains none of the inputs applied (traditional treatment) (Bluck et al., 2015). The traditional treatment in this trial contained the base N rate of 90 lbs. N A^{-1} with no other inputs applied. To evaluate the response to N an untreated control treatment was used with no inputs applied. To evaluate treatment effects of this trial in the omission design, inputs removed from the enhanced management system are compared to the enhanced treatment control, containing all inputs. Inputs removed from the traditional management system are compared only to the traditional treatment control, containing only the base N rate of 90 lbs N A^{-1} (Bluck et al., 2015).

Observations included plant tissue samples collected for nutrient analysis at F5 and F9. Bi-weekly canopy coverage and chlorophyll measurements were collected throughout the growing season to assess treatment effects. Disease and lodging ratings were collected weekly once/if instances occurred. Plant height measurements and grain head counts were collected from each plot pre-harvest. Grain moisture, test weight, and yield were taken at harvest and adjusted to 13.5% moisture. Grain quality (i.e., vomitoxin levels) was assessed through the use of deoxynivalenol (DON) testing following harvest. Economic analysis was performed using product cost estimates of \$5.40-6.40, \$11.70, \$15.84, \$17.94, \$14, \$39-47 A^{-1} for urease inhibitor, nitrification inhibitor, plant growth regulator, fungicide, foliar micronutrients, and nitrogen fertilizer, respectively. An additional \$7.50 A^{-1} was estimated as an application cost for plant growth regulator, fungicide, foliar micronutrients, and nitrogen fertilizer. Product and application cost estimates were from local agriculture retailers. Gross profit estimates were performed using a soft red winter wheat cash grain price of \$3.75 bu^{-1}, multiplied by yield (bu A^{-1}) of each treatment, and subtracting the cost (US\$ A^{-1}) of each treatment.

Statistical analyses were performed using SAS. Data was analyzed using the PROC GLIMMIX procedure of SAS at $\alpha = 0.1$. Mean separations were determined using single degree of freedom contrasts. To evaluate treatment effects in the omission design, a factor removed from the enhanced management system was compared to the enhanced treatment containing all factors, and conversely, a factor added into the traditional management system was compared to the traditional treatment containing no additional factors (Bluck et al., 2015).

PRELIMINARY RESULTS AND DISCUSSION

Removal and addition of the urease inhibitor, nitrification inhibitor, and increased nitrogen rate from and to the enhanced and traditional management systems, respectively did not significantly increase or reduce yield or gross profitability A^{-1} in 2016 (Table 2). Immediate rainfall following top-dress nitrogen fertilizer application, supplemented with average April rainfall accumulations suggests early N loss conditions were not present in 2016. Accumulated spring rainfall and timing was sufficient to reduce the risk for N loss from volatilization, yet not substantial enough to produce N loss conditions from leaching and/or denitrification. Dry spring 2016 soil conditions suggests adequate N fertilization was present in the wheat plant resulting in a reduced benefit from utilizing a urease inhibitor, nitrification inhibitor, and/or increased N rate.

Removal of the plant growth regulator from the enhanced treatment and addition of the plant growth regulator to the traditional treatment did not significantly increase or reduce grain yield or gross profitability A^{-1} in 2016. (Table 2) Plant lodging was non-existent across all treatments in 2016. Results suggest when lodging of the wheat plant does not occur, minimal benefits were observed from the use of a plant growth regulator.

Due to a significant presence of the foliar disease leaf rust, the addition of the fungicide to the traditional management system resulted in a significant yield increase in 2016 (Table 2). Fungicide was applied directly to the grain head at growth stage F10.5.1, with an objective of protecting the head from FHB which was not prevalent in 2016 due to below average rainfall conditions during anthesis. However, significant flag leaf disease protection from leaf rust was noted following fungicide application. These results and observations suggest fungicides applied directly to the grain head during anthesis have potential to protect the flag leaf as well as the grain head during prominent disease years, thus resulting in a significant increase in yield.

Removal of the foliar micronutrients from the enhanced treatment and addition of the foliar micronutrients to the traditional treatment did not significantly increase or reduce grain yield in 2016 (Table 2). However, a significant increase in profitability A^{-1} was observed when the foliar micronutrient was removed from the enhanced treatment (Table 2). The significant gross profitability A^{-1} increased as a result of a 9.8 bu A^{-1} increase in grain yield observed when the input was removed from the enhanced system (Table 2). Significant plant height decreases were observed on plots where the foliar micronutrients were tank-mixed applied with the PGR at F6, as compared to plots with only the PGR applied or neither the PGR nor foliar micronutrient applied (data not shown). The plant height observations may suggest increased GA inhibition, causing more significant plant height decreases through increased uptake of the PGR when combined with the foliar micronutrient. Corrleations between plant height and grain yield showed a negative effect of decreasing plant heights on grain yield (data not shown).

No significant yield or gross profitability responses occurred when the enhanced treatment containing all inputs was compared to the traditional treatment containing only the base N rate of 90 lbs A^{-1}. The traditional management system yielded 3.1 bu A^{-1} higher than the enhanced management system and resulted in a significant gross profit increase of \$84 A^{-1} in 2016 (Table

3). First-year preliminary results suggest in certain years and environments a high-input management system may not always increase grain yields and producer profitability when compared to a low-input management system.

PROJECT CONTINUATION

A second year of research for this study is currently underway and will continue to evaluate the individual effects of different agronomic inputs across two different management systems (enhanced and traditional). The primary goal of this research is to help producers maximize investment and fine-tune input management strategies, with a goal of making soft red winter wheat a more revenue generating cash crop.

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Table 1: Overview of omission trial design, treatment names, and inputs applied in 2016.

		Inputs					
Treatment	**Treatment name**	**UI†**	**NI‡**	**PGR§**	**Fungicide¶**	**Foliar Micro††**	**High-N#**
1	Enhanced (E)	Yes	Yes	Yes	Yes	Yes	Yes
2	E w/o UI	No	Yes	Yes	Yes	Yes	Yes
3	E w/o NI	Yes	No	Yes	Yes	Yes	Yes
4	E w/o PGR	Yes	Yes	No	Yes	Yes	Yes
5	E w/o fungicide	Yes	Yes	Yes	No	Yes	Yes
6	E w/o foliar micro	Yes	Yes	Yes	Yes	No	Yes
7	E w/o High-N	Yes	Yes	Yes	Yes	Yes	No
8	Traditional (T)	No	No	No	No	No	No
9	T w/ UI	Yes	No	No	No	No	No
10	T w/ NI	No	Yes	No	No	No	No
11	T w/ PGR	No	No	Yes	No	No	No
12	T w/ fungicide	No	No	No	Yes	No	No
13	T w/ foliar micro	No	No	No	No	Yes	No
14	T w/ High-N	No	No	No	No	No	Yes
15	Check	No	No	No	No	No	No

† Urease inhibitor applied at a rate of 1 qt/ton UAN at green-up growth stage.
‡ Nitrification inhibitor applied at a rate of 37 oz/A at green-up growth stage.
§ Plant growth regulator applied at a rate of 12 oz/A at F6 growth stage.
¶ Fungicide applied at a rate of 8.2 oz/A at F10.5.1 growth stage.
†† Foliar micronutrient containing Zn, Mn, B applied at a rate of 2 qt/A at F6 growth stage.
# High-nitrogen applied at a rate of 108 lbs/A

Table 2: Grain yield and gross profit values for 2016. Average yield and gross profit shown for enhanced and traditional treatments. Yield and gross profit changes shown from respective enhanced or traditional treatment.

Treatment	**Yield**	**Gross Profit**
	-------bu A^{-1}-----	----US$ A^{-1}----
Enhanced (E)	**77.9**	**173.04**
E w/o UI	+5.7	+28.90
E w/o NI	+2.2	+21.08
E w/o PGR	-0.5	+15.09
E w/o Fungicide	+0.3	+20.71
E w/o Foliar Micro	+9.8	+51.36*
E w/o High-N	-8.4	-21.37
Traditional (T)	**81**	**257.25**
T w/ UI	-2.8	-15.90
T w/ NI	+3.4	+1.05
T w/ PGR	+1.1	-19.73
T w/ Fungicide	+10.8*	+14.54
T w/ Foliar Micro	+7.2	+5.50
T w/ High-N	+4.1	+7.38

***** Significantly different at α=0.1 using single degree of freedom contrasts.

Table 3: Grain yield and gross profit value comparison between enhanced and traditional management systems in 2016.

Management System	**Yield**	**Gross Profit**
	--------bu A^{-1}-------	------US$ A^{-1}------
Enhanced†	77.9	173.04
Traditional‡	81	257.25*

***** Significantly different at α=0.1 using single degree of freedom contrasts.

† Enhanced treatment with all agronomic inputs applied.

‡ Traditional treatment containing only base N rate of 90 lbs. A^{-1} with no additional agronomic inputs applied.

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