Agronomic and Nutrient Management Strategies for Soft Red Winter Wheat

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ABSTRACT

Michigan produces some of the greatest non-irrigated wheat (*Triticum aestivum* L.) yields in the United States. Enhancing or lengthening the greenness of the flag-leaf has been suggested as a method to improve photosynthetic capabilities and nutrient uptake. The objective of this study was to evaluate growth, grain quality, grain yield, and economic profitability for multiple agronomic and nutrient inputs across different production intensity levels. An omission field trial with four replications was initiated in Lansing, MI and evaluated six agronomic inputs including: weekly nitrogen (N) applications (12.5 lbs N A^{-1} for 8 weeks starting at Feekes 4 growth stage), high (+33%) N rate (133 lbs N A^{-1}), seeding rate (1.8 million seeds A^{-1} and 0.9 million seeds A^{-1}), autumn-applied starter fertilizer (250 lbs A^{-1} 12-40-0-10S-1Zn), plant growth regulator, and fungicide. Due to high pressure of Fusarium head blight (FHB) (primarily caused by *Fusarium graminearum* Schwabe [teleomorph: *Gibberella zeae* (Schwein.) Petch]), removal of fungicide from the enhanced system significantly decreased yield 12.0 bu A^{-1}. Autumn starter fertilizer significantly increased grain yield by 10.1 bu A^{-1} within the traditional system and significantly decreased grain yield by 14.2 bu A^{-1} when removed from the enhanced system. Low seeding rate within the tradition system decreased yield 15.9 bu A^{-1}. Lack of rainfall in June during grain fill period likely contributed to decreased yield at the lower seeding rate within traditional management. Despite some observed yield increases under traditional management, no input resulted in an increase in profitability. Traditional management resulted in comparable yields and significantly increased profitability when compared to enhanced management.

INTRODUCTION

Michigan winter wheat yields ranked 4th in the U.S. in 2018. (USDA-NASS, 2018). Increases in grain commodity prices since 2000, along with state record yields in 2015 and 2016 (USDA-NASS, 2018), has generated interest in enhanced management systems to maximize yield (Bluck et al., 2015). The purpose of enhanced wheat management is to control limiting factors in grain yield by changing several management practices (Harms et al., 1989). In contrast, traditional management systems use recommended integrated pest management (IPM) strategies to justify input applications (Mourtzinis et al., 2016). In Virginia, Joseph et al., (1985) found that lower seeding rates yielded greater than higher seeding rates due to increased light interception and less interplant competition for moisture and nutrients. Enhanced management systems typically utilize a greater seeding rate, but decreased seeding rates may produce fewer heads per unit area and increase the number of kernels per head (Darwinkel et al., 1977). Lower seeding rates may maximize the use of other agronomic inputs utilized in an enhanced management system.

A phosphorus based autumn starter may increase autumn tillering which increases the number of heads (Hergert and Shaver, 2009). Fungicides are included within enhanced management programs to limit yield loss from foliar diseases (Beuerlein et al., 1989). Enhanced wheat management systems often include greater N rates which increases the potential for lodging. Adding a plant growth regulator to an enhanced management system may reduce yield loss during lodging occurrence (Roth and Marshall, 1987; Beuerlein et al., 1989). Split applications of nitrogen may reduce the amount of N loss when leaching or denitrification conditions are present which may improve yield. In Europe, Dilz (1971) found that two split applications of N increased yield 18 bu A^{-1}. However, weekly or spoon-fed applications of nitrogen (N) have not been broadly explored as a component within enhanced managed systems.

The objective of this study was to evaluate soft red winter wheat growth, grain quality, grain yield, and economic profitability in response to weekly nitrogen (N) applications, increased N rate, seeding rate, autumn-applied starter fertilizer, plant growth regulator, and fungicide across intensive (i.e. high-input) and traditional (i.e. low-input) production systems. An omission trial design was utilized to determine whether the removal of an input from an intensive management system or the addition of an input to a traditional management system affected grain yield or return on investment.

MATERIALS AND METHODS

Trials were conducted in Lansing, MI on a Capac loam soil with pre-plant soil characteristics (0-8 inch) including 7.0 pH, 12 ppm P, 80 ppm K, 8 ppm S, and 2.5 ppm Zn. A blanket application of 130 lbs P_2O_5 (0-45-0) and 36 lbs K_2O (0-0-62) were broadcast applied according to soil test recommendations. The field was previously cropped to corn (*Zea mays* L.) and tilled prior to planting. Individual plots measured 8 ft. in width by 25 ft. in length with a 7.5 in. row spacing. Plots were arranged in a randomized complete block design with four replications. Soft red winter wheat variety 'Starburst' (Michigan Crop Improvement Assoc., Okemos, MI), a short strawed, high yielding, mid maturing variety was planted on 20 Sept. 2017.

An omission treatment design was used to determine individual and a combination of inputs (Table 1). An omission design utilizes two treatment controls, one containing all studied inputs (enhanced management control with low seeding rate) and one containing none of the studied inputs (traditional management control with high seeding rate) (Bluck et al., 2015). In order to evaluate treatment effects, inputs removed from the enhanced management system are compared only to the enhanced management control and inputs added into the traditional management system are compared only with the traditional management control (Bluck et al., 2015). Specific inputs evaluated included seeding rate (1.8 million seeds A^{-1} and 0.9 million seeds A^{-1}), fungicide applied at Feekes 9, plant growth regulator applied at Feekes 6, autumn starter (12-40-0-10S-1Zn, MESZ) as autumn top-dress, weekly N applications starting at Feekes 4, and high N (+33%, 133 lbs. N A^{-1}).

Plots were trimmed to 21 feet to remove border effect. Grain yield was harvested from the center 3.75 ft. of each plot utilizing a small-plot combine (Almaco, Nevada, IA) on 11 July 2018 and adjusted to 13.5% moisture. Economic profitability was calculated from input cost estimates of US$21.60, $43.20, $19.88, $15.13, $73.13, $54.49, and $6.80/week A^{-1} for low seeding rate, high seeding rate, fungicide, plant growth regulator, autumn starter, high N, and weekly nitrogen application, respectively. An additional cost of \$7.75 A^{-1} was added as an application cost for nitrogen fertilizer, fungicide, and plant growth regulator; an additional cost of \$6.54 A^{-1} was added as an application cost for autumn starter. Net returns were calculated by multiplying a commodity grain price of \$4.51 bu^{-1} by grain yield and subtracting total treatment cost. Product, application, and harvest grain estimates were taken from local agriculture retailers and grain elevators.

PRELIMINARY RESULTS AND DISCUSSION

Weekly nitrogen applications and a 33% increase in N fertilizer (i.e. high N rate) did not significantly affect grain yield at either production intensity level (Table 2). Below average rainfall throughout the growing season and the ensuing lack of N-loss conditions may have contributed to the lack of response to the high N fertilizer rate (Table 3). Dry soil conditions may have prevented wetting fronts from moving N out of the rhizosphere resulting in minimal responses to weekly N applications. Total rainfall for the growing season was 46% less than the 30-yr mean suggesting minimal leaching and denitrification opportunities occurred. Gravelle et al (1988) found split N applications only increased yield under N loss conditions. Profitability decreased by US\$93.11 A^{-1} when weekly N applications were added to traditional management and increased US\$66.79 A^{-1} when removed from enhanced management indicating application costs overrode any yield response (Table 2).

Plant growth regulator decreased yield by 12.9 bu A^{-1} when added into the traditional management system (Table 2). Soft red winter wheat variety 'Starburst' is a shorter stature high stem strength variety much less susceptible to lodging. No lodging occurred during this study year. Results agree with Swoish and Steinke (2017) who determined yield increases from a PGR application were more probable in varieties with taller mean stature and weaker stem characteristics. Yield decreases when added to traditional management were likely due to the inability to effectively mobilize nutrients and capture light during the grain fill period due to plant growth restrictions from an already short-statured variety. Nonetheless, the idea that a prophylactic PGR application may allow the use of greater N rates was not supported in the current study.

Autumn starter fertilizer (i.e., MicroEssentials SZ (MESZ)) was the only input which increased yield when added to traditional management and decreased yield when removed from the enhanced management system. Yield decreased 14.2 bu A^{-1} with autumn starter removed from the enhanced management and increased 10.1 bu A^{-1} when added to the traditional management (Table 2). Autumn starter applied as a top-dress application soon after planting may promote additional autumn tillering as an additional 72 tillers ft^{-2} were observed with MESZ added to the traditional management system. Remember that a blanket P_2O_5 application occurred across all plots and that wheat is generally found as non-responsive to Zn in many Michigan soils despite testing below critical values in this field (Warncke et al., 2009). Within the enhanced management system, removal of autumn starter fertilizer decreased canopy coverage 5.5% at Feekes 4 but increased Feekes 4 canopy coverage by 9.3% when added to the traditional management system. At Feekes 5, removal of autumn starter from the enhanced management system decreased canopy coverage 17.4% but increased 10.9% when added to the traditional management system. Plant height data paralleled the canopy coverage with height reductions of 7.1 cm when removed from the enhanced management but height increases of 6.6 cm when added to traditional management. Despite a reduction in kernels per head, head counts increased by 17% with autumn starter added to traditional management.

Fungicide removal from the enhanced management system decreased yield 12.0 bu A^{-1} (Table 2). Prior rain events and warm temperatures during anthesis (F10.5.1) increased the risk for Fusarium Head Blight (FBH) infection. The quantity of heads affected by FHB increased 8.2% with fungicide removal from the enhanced management system (Table 4). Removal of the fungicide from the enhanced system also reduced 1000 kernel weight 4%. Although addition of a fungicide to traditional management did not affect yield, 1000 kernel weight increased 3.6%. Despite yield reductions with fungicide removal from enhanced management, profitability was not affected (Table 2).

Traditional management with low seeding rate reduced yield 15.9 bu A^{-1}, but seeding rate did not affect yield within the enhanced management system (Table 2). Dry conditions during grain fill likely contributed to the decreased yield. June rainfall was 58% lower than the 30 yr mean (Table 3). Low seeding rate under traditional management increased kernels per head 11%. During grain fill, wheat performs best under cool (below 80 degrees Fahrenheit) air temperatures as the plant utilizes energy for respiration at > 85 degrees Fahrenheit (Pennington et al., 2018). Profitability decreased US$49.91 A^{-1} under traditional management with low seeding rate (Table 2). Although yield was reduced, no difference occurred in head counts or tiller counts between either seeding rate across both enhanced and traditional management systems (data not shown). Lower winter wheat seeding rates do not come without some additional risk however as excessive winter snowfall and ice, lack of winter snowfall, or variable spring precipitation patterns may all adversely affect stand counts and survival.

Despite observed yield increases, no single input resulted in increased profitability (Table 2). Wheat prices in 2018 remained lower than the previous eight years with the exception for 2017 (USDA-NASS, 2018). The enhanced management system produced comparable yields under both seeding rates, however, the traditional management system increased yield 15.9 bu A^{-1} at the higher seeding rate compared to the lower seeding rate (Table 2). Profitability was not affected under either seeding rate in the enhanced management system. When compared to the lower seeding rate under traditional management, greater seeding rate increased profitability US$49.91 A^{-1} (Table 2). Management system did not affect yield, however, traditional management increased profitability US$96.96 A^{-1} over enhanced management (Table 2). All of the inputs contained in this study have shown positive responses under various management regimes. However both grain yield and profitability need continued emphasis moving forward in addition to matching specific inputs with varietal characteristic in lieu of prophylactic applications.

REFERENCES

Beuerlein, J. E., E. S. Oplinger, and D. Reicosky. 1989. Yield and Yield Components of Winter Wheat Cultivars as Influenced by Management—A Regional Study. J. Prod. Agric. 2:257-261. doi:10.2134/jpa1989.0257.

Bluck, G.M., L.E. Lindsey, A.E. Dorrance, and J.D. Metzger. 2015. Soybean yield response to rhizobia inoculant, gypsum, manganese fertilizer, insecticide, and fungicide. Agron. J., 107:1757-1765. doi:10.2134/agronj15.0094

Darwinkel, A., B.A. ten-Hag, and Kuizenga. 1977. Effect of Sowing Date and Seed Rate on Crop Development and Grain Production of Winter Wheat. Neth. J. Agric. Sci, 25;83-94.

Dilz, K. 1971. Effect of time of chlormequat application, level of nitrogen and split nitrogen on resistance to lodging and yield of winter wheat. Neth. Nitrogen Tech. Bull. no. 10.

Gravelle, W. D., M. M. Alley, D. E. Brann, and K. D. S. M. Joseph. 1988. Split Spring Nitrogen Application Effects on Yield, Lodging, and Nutrient Uptake of Soft Red Winter Wheat. J. Prod. Agric. 1:249-256. doi:10.2134/jpa1988.0249

Harms, C. L., J. E. Beuerlein, and E. S. Oplinger. 1989. Effects of Intensive and Current Recommended Management Systems on Soft Winter Wheat in the U.S. Corn Belt. J. Prod. Agric. 2:325-332. doi:10.2134/jpa1989.0325

Hergert, G. W., Shaver, T. M., 2009. Fertilizing Winter Wheat. Bull. EC143. University of Nebraska Lincoln Extension, Lincoln, NE.

Joseph, K. D. S. M., M. M. Alley, D. E. Brann, and W. D. Gravelle. 1985. Row Spacing and Seeding Rate Effects on Yield and Yield Components of Soft Red Winter Wheat1. Agron. J. 77:211-214. doi:10.2134/agronj1985.00021962007700020009x

Mourtzinis, S., D.A. Marburger, J.M. Gaska, and S.P. Conley. 2016. Characterizing soybean yield and quality response to multiple prophylactic inputs and synergies. Agron. J. 108:1337-1345. doi:10.2134/agronj2016.01.0023

National Agricultural Statistics Service. 2017. USDA-NASS agricultural statistics 2018. USDA-NASS. http://www.nass.usda.gov (accessed 30 Aug. 2018).

Pennington, D., E. Olson, J. Turkus, S. Martin. 2018. Michigan state wheat performance trials. https://varietytrials.msu.edu/wp-content/uploads/2018/08/2018-State-Report-Final (accessed 30 Aug. 2018).

Roth, G.W., and H.G. Marshall. 1987. Effect of time of nitrogen fertilization and a fungicide on soft red winter wheat. Agron. J. 79: 197-200.

Swoish, M., and K. Steinke. Plant growth regulator and nitrogen applications for improving wheat production in Michigan. Crop Forage Turfgrass Manage. 3:1-7. doi:10.2134/cftm2016.06.0049

Warncke, D., J. Dahl, and L. Jacobs. 2009. Nutrient Recommendations for field crops in Michigan. Bull. E2904. Michigan State Univ. Ext., East Lansing, MI.

Table 1. Overview of omission treatment design, treatment names, and inputs applied in 2017-18 (Bluck et al., 2015).

Treatment	Treatment Name	Agronomic Input Applied					
		LS†	Fungicide‡	PGR§	MESZ¶	28% SPN#	High-N††
1	**Enhanced (E)**	Yes	Yes	Yes	Yes	Yes	Yes
2	E without L.S.	No	Yes	Yes	Yes	Yes	Yes
3	E without Fungicide	Yes	No	Yes	Yes	Yes	Yes
4	E without PGR	Yes	Yes	No	Yes	Yes	Yes
5	E without MESZ	Yes	Yes	Yes	No	Yes	Yes
6	E without Weekly	Yes	Yes	Yes	Yes	No	Yes
7	E without High-N	Yes	Yes	Yes	Yes	Yes	No
8	**Traditional (T)**	No	No	No	No	No	No
9	T with L.S.	Yes	No	No	No	No	No
10	T with Fungicide	No	Yes	No	No	No	No
11	T with PGR	No	No	Yes	No	No	No
12	T with MESZ	No	No	No	Yes	No	No
13	T with Weekly N	No	No	No	No	Yes	No
14	T with High-N	No	No	No	No	No	Yes
15	Check	No	No	No	No	No	No

† Low seeding (L.S.) rate of soft red winter wheat (Starburst) at 0.9 million seeds A^{-1}.
‡ Fungicide applied at a rate of 8.2 oz A^{-1} at F10.5.1 growth stage.
§ Plant growth regulator applied at a rate of 12 oz A^{-1} at F6 growth stage.
¶ Granular fertilizer MESZ (12-40-0-10S-1Zn) at a rate of 250 lbs A^{-1} autumn applied.
# Weekly applications of UAN (28%) applied at a rate of 16.6 lbs N A^{-1} starting at F4 growth stage.
††High-nitrogen applied at a rate of 133 lbs N A^{-1} at F3 growth stage.

Table 2. Grain yield and economic net return values for 2018. Shown is average grain yield and economic profitability of enhanced and traditional control treatments. All other treatments show change in grain yield or economic profitability from respective enhanced or traditional control.

	Lansing, MI	
Treatment	**Yield**	**Profitability**
	------------bu A^{-1}-----------	**-------------US$ A^{-1}------------**
Enhanced (E)	**104.7**	**202.63**
E w/o L.S.†	+4.5	-1.42
E w/o Fungicide	-12.0*	-26.40
E w/o PGR	+3.6	+38.94
E w/o MESZ	-14.2*	+15.81
E w/o Weekly N	+2.8	+66.79*
E w/o High-N	+2.6	+24.90
Traditional (T)	**86.8**	**299.59**
T w/ L.S. ‡	-15.9*	-49.91*
T w/ Fungicide	-1.2	-33.13
T w/ PGR	-12.9*	-80.87*
T w/ MESZ	+10.1*	-34.17
T w/ Weekly N	-5.2	-93.11*
T w/ High-N	-2.8	-26.00
E vs T	ns§	*
Check¶	42.35	147.81

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

† Values in E w/o input rows indicate a yield (bu A^{-1}) or net return (US$ A^{-1}) change from respective enhanced (E) treatment.

‡ Values in T w/ input rows indicate a yield (bu A^{-1}) or net return (US$ A^{-1}) change from respective traditional (T) treatment.

§ Non-significant

¶ Untreated check containing no fertilizer or additional inputs was not included in statistical analysis.

Table 3. Monthly cumulative precipitation totals for the soft red winter wheat growing season, Lansing, MI, 2018.

Year	March	April	May	June	July	Total
			--------------------------- in ---------------------------------			
2018	0.99	2.38	4.97	1.44	1.07	10.85
30-yr avg.	2.06	3.36	8.53	3.45	2.84	20.24

† Precipitation data was collected from Michigan State University Enviro-weather (https://enviroweather.msu.edu/). 30-yr means were obtained from the National Oceanic and Atmospheric Administration (https://www.ncdc.noaa.gov/cdo-web/datatools/normals).

Table 4. Influence of Feekes 10.5.1 fungicide on head disease occurrence 3 weeks after application, 2018.

Location	Treatment			
	Enhanced (E)	E w/o Fungicide†	Traditional (T)	T w/ Fungicide‡
	------------------------------ % heads affected -------------------------------------			
Lansing	9.31	+8.16*	16.94	-6.97

† Values in E w/o fungicide column indicate a heads affected (%) change from respective enhanced (E) treatment.

‡ Values in T w/ fungicide column indicate a heads affected (%) change from respective traditional (T) treatment.

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