Intensive Management: Realizing Maximum Yield Potential of Winter Wheat Year 2
2019 Report to the Michigan Wheat Program
(17-08-06-BS)

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Location: Lansing, MI	**Tillage**: Conventional
Planting Date: October 19, 2018	**Nitrogen Rates**: 100 & 133 lbs. N/A
Soil Type: Capac Loam; 7.1 pH, 12.0 meq 100g^{-1} CEC, 2.8% OM 33 ppm P (Bray P), 8 ppm S, 3.4 ppm Zn	**Population**: 0.9 million seeds/A 1.8 million seeds/A
Variety: Starburst	**Replicated**: 4 replications

Location: Richville, MI	**Tillage**: Conventional
Planting Date: September 24, 2018	**Nitrogen Rates**: 130 & 173 lbs. N/A
Soil Type: Tappan-Londo Loam; 8.0 pH, 20.3 meq 100g^{-1} CEC 2.0% OM, 7 ppm P (Olsen P), 6 ppm S, 5.7 ppm Zn	**Population**: 0.9 million seeds/A 1.8 million seeds/A
Variety: Jupiter	**Replicated**: 4 replications

Introduction:

Heightened awareness of both climate and soil spatial variabilities combined with capacities to produce high-yielding, high-quality winter wheat (*Triticum aestivum* L.) have many growers focusing their input applications within enhanced (i.e. multiple-input) management systems (Rosenzweig et al., 2001; Crane et al., 2011; Quinn and Steinke, 2017). Enhanced management aims to reduce the risk of yield loss by adopting additional management practices (Harms et al., 1989; Mourtzinis et al., 2016). However, enhanced management systems may also include prophylactic applications of inputs, which may add significant production costs with minimal net return (Mourtzinis et al., 2016). In contrast, a traditional management system utilizes University recommended integrated pest management (IPM) strategies to justify input applications at certain thresholds, which may increase expected net return (Mourtzinis et al., 2016).

Previous research evaluating wheat response to multiple agronomic and nutrient inputs includes: nitrogen (N) fertilizer, seeding rate, plant growth regulator (PGR), and fungicide (Beuerlein et al., 1989; Paul et al., 2010; Knott et al., 2016; Swoish and Steinke, 2017). Due to increased light interception and less interplant competition, decreased seeding rates may improve grain yield (Joseph et al., 1985). Although increased seeding rates are typically utilized in enhanced management systems, decreased seeding rates may utilize each input more efficiently in a multiple-input management system (Darwinkel et al., 1977). Enhanced management systems often include fungicide applications to improve disease control and prevent yield reductions (Brinkman et al., 2014; Mourtzinis et al., 2017). Autumn starter fertilizer may increase autumn tillering thus producing a greater number of heads which may increase grain yield (Hergert and Shaver, 2009). Weekly N applications may reduce leaching or denitrification N losses when those conditions exist (Alcoz et al., 1993). Weekly N applications have not been broadly explored as a component within enhanced management systems.

Objective and Hypothesis:

Objective 1: Evaluate seeding rate, fungicide, plant growth regulator, autumn starter fertilizer, weekly N applications, and high N management effects on soft red and white wheat grain yield and profitability across different production intensity levels. Our *working* hypothesis is that an enhanced management system at a reduced seeding rate will allow each plant to utilize inputs more efficiently resulting in greater yield potential with subsequent yield potential losses as inputs are individually removed from the enhanced system. The traditional management system will result in the lowest yield potential with yield increases as inputs are individually added to the traditional system.

Methods and Procedures:

An omission trial design was used to determine individual and combination input responses (Table 1). An omission trial design contains two treatment controls, one containing all inputs (i.e., enhanced management system at the decreased seeding rate) and one containing no inputs (i.e., traditional management at the increased seeding rate). To evaluate treatment effects, inputs removed from the enhanced management system are only compared to the enhanced control and inputs added into the traditional management system are only compared to the traditional control.

Table 1. Overview of omission trial design, treatment names, and inputs applied in 2019.

		Agronomic Input Applied					
Treatme	Treatment Name	DS	Fung.‡	PGR§	A.S.¶	Weekly N#	High-N††
1	**Enhanced (E), D.S.†**	**Ye**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
2	E without D.S.	**No**	Yes	Yes	Yes	Yes	Yes
3	E without Fungicide	Ye	**No**	Yes	Yes	Yes	Yes
4	E without PGR	Ye	Yes	**No**	Yes	Yes	Yes
5	E without A.S.	Ye	Yes	Yes	**No**	Yes	Yes
6	E without Weekly N	Ye	Yes	Yes	Yes	**No**	Yes
7	E without High-N	Ye	Yes	Yes	Yes	Yes	**No**
8	**Traditional (T), I.S.** €	**No**	**No**	**No**	**No**	**No**	**No**
9	T with D.S.	**Ye**	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 A.S.	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

† Decreased seeding (D.S.) rate of SWWW (Jupiter) in Richville & SRWW (Starburst) in Lansing at 0.9 million seeds A^{-1}.

€ Increased seeding (I.S.) rate of SWWW (Jupiter) in Richville & SRWW (Starburst) in Lansing at 1.8 million seeds A^{-1}.

‡ Fungicide (Fung.) applied at a rate of 8.2 oz. A^{-1} at F10.5.1 growth stage.

§ Plant growth regulator (PGR) applied at a rate of 12 oz. A^{-1} at F6 growth stage.

¶ Autumn starter (A.S.) granular fertilizer (12-40-0-10S-1Zn) at a rate of 250 lbs. A^{-1} autumn applied.

Weekly applications (Weekly N) of UAN (28%) applied at a rate of 21.6 lbs. N A^{-1} in Richville and 16.6 lbs. N A^{-1} in Lansing starting at F4 growth stage.

††High-nitrogen applied at a rate of 173 lbs. N A^{-1} in Richville and 133 lbs. N A^{-1} in Lansing and at F3 growth stage.

Year Two (2018-2019) Results and Discussion:

Weekly nitrogen applications did not affect grain yield at either production intensity level or location (Table 2). June 2019 rainfall was 19 and 20% greater than the 30-year mean at Richville and Lansing (Table 3), respectively, but the increased rainfall was insufficient for promoting large enough N losses to realize benefits from weekly N applications. Results correlate with Gravelle et al (1988) who found split N applications only increased grain yield when N loss conditions were present. High N management, that is a 33% increase in N fertilizer, did not significantly affect grain yield within either production intensity level or location (Table 2). A lack of visual N deficiency symptoms at both locations suggests base N rates were sufficient and minimal N losses (i.e. leaching and denitrification) occurred. Results agree with Quinn and Steinke (2017) who found no positive yield response utilizing an increased (+20%) N rate under a multiple-input versus traditional-input management system. A prolonged period of above normal rainfall throughout the Michigan winter wheat growing season may better substantiate a grain yield benefit from weekly N applications or high N management. Removing weekly N applications from enhanced management increased expected net return US$73.30 and

$85.38 at Richville and Lansing, respectively, while weekly N applications decreased expected net return US$66.24 when added to traditional management at Richville (Table 4). Potential profitability results suggest that application costs of weekly N may override a potential grain yield response in the specific environments tested. Although high N management did not affect expected net return at either location, high N management decreased agronomic efficiency 11-38% and 10-33% in Richville and Lansing, respectively (Table 4).

Table 2: Grain yield changes shown for enhanced and traditional systems across both locations, 2019.

	Location	
Treatment	**Richville (White)**	**Lansing (Red)**
	----------------------------**Bu A^{-1}**----------------------------	
Enhanced (E), D.S. †	**125.1**	**114.7**
E without D.S. ‡	-1.2	+6.5
E without Fungicide	-9.1*	-9.5
E without PGR	-2.4	+4.3
E without Autumn Starter	-18.7*	-37.5*
E without Weekly N	+3.8	+6.6
E without High-N	+3.0	+0.1
Traditional (T), I.S.	**98.9**	**79.7**
T with D.S. §	-4.6	-4.7
T with Fungicide	+8.9	+12.3*
T with PGR	+8.2	+7.8
T with Autumn Starter	+17.4*	+25.9*
T with Weekly N	+0.7	+5.6
T with High-N	+9.3	+5.4
Check¶	46.8	51.6
E vs T#	*	*

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

† Decreased seeding rate (D.S.), trinexapac-ethyl plant growth regulator (PGR), weekly N applications (Weekly N), 33% increase in nitrogen fertilizer rate (High-N), increased seeding rate (I.S.).

‡Values in E - input rows indicate an expected return (US$ ha^{-1}) change from respective enhanced (E) treatment.

§Values in T + input rows indicate an expected return (US$ ha^{-1}) change from respective traditional (T) treatment.

¶ Non-treated check containing no fertilizer or additional inputs was not included in statistical analysis.

Comparison between the enhanced and traditional treatment utilizing single degree of freedom contrasts

Table 3. Monthly cumulative precipitation totals for the winter wheat spring growing season, Richville and Lansing, MI, 2019.

Location	Year	March	April	May	June	July	Total
		---------------------------- in ---------------------------------					
Richville	2019	1.33	2.27	5.02	6.97	2.37	17.96
	30-yr avg.	1.93	3.19	3.29	3.53	3.10	15.04
Lansing	2019	1.95	2.85	3.35	7.22	2.30	17.67
	30-yr avg.	2.06	3.03	3.36	3.45	2.84	14.74

† 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. Changes in expected net return for enhanced and traditional systems across locations, 2019.

	Location	
Treatment	**Richville (White)**	**Lansing (Red)**
	---------------------------US$ A^{-1}-----------------------------	
Enhanced (E), D.S. †	331.51	265.69
E without D.S. ‡	-25.15	+10.00
E without Fungicide	-17.82	-16.98
E without PGR	+11.50	+43.40
E without Autumn Stater	-13.07	-96.82*
E without Weekly N	+73.30*	+85.38*
E without High-N	+34.73	+15.54
Traditional (T), I.S.	386.87	280.60
T with D.S. §	-3.78	-1.56
T with Fungicide	+16.56	+30.26
T with PGR	+17.69	+13.52
T with Autumn Starter	+6.71	+41.79
T with Weekly N	-66.24*	-43.34
T with High-N	+26.45	+10.39
Check¶	195.12	201.98
E vs T#	*	ns††

* Significantly different at α=0.1 using single degree of freedom contrasts.
† Decreased seeding rate (D.S.), trinexapac-ethyl plant growth regulator (PGR), weekly N applications (Weekly N), 33% increase in nitrogen fertilizer rate (High-N), increased seeding rate (I.S.).
‡Values in E - input rows indicate an expected return (US$ ha^{-1}) change from respective enhanced (E) treatment.
§Values in T + input rows indicate an expected return (US$ ha^{-1}) change from respective traditional (T) treatment.
¶ Non-treated check containing no fertilizer or additional inputs was not included in statistical analysis.
# Comparison between the enhanced and traditional treatment utilizing single degree of freedom contrasts
†† Non-significant α=0.1 using single degree of freedom contrasts.

Removal of fungicide from enhanced management decreased grain yield 9.1 bu A^{-1} at Richville, but grain yield remained unaffected by fungicide removal at Lansing (Table 2). The quantity of heads affected by Fusarium head blight (FHB) increased 10.9% when fungicide was removed from enhanced management in Richville. Addition of fungicide to traditional management increased grain yield 12.3 bu A^{-1} at Lansing (Table 2). The quantity of heads affected by FHB decreased 2.9% when fungicide was added to traditional management at Lansing. At or above average May rainfall occurred at both locations. When rainfall occurs during growing stage Feekes 10.5.1 (i.e., flowering), FHB infection risk increases and may affect grain yield. Despite grain yield reductions with fungicide removal from enhanced management and grain yield increases with fungicide additions to traditional management, expected profitability was not affected at either location (Table 4).

Plant growth regulator did not affect grain yield at either location (Table 2). Richville and Lansing utilized varieties ‘Jupiter’ and ‘Starburst’, respectively, which both demonstrate short plant height and high stem strength plant characteristics. No significant lodging occurred at either location across both management intensity systems. Results agree with Swoish and Steinke (2017) who determined grain yield increases from a PGR application were more likely in varieties with taller height and weaker stem characteristics. Results from this study suggest positive responses to PGR application may depend more upon variety characteristics including lodging susceptibility rather than applying greater than recommended rates of N. Additionally any increases in overall tiller production must be sufficient to overcome reduction in shoot growth or biomass. Current results do not support the notion that PGR application may allow for the use of increased N rates to increase grain yield.

Autumn starter fertilizer was the only input to decrease grain yield when removed from enhanced management AND increase grain yield when added to traditional management across both locations. Grain yield decreased 18.7 and 37.5 bu A^{-1} when autumn starter fertilizer was removed from enhanced management, and grain yield increased 17.4 and 25.9 bu A^{-1} when autumn starter fertilizer was added to traditional management at Richville and Lansing, respectively (Table 2). The critical soil test P concentration for winter wheat is 25 ppm (Warncke et al., 2009). Pre-plant soil P concentrations consisted of 17-33 ppm, suggesting potential for a positive grain yield response to P applications (Table 5). However, blanket P_2O_5 applications occurred across all plots at both locations indicating positive grain yield response to P was unlikely. Additionally, wheat has generally classified as non-responsive to Zn applications in many Michigan soils despite testing below critical values thus likely eliminating a zinc response within the autumn starter fertilizer (Warncke et al., 2009). Grain yield responses may have been due to the N and or S components promoting early plant growth and development as pre-plant nitrate concentrations were < 5 ppm and significant yield responses to 25 lbs. S/A have become increasingly observed. Despite positive grain yield responses, autumn starter fertilizer did not increase expected net return at either location (Table 4).

Table 5. Site year and soil characteristics including soil chemical properties and mean P, K, S, and Zn soil test (0 – 15 cm) nutrient concentrations obtained prior to winter wheat planting, Richville and Lansing, MI, 2019.

		Soil	Soil Test†						
Site	Year	Description	P	K	S	Zn	pH	OM	CEC
			----------ppm------------					--%--	meq $100g^{-1}$
Richville	2019	Tappan-Londo Loam	7	137	6	5.7	8.0	2.0	20.3
Lansing	2019	Capac Loam	33	102	8	3.4	7.1	2.8	12.0

†P phosphorus (Bray–P1) or Olsen depending upon pH; K potassium (ammonium acetate extractable K); S sulfur (monocalcium phosphate extraction); Zn zinc (0.1 M HCl)

Seeding rate did not affect grain yield under either production intensity level across locations (Table 2). Seeding rate of 0.9 million seeds per acre resulted in similar grain yields compared to 1.8 million seeds per acre under enhanced and traditional management (Figs. 1, 2). Seeding rate did not influence expected net return at either location (Figs. 3, 4). Although grain yield and expected net return were similar for both seeding rates, heavy winter snowfall, winter ice sheeting, and variable spring precipitation all add additional risk to reduced winter wheat seeding rates, which may affect winter hardiness and spring plant survival.

Enhanced management including all inputs increased grain yield 26.2 and 35.0 bu A^{-1} compared to traditional management, which included no inputs and merely a base N rate at Richville and Lansing, respectively (Fig. 5). When added to traditional management, autumn starter fertilizer accounted for 66 and 71% of the grain yield difference between enhanced and traditional management in Richville and Lansing, respectively. Traditional management increased expected net return US$55.36 A^{-1} compared to enhanced management at Richville (Fig. 6). At Lansing, however, larger grain yield increases from enhanced management offset cost of inputs resulting in similar expected net return compared to traditional management (Fig. 6). Despite the observed grain yield increases, no single input resulted in an increased expected net return (Table 4).

All of the inputs utilized in this study have shown positive yield responses under various management conditions. However, lack of wide-ranging positive yield responses to specific agronomic and nutrient inputs emphasizes the need for justifying inputs. Agronomic and nutrient input responses may depend on environmental and growth conditions along with variety characteristics and pre-plant soil nutrient concentrations. Results suggest producers should consider crop price, fertilizer cost, and potential yield response prior to adopting widely implemented enhanced management systems.

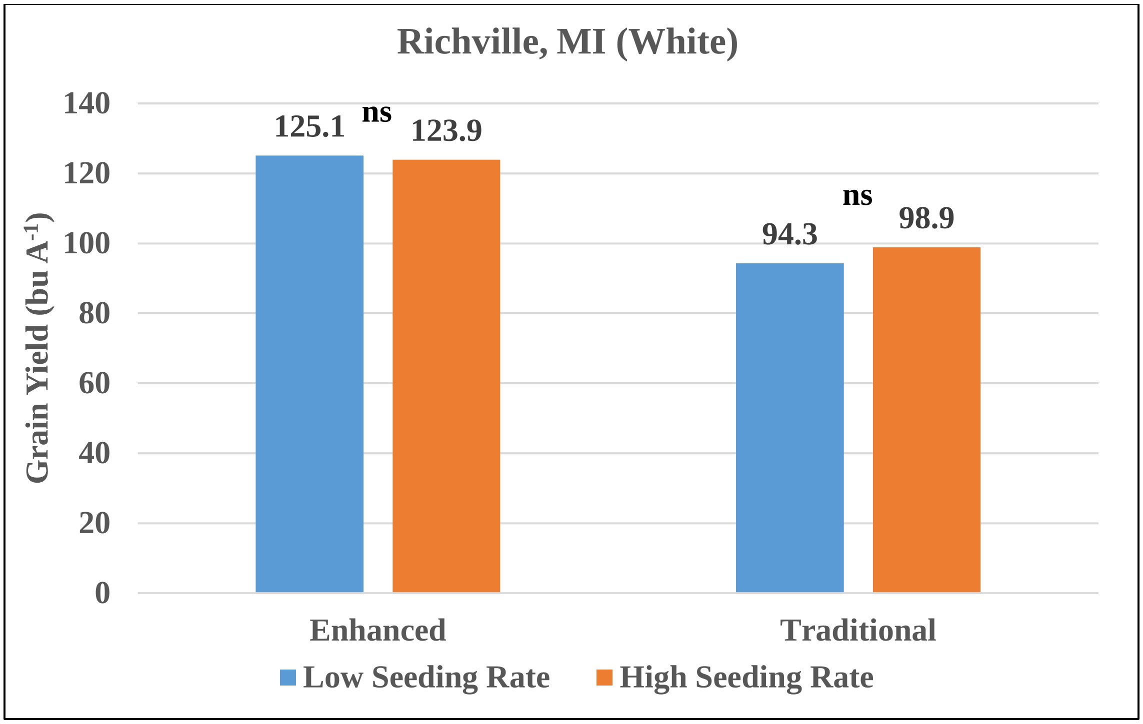

Figure 1. Grain yield comparison between enhanced and traditional management at both seeding rates (0.9 million seeds A^{-1} and 1.8 million seeds A^{-1}) in soft white winter wheat.

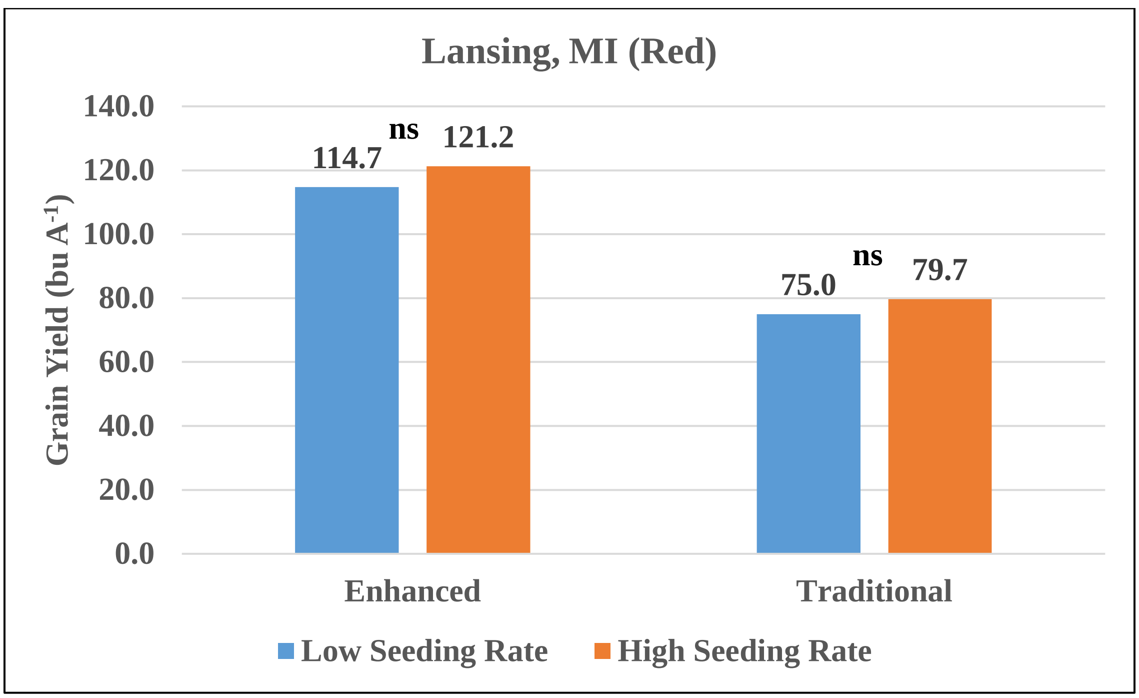

Figure 2. Grain yield comparison between enhanced and traditional management at both seeding rates (0.9 million seeds A^{-1} and 1.8 million seeds A^{-1}) in soft red winter wheat.

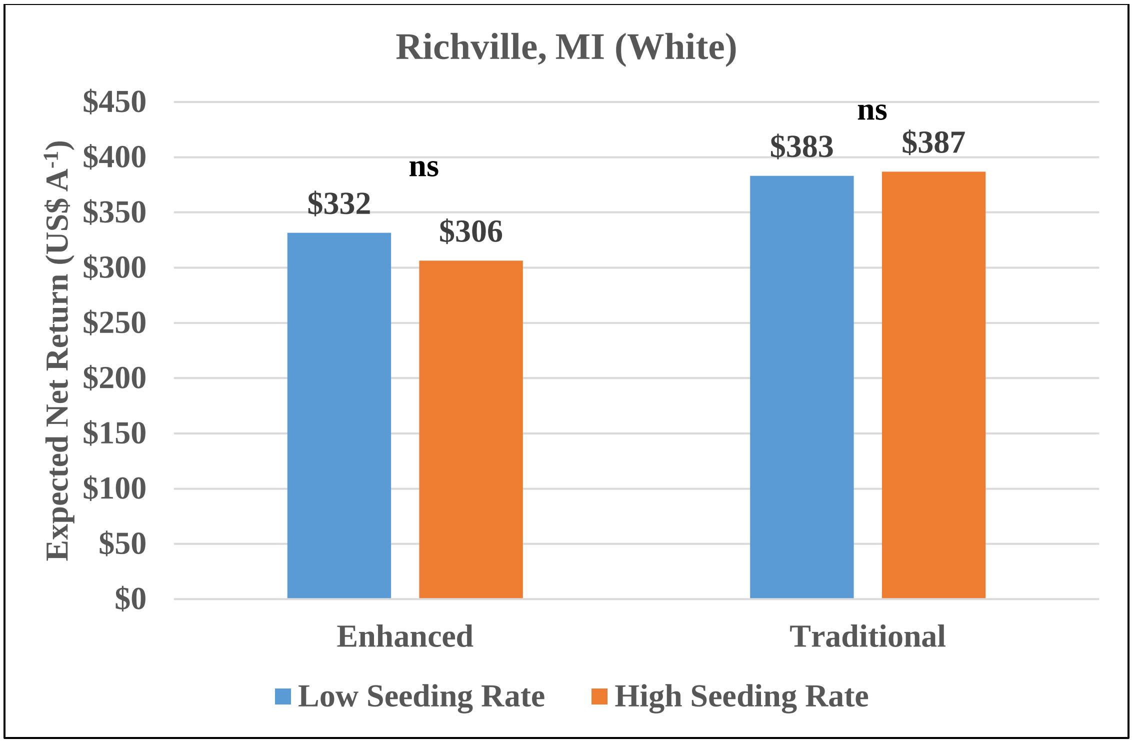

Figure 3. Profitability comparison between enhanced management and traditional management at both seeing rates (0.9 million seeds A^{-1} and 1.8 million seeds A^{-1}) in soft white winter wheat.

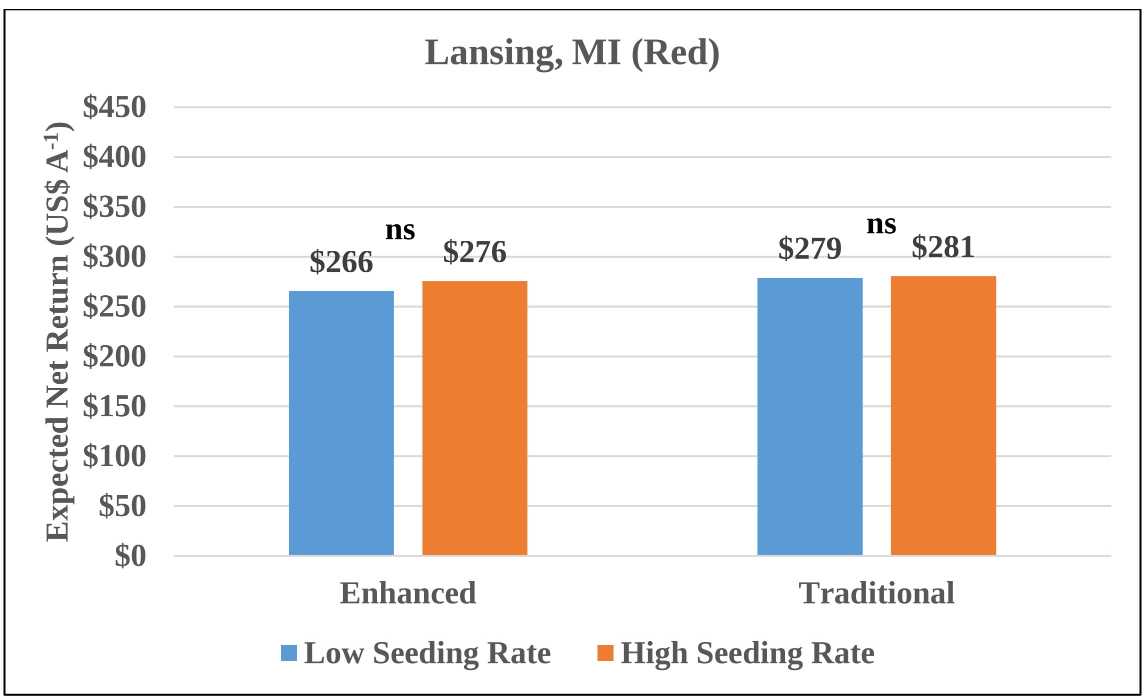

Figure 4. Profitability comparison between enhanced management and traditional management at both seeing rates (0.9 million seeds A^{-1} and 1.8 million seeds A^{-1}) in soft red winter wheat.

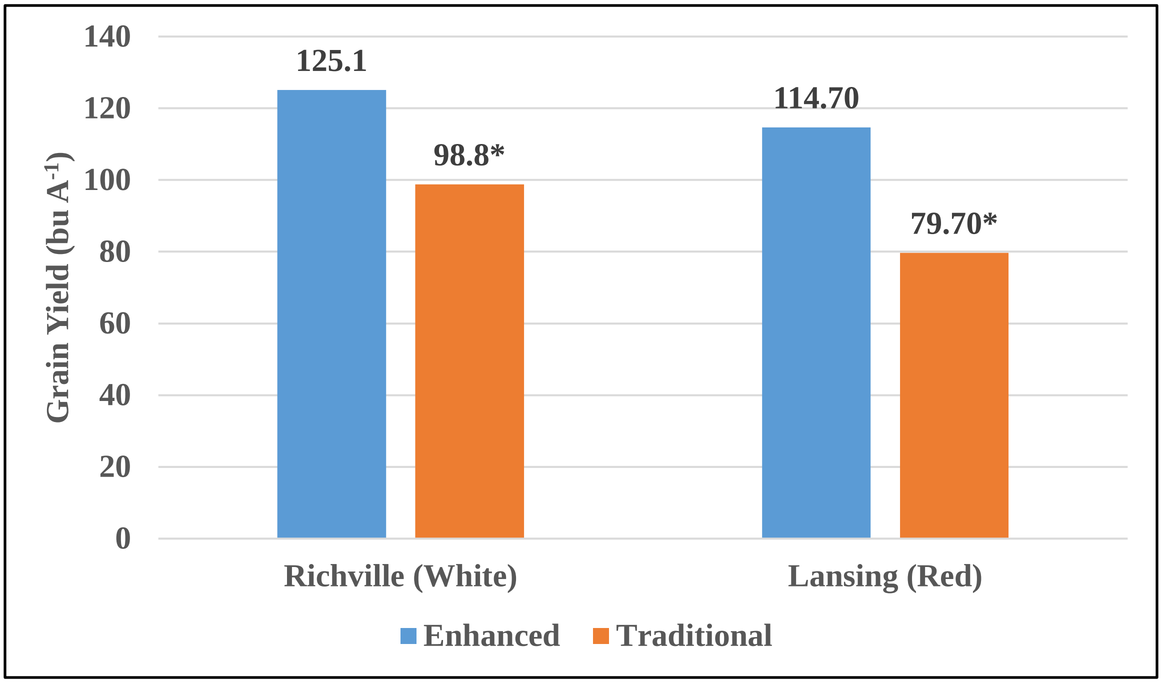

Figure 5. Grain yield comparison between enhanced management containing all inputs and traditional management containing only base N rate (100 or 130 lbs A^{-1}) across both locations in 2019. ***Significantly different at α=0.1

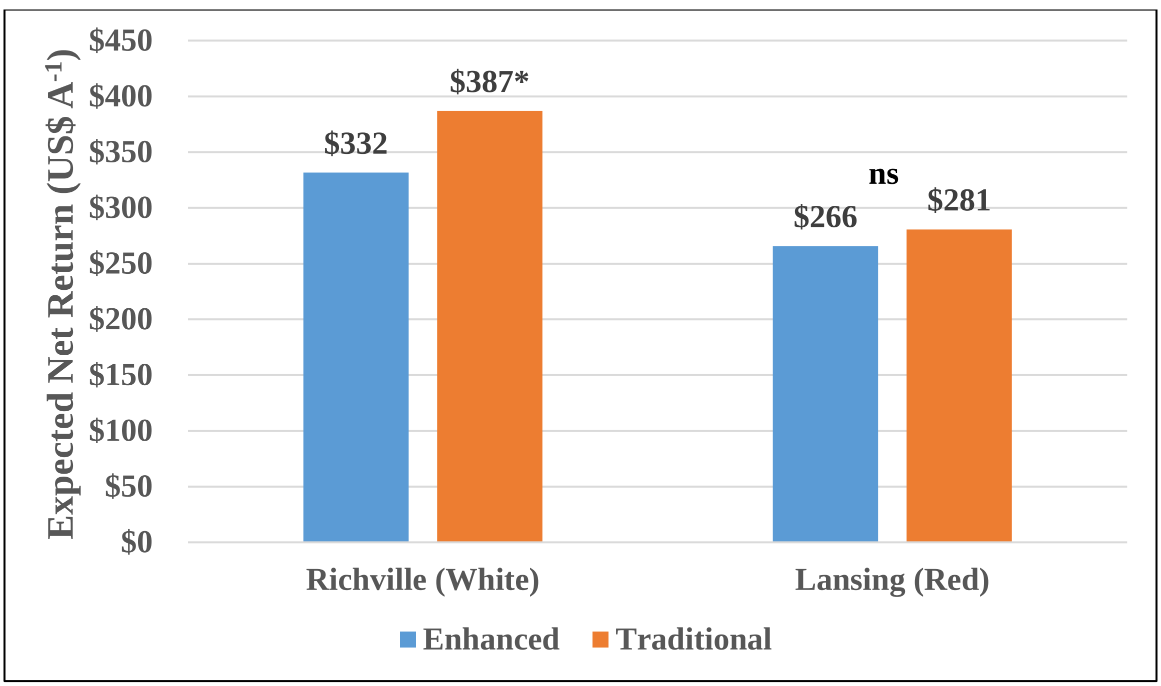

Figure 6. Profitability comparison between enhanced management containing all inputs and traditional management containing only base N rate (100 or 130 lbs A^{-1}) across both locations in 2019. ***Significantly different at α=0.1

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