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SUSTAINABLE FUNGICIDE AND NITROGEN MANAGEMENT TO MALTING BARLEY

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ABSTRACT

Malted grains, principally barley *(Hordeum vulgare L.),* are essential raw materials for brewing. Demand is increasing for more sustainable crop production practices and locally grown brewing ingredients, including malting barley for a nationally expanding microbrewing industry. At the same time, climate change makes it imperative to identify new production zones and cropping systems for malting barley using sustainable production practices. Sustainable malting barley management when added to an existing cropping system rotation such as corn, soybean, and alfalfa can provide an alternative crop in many of the cooler growing areas of the nation. The purpose of the two studies were to determine sustainable economic application rates of nitrogen and fungicides to malting barley varieties. University of Wisconsin-Madison Division of Extension faculty investigated production practices of nitrogen and fungicide applications to ten malting barley varieties and their effect on yield over three years. One study tested specific varieties with nitrogen rates at 0, 30, 60, and 90 pounds per acre. The other study investigated the application timing and fungicide product efficacy to eight malting barley varieties for control of Fusarium Head Blight and the effect on yield. The studies were conducted at two locations at Buffalo County and Chippewa County in 2018, 2019, and 2020. Results indicated significant differences within the nitrogen and fungicide applications to specific varieties during specific years and locations.

INTRODUCTION

The renaissance of the craft brewing industry in the United States over the past decade has raised interest in growing local ingredients for the industry. The number of craft breweries in the United States grew from 1,409 in 2006 to 8,275 in 2019 (Brewers Association, 2021). A major ingredient for beer is malt, primarily processed from specific malting barley varieties. Malting industry standards are very strict for malting barley varieties and if the standards are not met, the malting barley cannot be sold for brewing. A price difference exists between malting quality and feed grade barley. In 2018, an average price for malting barley was $5.90 per bushel versus $1.98 per bushel for feed grade barley.

The addition of an annual small grain such as malting barley to an existing cropping system can provide crop rotation and environmental benefits. Existing cropping systems such as those including corn, soybean, and alfalfa can benefit from the addition of malting barley to extend the length of the crop rotation. These benefits include potential breaking or delaying of pest emergence issues, especially those related to crop disease management (Marburger et al., 2015). Nitrogen and fungicide applications are two production practices requiring additional inputs for farmers to economically produce high quality malting barley. Management of these two inputs can impact quality of malting barley and long-term sustainability for the crop to remain in a cropping system.

Fusarium Head Blight (FHB; *Fusarium spp.)* is one of the most significant diseases to control when producing quality malting barley. The level of the mycotoxin Deoxynivalenol (DON) is used as a marker or predictor for the presence of Fusarium and other potential fungus organisms in malting barley varieties. Fungicides are available for treatment of barley for FHB that potentially will reduce infection by about 50% from untreated fields (Nagelkirk, 2016). The food industry standard for DON varies depending on use. The malting industry standard for DON is <1 ppm (Zhong et al., 2019).

Nitrogen is a primary nutrient to produce malting barley and the addition of nitrogen can influence yield. Nitrogen recommendations for growing malting barley depends on soil type and organic matter content with a range of 15 to 70 pounds of nitrogen per acre in Wisconsin (Laboski & Peters, 2012). Nitrogen influences yield and protein levels in the grain. High protein levels in malting barley reduces quality when protein levels rise above 12%. Nitrogen application rates need to be monitored to meet malting barley quality standards without compromising yield.

The main purpose of the study was to determine yield and economic impact of sustainable nitrogen and fungicide application rates to malting barley. No local research data are currently available to assist farmers with decisions on nitrogen and fungicide applications in the production of malting barley in western Wisconsin.

METHODS AND MATERIALS

The research team established the research projects on a private farm in Buffalo County and county owned land in Chippewa County. Soil types were Seaton Silt Loam in Buffalo County and Scott Lake Sandy Loam in Chippewa County. The fungicide and nitrogen rate studies used a randomized complete block

design. Individual plots were 4 feet by 10 feet and replicated four times. Malting barley was planted into soybean residue at both locations during each year of the study using a Hegge four-foot grain drill. Harvest was conducted at each location using a Hegge four-foot combine with a Draper head. Grain was tested for moisture and yields adjusted to 10% moisture standard.

The nitrogen rate study used four treatments in 2018, 2019, and 2020. Varieties used for the study were selected with referral from Oregon State University's Barley World program and in collaboration with Rahr Malting of Shakopee, Minnesota and New Glarus Brewing of New Glarus, Wisconsin. 'Full Pint', 'Conlon', 'Tinka', 'CU31', and 'Odyssey' were the varieties used depending on the year and seed availability. The four treatments consisted of 0 (check), 30, 60, and 90 pounds per acre nitrogen equivalent. Urea was used as a nitrogen source and hand applied at the late tillering stage (Feekes 5). Weed control consisted of pyrasulfotole (Huskie®) applied at 12.0 ounces per acre at the Buffalo County location and thifensulfuron-methyl plus tribenuon-methyl (Affinity Broadspec®) applied at 1.0 ounces per acre at the Chippewa County location. Two applications of fungicide were used at each location with picoxystrobin (Approach®) applied at 12.0 oz/acre at stage at the late stem elongation period or "Boot Stage" (Feekes 10) and pydiflumetofen plus propiconazole (Miravis Ace®) applied at 13.7 oz/acre at the flowering stage (Feekes 10.5). 'Conlon', 'Odyssey', and 'Tinka' varieties were used in 2018 at both locations. Weather limited data collection in Buffalo County in 2019 resulting in 'Odyssey' and 'Tinka' varieties investigated in 2019 at Chippewa County. Seed availability limited 'CU31' and 'Full Pint' varieties to be used in Buffalo County in 2020 and 'Full Pint' in Chippewa County.

The fungicide application study was conducted in 2018, 2019, and 2020. Three varieties 'Pinnacle', 'Robust', and 'Odyssey' were planted in 2018 at each location with six treatments applied to each variety. Fungicides applied included Approach®, Miravis Ace®, and prothioconazole plus tebuconazole (Prosaro®). Treatments, application rates, and stage of growth applied are listed in Table 1. Weed control consisted of Huskie® herbicide applied at 12.0 ounces per acre at the Buffalo County location and Affinity Broadspec® applied at 1.0 ounces per acre at the Chippewa County location. All herbicide and fungicides products were labeled for use in malting barley and in Wisconsin for both locations of the experiments.Thirty pounds of actual nitrogen as urea was applied to each individual plot.

Individual plots were harvested with a Hegge four-foot combine with a Draper head. Grain was collected, weighed, and tested for moisture. Yields were adjusted to 10% moisture standard for both nitrogen and fungicide application studies. Yield and quality data were evaluated using Ag Resource Management Software.

Table 1. 2018 Fungicide Treatments, Application Rates, and Stage of Application.

Treatment		Rate oz/acre	Stage of growth applied (Feekes) Heading	Product	Rate oz/acre	Stage of growth applied (Feekes) After Heading
1	None (check)					
2	Approach®	12.0	10.0			
3	Approach®	12.0	10.0	Prosaro®	8.0	10.5
4	Approach®	12.0	10.0	Miravis Ace®	13.7	10.5
5	Approach®	12.0	10.0	Prosaro®	8.0	10.7
6	Approach®	12.0	10.0	Miravis Ace®	13.7	10.7

The fungicide application study in 2019 consisted of four varieties and three treatments at one location in Chippewa County. The four varieties included 'ACC Connect', 'Explorer', 'Full Pint', and 'Tinka'. A trial was implemented in 2019 in Buffalo County and due to severe weather data was not collected. Treatments applied during this study included no treatment (check), Approach® applied at 12.0 oz/acre at Feekes 10.0, and Approach® applied at 12.0 oz/acre at Feekes 10.0 with Prosaro® applied at 8.0 oz/acre at Feekes 10.5. Weed control consisted Affinity Broadspec® applied at 1.0 ounces per acre. Thirty pounds of actual nitrogen as urea was applied to each individual plot. Fungicide, treatments, and application rates are listed in Table 2.

Table 2. 2019 Fungicide Treatments, Application Rates, and Stage of Application.

Treatment		Rate oz/acre	Stage of growth applied (Feekes) Heading	Product	Rate oz/acre	Stage of growth applied (Feekes) After Heading
1	None (check)					
2	Approach®	12.0	10.0			
3	Approach®	12.0	10.0	Prosaro®	8.0	10.5

Weather cooperated in 2020 and allowed Buffalo and Chippewa locations to be part of the fungicide application study. The study consisted of two varieties 'Full Pint' and 'DH120285' with five treatments at both locations. A third variety, 'Explorer', was planted and due to limited seed availability only three

treatments were investigated in Buffalo County and two treatments in Chippewa County. Treatments, application rates, and stage of growth applied are in Table 3. Weed control consisted of Huskie® herbicide applied at 12.0 ounces per acre at the Buffalo County location and Affinity Broadspec® applied at 1.0 ounces per acre at the Chippewa County location. Thirty pounds of actual nitrogen as urea was applied to each individual plot.

Table 3. 2020 Fungicide Treatments, Application Rates, and Stage of Application

Treatment		Rate oz/cwt At planting	Product	Stage of growth applied (Feekes) Heading	Rate oz/acre	Product	Rate oz/acre	Stage of growth applied (Feekes) After Heading
1	None (check)							
2	Tebustar ST®	1						
3	Tebustar ST®	1	Approach®	10.0	12.0			
4	Tebustar ST®	1	Approach®	10.0	12.0	Prosaro®	8.0	10.5
5	Tebustar ST®	1	Approach®	10.0	12.0	Miravis Ace®	13.7	10.5

RESULTS

Fungicide Application Study

Yield and quality testing for the mycotoxin deoxynivalenol (DON) was conducted in 2018 on the fungicide trial represented in Table 4. There was a significant yield difference between varieties and treatments at both locations. Non treated areas yielded significantly lower with all varieties at both locations. The malting industry standard for DON is <1 ppm for large scale brewers and <0.5 ppm for craft brewers.

Table 4. Yield and deoxynivalenol levels response to fungicide treatments

		Buffalo		Chippewa	
Variety	Treatment	Yield Bushels/Acre	DON (ppm)	Yield Bushels/Acre	DON (ppm)
Robust	NT	49.2d	4.53d	40.5e	0.61d
	LD	57.7cd	3.45b	48.5cd	0.58d
	LD+PR (HE)	51.9e	3.22b	51.8c	0.49c
	LD+MIR (HE)	53.0de	2.45a	52.2c	0.48c
	LD+PR (AHE)	57.5c	3.07a	44.9e	0.56d
	LD+MIR (AHE)	58.26c	2.55a	50.5c	0.56d
Pinnacle	NT	74.7b	3.75b	23.6f	0.06a
	LD	81.9a	4.20c	37.4e	0.09a
	LD+PR (HE)	84.9a	4.25c	67.2ab	0.22a
	LD+MIR (HE)	85.0a	2.80a	83.3a	0.07a
	LD+PR (AHE)	81.3a	2.67a	58.0b	0.08a
	LD+MIR (AHE)	75.2ab	1.66a	83.0a	0.10a
Odyssey	NT	39.7e	3.90bc	37.9e	0.56d

	LD	54.0e	7.43e	51.9c	0.43c
	LD+PR (HE)	56.8d	5.80d	79.3a	0.31b
	LD+MIR (HE)	49.7d	4.98d	62.6b	0.24a
	LD+PR (AHE)	62.3c	3.17b	73.2a	0.42c
	LD+MIR (AHE)	61.9c	4.17d	81.3a	0.25a
LSD (P=.05)		10.25	1.80	15.21	0.5
Standard Deviation		7.42	1.20	8.78	0.1
CV		8.48	1	9.28	1

Means followed by same letter do not significantly differ (P=.05, Duncan's New MRT)

NT= No Treatment

LD=Approach® @ 12.0 oz./acre

PR=Prosaro® @ 8.0 oz./acre

MIR=Miravis Ace® @ 13.7 oz./acre

HE=Heading

AHE=After Heading

Table 5 yield data show significant difference (P=.05) between varieties and treatments. There was a significant difference in yield in three of the four varieties ('Full Pint', 'Tinka', 'ACC Connect') with a leaf disease (LD) and/or a LD and flowering (PR) fungicide application.

Table 5. Effect of fungicide application and timing on malting barley varieties 2019

Variety	Treatment	Yield Bushels/Acre
Full Pint	NT	29.0f
	LD	51.2de
	LD+PR	62.7c
Tinka	NT	46.3e
	LD	52.1de
	LD+PR	60.1cd
Explorer	NT	70.1bc
	LD	69.0bc
	LD+PR	77.8ab
ACC Connect	NT	77.2ab
	LD	81.1a
	LD+PR	85.7a
LSD (P=.05)		9.59
Standard Deviation		6.64
CV		10.46

Means followed by same letter do not significantly differ (P=.05, Duncan's New MRT)

NT= No Treatment

LD=Approach® @ 12.0 oz./acre

PR=Prosaro® @ 8.0 oz./acre

Table 6 yield data show significant difference (P=.05) between varieties and treatments in Buffalo County. All varieties in Buffalo County were significantly different with fungicide or seed treatments applied compared to the untreated check. No significant difference was observed in Chippewa County.

Table 6. Effect of fungicide application and timing on malting barley varieties 2020

Variety	Treatment	Location	
		Buffalo	Chippewa
		Yield Bushels/Acre	
Full Pint	NT	70.9de	55.2a
	ST	75.9cd	65.2a
	ST+LD	76.3cd	68.0a
	ST+LD+PR	81.3c	59.5a
	ST+LD+MIR	91.2b	84.2a
DH120285	NT	63.7ef	66.6a
	ST	61.0f	36.6a
	ST+LD	68.6def	55.8a
	ST+LD+PR	80.3c	99.7a
	ST+LD+MIR	80.0c	63.3a
Explorer	NT	96.4b	33.0a
	ST+LD+PR	108.0a	45.4a
	ST+LD+MIR	113.3a	NA
LSD (P=.05)		*7.60*	*NS*
Standard Deviation		*5.32*	*26.94*
CV		*6.48*	*44.13*

Means followed by same letter do not significantly differ (P=.05, Duncan's New MRT)

NT= No Treatment

ST=Tebustar ST® @ 1 oz./cwt

LD=Approach® @ 12.0 oz./acre

PR=Prosaro® @ 8.0 oz./acre

MIR=Miravis Ace® @ 13.7 oz./acre

Nitrogen Application Study

Three varieties were planted in 2018 in Buffalo County and two varieties in Chippewa County. Data in Table 7 show there was a significant difference in Buffalo County at the 30 pound per acre rate with 'Conlon'. There was a significant difference in Chippewa County at the 30, 60, and 90 pound per acre rate depending on the variety. The zero-application rate was significantly different in Buffalo County.

Table 7. Effect of nitrogen application on malting barley yield 2018

2018			
		Yield bushels/acre	
Variety	N Rate (lbs/acre)	Buffalo	Chippewa
Conlon	0	63.1b	29.1c

	30	86.4a	48.3ab
	60	62.5b	41.5b
	90	63.8b	48.3ab
Tinka	0	45.6c	44.5b
	30	64.0b	69.4b
	60	66.3b	52.0a
	90	66.3b	46.4ab
Odyssey	0	39.6c	NA
	30	60.6b	NA
	60	62.2b	NA
	90	61.2b	NA
LSD P=0.05		*15.9*	*11.27*
Standard deviation		*8.85*	*9.26*
CV		*14.33*	*20.27*

Means followed by same letter do not significantly differ (P=.05, Duncan's New MRT)

Table 8 indicates there was a significant difference (P=.05) with 'Odyssey' at the 30, 60, and 90 pound per acre application rates compared to the untreated check. There was no significant difference between the 30 and 90 pound per acre application rates. No significant difference was observed with 'Tinka'.

Table 8. Effect of nitrogen application on malting barley yield 2019

2019		
	Yield bushels/acre	
N Rate (lbs/acre)	Tinka	Odyssey
0	53.6a	40.7c
30	79.3a	69.2b
60	90.7a	85.2a
90	66.7a	79.5ab
LSD P=0.05	NS	10.97
Standard deviation	18.96	5.49
CV	26.13	8

Means followed by same letter do not significantly differ (P=.05, Duncan's New MRT)

Table 9 data shows there was a significant difference between varieties and treatments in Buffalo County in 2020. The yield from the 60 and 90 pound per acre rate with the CU31 variety. No significant difference was observed with 'Full Pint' in Buffalo County at the 30, 60, or 90 pound per acre rate. There was no significant difference with 'Full Pint' in Chippewa County.

Table 9. Effect of nitrogen application on malting barley yield 2020

2020		
		Yield bushels/acre

Variety	N Fert (lbs)	Buffalo	Chippewa
CU31	0	74.6def	NA
	30	99.4bc	NA
	60	109.8ab	NA
	90	118.4a	NA
Full Pint	0	68.7ef	44.5a
	30	82.8de	53.1a
	60	86.6cd	47.6a
	90	83.4de	47.2a
LSD (P=.05)		*14.71*	*18.25*
Standard Deviation		*8.69*	*9.14*
CV		*9.64*	*19*

Means followed by same letter do not significantly differ (P=.05, Duncan's New MRT)

Table 10. Average economic return ($/acre) to different nitrogen application rates to different varieties at Buffalo and Chippewa Counties 2018-2020

	2020		2020	2019		2018			2018	
Nitrogen Rate lbs./acres	Buffalo		Chippewa	Chippewa		Buffalo			Chippewa	
	Variety		Variety	Variety		Variety			Variety	
	Full Pint	CU31	Full Pint	Tinka	Odyssey	Tinka	Conlon	Odyssey	Tinka	Conlon
0	315.24	342.60	262.49	315.96	239.88	269.04	372.35	233.64	262.59	171.47
30	367.96	444.11	301.46	455.93	396.06	365.42	497.70	345.30	294.77	273.07
60	373.49	479.75	256.59	511.24	478.36	367.40	344.75	242.92	282.89	221.04
90	346.90	507.23	242.35	357.25	433.00	354.99	340.54	324.79	237.58	248.71

Economic return is based on a malting barley price of $5.90/bushel and nitrogen per unit price of $0.40/pound of actual nitrogen. The 30 pound/acre rate provided the highest return in three of five trials in Chippewa County. In Buffalo County, the 30 and 60 pound/acre rates provided the highest returns in 5 of the trials. The 90 pound/acre rate provided the highest return in one trial. The non-treated check provided the lowest return in seven of the ten trials.

CONCLUSIONS

The purpose of the study was to determine the effect of nitrogen and fungicide applications to malting barley yield. The results of the nitrogen application study indicate a minimum of 30 pounds per acre of nitrogen is needed to statistically increase yield. The response to nitrogen is dependent on location, variety, and soil type. The results also indicate an application of 30 pounds of nitrogen resulted in yields statistically comparable to higher rates. The economic analysis on return to nitrogen indicate a nitrogen application rate between 30 and 60 pounds/acre provide the highest returns. The 90 pound/acre rate resulted in the highest yield in one of the trials.

The results of the fungicide application study indicate an application of fungicide at Feekes 10.0 (boot stage) and/or 10.5 (flowering) statistically increased yield compared to the non-treated check except for the 2020 Chippewa location where no statistically significant differences were noted between treatments. 2018 data indicate fungicide applications may not keep deoxynivalenol levels to acceptably low levels. Location, weather, and variety are variables in determining deoxynivalenol infection.

Malting barley is a viable option to introduce into a cropping system either as a primary crop or secondary crop in another crop rotation. Sustainable management of the applications of nitrogen and fungicide can potentially lead to more enterprise profitability. Additional and continued research needs to continue to strengthen the findings of this study.

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