Date of Planting and Nitrogen management for Malt Barley production in the Northeast

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Introduction: Growers who are interested in growing malt barley as a new crop in the Northeastern region of the United States are concerned that their barley may exceed the accepted malt quality protein maximum of 13-13.5%. While increasing nitrogen (N) application rates may boost yields, growers in the region have expressed their interest regarding N management in malt barley. In previous research studies on spring barley, date of planting and nitrogen application rates have been shown to have significant effects on both protein content and grain yield. Winter survival is also of significant concern to those growers seeking to plant winter barley in the fall. Another significant concern is the severity of DON (the mycotoxin Deoxynivalenol aka ‘vomitoxin’, caused by Fusarium Head Blight) as a possibly influenced by N application and date of winter barley planting. The impact of fall and spring N applications and any interaction with date of planting have not been established in this region. This study aims to rectify this gap in regionally specific knowledge by examining the impact of date of planting, as well as fall and spring N applications, on winter barley survival, grain yield, and various malt quality indices in western Massachusetts.

While growers in the Northeast can choose between winter or spring barley varieties, either choice brings challenges not encountered in the major barley growing regions of the United States. While spring barley varieties do not bring the associated risk of crop failure due to winter kill, they are less competitive against spring weed pressure. Many chemicals commonly utilized to control weeds in major barley production regions are not registered for application on malt barley in Massachusetts. Winter barley varieties have a significant advantage in weed competition and can typically be grown with no herbicide applications. This has clear economic and environmental advantages over spring barley. It is especially beneficially for organic or ‘no-spray’ growers seeking to meet the demands of a burgeoning locavore movement in the regional farm to brewery consumer environment.

Rational: While the advantages of winter barley are significant, New England winters pose risks to its production. Cold snaps, combined with freeze-thaw events can decimate a winter barley crop. Preliminary trials conducted during over the ‘Polar Vortex” winter of 2013-2014 found 0% winter survival in Wintmalt planted on September 1, 20% survival in barley planted September 15 and 50% survival in barley planted on the first of October. Many factors play a role in winter survival, significantly cultivar species, as examined in the ‘Winter Barley Cultivar Trial Report: 2015-2016’ (LINK), but also planting date. In current study, Wintmalt was selected due to its moderate winter hardiness.

Materials and Methods:

Experimental Site: All years of the trial were conducted at the University of Massachusetts Agricultural Experiment Station Farm in South Deerfield, MA (42° N, 73° W). Soil at this site in the Connecticut River Valley, is characterized as fine Hadley loam. In the 2014-2015 growing season the barley was planted into a block which had previously grown spring buckwheat. In the

2015-2016 growing season the barley was planted into a block which had previously grown fava beans. The first year's winter was characterized by significant snow cover, whereas the second winter was warmer than the norm for the location and had several free-thaw events, contributing to increased winterkill in the 2015-2016 year of the trial (Table1).

Experimental design: Treatments consisted of three dates of planting (Sept 5, 15 and 15), either 0 or 25 lbs N/ac at fall planting, and 25, 45 or 65 lbs N/ac in the following spring at GS 30 stage. These were combined for a total of 18 treatments in the 2014-2015. In the 2015-2016 an additional treatment of zero N was included. All combinations of treatments were replicated 4 times in a randomized complete block design.

Statistical Analysis: Data were analyzed using PROC GLM in SAS version 9.4, and the significance of relationships between Days of planting (DOP) and spring N and any of the measured indices was determined using ANOVA followed by orthogonal polynomial comparisons when significant. The significance of the impact of fall N was determined through ANOVA.

Field Methods: A pre-planting baseline soil sample of the top 6" inches of soil was collected in both years by sampling a 5x4 grid of 20 sub-samples across the block. The block was then amended appropriately as recommended by the UMass soil testing lab for barley production. In both years the experimental sites were disked within the week prior to planting. Winter malt barley cultivar Wintmalt was planted at 110 lbs seed per ac, at ¾ inch depth using a cone drill planter. Fall N treatments were applied at 25 lbs/ac, in the form of calcium ammonium nitrate (CAN) which was watered into the soil at time of sowing. Spring N treatments were applied in the same manner in 2015 and later in 2016 when the mean growth stage of plants across the trial was approximately at GS 30.

Field Measurements: Winter survival was determined by a visual assessment of the surviving area of the plot. Each plot was ranked from 0-10 to reflect the percentage of the plot surviving on April 29, 2015 and on April 11, 2016. Foliar disease was estimated as a percentage of leaf surface area infected using the diseases specific percentage guides in the American Phytopathological Society's 'A manual of assessment keys for plant disease' (Clive, J., 1971), on June 17, 2015. Due to rapid drought induced foliar desiccation, foliar disease load was not a significant factor in 2016. Heading date was declared when 50% of tillers had emerged heads and reported here in Julian days in both years of the trial.

Harvest: Barley was harvested using a 1995 ALMACO SPC20 plot combine on Aug 11, 2015, and July 20, 2016. Grain was stored in a 100° F forced air oven until processed to preserve kernel integrity. Germination and test weight were determined utilizing standard procedures. Sub- samples from each plot analyzed for malt quality at the University of Vermont's cereal grain testing lab. All yield values were reported at 13.5% moisture, and all protein reported at 12% moisture.

Table 1. Weather Data for the Date of Planting and Nitrogen Trial for the University of Massachusetts Agricultural Research Farm, South Deerfield, MA*

Year	Month	Avg. Temp (F)	Departure from avg.	Max Temp (F)	Departure from avg.	Min Temp (F)	Departure from avg.	Total Rain (in)**	Departure from avg.	GDD 32***	Departure from avg.
2014	September	61.4	0.1	87.3	1.5	38.6	4.2	1.6	-2.6	921.8	3.3
	October	52.8	4.1	75.8	-0.6	31.3	7.4	6.3	2.0	638.3	97.4
	Nov	37.7	-1.3	63.9	-1.8	13.7	-0.1	3.5	0.5	196.6	-52.7
	Dec	32.8	3.4	53.2	-5.1	10.6	9.0	4.6	1.3	87.1	1.3
2015	January	20.0	-2.7	39.9	-11.6	-5.7	4.1	3.3	0.6	1.1	-39.1
	February	13.4	-12.0	38.6	-13.0	-17.6	-13.6	1.5	-1.1	0.1	-37.2
	March	29.4	-4.3	54.9	-9.5	-4.5	-7.8	1.7	-1.8	52.4	-111.9
	April	45.8	-0.1	73.6	-7.4	20.4	-0.9	2.0	-1.1	406.0	-45.7
	May	63.6	6.6	88.6	1.4	35.0	5.3	1.0	-2.3	975.2	166.2
	June	64.3	-1.2	86.2	-4.0	43.2	2.3	7.6	3.0	989.6	-49.8
	July	69.9	-0.6	90.8	-0.6	52.3	4.0	3.3	-0.3	1217.3	-10.6
	August	70.0	1.2	90.5	0.6	52.3	6.8	2.5	-1.1	1222.9	39.1
	September	65.0	3.7	91.4	5.6	40.8	6.4	6.4	2.2	1044.9	126.5
	October	48.6	-0.1	73.9	-2.5	18.7	-5.2	2.2	-2.0	520.3	-20.6
	November	43.1	4.1	73.6	7.9	15.9	2.1	2.0	-1.1	348.7	99.5
	December	39.2	9.8	61.6	3.3	22.1	20.5	4.7	1.4	250.3	164.4
2016	January	27.1	4.4	51.8	0.3	4.1	13.9	1.5	-1.2	34.4	-5.7
	February	28.6	3.2	58.9	7.3	-15.0	-11.0	4.1	1.6	100.1	62.7
	March	40.5	6.8	77.9	13.5	17.6	14.3	3.3	-0.2	310.7	146.4
	April	45.4	-0.5	79.2	-1.8	12.2	-9.1	2.1	-1.0	414.0	-37.6
	May	57.5	0.5	90.6	3.4	29.0	-0.7	2.6	-0.8	807.5	-1.5
	June	66.3	0.8	87.7	-2.5	41.6	0.7	1.4	-3.2	1039.1	-0.3
	July	72.2	1.7	93.9	2.5	49.9	1.6	1.7	-2.0	1263.9	36.0

*Averages of weather data were obtained from the airport weather station in Orange, MA 23 mi from the South Deerfield location due to increased number of years available

**Rain data were obtained from the airport weather station in Orange, MA

***GDD: Growing degree days are calculated using the following formula: $GDD = \Sigma\left(\frac{[illegible] + [illegible]}{2}\right) - [illegible]$, where [illegible] [illegible] [illegible] = The maximum and minimum daily temperatures and [illegible] = [illegible] (32°F)

2014-2015 results

Neither DOP nor fall N treatments had any significant impact on winter survival or on heading date as individual treatments in 2014-2015. However, there was a significant interaction between DOP and fall N on heading date. In plots that received fall N, earlier planting dates had later heading dates. While statistically significant, all treatments were heading within 24-36 hrs of one another. The importance of this relationship is minimal, as is its strength.

Foliar disease: Foliar disease, primarily powdery mildew (*Erysiphe graminis* f. sp. *hordei*), had a highly significant response to date of plating in 2014-2015. Earlier dates of planting, which had stronger and denser stand establishment in the spring, also had higher rates of foliar disease. This is to be expected, as with increased stand density, air flow is reduced, and the duration of wetting periods increased. *E. graminis*, among the earliest recognized cereal pathogens, can cause significant damage to cereal crops, primarily through reduction in photosynthesis. Reduction in photosynthetic capacity via any mechanism can reduce tillering, heading and root development decreasing yield, kernel weight and protein. Agronomic costs due to *E. graminis* are greatest in early infections. These consequences of infection were not directly observed in this trial, possibly due to a relatively late infection development. This increase in foliar disease did not appear to have a significant impact on grain yields or quality. While higher rates of Spring N and earlier dates of planting had numerically higher yields than lower rates of spring N and later dates of planting, none of the treatments had a significant impact on yield (Table 2 A).

Table 2 A. Yield and Growth metrics for the Date of Planting and Nitrogen Trial for the University of Massachusetts Agricultural Research Farm, South Deerfield, MA. 2014-2015

DOP	Fall N (lbs/ac)	Spring N (lbs/ac)	Winter Survival (0-10)	50% Heading Date	Foliar disease (%)	Yield (bu /ac)
Sept. 5	25	25	8.3	145.5	22.6	72.5
		45	8.3	146.5	18.3	69.7
		65	8.6	145.5	24.8	67.0
	0	25	8.5	145.8	25.8	62.7
		45	8.9	147.0	21.4	72.7
		65	8.8	145.8	29.2	59.3
Sept. 15	25	25	8.9	145.3	20.3	63.8
		45	8.8	145.8	17.0	67.2
		65	9.4	144.5	19.2	72.2
	0	25	8.9	144.3	14.9	54.4
		45	9.3	143.8	19.8	64.9
		65	8.9	144.3	18.3	85.9
Sept. 25	25	25	8.3	144.8	10.7	56.2
		45	8.5	145.5	8.5	50.0
		65	8.8	144.3	14.2	65.9
	0	25	7.5	147.5	9.6	48.4
		45	8.3	145.8	10.6	57.5
		65	8.5	146.8	8.1	44.1
DOP						
Sept. 5			8.6	146.0	23.7	67.3
Sept. 15			9.0	144.6	18.3	68.1
Sept. 25			8.3	145.8	10.3	53.7
Fall N (lbs/ac)						
25			8.6	145.6	17.5	61.1
0			8.7	145.3	17.3	65.0
Spring N (lbs/ac)						
25			8.4	145.5	17.3	59.7
45			8.7	145.7	15.9	63.7
65			8.8	145.2	19.0	65.7
Significance[1] by main factors						
DOP			NS	t	**	NS
Fall N			NS	NS	NS	NS
Spring N			NS	NS	NS	NS
DOPxFall N			NS	*	NS	NS
DOPxSpring N			NS	NS	NS	NS
Fall NxSpring N			NS	NS	NS	NS

[1] t indicates P≤0.1, *indicates a significant relationship or difference (P≤0.05), **indicates a highly significant relationship or difference (P≤0.01), ***(P≤0.001) indicates a very highly significant relationship or difference

Table 2 B. Yield and Growth metrics for the Date of Planting and Nitrogen Trial for the University of Massachusetts Agricultural Research Farm, South Deerfield, MA. 2014-2015

DOP	Fall N (lbs/ac)	Spring N (lbs/ac)	Agronomic NUE (g grain/g N)	Test Weight (kg/hL)	Germination (%)	Protein (%)	Falling number (sec.)	DON (ppm)
Sept. 5	25	25	56.5	56.5	85.8	8.7	117.0	0.18
		45	49.4	61.6	86.8	9.2	108.8	0.08
		65	41.9	62.7	90.0	9.6	109.5	0.15
	0	25	52.9	61.0	87.8	8.5	113.8	0.18
		45	45.8	59.6	86.5	9.0	105.5	0.63
		65	41.3	59.2	86.5	9.6	105.5	0.25
Sept. 15	25	25	57.4	61.9	81.5	8.7	104.0	0.2
		45	52.7	61.3	81.8	8.5	89.0	0.4
		65	43.7	60.7	82.3	9.1	91.5	0.4
	0	25	51.0	61.7	83.5	8.1	94.5	0.55
		45	49.6	59.3	81.5	8.7	101.3	0.55
		65	50.0	61.3	83.3	8.9	79.0	0.55
Sept. 25	25	25	61.9	60.5	85.5	8.4	100.3	0.45
		45	55.3	59.8	82.8	8.9	105.8	0.43
		65	45.8	59.4	85.8	9.6	103.3	0.58
	0	25	46.5	61.2	90.8	8.6	126.0	0.48
		45	49.4	60.9	84.3	8.9	114.8	0.6
		65	45.3	61.6	85.8	9.2	114.0	0.59
DOP								
Sept. 5			48.0	60.1	87.2	9.1	110.0	0.2
Sept. 15			50.7	61.0	82.3	8.7	93.2	0.4
Sept. 25			50.7	60.6	85.8	8.9	110.7	0.5
Fall N (lbs/ac)								
25			48.0	60.6	85.5	8.8	106.0	0.5
0			51.6	60.5	84.7	9.0	103.2	0.3
Spring N (lbs/ac)								
25			54.4	60.5	85.8	8.5	109.3	0.3
45			50.4	60.4	83.9	8.9	104.2	0.4
65			44.7	60.8	85.6	9.3	100.5	0.4
Significance[1] by main factors								
DOP			NS	NS	t	**	**	**
Fall N			*	NS	NS	NS	NS	t
Spring N			*	NS	NS	**	NS	NS
DOPxFall N			NS	NS	NS	NS	*	NS
DOPxSpring N			NS	NS	NS	NS	NS	NS
Fall NxSpring N			NS	NS	NS	NS	NS	NS

[1] t indicates P≤0.1, *indicates a significant relationship or difference (P≤0.05), **indicates a highly significant relationship or difference (P≤0.01), ***(P≤0.001) indicates a very highly significant relationship or difference

Quality Indices: All levels of grain protein were within the acceptable malting range (below 13-13.5%). Indeed, Spring N levels could be increased significantly to increase yields without risking excessive protein in the grain for malting. Levels of grain protein increased significantly as spring N levels increased (8.3, 8.6, and 9.1%, respectively). Additionally, there was a significant, though weak, relationship between DOP and grain protein. However, this relationship was polynomial and likely an artifact of the data. Falling numbers throughout this trial were well lower than would be acceptable for malt barley. This is assumed to be due to pre-harvest germination due to a delay in harvest. There was a significant polynomial relationship between falling number and DOP. There was also a significant interaction between Fall N and DOP in falling number. This polynomial relationship exists only when no nitrogen was applied in the fall and is believed to be an artifact of the data. DON increased by a small but statistically significant amount with later planting dates in 2014-2015, with the latest DOP having an average DON level above the ideal >0.5 ppm. Unlike heading date, there was no significant interaction effect of any treatments in determining DON levels (Table 2B). Agronomic NUE, (g grain yield/g N applied), was significantly lower in plots that received fall N in comparison to plots that did not. NUE also decreased significantly with increasing spring N applications (Figure 1).

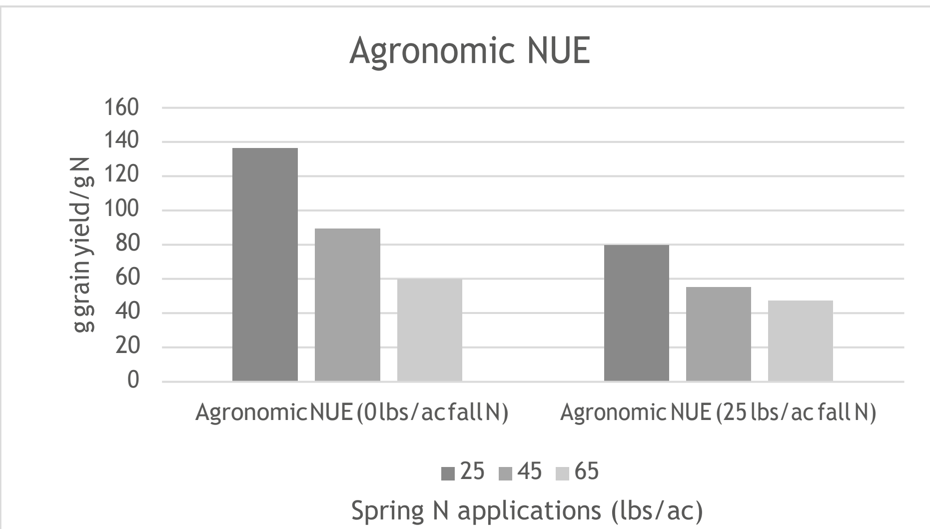

Figure 1. Agronomic NUE by spring and Fall N applications, S. Deerfield, 2014-2015

2015-2016 Results:

Earlier dates of planting had significantly lower rates of winter survival. Numerically lower yields were associated with lower winter survival in the second year of the trial. There were no meaningful impacts of any of the treatments on either height or heading date. Lodging/stem breakage was significantly impacted by spring N applications, with treatments receiving no spring N having less lodging/stem breakage due to reduced growth and stem elongation (Table 3A). Yield was significantly impacted by applications of Spring N, increasing with increased applications. Agronomic Nitrogen Use efficiency decreased significantly with increasing spring N applications. Thousand grain weight and test weight were not significantly impacted by any of the main factors tested in this trial. Falling number was higher in the later planting dates. While DON did increase with the later planting dates, all dates were below 0.5ppm (Table 3B).

Table 3 A. Yield and Growth metrics for the Date of Planting and Nitrogen Trial for the University of Massachusetts Agricultural Research Farm, South Deerfield, MA. 2015-2016

DOP	Fall N (lbs/ac)	Spring N (lbs/ac)	Fall biomass (lb/ac)	Winter Survival (0-10)	Plant Height (in)	50% Heading Date	Lodging/Stem breakage (0-10)
Sept. 5	25	25	3705	7.3	24.8	140.5	2.4
		45	4736	6.7	19.4	140.3	4.3
		65	4322	7.5	25.3	140.3	5.4
	0	25	2698	8.3	16.9	141.7	1.7
		45	2828	8.6	24.2	141.0	3.5
		65	3213	8.4	24.9	141.3	3.8
		0	4786	8.5	14.9	141.7	2.0
Sept. 15	25	25	2862	9.4	23.5	141.3	3.0
		45	3732	9.5	25.5	141.0	2.0
		65	2135	9.1	25.6	141.0	2.9
	0	25	3218	9.0	24.0	141.0	1.6
		45	3478	9.1	23.6	140.5	1.8
		65	2970	9.3	23.9	141.3	1.9
		0	2248	9.1	20.0	141.8	0.1
Sept. 15	25	25	1489	9.8	24.6	139.5	0.4
		45	2507	9.9	25.6	139.8	1.5
		65	1779	9.6	24.6	140.0	0.9
	0	25	1954	9.5	23.5	140.3	0.3
		45	1737	9.3	24.3	140.3	0.8
		65	1799	9.5	24.6	140.0	1.0
		0	2109	9.6	22.9	140.3	0
DOP							
Sept. 5			3755	7.9	21.5	141.0	3.3
Sept. 15			2949	9.2	23.7	141.1	1.9
Sept. 25			1911	9.6	24.3	140.0	0.7
Fall N (lbs/ac)							
25			2753	9.0	22.3	140.9	1.5
0			3030	8.7	24.3	140.4	2.5
Spring N (lbs/ac)							
25			2654	8.9	22.9	140.7	1.5
45			3169	8.8	23.8	140.5	2.3
65			2703	8.9	24.8	140.6	2.6
0			3048	9.1	19.2	141.2	0.7
Significance[1] by main factors							
DOP			***	*	NS	NS	t
Fall N			NS	NS	NS	NS	NS
Spring N			NS	NS	NS	NS	*
DOPxFall N			NS	NS	NS	NS	NS
DOPxSpring N			NS	NS	NS	NS	NS
Fall NxSpring N			NS	NS	NS	NS	NS

[1] t indicates P≤0.1, *indicates a significant relationship or difference (P≤0.05), **indicates a highly significant relationship or difference (P≤0.01), ***(P≤0.001) indicates a very highly significant relationship or difference

Table 3 B. Yield and Growth metrics for the Date of Planting and Nitrogen Trial for the University of Massachusetts Agricultural Research Farm, South Deerfield, MA. 2015-2016

DOP	Fall N (lbs/ac)	Spring N (lbs/ac)	Yield (bu/ac)	Agronomic NUE (g grain/g N)	Test Weight (kg/hL)	TGW (g)	Germination (%)[2]	Protein (%)	Falling number (sec.)	DON (ppm)
Sept. 5	25	25	70.6	67.8	59.2	44.1	92.7	9.3	104.8	0.3
		45	78.8	40.5	45.0	33.6	94.7	9.6	89.0	0.2
		65	74.1	39.5	58.0	42.8	86.3	10.1	80.3	0.3
	0	25	65.2	93.9	44.4	33.5	96.0	8.7	135.7	0.3
		45	74.0	78.9	58.6	43.4	92.7	9.5	82.5	0.3
		65	83.9	62.0	59.2	43.6	89.7	9.8	71.3	0.3
		0	58.2	---	43.9	33.5	97.5	8.9	160.3	0.2
Sept. 15	25	25	69.2	66.4	58.9	46.5	88.0	8.8	152.8	0.2
		45	92.7	63.5	63.6	34.9	97.0	8.9	142.8	0.4
		65	83.0	44.3	96.7	46.8	95.7	9.0	139.5	0.2
	0	25	84.2	161.7	59.0	46.2	96.7	9.2	149.0	0.1
		45	79.4	84.7	60.6	45.5	96.7	9.0	143.3	0.2
		65	78.3	57.8	59.2	46.0	97.3	9.5	140.8	0.2
		0	51.3	---	58.3	45.6	98.0	9.1	190.8	0.3
Sept. 15	25	25	83.1	79.8	59.9	46.9	97.0	9.4	172.3	0.4
		45	88.6	60.8	60.7	46.1	101.3	9.3	127.0	0.4
		65	87.3	46.6	59.4	46.3	94.7	10.2	118.5	0.2
	0	25	77.1	148.1	59.7	46.8	96.0	9.2	156.3	0.3
		45	79.1	84.4	60.9	46.3	96.7	9.7	134.5	0.1
		65	77.9	57.5	61.0	47.2	95.7	10.0	157.5	0.6
		0	63.7	---	59.4	47.4	96.3	9.4	168.5	0.2
DOP										
Sept. 5			72.1	63.8	52.6	39.2	92.8	9.4	103.4	0.3
Sept. 15			76.9	79.7	65.2	44.5	95.6	9.1	151.3	0.2
Sept. 25			79.5	79.5	60.2	46.7	96.8	9.6	147.8	0.3
Fall N (lbs/ac)										
25			72.7	92.1	57.0	43.7	95.8	9.4	140.9	0.2
0			80.8	56.6	62.4	43.1	94.1	9.4	125.2	0.3
Spring N (lbs/ac)										
25			74.9	102.9	56.8	44.0	94.4	9.1	145.1	0.2
45			82.1	68.8	58.2	41.6	96.5	9.3	119.8	0.3
65			80.8	51.3	65.6	45.4	93.2	9.8	118.0	0.3
0			57.7	---	53.9	42.2	97.3	9.2	173.2	0.2
Significance[1] by main factors										
DOP			NS	NS	NS	NS	NS	NS	*	*
Fall N			t	NS	NS	NS	NS	NS	NS	NS
Spring N			*	***	NS	NS	NS	NS	NS	NS
DOPxFall N			NS	NS	NS	NS	NS	NS	NS	NS
DOPxSpring N			NS	t	NS	NS	t	NS	NS	NS
Fall NxSpring N			NS	*	NS	NS	NS	NS	NS	NS

[1] t indicates P≤0.1, *indicates a significant relationship or difference (P≤0.05), **indicates a highly significant relationship or difference (P≤0.01), ***(P≤0.001) indicates a very highly significant relationship or difference

[2] Three replicates reported for highly abnormal germination rates in one of the 4 replicates.

Conclusion:

In the first year of the trial, earlier planting dates had numerically higher yields than later planting dates. However, the earlier planting dates suffered higher foliar diseases, primarily powdery mildew. DON was lower in earlier planting dates than later. However, protein levels of all barley grain in all treatments were much lower than 13%, and were on the low side of acceptable range. Fall N applications had no significant impact on any of the quantified metrics. Larger applications of N in the spring resulted in numerically increased yields, however higher foliar disease was associated with the highest rate of application. Although protein levels increased with increased spring N application rates all harvested grains were in the acceptable range for malting purpose, and increased Spring N applications would benefit the grower by increasing yields.

Nitrogen applied in the fall represents a fertilizer expenditure for growers and the potential N loss to the environment with no measureable benefit at harvest. The decreasing NUE in relationship to increasing spring N applications is to be expected, however, is counterbalanced by numerically increasing total yields. Appropriate application of spring N to winter barley should be informed by this relationship, as well as by the cost of N fertilizer, expected market price of malt barley and input costs specific to the grower. While foliar disease at plant maturity has limited impact on yield, the presence of DON due to *Fusarium* infestation can render the crop unsuitable for malting, significantly reducing or eliminating the market value of the crop. In both years of this trial, all DOP were within the marketable range of DON levels.

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