Effect of Nitrogen, Sulfur, and Planting Rate on Dryland Malt Barley

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Abstract

Dryland malting barley (*Hordeum vulgare* L.) experiments were initiated in north central Montana to evaluate the effects of planting, N, and S rates on grain yield and quality. Planting rates of 10, 15, and 20 seeds/ft^2, nitrogen (N) rates of 0, 30, and 60 lbs N/acre, and S rates of 0, 10, and 20 lbs/acre were applied in all possible combinations to Metcalfe barley at 11 locations in 2004 and 2005. Optimal grain yields were generally achieved with a planting rate of 15 seeds/ft^2, but 10 seeds/ft^2 produced grain with the highest kernel plumpness and the highest grain protein content. Barley responses to N were similar to previously published data i.e. increasing N resulted in higher yield and protein content but lower kernel plumpness. Sulfur fertilization had little effect on grain quality but increasing S significantly lowered grain yields at several locations.

Introduction

Acreage of malting barley is expected to increase in non-traditional barley production areas of north central Montana due to the expected increase in malting barley contracts from the new International Malt facility located at Great Falls, MT and traditional spring wheat producers seeking alternative crops with less nitrogen (N) fertilizer requirements. Generally the requirements and the effects of N on malt barley are well known (Jackson, 2000; Jackson et al., 2001; McKenzie and Jackson, 2005); however, little information about effects of N, sulfur (S), and planting rate are available in the literature. Thus field research was initiated at several locations to evaluate planting rate, N fertilizer, and S fertilizer rate on the yield and quality of Metcalf barley.

Methods and Materials

Planting rates of 10, 15, and 20 seeds/ft^2, N rates of 0, 30, and 60 lbs N/acre, and S rates of 0, 10, and 20 lbs/acre were applied in all possible combinations to Metcalfe barley at the following locations in 2004: Western Triangle Agric. Research Center (WTARC) north of Conrad, Knees community east of Brady, north of Joplin, east of Sunburst, and east Ethridge. The same locations were established in 2005 with an additional location north of Cut Bank. In 2004 plots were planted with a double disc drill that broadcast N as urea and 25 lbs/acre of potassium (K) as KCl while planting, and S as potassium thiosulfate or ammonium thiosulfate was dribbled on the soil surface about two inches from the seed row while planting. In 2005 N as urea, 25 lbs/acre of K as KCl, and S as potassium sulfate was applied while seeding in a band approximately one inch above and to the side of the seed row using a

hoe opener. All plots received 30 lbs P_2O_5/ acre as 0-45-0 applied with seed as well as KCl. Plot size was 6 rows wide, 12 inch spacing, (10 inch spacing in 2005) and 25 feet long. Soils at each location were sampled initially for water, nitrate-N, and sulfate-S in foot increments to a depth of three feet. Surface soil samples (0-6") were collected for standard soil analyses of pH, organic matter, phosphorus, etc. Results along with other site characteristics are shown in Table 1. Plots were harvested with a small plot combine, and the grain weighed and tested for protein and S content.

Table 1. Soil Test Results and Selected Site Characteristics. 2005-2005.

Soil test or Character	Location-Year										
	Cut Bank	Ethridge		Joplin		Knees		Sunburst		WTARC	
	2005	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
OM, %	2.2	2.1	2.0	1.3	1.5	-	2.2	3.6	3.4	2.4	2.1
pH	8.4	8.6	8.4	8.0	8.2	-	7.5	6.3	6.1	8.5	7.9
P, ppm	7.4	26	6	19	10.0	-	19	34	29	16	20
N	32	47	46	57	70	80	89	39	122	63	94
S	127	212	1969	2089	1476	609	367	244	99	7110	391
Previous Crop	----------Chemical Fallow----------							Barley	Chemical Fallow	Conventional Fallow	
Precip.	8.5	-	-	5.4	5.3	4.8	7.3	5.2	8.5	5.9	6.2
Planting Date	April 25	April 14	April 11	May 3	April 19	April 27	April 12	April 26	April 20	April 13	April 26
Harvest Date	August 29	August 4	August 9	August 13	August 16	August 10	August 15	August 13	August 28	August 11	August 11

Precip.=Growing Season Precipitation, inches; N=Nitrate N, lbs/acre; S=Sulfate S, lbs/acre.

Results and Discussion

Grain yield results are shown in Tables 2 and 3. Yields averaged between 32 and 97 bu/acre, but most were in the 70 to 80 bushel range depending upon available water levels. Five of the 11 locations had significant yield responses to increased planting rate, with the optimum planting rate usually being 15 seeds/ft^2. Seven of the locations had significant yield increases from increasing N rate while two locations experienced significant yield reductions due to increasing N rate. Two locations were unaffected by N rate. Sulfur fertilization did not increase yield at any location, but increasing S rate significantly decreased yields at four locations.

Grain plump kernel data are summarized in Tables 4 and 5. As expected, percent plump declined with increasing planting rate at most locations; however, only two locations averaged less than 75 % plump (the malting industry will usually accept barley with percent plump kernels of at least 75 %). Also N fertilization reduced kernel plumpness at seven locations, but increased plump at one location. At the other locations, N did not affect kernel plump. Sulfur fertilization significant increased plump slightly at one location, and the remaining locations were unaffected by S.

The grain protein content data are presented in Tables 6 and 7. Increasing planting rate resulted in significant protein content declines at five locations, at the other six locations, protein levels were unaffected by planting rate. As expected most locations (nine) had significant protein increases due to increasing N levels. Interestingly protein response to S was a "mixed bag", two locations had significant protein reduction with increasing S rate in 2004, and two locations had significant protein increases with increasing S rate in 2005. In general S did not affect protein content.

Average grain S content ranged from 0.133 to 0.179 % (data not shown) and generally increased slightly with increasing N and S fertilizer rate and declined slightly with increased planting rate.

Table 2. Effect of nitrogen, sulfur, and planting rate on yield of dryland malt barley. Western Triangle Ag. Research Center. 2004.

Treatment	Location				
	Ethridge	**Joplin**	**Knees**	**Sunburst**	**WTARC**
	----------bu/acre----------				
Planting Rate Summary					
10 seeds/ft^2	78.3 a	79.2 a	71.1 a	31.2 a	94.5 a
15 seeds/ft^2	78.6 a	78.3 a	71.5 a	31.5 a	97.4 b
20 seeds/ft^2	77.7 a	79.6 a	71.0 a	32.8 a	98.6 b
P-value, Linear contrast	0.688	0.705	0.974	0.199	0.003
P-value, Quad. contrast	0.642	0.405	0.688	0.638	0.452
Nitrogen Summary					
0 lbs N/acre	77.8 a	74.2 a	72.2 a	33.9 a	93.0 a
30 lbs N/acre	78.0 a	80.3 b	72.2 a	32.6 b	97.0 b
60 lbs N/acre	78.8 a	82.6 b	69.3 b	29.1 b	100.0 c
P-value, Linear contrast	0.493	0.001	0.046	0.001	0.001
P-value, Quad. contrast	0.816	0.184	0.244	0.308	0.791
Sulfur Summary					
0 lbs S/acre	78.3 a	82.0 a	75.1 a	32.1 a	99.8 a
10 lbs S/acre	78.6 a	77.2 b	69.1 b	32.1 a	95.2 b
20 lbs S/acre	77.7 a	78.0 b	69.4 b	31.4 a	95.5 b
P-value, Linear contrast	0.097	0.027	0.001	0.602	0.002
P-value, Quad. contrast	0.142	0.123	0.011	0.728	0.037
Statistical Summary					
Mean	78.2	79.0	71.2	31.9	96.8
CV (%)	7.8	9.6	8.5	16.4	5.9
Interaction	**Interaction p-values**				
Plt Rate x N Rate	0.932	0.619	0.680	0.789	0.936
Plt Rate x S Rate	0.607	0.946	0.677	0.621	0.649
N Rate x S Rate	0.252	0.245	0.925	0.606	0.219
N Rate x S Rate x Plt rate	0.223	0.601	0.569	0.541	0.730

Yield means with the same letter are not significantly different accord to the LSD (p=0.05).

Table 3. Effect of nitrogen, sulfur, and planting rate on yield of dryland malt barley. Western Triangle Ag. Research Center. 2005.

Treatment	Location					
	Cut Bank	Ethridge	Joplin	Knees	Sunburst	WTARC
	bu/acre					
Planting Rate Summary						
10 seeds/ft^2	56.5 a	73.8 a	80.7 a	79.0 a	83.7 a	78.2 a
15 seeds/ft^2	59.7 a	74.4 a	85.5 b	84.1 b	88.2 b	83.6 b
20 seeds/ft^2	58.8 a	79.0 a	84.6 b	89.1 c	93.1 c	85.1 b
P-value, Linear contrast	0.373	0.135	0.005	0.001	0.001	0.001
P-value, Quad. contrast	0.362	0.504	0.020	0.925	0.878	0.256
Nitrogen Summary						
0 lbs N/acre	38.2 a	59.0 a	78.5 a	75.8 a	82.9 a	80.6 a
30 lbs N/acre	61.2 b	77.0 b	85.5 b	86.7 b	89.1 b	83.7 a
60 lbs N/acre	75.7 c	91.1 c	86.8 b	89.6 c	93.0 c	82.6 a
P-value, Linear contrast	0.001	0.001	0.001	0.001	0.001	0.308
P-value, Quad. contrast	0.058	0.527	0.019	0.002	0.485	0.227
Sulfur Summary						
0 lbs S/acre	62.1 a	72.8 a	83.6 a	82.9 a	85.9 a	80.7 a
10 lbs S/acre	57.6 ab	76.9 a	83.1 a	85.2 a	89.7 a	83.0 a
20 lbs S/acre	55.4 b	77.3 a	84.1 a	84.1 a	89.4 a	83.2 a
P-value, Linear contrast	0.012	0.196	0.684	0.415	0.060	0.208
P-value, Quad. contrast	0.600	0.540	0.533	0.164	0.191	0.549
Statistical Summary						
Mean	58.4	75.7	83.6	84.1	88.3	82.3
CV (%)	18.8	16.7	7.0	7.2	8.9	10.2
Interaction	**Interaction p-values**					
Plt Rate x N Rate	0.447	0.341	0.844	0.418	0.945	0.348
Plt Rate x S Rate	0.999	0.949	0.826	0.999	0.703	0.685
N Rate x S Rate	0.915	0.300	0.947	0.573	0.591	0.550
N Rate x S Rate x Plt rate	0.601	0.456	0.651	0.968	0.652	0.812

Yield means with the same letter are not significantly different accord to the LSD (p=0.05).

Table 4. Effect of nitrogen, sulfur, and planting rate on kernel plumpness of dryland malt barley. Western Triangle Ag. Research Center. 2004.

Treatment	Location				
	Ethridge	Joplin	Knees	Sunburst	WTARC
	----------%----------				
Planting Rate Summary					
10 seeds/ft^2	80.8 a	90.0 a	69.5 a	21.5 a	91.3 a
15 seeds/ft^2	85.9 a	87.4 a	61.3 b	21.1 a	87.1 b
20 seeds/ft^2	83.4 a	86.7 a	53.4 c	17.3 a	84.9 b
P-value, Linear contrast	0.288	0.169	0.001	0.168	0.001
P-value, Quad. contrast	0.099	0.624	0.968	0.529	0.477
Nitrogen Summary					
0 lbs N/acre	81.1 a	93.9 a	73.5 a	34.9 a	92.3 a
30 lbs N/acre	85.1 a	89.7 a	62.7 b	17.4 b	86.9 b
60 lbs N/acre	84.0 a	80.5 b	48.0 c	7.6 c	83.9 b
P-value, Linear contrast	0.274	0.001	0.001	0.001	0.001
P-value, Quad. contrast	0.274	0.181	0.409	0.145	0.375
Sulfur Summary					
0 lbs S/acre	82.9 a	88.4 a	60.0 a	19.9 a	87.8 a
10 lbs S/acre	83.2 a	87.4 a	61.0 a	19.1 a	86.4 a
20 lbs S/acre	84.1 a	88.2 a	63.2 a	20.9 a	88.9 a
P-value, Linear contrast	0.650	0.928	0.247	0.727	0.494
P-value, Quad. contrast	0.869	0.481	0.817	0.819	0.175
Statistical Summary					
Mean	83.4	87.8	61.4	20.0	87.7
CV (%)	13.3	10.2	19.1	64.1	7.8
Interaction	**Interaction p-values**				
Plt Rate x N Rate	0.176	0.876	0.539	0.832	0.817
Plt Rate x S Rate	0.841	0.644	0.934	0.771	0.667
N Rate x S Rate	0.044	0.051	0.746	0.022	0.918
N Rate x S Rate x Plt rate	0.168	0.245	0.826	0.848	0.272

Yield means with the same letter are not significantly different accord to the LSD (p=0.05).

Table 5. Effect of nitrogen, sulfur, and planting rate on kernel plumpness of dryland malt barley. Western Triangle Ag. Research Center. 2005.

Treatment	Location					
	Cut Bank	Ethridge	Joplin	Knees	Sunburst	WTARC
	bu/acre					
Planting Rate Summary						
10 seeds/ft^2	95.5 a	96.5 a	91.8 a	95.1 a	92.3 a	88.4 a
15 seeds/ft^2	94.1 a	95.4 b	88.7 b	94.8 ab	89.9 b	85.3 ab
20 seeds/ft^2	91.6 a	94.6 c	85.6 c	94.3 b	89.7 b	81.6 b
P-value, Linear contrast	0.067	0.001	0.001	0.031	0.001	0.001
P-value, Quad. contrast	0.760	0.616	0.989	0.841	0.105	0.854
Nitrogen Summary						
0 lbs N/acre	94.9 a	94.7 a	93.8 a	94.9 a	93.5 a	90.7 a
30 lbs N/acre	91.9 a	95.9 b	89.5 b	94.9 a	91.1 b	85.1 b
60 lbs N/acre	94.3 a	96.0 b	83.1 c	94.4 a	87.2 c	79.5 c
P-value, Linear contrast	0.771	0.001	0.001	0.177	0.001	0.001
P-value, Quad. contrast	0.141	0.041	0.442	0.425	0.194	0.993
Sulfur Summary						
0 lbs S/acre	92.7 a	95.3 a	88.9 a	95.0 a	90.8 a	83.0 a
10 lbs S/acre	94.8 a	95.6 a	89.0 a	94.9 a	90.9 a	85.5 a
20 lbs S/acre	93.8 a	95.7 a	88.3 a	94.3 a	90.3 a	86.8 a
P-value, Linear contrast	0.606	0.217	0.628	0.066	0.451	0.052
P-value, Quad. contrast	0.406	0.566	0.695	0.532	0.601	0.738
Statistical Summary						
Mean	93.7	95.5	88.7	94.7	90.6	85.1
CV (%)	9.5	1.1	5.5	1.7	3.4	9.5
Interaction	**Interaction p-values**					
Plt Rate x N Rate	0.675	0.489	0.240	0.118	0.052	0.664
Plt Rate x S Rate	0.346	0.462	0.494	0.947	0.357	0.425
N Rate x S Rate	0.523	0.546	0.833	0.623	0.085	0.831
N Rate x S Rate x Plt rate	0.458	0.125	0.988	0.081	0.357	0.430

Yield means with the same letter are not significantly different accord to the LSD (p=0.05).

Table 6. Effect of nitrogen, sulfur, and planting rate on grain protein content of dryland malt barley. Western Triangle Ag. Research Center. 2004.

Treatment	Location				
	Ethridge	Joplin	Knees	Sunburst	WTARC
	----------%----------				
Planting Rate Summary					
10 seeds/ft^2	12.0 a	12.6 a	14.7 a	13.8 a	11.6 a
15 seeds/ft^2	11.8 a	12.6 a	14.6 a	13.9 a	11.1 b
20 seeds/ft^2	12.0 a	12.6 a	14.5 a	14.4 a	10.9 b
P-value, Linear contrast	0.954	0.829	0.514	0.119	0.003
P-value, Quad. contrast	0.336	0.940	0.891	0.675	0.443
Nitrogen Summary					
0 lbs N/acre	12.2 a	11.7 a	14.0 a	12.9 a	10.1 a
30 lbs N/acre	11.7 a	12.3 a	14.3 a	13.9 b	11.3 b
60 lbs N/acre	12.0 a	13.9 b	15.5 b	15.2 c	12.3 c
P-value, Linear contrast	0.504	0.001	0.001	0.001	0.001
P-value, Quad. contrast	0.151	0.159	0.099	0.674	0.419
Sulfur Summary					
0 lbs S/acre	12.2 a	12.4 a	14.2 a	13.5 a	11.0 a
10 lbs S/acre	12.0 a	12.7 a	14.9 b	14.2 ab	11.2 a
20 lbs S/acre	11.7 a	12.8 a	14.8 b	14.4 b	11.4 a
P-value, Linear contrast	0.072	0.522	0.048	0.031	0.081
P-value, Quad. contrast	0.727	0.521	0.062	0.447	0.888
Statistical Summary					
Mean	12.0	12.6	14.6	14.0	11.2
CV (%)	10.0	11.3	8.5	12.5	8.3
Interaction	**Interaction p-values**				
Plt Rate x N Rate	0.060	0.242	0.670	0.266	0.648
Plt Rate x S Rate	0.313	0.924	0.489	0.664	0.628
N Rate x S Rate	0.258	0.260	0.509	0.078	0.745
N Rate x S Rate x Plt rate	0.151	0.646	0.697	0.965	0.310

Yield means with the same letter are not significantly different accord to the LSD (p=0.05).

Table 7. Effect of nitrogen, sulfur, and planting rate on grain protein content of dryland malt barley. Western Triangle Ag. Research Center. 2005.

Treatment	Location					
	Cut Bank	Ethridge	Joplin	Knees	Sunburst	WTARC
	bu/acre					
Planting Rate Summary						
10 seeds/ft^2	10.0 b	10.3 a	12.4 a	12.3 a	12.6 a	13.8 a
15 seeds/ft^2	9.8 ab	9.9 b	12.4 a	12.1 a	12.4 b	13.5 a
20 seeds/ft^2	9.5 a	9.7 b	12.2 a	11.7 b	12.1 c	13.4 a
P-value, Linear contrast	0.004	0.004	0.389	0.002	0.001	0.081
P-value, Quad. contrast	0.835	0.473	0.595	0.439	0.804	0.847
Nitrogen Summary						
0 lbs N/acre	9.9 a	9.3 a	11.5 a	11.3 a	11.7 a	12.6 a
30 lbs N/acre	9.6 a	9.6 a	12.2 b	12.0 b	12.2 b	13.6 b
60 lbs N/acre	9.9 a	10.9 b	13.4 c	12.9 c	13.1 c	14.5 c
P-value, Linear contrast	0.959	0.001	0.000	0.001	0.001	0.001
P-value, Quad. contrast	0.030	0.002	0.190	0.385	0.097	0.826
Sulfur Summary						
0 lbs S/acre	10.0 b	9.9 a	12.4 a	11.9 a	12.5 a	13.9 a
10 lbs S/acre	9.8 ab	9.8 a	12.3 a	12.2 a	12.1 b	13.6 ab
20 lbs S/acre	9.6 a	10.1 a	12.3 a	12.1 a	12.4 a	13.2 b
P-value, Linear contrast	0.037	0.252	0.609	0.279	0.511	0.006
P-value, Quad. contrast	0.906	0.277	0.463	0.094	0.008	0.826
Statistical Summary						
Mean	9.8	9.9	12.3	12.1	12.3	13.6
CV (%)	7.3	6.7	6.5	5.7	4.2	7.6
Interaction	**Interaction p-values**					
Plt Rate x N Rate	0.526	0.568	0.096	0.519	0.456	0.361
Plt Rate x S Rate	0.769	0.698	0.960	0.859	0.562	0.537
N Rate x S Rate	0.723	0.970	0.967	0.985	0.079	0.326
N Rate x S Rate x Plt rate	0.612	0.309	0.969	0.172	0.206	0.597

Yield means with the same letter are not significantly different accord to the LSD (p=0.05).

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