

Nitrogen Management for Irrigated Malting Barley

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Executive Summary

Studies were conducted in 2008, 2009, and 2010 to evaluate variety response to nitrogen (N) rates and application strategies. A split-split plot design with three factors (N rate, application strategy, and variety) was used. The N rates were 0, 30, 60, 90, and 120 lbs N/ac. The application strategies were 100 percent applied pre-plant incorporated (PPI), 100 percent applied polymer coated pre-plant incorporated (PC PPI), and a split-application with 50 percent applied pre-plant incorporated followed by 50 percent post-emergence. The N fertilizer source material was urea. The polymer coated urea was Nutrisphere-N from Simplot. The barley varieties evaluated were Stellar-ND, Tradition, Pinnacle, and 2ND21867.

A separate study was established in 2010 to help compare the three application strategies: 100 percent applied PPI, 100 percent applied PC PPI, and split with 50 percent applied pre-plant incorporated followed by 50 percent post-emergence at a rate of 90 lbs N/ac. Soil samples (0-24 inches) were taken April 21 (pre-plant), June 2 (6-leaf stage), and post-harvest on September 23. Plant tissue samples were also taken from the corresponding plots on June 2. In addition to soil sampling, Plant Root Simulator (PRS™) probes were used to compare plant available nitrate and ammonia between the three application methods.

Results

Nitrogen Rate, Application Strategy, and Variety

2010

- ◆ Grain yield was similar among application strategies.
- ◆ Grain yield generally increased as the N rate increased.
- ◆ Pinnacle and 2ND21867 had the highest yield and number of heads per acre.

2009

- ◆ Grain yield was similar among application strategies.
- ◆ Grain yield ranged from 101 to 121 bushels per acre with no applied N. Pinnacle and 2ND21867 produced about 140 bushels per acre with 30 pounds of applied N.

2008

- ◆ The method of N application affected grain yield. At the 90 lbs N rate, grain yield increased 23 bu/ac with the split application when compared at PPI application.

The highest grain yield and the lowest total N per bushel were produced in 2009. Average monthly temperatures were below normal in 2009. The previous crop was field pea in 2009 and soybean in 2008 and 2010. The field pea residue was managed to foster volunteer regrowth. A 40 lb N legume credit was assumed for field pea but it is not known how much additional N the volunteer regrowth may have provided.

Application Strategy

- ◆ The PRS™ data was very variable. Only large differences in N could be statistically separated.

Objective

The objective of the study was to measure the impact of varying N rates and application strategies on the grain yield and protein composition of irrigated barley.

Materials and Methods

Two studies were established in 2010 at the NDSU Carrington Research Extension Center to evaluate the effect of polymer coated urea and split applications of N on irrigated barley.

To evaluate variety response to N rates and application strategies, a split-split plot design with three factors (N rate, application strategy, and variety) and 4 replicates was used. The N rates were: 0, 30, 60, 90, and 120 lbs N/ac. The application strategies were 100 percent applied PPI, 100 percent applied PC PPI, and split with 50 percent applied PPI followed by 50 percent post-emergence. The N fertilizer source material was urea. The polymer coated urea was Nutrisphere-N from Simplot. The barley varieties evaluated were: Stellar-ND, Tradition, Pinnacle, and 2ND21867. The previous crop was soybean. A spring 0-24 inch soil test indicated 35 lbs N/ac. The PPI fertilizer was applied April 20 and incorporated shortly after application. The trial was seeded April 21 in 7-inch rows at 1.2 million pure live seeds per acre. The post-emergence fertilizer applications occurred June 2 at the 6-leaf stage. The trial was harvested August 5.

A separate study was established to help compare the three application strategies 100 percent applied PPI, 100 percent applied PC PPI, and split with 50 percent applied PPI followed by 50 percent post-emergence at a rate of 90 lbs N/ac. Two additional treatments were also added to evaluate PPI and pre-emergence (PRE) applications of Agrotain. The study design was a randomized complete block with four replicates. The PPI fertilizer was applied April 21 and incorporated shortly after application. Barley 'Tradition' was planted April 21 in 7-inch rows at 1.2 million pure live seeds per acre. The PRE fertilizer was applied April 23. The post-emergence fertilizer applications occurred on June 2 at the 6-leaf stage. The trial was harvested August 5. Soil samples (0-24 inches) were taken April 21 (pre-plant), June 1 (6-leaf stage), and post-harvest on September 23. Plant tissue samples were also taken on June 1. In addition to soil sampling, PRS™ probes were used to compare plant available nitrate and ammonia between the three application methods. Three pairs (i.e., three cation- and three anion-exchange) of PRS™ probes were spread throughout each plot and then combined for analysis. Another three pairs were placed individually in 6" by 14" root exclusion tubes to measure nutrient supply without root interference. A cumulative measure of nutrient supply throughout the growing season was measured by removing buried PRS™ probes every 14 days (starting 26 days after planting) and then re-inserting fresh PRS™ probes in the same soil slot for a total of eight burials. The pulled probes were analyzed for nitrate-N and ammonium-N levels.

2010 Results

Nitrogen Rate, Application Strategy, and Variety

Nitrogen rate: There was an N rate by application strategy interaction for days to head. Heading was delayed slightly as the N rate increased (Table 1). The exception was the split application of 120 lbs N/ac. There was also an N rate by variety interaction for grain protein. Protein response to N rate was greater with Pinnacle and 2ND21867 than Tradition and Stellar-ND (Table 2). Pinnacle had the lowest grain protein content at each N rate.

Table 1. Days to head averaged over variety.

N Rate lb/ac	Application Strategy		
	PPI	PC PPI	Split
	Days to head		
0	66.6	66.0	66.2
30	66.3	66.3	66.9
60	66.4	66.3	66.7
90	66.2	67.6	67.3
120	67.2	67.1	65.9
LSD 0.05	0.6		

Table 2. Grain protein content averaged across application strategies.

Variety	Nitrogen Rate (lb/ac)				
	0	30	60	90	120
	Grain Protein (%)				
Stellar-ND	11.6	11.3	11.3	11.6	11.9
Tradition	11.6	11.4	11.8	11.9	12.4
Pinnacle	9.5	9.5	9.9	10.4	10.9
2ND21867	10.7	10.8	11.2	11.8	12.0
LSD 0.05	0.3				

Plant height, plant lodge, and grain yield generally increased as the N rate increased (Table 3). The number of heads/ac was similar with rates of 30, 60, and 90 lbs N/ac but increased when 120 lbs N/ac was applied. The percentage of plump kernels decreased and the percentage of thin kernels increased with N rates of 90 and 120 lbs/ac. Test weight increased slightly as the N rate increased to 60 lbs/ac.

Table 3. Barley response to N rate and pounds of N per bushel produced averaged over application strategy and variety.

N Rate lb/ac	Total N ^a lb/ac	Days to Head	Plant Height inch	# of Heads million/ac	Plant Lodge 0-9	Plump >6/64 %	Thin <5/64 %	Test Weight lb/bu	Grain Protein %	Grain Yield bu/ac	Lb N per bu
0	75	66.3	29.4	1.6	0.1	97.3	0.2	48.4	10.8	75.9	1.0
30	105	66.5	33.5	1.8	1.1	97.4	0.2	48.5	10.7	95.7	1.1
60	135	66.5	36.3	1.8	1.5	97.5	0.2	48.7	11.0	105.3	1.3
90	165	67.0	36.3	1.7	1.6	97.0	0.3	48.7	11.4	109.2	1.5
120	195	66.7	37.4	1.9	2.5	96.6	0.3	48.7	11.8	115.6	1.7
LSD 0.05		0.3	1.0	0.1	0.3	0.3	0.1	0.2	0.2	5.2	

^aTotal N = 35 lb soil + 40 lb soybean credit + applied N.

Application strategy: Plant lodge, percentage of thin kernels, grain protein, and grain yield were similar among application strategies (Table 4). Plant height was 2 inches shorter when N was applied as a split application.

Table 4. Barley response to application strategy averaged over N rate and variety.

Application Strategy	Days to Head	Plant Lodge 0-9	Plant Height inch	# of Heads million/ac	Plump >6/64 %	Thin <5/64 %	Test Weight lb/bu	Grain Protein %	Grain Yield bu/ac
PPI	66.5	1.4	35.3	1.75	97.2	0.23	48.6	11.2	102.1
PC PPI	66.7	1.4	35.2	1.73	97.5	0.23	48.6	11.2	100.4
Split	66.6	1.3	33.2	1.73	96.8	0.26	48.4	11.1	98.6
LSD (0.05)	NS	NS	0.8	NS	0.3	NS	0.2	NS	NS

Variety: On average, all varieties headed about 66 days after planting (Table 5). Pinnacle and 2ND21867 had the highest grain yield and number of heads/ac.

Table 5. Variety characteristics averaged over N rates and application strategies.

Variety	Days to Head	Plant Lodge 0-9	Plant Height inch	# of Heads million/ac	Plump >6/64 %	Thin <5/64 %	Test Weight lb/bu	Grain Protein %	Grain Yield bu/ac
Stellar-ND	66.4	1.3	35.6	1.40	97.3	0.21	47.1	11.4	94.8
Tradition	66.6	1.6	36.1	1.42	97.3	0.20	48.4	11.8	97.3
Pinnacle	66.8	1.4	34.1	2.11	97.0	0.27	48.9	10	104.6
2ND21867	66.6	1.3	32.6	2.01	97.0	0.29	50.0	11.3	104.7
LSD 0.05	0.4	NS	0.9	0.12	0.3	0.04	0.2	0.2	5.2

In 2009 grain yield ranged from 101 to 121 bushels per acre with no fertilizer (Table 6). Pinnacle and 2ND21867 produced about 140 bushels per acre with 30 pounds of applied N. A maximum grain yield of 158 bushels per acre was achieved with 2ND21867 and 120 lbs N/ac. The amount of N available per bushel produced is low compared to 2010 and 2008 (Tables 3, 6, 7). The previous crop was field pea instead of soybean. The field pea residue was managed to foster volunteer regrowth. A 40 lbs N legume credit was assumed for field pea but it is not known how much additional N the volunteer regrowth may have provided.

In 2008 there was an N rate by application strategy interaction for grain yield (Table 7). Rainfall of 5.01 inches was recorded in June. This made irrigation scheduling more difficult and could be part of the reason for differences in grain yield between the application strategies. An average of about 74 bushels per acre was produced when no fertilizer was applied. At the 30 and 60 lbs N rates there was no difference in grain yield among the three application strategies. At the 90 lbs N rate, the polymer-coated urea applied pre-emergence (PC PRE) produced 9 bu/ac more and the split application produced 23 bu/ac more than the PRE treatment. The highest grain yields occurred with 90 and 120 lbs N applied as a split application and 120 lbs N applied PC PRE.

Table 6. Grain yield and the amount of N per bushel produced, 2009.

Variety	N Rate (lb/ac)						Total Available N ^a					
	0	30	60	90	120	Mean	95	125	155	185	215	Mean
	Grain Yield (bu/ac)						lb N/bu					
Stellar-ND	101	123	134	136	141	127	1.00	1.06	1.20	1.40	1.57	1.25
Tradition	103	120	140	145	150	132	0.98	1.09	1.15	1.32	1.47	1.20
Pinnacle	114	140	143	144	147	138	0.89	0.94	1.12	1.33	1.50	1.16
2ND21867	121	142	154	151	158	145	0.83	0.92	1.05	1.27	1.40	1.09
Mean	110	131	143	144	149	--	0.93	1.00	1.13	1.33	1.49	--

LSD 0.05. Variety x N Rate interaction = 8. N Rate = 4. Variety = 4.

^aTotal N = 60 lb soil + 40 lb field pea credit + applied N.

Table 7. Grain yield and the amount of nitrogen per bushel produced, 2008.

N Rate	Total	Application Strategy				Application Strategy			
	N ^a	PRE	PC PRE	Split	Mean	PRE	PC PRE	Split	Mean
lb/ac		Grain Yield (bu/ac)				lb N/bu			
0	90	81	68	72	73	1.22	1.35	1.27	1.28
30	120	83	85	86	85	1.48	1.51	1.41	1.47
60	150	110	111	116	112	1.39	1.37	1.30	1.35
90	180	112	121	135	122	1.62	1.51	1.34	1.49
120	210	124	132	137	131	1.70	1.60	1.55	1.62
Mean		102	103	109	N	1.48	1.47	1.37	

LSD 0.05. Application Strategy x N Rate interaction = 8. Application Strategy = 4. N Rate = 5.

^aTotal N = 50 lb soil + 40 lb soybean credit + applied N.

Weather: The average monthly temperature and rainfall for 2008-2010 are listed in table 8. In 2008, the monthly average air temperature was below normal April-June. In 2009, it was below normal April-August. The period from heading to physiological maturity was also longer in 2009 (personal observation). In 2010, average monthly temperatures were near normal. Monthly rainfall each year was below or near normal with the exception of June 2008 with 5.01 inches of rainfall.

Table 8. Average monthly temperature and rainfall.

Month	Temperature (°F)				Rainfall (inches)				
	2008	2009	2010	Normal	2008	2009	2010	Normal	
April	40	38	48	43	1.68	1.68	1.40	1.44	
May	51	51	54	56	1.17	1.36	2.60	2.49	
June	61	61	63	65	5.01	1.61	3.22	3.79	
July	67	64	68	69	1.85	1.50	1.95	3.11	
August	67	64	69	68	1.53	1.99	1.64	2.48	
Average	57	56	60	60	Total	11.24	8.14	10.81	13.31

Results

Application Strategy

Barley response to nitrogen application strategies: Days to head, test weight, grain protein, and grain yield were similar among fertilizer treatments (Table 9). Plant height was reduced when urea was applied as a split application or as a PRE application with Agrotain when compared to the PPI application of urea.

Table 9. Barley response to application strategies.

Treatment	Placement	Rate lb N/ac	Days to	Plant	Test	Grain	Grain
			Head	Height	Weight	Protein	Yield
				inch	lb/bu	%	bu/ac
Untreated Check			68.0	28.0	49.8	9.4	77
Urea	PPI	90	65.5	37.6	49.4	10.5	125
NSN Urea	PPI	90	66.0	35.6	49.5	10.3	116
Urea	PPI/POST	45/45	65.8	33.8	49.4	10.6	121
Agrotain Urea	PPI	90	66.0	34.7	49.6	10.1	116
Agrotain Urea	PRE	90	65.8	33.4	49.7	9.9	113
LSD P = 0.05			1.5	2.7	NS	0.6	22

Soil and plant tissue results: An April 21 soil test indicated an average of 29 lbs N (Table 10). Data for the June 1 soil test were variable. The June 1 soil test indicated 19 lbs N/ac in the untreated check, 38 lbs N/ac for the split application, and an average of 61 lbs N/ac for the PPI and PRE applications. Total N in the plant tissue was less in the untreated check and less in the PRE application of Agrotain compared to the other fertilizer treatments. Soil N was similar on August 26.

Table 10. Soil and plant tissue test results.

Treatment	Placement	Rate lb N/ac	Sampling Date			
			4/21	6/1	6/1	8/26
			Soil 0-24"	Soil 0-24"	Plant Tissue	Soil 0-24"
			lb N/A	lb N/A	Total N	lb N/A
Untreated Check			31	19	4.28	23
Urea	PPI	90	31	78	5.80	25
NSN Urea	PPI	90	26	61	5.80	22
Urea	PPI/POST	45/45	32	38	5.78	24
Agrotain Urea	PPI	90	28	39	5.73	21
Agrotain Urea	PRE	90	29	66	5.33	17
LSD P = 0.05			NS	30	0.36	NS
C.V. (%)			20	40	4	19

PRS™ probes with root interaction: There is a high amount of variability in the PRS™ data. For the 14-day period 26 to 42 days after planting, the amount of N in the urea treatments was higher than the untreated check (Table 11). Numerically the amount of N was lower in the split application compared to the PPI and PRE applications but due to the high variability, statistical differences cannot be detected. There may also be a trend for higher N levels for the Agrotain PPI application when compared to urea. The POST split application was applied at the beginning of the second PRS™ probe cycle (42 days after planting). N levels were numerically

higher in the split and the Agrotain PRE applications during this sampling period. The majority of the N from the POST split application is detected in the 14-day period 56 to 70 days after planting.

Table 11. Soil N with root interaction.

Treatment	Placement	Rate	Sampling period (days after planting)							
			26-42	42-56	56-70	70-84	84-98	98-112	112-126	126-140
			PRS TM probe N supply rate at 0-6 in (µg NO ₃ -/10cm ² /14 day period)							
lb N/ac										
Untreated Check			56	34	22	18	21	145	241	200
Urea	PPI	90	320	95	71	29	34	140	200	116
NSN Urea	PPI	90	389	101	52	20	14	66	149	157
Urea	PPI/POST	45/45	227	160	239	44	20	107	200	161
Agrotain Urea	PPI	90	447	134	33	16	18	99	136	128
Agrotain Urea	PRE	90	391	163	43	30	24	65	124	102
LSD P = 0.05			170	115	117	33	19	62	91	93
C.V. (%)			37	67	101	85	57	40	34	43

PRSTM probes with root exclusion: While the amount of N available with root exclusion is higher, the patterns among treatments are similar (Table 12). The split application tends to be lower in the 14-day period 26 to 42 days after planting and tends to be higher in the 14-day period (56 to 70 days after planting) after the POST split application.

Table 12. Soil N with root exclusion.

Treatment	Placement	Rate	Sampling period (days after planting)							
			26-42	42-56	56-70	70-84	84-98	98-112	112-126	126-140
			PRS TM probe N supply rate at 0-6 in (µg NO ₃ -/10cm ² /14 day period)							
lb N/ac										
Untreated Check			355	450	466	279	304	523	318	395
Urea	PPI	90	799	753	597	256	241	357	286	301
NSN Urea	PPI	90	941	870	585	166	230	375	267	285
Urea	PPI/POST	45/45	611	760	817	224	245	304	266	324
Agrotain Urea	PPI	90	845	692	571	251	267	326	324	266
Agrotain Urea	PRE	90	721	697	501	215	190	401	322	280
LSD P=0.05			281	239	NS	67	NS	NS	NS	83
C.V. (%)			26	23	33	19	28	30	22	18