Fertilizing Malting and Feed Barley SF-713 (Revised)
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Barley has been an important cash and rotational crop in North Dakota and the region for many years. It is important as a feed grain, but by far its economic value is linked to the malting industry. Barley requires adequate nitrogen (N) for good yields, but since grain protein in excess of industry limits often results in rejection of the crop as malting grade, and since excess N may lead to smaller kernel size, the line between adequate N and excessive N is fine. In addition, excessive N may result in lodging, which lowers yields and increases the incidence and severity of fusarium head blight (scab) and other diseases in some year.
In recent years, the brewing industry has largely moved to the use of 2-row barley cultivars in their malting process due to more consistently favorable protein concentrations and other malting-friendly properties. Nitrogen rate studies were specifically conducted to determine the most profitable N-rate to use in 2-row cultivars and to help develop an N calculator to better find the most profitable rates under different N fertilizer costs and 2-row barley prices that farmers might receive.
Due to the irregularity of rainfall in the region, a preplant N application is important to adequately feed the crop through its short growing season. All of the N intended for the barley crop should be applied preplant. Top-dressing N after crop establishment is discouraged because it contributes more to increased grain protein than increased yield.

Once the N application is made, managing the crop for high yield is important. Although yield is most directly related to temperature, soil moisture and rainfall within a growing season, growers have a number of important management factors that influence yield in any given year. High fertilizer application rates will not result in yield greater than environment and management decisions allow. Also, yield and N rate are not related between environments, so fertilizer rates are instead based on the rate that maximizes yield/quality in any given year, and not on yield prediction. Feed barley N rates are a little higher than those intended for malting contracts, which are more conservative due to the importance of lower protein. However, excessive N rates may result in pre-anthesis lodging, increasing the severity of disease and decreasing grain recovery during harvest.

Date of Planting
Research at NDSU has shown that seeding barley early is extremely important to achieving highest yield for the season. Seeding before May 15 provides the greatest chance of achieving malting grade south of Highway 2, and May 25 for northern-tier county growers. Seeding two weeks later than these dates result in almost no chance of achieving malting grade unless N rates are greatly reduced. Very low yields that result from late planting and low N rates are not economically acceptable to most growers.

Seeding Rate-
Adequate seeding rate with an approved malting barley variety is important for growing and marketing the crop effectively. Current barley seeding rates are 1.5 to 2.0 bushels per acre (65-90 pounds live seed per acre). Growers would be advised to determine the number of seeds per pound and germination percentage to provide a more accurate seeding rate. Target plant population is 1.25 million to 1.30 million plants per acre, or approximately 30 plants per square foot.

Other management tools-
It is important to adequately control insects, weeds and diseases for successful malting barley, or even quality feed barley production. NDSU has a variety of publications to help these decisions

available from County Extension offices, or from the NDSU Extension Publication website available at https://www.ag.ndsu.edu/publications/crops .

Abandonment of yield goal as a consideration of fertilizer rate

The most important reason for abandoning yield goal as a consideration in fertility recommendations is that the data from modern fertilizer rate trials indicate that a similar rate of nutrient results in highest yield regardless of the maximum yield in any experiment. In other words, the rate of nutrient resulting in highest yield in a low-yield environment was similar to the rate that resulted in highest yield in a high-yield environment. A logical way to explain this is that in a low-yield environment resulting from too wet or too dry conditions, nutrient use efficiency is quite low, so a greater rate of nutrient is required to produce a unit of yield. In a high-yield environment, nutrient use efficiency is quite high as release from the soil is maximized, root growth is maximized, movement of nutrient to the root is maximized, and so a lower rate of nutrient is required to produce a unit of yield. The recommended N-rate table values should therefore be utilized regardless of what yield a grower believes will result from their barley cultivation.

Nitrogen rate adjustments-

The total N requirements for 6-row barley production are indicated in Tables 1-2. Total N requirements are the sum of residual nitrate-N soil analysis to 2 feet in depth, previous crop credits (Table 7), and an adjustment for 6 years or more continuous no-till/one-pass seeding. Soil sampling is usually conducted the fall before planting, although early spring sampling can also be conducted. Neither time is superior to the other in terms of nitrate-N values it will generate. Site-specific zone soil sampling may help to reduce over- or under-fertilization in areas of the field compared to a composite soil sampling approach. The adjustment for long-term no-till production is due to an apparent decrease in N rate required for maximum yields in spring wheat, corn and sunflower research conducted at NDSU over the past 10 years. In fields that are transitioning to no-till, or are no-till during only part of the rotation, an additional 20 pounds N per acre would be required to overcome the tie-up of N by residue before soil microbial communities convert to a more efficient N cycling system. In the Langdon region, subtract an additional 30 lbs N/acre from the 6-row barley N recommendation.

The N rates for yield and to achieve malting grade protein of less than 14%, the N rates are more conservative than for barley grown for feed. For 6-row barley, the crop needs to be slightly N deficient in order to achieve malting grade protein. For 2-row barley, N rates can be slightly greater. In drought years, the chances of making malting grade protein are low, as any beginning residual nitrate along with the most conservative N rates will result in higher protein barley. The alternative to recommended N rates applied at planting in a year with limited spring subsoil moisture is to split the N required, with perhaps half the N rate applied by seeding, and then guessing on what rainfall might be received the next 6 weeks and applying either the other half of the recommended N, and less N or no additional N should the outlook be bleak for rainfall the next 30 days. No additional N should be applied after 5-leaf barley, as a great share of the application will produce more protein than grain. The economic optimal N rate for 2-row barley for the western, eastern and Langdon regions of ND are provided in Tables 3-5. The values need to be adjusted for soil nitrate-N to a depth of 2 feet, long-term no-till (subtract 50 lbs N/acre) and for previous crop N credits (Table 6).

Nitrogen application methods-

Nitrogen can be applied with the seed at planting as long as it does not exceed the limits recommended in Table 5. For more detailed charts that include variation in soil texture and soil moisture, please refer to NDSU Extension Circular SF1751 https://www.ag.ndsu.edu/pubs/plantsci/soilfert/sf1751.pdf . Some growers also use a mid-row band

application of anhydrous ammonia, urea, or nitrogen solutions successfully. As long as seed and fertilizer are separated by at least 1 ½ inches for urea and nitrogen solutions, and separated laterally by at least 3 inches for anhydrous ammonia, application of reasonable rates of nitrogen can be safely applied.

Fall application has been used successfully when the application is made after October 1, and only when soil temperatures have declined below 50°F in the morning at the 4-inch depth. Fall application should not be made to sandy soils, nor should it be made to heavier soils that are prone to early spring saturation. Nitrapyrin and DCD are the two chemistries that have nitrification inhibiting properties in NDSU research. A full description of the chemistry and properties of nitrification inhibitors, see NDSU Extension Circular 1581, https://www.ag.ndsu.edu/publications/crops/nitrogen-extenders-and-additives-for-field-crops/sf1581.pdf .

Surface application of urea is possible if an NBPT-based urease inhibitor is impregnated onto the urea before application. Under no-till, subsurface application of urea or UAN (28-0-0) at least to the 2-inch depth is the most efficient application method, as the conversion from urea to free ammonia from urease enzyme in these soils is very fast when residues are present. Also, N is at risk for ammonia volatilization if soil pH under conventional tillage is greater than 7 when urea is surface applied or subjected to shallow tillage. There is evidence that shallow (less than 2 inches in depth) incorporation of urea may be worse than no incorporation at all. A urease inhibitor containing an effective rate of NBPT or NBPT/NPPT will inhibit ammonia volatility almost completely for about 10 days. For more information regarding urease inhibitors, refer to NDSU Extension Circular 1581 with the web address previously linked.

Phosphorus application-

Banding phosphorus (P) with or near the seed in barley at planting is very important for highest yield and P use efficiency. If the rate of P recommended exceeds the $N+K_2O$ limit recommended in Table 8, the P fertilizer may be split, with some applied as a band and some as a broadcast application. Phosphorus application is most efficient and results in the highest yield and economic returns if banded near or with the seed. If phosphorus is banded near or with the seed, rates at the VL and L level soil test P levels can be reduced by one-third compared to chart rates in Tables 1-4. There are limits to the amount of fertilizer that can be safely applied with the seed. The restrictions have more to do with the ammonium-N content of the fertilizer than with the salt-index, although fertilizer salt still needs to be considered. For an abbreviated chart of the maximum urea-N fertilizer rates recommended with barley seed at planting, see Table 5. For a more detailed chart that includes variation in soil texture and soil moisture, please refer to NDSU Extension Circular SF1751 https://www.ag.ndsu.edu/pubs/plantsci/soilfert/sf1751.pdf .

Potassium/Chloride application-

Potassium may be required for some sandy soils, but the main reason for its application is as a carrier for chloride. Potassium chloride is approximately 50% chloride (Cl). The indicator for the need of chloride is a soil test from 0-2 feet in depth. If soil levels are below 30 pounds per acre Cl, then an application of 10-20 pounds Cl per acre might result in an increase in yield and some additional tolerance to certain soil and leaf diseases. This will not be a substitute for a needed fungicide application later in the season. It is not necessary to band the Cl, but if the other fertilizer is being banded, and the addition of the fertilizer does not result in exceeding the $N+K_2O$ limit in Table 6 or in NDSU Extension Circular SF1751 https://www.ag.ndsu.edu/pubs/plantsci/soilfert/sf1751.pdf , then banding may provide convenience to the grower. Research in North Dakota has shown a yield increase, mostly due to larger kernel size, about half of the time when soil levels are low. Increased kernel size is important in malting barley, since kernel 'plump' is category considered by the malting industry for contract acceptance of grain.

Table 1. Barley, feed grade in North Dakota in conventional tillage systems.

Total available N*, pounds per acre	Soil Test P, ppm					Soil Test K, ppm				
	VL	L	M	H	VH	VL	L	M	H	VH
	0-3	4-7	8-11	12-15	16+	0-40	41-80	81-120	121-150	151+
	Pounds P_2O_5 per acre					Pounds K_2O per acre				
150	78	60	52	26	0	90	60	45	30	0

*Total available N includes residual soil nitrate-N to a 2-foot depth, previous crop N credit, and supplemental N from fertilizers, manures or other sources. In the Langdon region, subtract 30 lbs N/acre from N recommendation.

Table 2. Barley, feed grade in North Dakota in no-till systems.

Total available N*, pounds per acre	Soil Test P, ppm					Soil Test K, ppm				
	VL	L	M	H	VH	VL	L	M	H	VH
	0-3	4-7	8-11	12-15	16+	0-40	41-80	81-120	121-150	151+
	Pounds P_2O_5 per acre					Pounds K_2O per acre				
120	78	60	52	26	0	90	60	45	30	0

*Total available N includes residual soil nitrate-N to a 2-foot depth, previous crop N credit, and supplemental N from fertilizers, manures or other sources. In the Langdon region, subtract 30 lbs N/acre from N recommendation.

Table 3. Malting 2-row barley, western region, economic N rates with N cost and barley price.

	Cost of N, $/pound N																		
$/bu	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00
3	140	130	120	102	103	94	84	74	65	55	46	38	28	19	10	0	0	0	0
4	144	137	131	124	117	110	102	96	89	82	75	68	61	54	47	40	32	26	19
5	147	142	136	131	125	120	114	108	102	97	92	86	81	75	69	64	58	53	47
6	149	144	140	135	131	126	121	117	112	109	103	98	94	89	84	80	75	70	65
7	150	146	143	138	135	131	127	123	119	115	111	107	103	99	95	91	87	83	79
8	151	148	144	141	137	135	132	127	124	120	117	113	110	106	103	99	96	92	89
9	152	149	146	143	140	137	134	131	127	124	121	118	115	112	109	106	103	100	97
10	153	150	147	144	142	139	136	133	131	128	125	123	119	119	114	111	108	106	103

Table 4. Malting 2-row barley, eastern region, economic N rates with N cost and barley price.

	Cost of N, $/pound N																		
$/bu	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.10	1.20	1.30	1.40	1.50	1.60	1.70	1.80	1.90	2.00
3	145	138	131	125	117	110	104	97	89	82	75	68	61	54	46	40	33	26	19
4	148	144	137	132	127	122	117	111	106	101	96	91	85	80	75	70	65	59	54
5	150	146	142	137	133	129	125	121	117	112	108	104	100	96	92	87	83	79	75
6	151	148	144	141	137	134	131	127	124	120	117	113	110	106	103	99	96	92	89
7	152	149	146	146	140	137	135	132	129	126	123	120	117	114	111	108	105	102	99
8	153	151	148	148	143	140	137	135	132	130	127	124	122	119	117	114	111	109	106
9	154	152	149	149	144	142	140	137	135	133	131	128	126	124	121	120	117	114	112
10	154	152	150	150	146	144	142	140	137	135	133	131	131	127	125	123	121	119	117

Table 5. Malting 2-row barley, Langdon area, economic N rates with N cost and barley price.

	Cost of N, $/pound N																		
$/bu	**0.20**	**0.30**	**0.40**	**0.50**	**0.60**	**0.70**	**0.80**	**0.90**	**1.00**	**1.10**	**1.20**	**1.30**	**1.40**	**1.50**	**1.60**	**1.70**	**1.80**	**1.90**	**2.00**
3	115	108	101	95	87	80	84	67	59	52	45	38	31	24	46	10	0	0	0
4	118	114	107	102	97	92	87	81	76	71	66	61	55	50	45	40	35	29	24
5	120	116	112	107	103	99	95	91	87	82	78	74	70	66	62	57	53	49	45
6	121	118	114	111	107	104	101	97	94	90	87	83	80	76	73	69	66	62	59
7	122	119	116	116	110	107	105	102	99	96	93	90	8/7	84	81	78	75	72	69
8	123	121	118	118	113	110	107	105	102	100	97	94	92	89	87	84	81	79	76
9	124	122	119	119	114	112	110	107	105	103	101	98	96	94	91	90	87	84	82
10	124	122	120	120	116	114	112	110	107	105	103	101	101	97	95	93	91	89	87

Table 6. Previous Crop Credits

Previous crop	**Credit**
Soybean	40 lb N/acre
Dry edible bean	40 lb N/acre
Other grain legume crops (field pea, lentil, chickpea, faba bean, lupin)	40 lb N/acre
Harvested sweet clover	40 lb N/acre
Alfalfa that was harvested and unharvested sweet clover:	
>5 plants/sq. ft.	150 lb N/acre
3-4 plants/sq. ft.	100 lb N/acre
1-2 plants/sq. ft.	50 lb N/acre
<1 plant /sq. ft.	0 lb N/acre
Sugar beet	
Yellow leaves	0 lb N/acre
Yellow/green leaves	30 lb N/acre
Dark green leaves	80 lb N/acre

Second-year N Credits

Half of the N credit indicated for the first year for sweet clover and alfalfa is recommended, but no N credit is recommended after the second year for other crops.

Table 4. Maximum N + K_2O recommended for application with the seed, based on planter row-spacing, planter type, and seed spread. This table assumes a coarse textured soil for the lower end of each range, and a heavier texture for the upper end of the range. For more detail, see NDSU Extension Circular SF1751 https://www.ag.ndsu.edu/pubs/plantsci/soilfert/sf1751.pdf

	Seed	------- Planter Spacing, inches ----------			
	Spread	6	7.5	10	12
Planter type	inches	---------- pound N + K_2O per acre ----------			
Double disc	1	20-30	19-28	17-23	15-20
Hoe opener	2	32-44	27-38	23-31	20-27
	3	44-58	37-48	30-40	26-34
Air Seeder	4	56-72	46-58	37-48	32-42
	5	68-86	56-68	51-55	38-49
	6	80-100	66-79	58-74	44-56
	7		76-90	66-83	50-64
	8			73-92	56-71
	9			80-100	62-78
	10				68-86
	11				74-93
	12				80-100

Sulfur and micronutrient requirements

Sulfur deficiencies are more common throughout North Dakota than in the past due to higher crop demand from higher yield, increased rainfall in many years and low S deposition from rainfall. There is no soil test that is diagnostic for S availability. Sulfur deficiency has also been observed on higher organic matter soils (>3%) in addition to lower organic matter soils (<3%), and in higher clay soils (>40% clay) as well as sandy soils. If the recent history of a field going to barley has been wet the fall before, and/or snowfall has been normal to high, and/or pre-seeding spring rainfall has been high, the grower would be advised to apply 10 pounds per acre of S as a sulfate or thiosulfate form before or at seeding. Thiosulfate forms should not be placed with the seed. Ammonium sulfate may be applied as long as the limits outlined in Table 5 are considered. There are no micronutrients other than chloride that need to be considered for barley production in North Dakota.

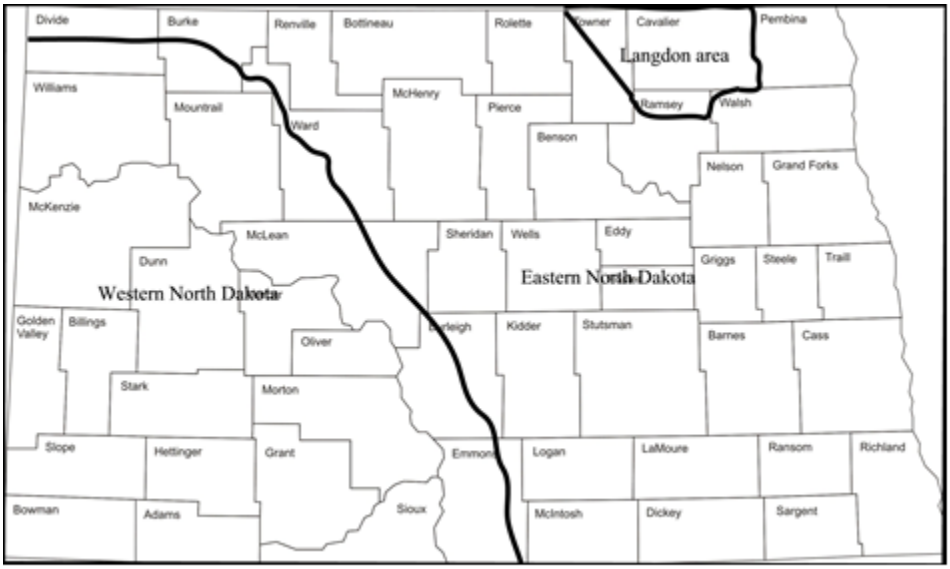

Figure 1. Map of recommendation regions with regards to barley production in North Dakota.