SF712 (Revised Sept. 2022)

Fertilizing Hard Red Spring Wheat and Durum

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Nitrogen recommendations for spring wheat and durum have been revised completely.

Nitrogen (N) management is a key to successful wheat production. Recommendations include consideration of wheat yield and protein response to added N within three major regions, and the use of wheat price and N cost in determining N rate. These recommendations are based on the concept that identifies an optimal N rate for greatest net income, not greatest yield.

For the interactive North Dakota Spring Wheat and Durum Nitrogen Calculator, go to *https://www.ag.ndsu.edu/temp/cnc/*.

Nitrogen fertilizer costs are much higher and more volatile than in the past. Using site-specific technologies, growers have the ability to vary fertilizer rates on different areas of fields to manage their input risks. Government policies and regulations increasingly push growers toward more judicious use of plant nutrients.

These N-rate recommendations are the result of compiling archived N-rate studies from 1970 to 2004, and include data from a statewide N-rate research program conducted from 2005 to 2021. Studies contained yield and protein data, location, fertilizer N-rate and residual soil nitrate to 2 feet in depth. Approximately one-third of the data for the recommendations come from archived data and the other two-thirds were generated since 2005.

Wheat response to N fertilizer is closely linked to wheat protein concentration. Growers rely on higher protein markets to maintain their profitability. A protein of 14% or greater is necessary to avoid discounts at the point of sale. Sometimes premiums are available to growers for protein greater than 14%.

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North Dakota data on analysis segregated into three regions: western, eastern and the Langdon region.

The western region is composed mostly of long-term no-till fields, with no-till continuous for at least six years in most fields, either pure no-till using only an opener for seed/fertilizer, or one-pass seeding, which only disturbs a couple inches at the soil surface at planting time. The western region is also typified by only sediment soils, a drier and warmer climate compared to conditions in the eastern region. The Langdon region segregates from the rest of the eastern region due to the shale pieces found commonly through the soil. The shale pieces contain high amounts of mineralizable ammonium, making the Langdon region soils essentially a slow-release natural fertilizer. The Langdon region requires less N for similar yields compared to the eastern region.

Higher-than-recommended N rates in the Langdon region results in pre-anthesis lodging. The amount of N required per bushel in the west was higher than in the east. Therefore, for the purposes of N recommendations for spring wheat and durum the state have been divided into three regions as shown in **Figure 1**.

Data from each zone were segregated and the relationships between wheat yield and available-N, and wheat protein and available-N, were established. Using the concept of "Return to N" from Sawyer and Nafziger (2005), the economic optimal N rate for wheat prices between between $3/bushel and $15/bushel and N costs from 20 cents/pound of N to $2/pound of N were developed using wheat price and protein discount or premium. The protein discount varies with grain elevator and the year.

The calculations used in developing these relationships used a 50 cent per point discount if protein were less than 14%, and a 50 cent per point premium from 14% to 15%, with no additional premium for greater protein than 15%. The gross N recommendations on the regional tables **(Tables 1-9)** contain the regional economic data for wheat yield and protein in the model.

Within each region, the optimal available N for three different productivities are defined as low, medium and high. The yield potential within each productivity category is defined for each region. This is done entirely for economic reasons, not for differences within region of yield/protein responses to N.

Productivity category definitions:

Langdon Region

Low = less than 40 bushels/acre

Medium = 41-60 bushels/acre

High = greater than 60 bushels/acre

Eastern Region

Low = less than 40 bushels/acre

Medium = 41-60 bushels/acre

High = greater than 60 bushels/acre

Western Region

Low = less than 30 bushels/acre

Medium = 31-50 bushels/acre

High = greater than 50 bushels/acre

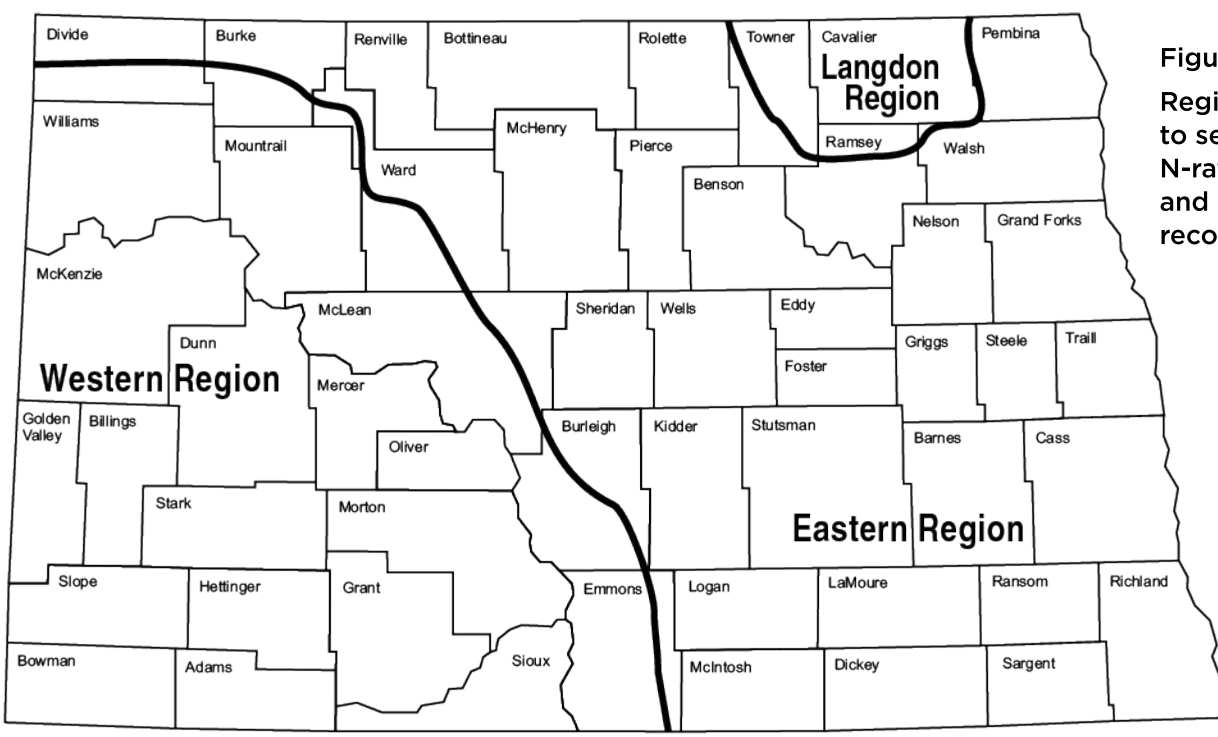

Figure 1.

Regions used to segregate N-rate data and develop N recommendations.

To determine recommended N rate

1. Find the region of the farm and look up the gross optimal available-N from the appropriate region/productivity table (**Tables 1-9**).
2. Subtract the soil test nitrate-N from the 0- to 2-foot depth.
3. Subtract any previous crop N credits (**Table 10**).
4. Subtract or add no-till system N credits:
   – If field has been in no-till less than five consecutive years, add 20 pounds of N/acre.
   – If field has been in no-till greater than five consecutive years, subtract 50 pounds of N/acre.
5. Organic matter credit for soils greater than 5.9% organic matter:
   Subtract 50 pounds of N/acre for each full percent organic matter above 5%.

From the optimum rates, the grower and adviser may choose to adjust plus/minus up to 30 pounds of N/acre. This adjustment may be used to anticipate a host of issues, including the following:

- Subtract N for high protein varieties.
- Add N for lower protein varieties.
- Subtract N for areas with a history of early lodging.
- Add N for soils with denitrification issues.
- Add N for N application practices that are not ideal.
- For wheat after small grains, we assume about 2,000 pounds/acre of straw residue. For every 2,000 pounds/acre of straw greater than this, add 30 pounds of N/acre.

As N costs increase and wheat price decreases, optimum N will not be highest yield or protein. However, from our database, these rates will provide the greatest net income.

Table 1. Langdon region, conventional tillage low productivity (less than 40 bushels per acre).

Wheat $ per bu	N cost $ per pound																		
	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
	Nitrogen Recommended, pounds per acre																		
3	112	100	90	52	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	124	100	100	87	62	37	0	0	0	0	0	0	0	0	0	0	0	0	0
5	132	116	100	100	85	66	47	42	0	0	0	0	0	0	0	0	0	0	0
6	137	123	110	100	99	84	69	52	47	30	14	0	0	0	0	0	0	0	0
7	141	129	117	106	100	97	84	71	57	47	41	22	0	0	0	0	0	0	0
8	143	133	123	113	103	100	94	83	72	60	47	47	16	0	0	0	0	0	0
9	145	136	127	118	109	100	100	93	83	73	63	52	47	40	17	13	0	0	0
10	145	139	131	123	115	107	100	100	91	83	74	65	56	47	35	34	23	11	0
11	145	141	134	126	119	112	104	100	98	90	82	74	66	58	50	47	39	30	20
12	145	145	134	127	125	114	107	100	98	95	89	80	73	65	58	50	45	42	33
13	145	145	136	130	125	117	111	105	98	98	93	87	82	73	66	60	53	47	46
14	145	145	138	132	127	121	115	109	103	98	98	92	86	80	74	67	61	55	48
15	145	145	140	134	129	123	118	112	104	101	98	97	91	86	80	74	68	62	56

Table 2. Langdon region, conventional tillage medium productivity (41-60 bushels per acre).

Wheat $ per bu	N cost $ per pound																		
	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
	Nitrogen Recommended, pounds per acre																		
3	130	125	120	115	110	100	80	50	50	30	20	15	10	0	0	0	0	0	0
4	135	130	125	120	115	100	90	80	70	50	40	30	25	0	0	0	0	0	0
5	140	135	130	125	120	115	100	90	80	60	50	40	35	10	0	0	0	0	0
6	145	140	135	130	120	115	105	95	85	65	60	50	45	25	10	0	0	0	0
7	150	145	140	135	125	120	110	100	95	70	70	60	55	35	30	20	10	0	0
8	155	150	145	140	130	125	115	105	100	80	80	70	65	45	40	30	20	15	0
9	160	155	150	145	135	130	120	110	105	90	90	80	75	55	50	40	30	25	10
10	165	160	155	150	145	135	125	120	110	100	95	85	80	65	60	50	40	35	20
11	175	170	165	155	150	140	130	125	115	110	100	90	85	75	65	60	50	40	30
12	178	171	165	157	150	143	136	128	121	114	107	99	92	84	77	69	62	54	46
13	178	172	165	159	152	146	139	132	126	119	112	106	99	92	86	78	72	65	58
14	178	172	166	160	154	148	142	136	130	124	118	111	105	99	93	86	80	74	67
15	178	173	167	162	156	150	145	139	133	128	122	116	110	104	99	93	87	81	75

Table 3. Langdon region, conventional tillage, high productivity (greater than 60 bushels per acre.

Wheat $ per bu	N cost $ per pound 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
	Nitrogen Recommended, pounds per acre																		
3	167	165	163	160	155	148	135	120	101	77	35	20	0	0	0	0	0	0	0
4	172	168	165	162	156	150	141	131	121	110	98	84	50	30	20	0	0	0	0
5	177	170	168	164	157	151	144	137	130	122	114	105	96	86	76	65	52	30	10
6	178	172	170	168	158	152	146	140	134	128	122	116	109	102	95	88	80	72	50
7	178	174	172	170	160	152	147	143	139	133	128	121	117	112	106	101	95	89	83
8	178	175	173	171	161	152	147	144	142	136	131	127	123	118	114	109	104	99	94
9	178	176	174	172	162	154	149	146	142	138	133	131	127	123	119	115	111	107	103
10	178	176	174	172	162	154	149	146	142	138	134	133	130	126	123	119	116	112	109
11	178	176	174	172	162	154	149	146	142	138	134	133	130	129	126	123	120	117	113
12	178	176	174	172	162	154	149	146	142	138	134	133	130	129	127	126	123	120	117
13	178	176	174	172	162	154	149	146	142	138	134	133	130	129	127	126	126	123	121
14	178	176	174	172	162	154	149	146	142	138	134	133	130	129	127	126	126	125	123
15	178	176	174	172	162	154	149	146	142	138	134	133	130	129	127	126	126	125	124

Table 4. Eastern region, conventional tillage, low productivity (less than 40 bushels per acre).

Wheat $ per bu	N cost $ per pound 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
	Nitrogen Recommended, pounds per acre																		
3	142	130	120	82	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	154	130	130	117	92	77	39	0	0	0	0	0	0	0	0	0	0	0	0
5	162	146	130	130	115	96	77	72	34	0	0	0	0	0	0	0	0	0	0
6	167	153	140	130	129	114	99	82	77	60	44	0	0	0	0	0	0	0	0
7	171	159	147	136	130	127	114	101	87	77	71	52	30	0	0	0	0	0	0
8	173	163	153	143	133	130	124	113	102	90	77	77	46	29	0	0	0	0	0
9	175	166	157	148	139	130	130	123	113	103	93	82	77	70	57	43	29	13	0
10	175	169	161	153	145	137	130	130	121	113	104	95	86	77	75	64	53	41	28
11	175	171	164	156	149	142	134	130	128	120	112	104	96	88	80	77	69	60	50
12	175	175	164	157	155	144	137	130	128	125	119	110	103	95	88	80	75	72	63
13	175	175	166	160	155	147	141	135	128	128	123	117	112	103	96	90	83	77	76
14	175	175	168	162	156	151	145	139	133	128	128	122	116	112	104	97	91	85	78
15	175	175	170	164	159	153	148	142	137	131	128	127	121	116	110	104	98	92	86

Table 5. Eastern region, conventional tillage, medium productivity (41-60 bushels per acre).

Wheat $ per bu	N cost $ per pound 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
	Nitrogen Recommended, pounds per acre																		
3	178	150	120	117	100	42	0	0	0	0	0	0	0	0	0	0	0	0	0
4	182	161	141	118	118	103	72	33	0	0	0	0	0	0	0	0	0	0	0
5	183	167	150	133	120	118	103	82	57	29	0	0	0	0	0	0	0	0	0
6	184	171	157	143	128	118	118	105	86	69	49	28	0	0	0	0	0	0	0
7	185	173	162	150	137	125	118	118	118	91	76	60	44	27	8	0	0	0	0
8	186	176	165	155	144	133	122	118	118	105	93	81	68	54	40	26	11	0	0
9	186	177	168	159	149	140	130	121	118	118	118	95	84	73	62	50	38	26	13
10	187	178	170	162	155	145	136	130	119	118	118	105	96	87	77	68	57	47	36
11	187	179	172	164	158	149	141	134	126	118	118	118	106	97	89	80	71	61	53
12	187	180	173	166	160	153	146	138	131	124	118	118	118	106	98	90	83	75	67
13	187	181	175	168	162	155	149	143	136	129	123	122	118	113	106	99	92	85	77
14	188	182	176	170	164	158	152	146	140	135	128	122	118	118	118	106	99	93	86
15	188	182	177	171	166	160	154	149	143	138	132	126	121	118	118	118	106	100	94

Table 6. Eastern region conventional tillage, high productivity (greater than 60 bushels per acre).

	N cost $ per pound																		
Wheat $ per 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
	Nitrogen Recommended, pounds per acre																		
3	218	202	185	167	148	147	145	129	109	81	50	35	20	10	0	0	0	0	0
4	227	213	199	184	169	154	147	147	137	123	106	85	65	40	30	15	0	0	0
5	233	221	209	196	184	171	158	147	147	143	131	118	104	86	63	40	30	20	10
6	237	227	216	205	195	184	173	161	150	147	147	137	127	115	102	88	70	43	30
7	241	231	222	212	203	193	184	174	164	153	147	147	142	133	123	112	101	88	74
8	244	235	227	218	210	205	193	183	175	165	156	147	147	146	137	129	120	110	100
9	246	238	231	223	215	207	199	191	183	174	167	159	149	147	147	141	133	125	117
10	248	241	234	227	220	212	205	198	191	184	176	168	161	153	147	147	144	137	130
11	250	243	237	230	223	217	210	203	197	190	183	176	169	162	155	148	147	147	141
12	250	245	239	233	227	221	214	208	201	196	189	183	177	170	164	157	151	147	147
13	250	247	241	235	230	224	218	212	206	201	195	194	183	176	171	165	159	153	147
14	250	247	243	237	232	227	221	216	210	205	199	194	188	183	177	172	166	160	155
15	250	250	245	239	235	229	224	219	214	209	204	198	193	188	183	178	172	167	162

Table 7. Western region, conventional tillage, low productivity (less than 30 bushels per acre).

	N cost $ per pound																		
Wheat $ per 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
	Nitrogen Recommended, pounds per acre																		
3	99	95	93	76	59	55	30	0	0	0	0	0	0	0	0	0	0	0	0
4	102	97	95	85	68	60	54	42	0	0	0	0	0	0	0	0	0	0	0
5	105	99	97	90	71	64	60	52	33	0	0	0	0	0	0	0	0	0	0
6	108	103	98	93	78	68	66	60	52	50	45	28	9	0	0	0	0	0	0
7	111	107	100	96	86	74	72	65	58	58	52	51	39	26	11	0	0	0	0
8	114	110	103	99	90	82	77	70	64	66	57	55	45	35	25	13	0	0	0
9	117	112	106	100	93	86	82	77	72	73	64	60	52	46	35	41	13	11	10
10	120	114	109	103	96	92	88	84	80	77	68	62	59	54	45	44	23	20	15
11	120	116	110	105	100	95	93	90	86	84	79	74	68	63	56	47	42	38	20
12	120	118	112	107	102	98	96	94	92	88	83	79	74	69	64	59	48	45	40
13	120	120	114	108	104	101	98	96	94	92	86	83	78	73	69	65	60	56	50
14	120	120	120	111	107	104	100	97	96	95	90	86	82	78	74	70	65	61	58
15	120	120	120	120	112	108	101	98	97	96	93	89	85	82	78	74	70	66	62

Table 8. Western region, conventional tillage medium productivity (31-50 bushels per acre).

	N cost $ per pound																		
Wheat $ per 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
	Nitrogen Recommended, pounds per acre																		
3	148	139	139	138	121	102	102	101	60	50	30	15	0	0	0	0	0	0	0
4	162	139	139	139	139	138	115	102	102	101	80	60	40	20	0	0	0	0	0
5	172	153	139	139	139	138	117	102	102	101	80	65	55	45	30	10	0	0	0
6	178	162	146	139	139	138	134	102	102	102	101	90	70	50	40	30	20	0	0
7	182	169	155	141	139	139	138	113	113	102	102	101	96	65	50	40	30	20	0
8	186	174	162	149	139	139	139	127	127	113	102	102	101	98	76	48	35	25	15
9	188	178	167	156	145	139	139	136	136	124	113	102	102	101	100	83	63	38	20
10	190	181	171	162	151	142	139	137	137	135	124	112	102	102	101	101	87	71	53
11	192	183	174	165	157	148	139	139	139	138	132	122	112	102	102	101	101	90	77
12	194	186	177	169	161	153	145	139	139	139	138	130	121	112	103	102	101	101	92
13	194	187	180	172	165	157	150	142	139	139	138	138	129	121	112	103	102	101	102
14	196	189	183	176	168	162	154	147	140	139	139	138	135	127	119	112	105	102	102
15	196	190	184	177	171	164	158	151	145	139	139	139	138	133	126	119	111	104	102

Table 9. Western region conventional tillage high productivity (greater than 50 bushels per acre).

Wheat $ per bu	N cost $ per pound																		
	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
	Nitrogen Recommended, pounds per acre																		
3	164	157	127	95	61	25	0	0	0	0	0	0	0	0	0	0	0	0	0
4	164	164	147	125	101	77	52	26	0	0	0	0	0	0	0	0	0	0	0
5	172	164	159	141	123	104	85	66	46	26	0	0	0	0	0	0	0	0	0
6	178	164	164	152	137	122	106	91	75	59	43	26	0	0	0	0	0	0	0
7	182	169	165	158	147	134	122	108	95	81	68	54	27	0	0	0	0	0	0
8	185	174	166	164	154	143	132	120	109	98	86	74	63	51	39	27	0	0	0
9	187	177	168	164	160	155	140	130	120	110	100	90	79	69	59	48	38	27	0
10	189	180	170	164	164	156	147	138	129	120	111	102	92	83	74	65	55	46	37
11	190	181	175	167	164	160	152	144	136	128	120	111	103	95	86	78	70	61	53
12	192	184	177	170	164	164	157	149	142	134	127	119	112	103	97	89	81	74	66
13	193	186	180	172	166	164	160	154	147	140	133	128	119	112	105	98	91	84	77
14	194	187	181	175	169	164	164	157	151	145	138	133	125	119	113	106	100	93	87
15	195	189	183	177	171	164	164	161	155	149	143	137	131	125	119	113	107	101	95

Second-year N Credits

Half of credit given for the first year for sweet clover and alfalfa; none for other crops.

Nitrogen Application

Where acceptable, fall application of ammonia is a preferred method of N application. Fall application is acceptable on loam soils or heavier in areas not prone to spring flooding after snowmelt. Fall application of ammonia should not begin before Oct. 1, and then only after soil temperatures measured at the 4-inch depth fall to 50 degrees Fahrenheit between 8 a.m. and 10 a.m. Banded urea may be applied a week after this date, and broadcast and incorporated urea should wait two weeks after the ammonia-safe date.

For greatest efficiency, urea should be applied below the soil surface. In no-till management, this can be accomplished with seeding tools that spread the urea at or near seed-depth if rate is sufficiently low, or in a band with seed to fertilizer separation of at least 1 inch. If urea is applied to the soil surface, it should be applied using a urease inhibitor. The urease inhibitor shown most effective is NBPT, which is marketed under a number of trade names. The proper NBPT rate is 1.78 pounds active ingredient per ton of urea (3 quarts per ton, 26.7% a.i., density 8.9 pounds per gallon). The NBPT at the proper rate almost completely renders soil urease inactive for about 10 days, during which time rainfall usually moves the urea into the soil, preventing ammonia volatilization. For additional information about urease inhibitors, see Nitrogen Extenders and Additives for Field Crops at *https://www.ndsu.edu/agriculture/extension/publications/nitrogen-extenders-and-additives-field-crops*.

Liquid N sources, including UAN/ 28-0-0, are also best applied below the surface. If spring conditions prevent below-surface application, banding the 28% on the surface may delay volatilization several days, compared with broadcast application.

Table 10. Previous crop N credits

Previous crop	Credit
Soybean	40 lb N/acre
Edible bean	40 lb N/acre
Pea and lentil	40 lb N/acre
Chickpea	40 lb N/acre
Sweet clover that was harvested	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
Sugarbeet	
Yellow leaves	0 lb N/acre
Yellow/green leaves	30 lb N/acre
Dark green leaves	80 lb N/acre

Protein Enhancement

North Dakota research has shown that the best chance of protein enhancement of spring wheat and durum is accomplished by waiting until the end of flowering (post-anthesis) and broadcasting 10 gallons per acre of UAN/28-0-0 (30 pounds of N per acre) mixed with 10 gallons per acre of water over the wheat in the cool of the day. Some leaf burning will result. The use of an equivalent N rate of urea solution also has been effective, and if the urea is low in biuret content, the addition of water dilution is not necessary and leaf burn is reduced. For research studies on protein enhancement in spring wheat, see *https://www.ndsu.edu/agriculture/ag-hub/publications/post-anthesis-n-application-studies-north-dakota-region-and-elsewhere*

The addition of some herbicides, fungicides and insecticides may increase the intensity of leaf burn and limit the efficacy of the pesticide application. About a 0.5% grain protein increase has been achieved using this method. The use of low rates of slow-release N products before or after anthesis has not been shown to increase grain protein effectively. For more information regarding the use of low rates of specialty N products for protein enhancement see *https://www.ndsu.edu/agriculture/ag-hub/publications/studies-slow-release-liquid-fertilizers-applied-low-rates-foliar-application*

Phosphate

The phosphate (P) recommendation in North Dakota currently is based on the Olsen P soil test. The broadcast recommendations appear in **Table 11**.

If the fertilizer is applied as a band, rates in **Table 11** can be reduced by one-third. Reducing rates in low-testing soils will result in soil test levels that do not increase through time.

Reducing rates is suggested when P costs are high. At P costs of 30 cents/pound of P_2O_5 and less, the profitability of applying P to wheat is positive at soil test values indicated in Table 11. However, when 11-52-0 sells for more than $350/ton, using more than a minimum amount of P as a starter becomes unprofitable at a wheat price of $6/bushel. As wheat prices increase above $6/bushel, the grower can apply P at higher cost profitably **(Figure 2)**.

Wheat benefits greatly from banded fertilizer placement near the row or in the row at seeding, provided that rates are moderate. Yield increases of several bushels per acre due to banded P are common in P banding vs. broadcast studies in wheat.

The rate of fertilizer that can be applied safely with wheat seed is more dependent on the N content of the fertilizer than the P content. Maximum N fertilizer rates that can be used with the seed are provided in **Tables 12 and 13**.

Table 11. Broadcast fertilizer phosphate recommendations for North Dakota for spring wheat and durum based on soil test (Olsen sodium bicarbonate).

Soil Test Phosphorus, ppm				
VL 0-3	L 4-7	M 8-11	H 12-15	VH 16+
Pounds P_2O_5/acre				
90	60	35	20	15*

* Wheat seeding always should include a small amount of starter fertilizer in a band regardless of soil test. If starter fertilizer banding is not used, rates in H and VH categories should be zero.

Table 12. Maximum N fertilizer rates with wheat seed at planting based on row spacing, planter opener type and seedbed utilization (From Franzen, 2015a). SU = seedbed utilization.

Planter Opener tType	Seed Spread inches	Row spacing, inches: 6 SU	6 lb N/acre	7.5 SU	7.5 lb N/acre	10 SU	10 lb N/acre	12 SU	12 lb N/acre
Double-disc	1	17%	20-30	13%	19-28	10%	17-23	8%	15-20
Hoe	2	33%	32-44	27%	27-38	20%	23-31	17%	20-27
	3	50%	44-58	40%	37-48	30%	30-40	25%	26-34
Air-Seeder	4	66%	56-72	53%	46-58	40%	37-48	33%	32-42
	5	83%	68-86	68%	56-68	50%	44-57	44%	38-49
	6	100%	80-100	80%	66-79	60%	51-55	50%	44-56
	7			94%	76-90	70%	58-74	58%	50-64
	8					80%	66-83	67%	56-71
	9					90%	73-92	75%	62-78
	10					100%	80-100	83%	68-86
	11							92%	74-93
	12							100%	80-100

Table 13. Maximum N fertilizer rates with wheat at planting based on soil texture and seedbed utilization. From Franzen, 2015a.

Soil texture	Particle size: Sand	Silt	Clay	Percent seedbed utilization: 10-20 Double-disc 1 inch	30-50 Hoe 2-3 inches	60-100 Air seeder 4-12 inches
	Percent			Pounds N per acre		
Loamy sand	80	10	10	5	10-20	25-40
Sandy loam	60	35	15	10	15-25	30-45
Sandy clay loam	55	15	30	15	20-30	35-50
Loam	40	40	20	20	25-35	40-55
Silt loam	20	65	15	25	30-40	45-60
Silty clay loam	10	55	35	30	35-45	50-70
Clay loam	30	30	40	35	40-50	55-80
Clay	20	20	60	40	45-55	60-100

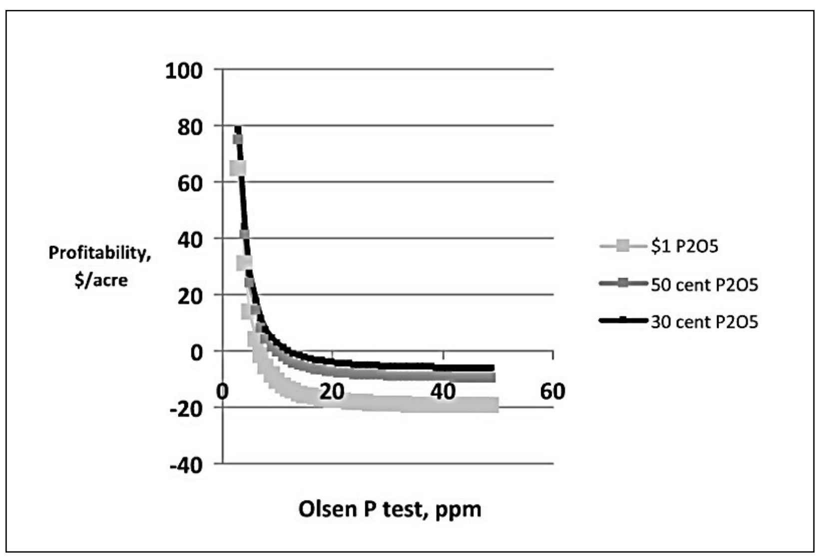

Figure 2. Profitability of using P for $6/bushel wheat at 30 cent/pound of P_2O_5, 50 cent/pound P2O5, and $1/pound P_2O_5. From Halvorson (1978).

Potassium

The potassium (K) recommendations have changed. Finding responses to K is difficult when soil test K levels are greater than 100 parts per million (ppm). Nearly all of the higher K responses are related to a chloride response.

Most soils in North Dakota have high enough potassium (K) levels to support excellent wheat production. Exceptions might be sandier soils or soils with a history of many years of continuous soybean.

Current K fertilizer recommendations are based on a soil test critical level of 100 ppm. The recommendation in higher-testing soils is provided to replace K that the crop will remove and to provide chloride if necessary. If chloride (Cl) values are adequate and other crops in the rotation regularly receive K fertilizer, then KCl application when K and Cl are in the high range category are not necessary.

Potassium Recommendations

Soils with smectite-to-illite clay chemistry ratio of 3.5 or less (Figure 3)

- Soil test K > 150 ppm, no additional K required.
- KCl (0-0-60-50Cl) may be applied if soil Cl levels are less than 40 pounds of Cl in a 2-foot depth.
- Soil test K 150 ppm or less, apply 50 pounds/acre KCl (25 pounds/acre K_2O)

Soils with smectite-to-illite clay chemistry ratio more than 3.5 (Figure 3)

- Soil test K > 100 ppm, no additional K required.
- KCl (0-0-60-50Cl) may be applied if soil Cl levels are less than 40 pounds Cl/2-foot depth.
- Soil test K 100 ppm or less, apply 50 pounds/acre KCl (25 pounds/acre K_2O)

Sulfur

Sulfur (S) has become more important than K or Cl in North Dakota as the third major crop nutrient. Environmental regulations on fossil fuel emissions have put stringent restrictions on sulfur emissions in recent years. Industry response to regulation has resulted in less S received in North Dakota fields from precipitation (Franzen 2015b).

The S soil test is a very poor predictor of soil S status. Sulfur deficiency has become so prevalent in small grains and corn that for spring wheat/durum, a base application of 10 pounds of S per acre would be prudent, particularly if the fall, winter or early spring before seeding has received normal to above normal precipitation. Soils with sandy loam or coarser textures and less than 3% organic matter on higher landscape positions are most at risk, but all soils are at risk in wetter seasons.

Sulfur fertilizer application is a spring operation because sulfate leaches easily beyond the rooting zone. The spring fertilizer application should consist of a soluble sulfur fertilizer. Ammonium sulfate at rates of about 10 pounds of S per acre or gypsum (calcium sulfate) at 20 pounds of S per acre would be excellent sources of sulfur. Ammonium thiosulfate (ATS) is a liquid formulation of S that is highly plant-available. However, ATS should not be applied with the seed at planting, nor should it be broadcast over wheat after emergence.

Elemental S, even premium bentonite-blended forms, are not nearly as useful in correcting a deficiency as sulfate/thiosulfate fertilizers. Composite blended granules of phosphate fertilizers that include sulfur could be used, but rates need to be high enough to supply the 10 pounds of S per acre needed as the ammonium sulfate portion of the fertilizer, or the application should be supplemented with a sulfate containing fertilizer.

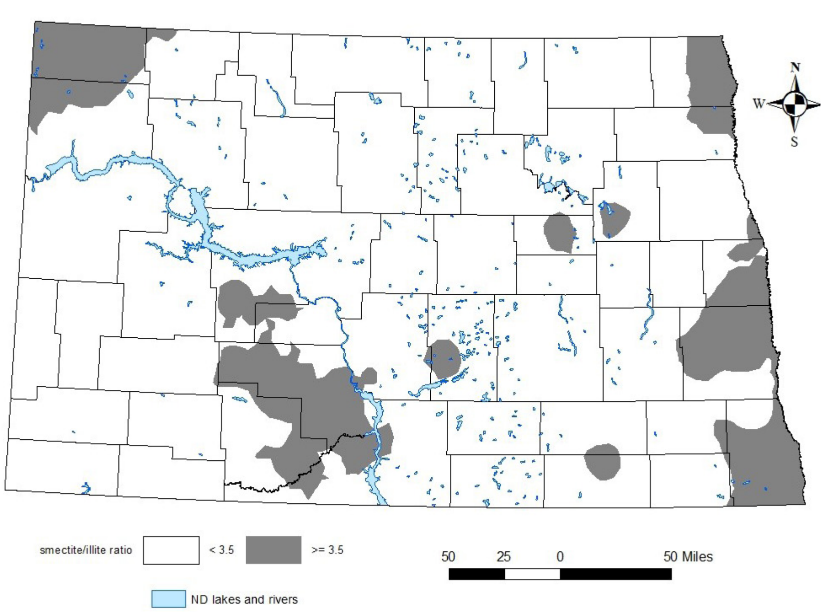

Figure 3. Smectite-to-illite clay chemistry for soils in North Dakota from soil sampling survey conducted in 2017.

Copper

Increases in yield and decreases in fusarium head blight (scab) have been documented in North Dakota (Franzen et al., 2008) with copper application. The responses to copper were seen mostly on low-organic matter, sandy soils. However, only about 15% of sites that fit these criteria in the study responded.

Predicting whether wheat grown on these soils would respond to copper is difficult. Copper application is a site-specific nutrient at best. Applying it on loam or heavier soils, or in soils between 3% and 8% organic matter, provides no benefit. An application of copper sulfate at a rate of 5 pounds of Cu/acre will last many years.

Chloride

Chloride responses are well-documented for spring wheat and durum. Studies in the state and the region show that wheat tends to respond positively to chloride about half the time, with yield increases of 2 to 5 bushels/acre. Studies in consecutive years investigating varietal responses to chloride provided inconsistent results.

Yield increases from Cl arise from increased resistance to certain root and leaf diseases and an increase in kernel size. The critical soil test value of Cl is 40 pounds per acre in the surface 2-feet of soil. If the soil test is less than 40 pounds of Cl per acre, fertilizing with 5 to 10 pounds of Cl per acre with or near the seed at planting should sufficiently supply the crop for the year.

Other Nutrients

No evidence exists that supplemental zinc, iron, manganese or boron are required for spring wheat or durum wheat in North Dakota. Although numerous reports have been made in the U.S. and around the world of these nutrients being required as fertilizer, our soils apparently supply enough of these nutrients and our wheat is adapted to these soils; therefore, these nutrients do not need to be supplied artificially.

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