SF712 (Revised)

Fertilizing Hard Red Spring Wheat and Durum

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

Nitrogen management is a key to successful wheat production. Recommendations include consideration of wheat yield and protein response to added N within three major state agri-climatology zones, 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.

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Previous N recommendations were straightforward yield potential formulas based on the assumption that N costs are cheap and stable. Research from the 1950s and 1960s has been the foundation for recommendations for the past 30 years in spring wheat and durum. Since the previous recommendations were established, wheat varieties have changed and no-till and conservation tillage have been adopted. 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 2009. Studies contained yield and protein data, location, fertilizer N-rate and residual soil nitrate to 2 feet in depth. Approximately half of the data for the recommendations come from archived data and the other half were generated since 2005. The statewide data are shown in Figure 1.

Wheat response to N fertilizer is closely linked to wheat protein concentration. Growers rely on higher protein markets to maintain their profitability. Currently, a protein of 14 percent or greater is necessary to avoid dockage at the point of sale. Sometimes substantial premiums are available to growers for protein greater than 14 percent. The relationship between wheat yield and protein statewide is shown in Figure 2.

If nitrogen fertilizers were very inexpensive and other factors were not important, the statewide optimal N rate would be a flat 225 pounds of nitrogen per acre (lb N/acre) less N credits. However, in examining the data, certain parts of the state clearly reacted differently to N fertilizer.

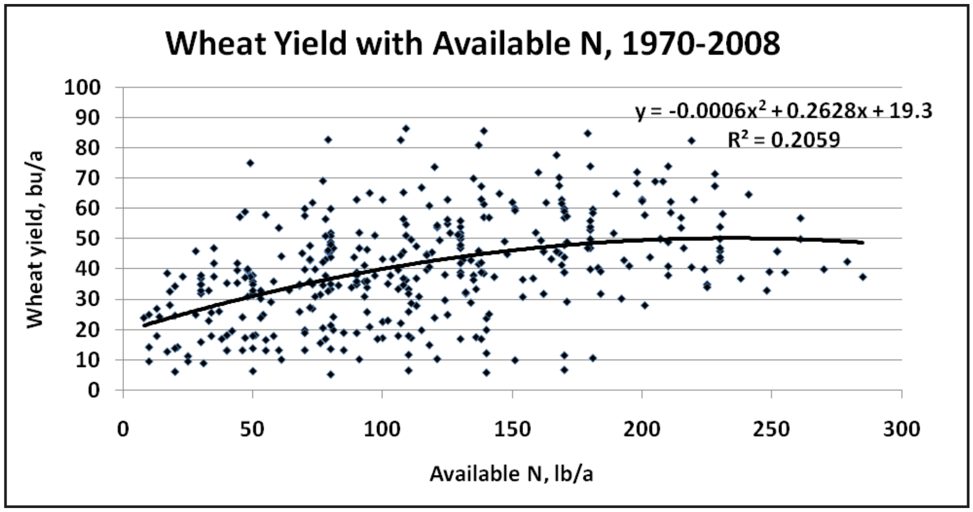

Figure 1. Statewide N-rate data and wheat yield from 1970 to 2008. Available-N includes soil test nitrate-N to 2 feet in depth, fertilizer N rate and any previous crop N credit.

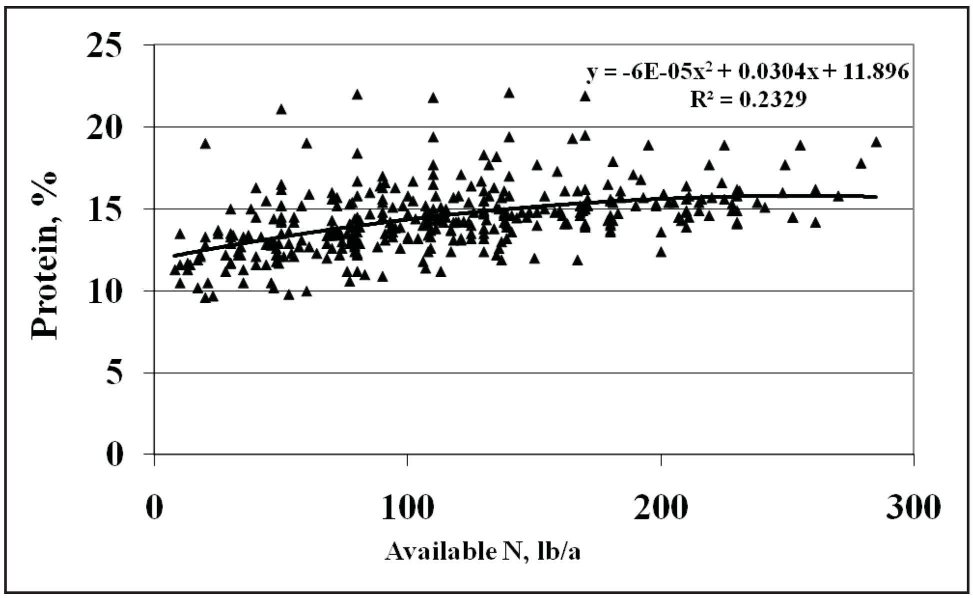

Figure 2. The relationship between available N and wheat protein from studies in North Dakota conducted from 1970 to 2008. Available N includes soil test nitrate-N to 2 feet in depth, fertilizer N rate and any previous crop N credit.

High rates of N in the Langdon region resulted 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 has been divided into three agri-climatology zones as shown in Figure 3.

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 $3/bushel and $10/bushel and N costs from 20 cents/lb N and $1/lb N were developed using both wheat price and protein dock/premium.

The protein dock varies with grain elevator and the year. The figures used in developing these relationships used

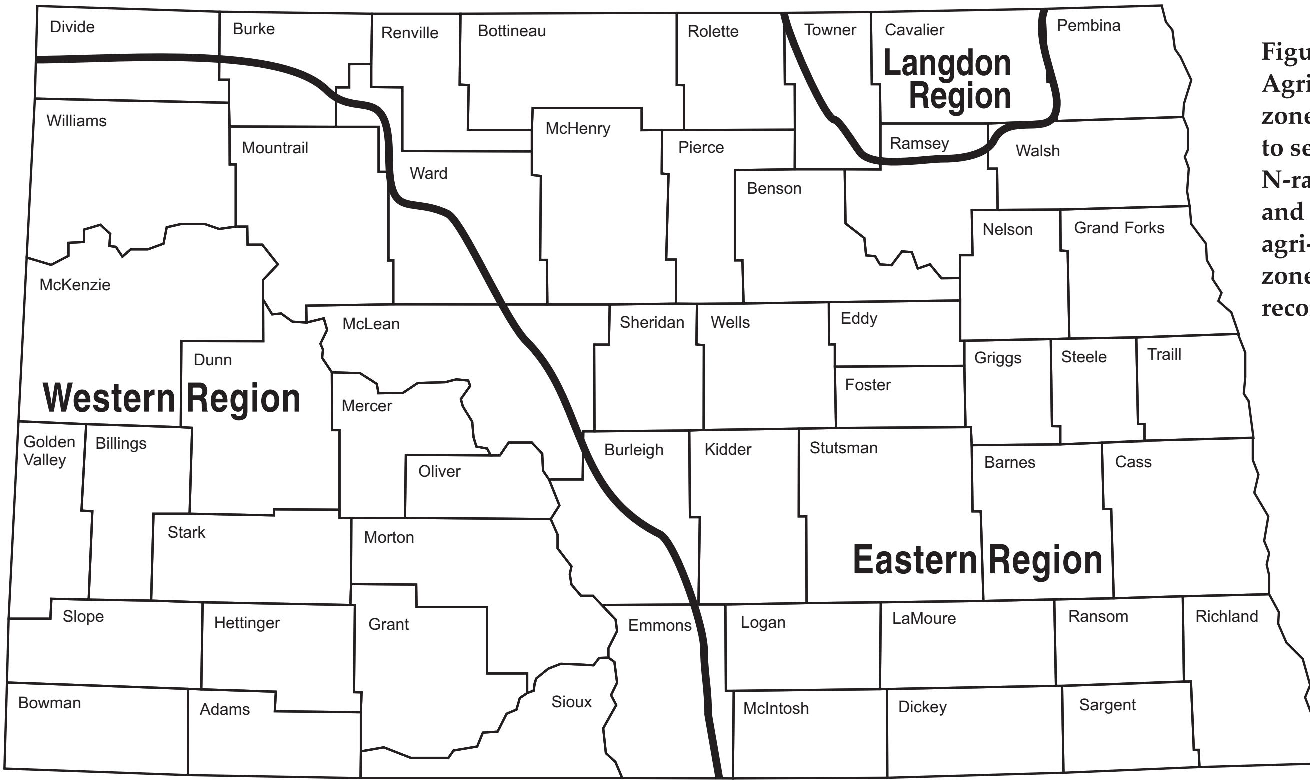

Figure 3. Agri-climatology zones used to segregate N-rate data and develop agri-climatology zone N recommendations.

a 50-cent/point dockage if protein was less than 14 percent and a 50-cent/point premium for protein from 14 percent to 15 percent, with no additional premium for greater protein. The gross N recommendations on the regional tables (Tables 1-9) contain the regional economic data for both 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.

Productivity category definitions:

Langdon Region
- Low = less than 40 bushels/acre
- Medium = 41 to 60 bushels/acre
- High = greater than 60 bushels/acre

Eastern Region
- Low = less than 40 bushels/acre
- Medium = 41 to 60 bushels/acre
- High = greater than 60 bushels/acre

Western Region
- Low = less than 30 bushels/acre
- Medium = 31 to 50 bushels/acre
- High = greater than 50 bushels/acre

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 lb N/acre.
   – If field has been in no-till more than five consecutive years, subtract 50 lb N/acre.
5. For organic matter credit for soils greater than 5 percent organic matter, subtract 50 lb N/acre for each full percent of organic matter above 5 percent.

From these optimum rates, the grower and adviser may choose to adjust plus/minus up to 30 lb 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 lb/acre of straw residue. For every 2,000 lb/acre straw greater than this, add 30 lb 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 low productivity (<40 bu/acre).

Wheat	Cost cents per pound N								
price	20	30	40	50	60	70	80	90	100
	Gross optimal N								
$3	100	90	80	70	60	50	40	30	20
$4	110	100	90	80	70	60	50	40	30
$5	120	110	100	90	80	70	60	50	40
$6	120	115	110	100	90	80	75	65	60
$7	120	115	110	100	95	90	80	75	70
$8	120	115	110	105	95	90	85	80	75
$9	120	115	110	105	100	95	90	85	80
$10	120	115	110	110	105	100	95	90	85

Table 2. Langdon region medium productivity (41-60 bu/acre).

Wheat	Cost cents per pound N								
price	20	30	40	50	60	70	80	90	100
	Gross optimal N								
$3	130	125	120	115	110	100	80	50	20
$4	135	130	125	120	115	100	90	80	70
$5	140	135	130	125	120	115	100	90	80
$6	140	135	130	125	120	115	105	95	85
$7	140	135	130	125	120	115	110	100	85
$8	140	135	130	130	125	120	115	105	85
$9	140	135	135	130	125	120	115	110	95
$10	140	135	135	130	125	120	115	110	100

Table 3. Langdon region high productivity (>60 bu/acre).

Wheat	Cost cents per pound N								
price	20	30	40	50	60	70	80	90	100
	Gross optimal N								
$3	160	145	130	125	110	100	90	75	40
$4	160	150	140	130	120	110	100	90	80
$5	160	155	150	140	130	120	115	105	100
$6	160	155	150	140	135	125	120	116	110
$7	160	155	150	145	135	130	125	120	115
$8	160	155	150	145	140	135	130	125	120
$9	160	155	150	145	140	135	130	130	125
$10	160	155	150	145	140	140	135	135	130

Table 4. Eastern North Dakota low productivity (<40 bu/acre).

Wheat	Cost cents per pound N								
price	20	30	40	50	60	70	80	90	100
	Gross optimal N								
$3	75	70	60	50	25	0	0	0	0
$4	80	75	70	60	50	40	30	20	0
$5	100	90	80	70	60	50	40	30	20
$6	125	120	115	110	105	100	90	80	70
$7	140	130	120	115	110	105	95	85	75
$8	150	140	130	120	115	110	105	100	95
$9	155	150	145	140	135	130	125	120	115
$10	160	155	150	145	140	135	130	125	120

Table 5. Eastern North Dakota medium productivity (41-60 bu/acre).

Wheat	Cost cents per pound N								
price	20	30	40	50	60	70	80	90	100
	Gross optimal N								
$3	125	115	105	90	60	30	0	0	0
$4	150	140	130	120	110	100	80	50	0
$5	160	150	140	130	120	110	100	90	80
$6	170	160	150	140	130	120	110	100	90
$7	180	170	160	150	140	130	120	110	100
$8	185	175	170	165	160	150	140	130	120
$9	190	180	175	170	165	160	150	140	130
$10	200	190	185	180	170	165	160	150	140

Table 6. Eastern North Dakota high productivity (>60 bu/acre).

Wheat	Cost cents per pound N								
price	20	30	40	50	60	70	80	90	100
	Gross optimal N								
$3	250	190	175	150	125	60	0	0	0
$4	250	235	220	200	180	160	120	100	0
$5	250	235	220	200	190	180	160	140	120
$6	250	250	225	210	200	190	180	160	150
$7	250	250	250	240	220	200	190	180	175
$8	250	250	250	250	225	210	200	190	180
$9	250	250	250	250	250	220	210	200	190
$10	250	250	250	250	250	240	230	220	200

Table 7. Western North Dakota low productivity (<30 bu/acre).

Wheat price	Cost cents per pound N 20	30	40	50	60	70	80	90	100
	Gross optimal N								
$3	100	80	70	60	50	45	40	0	0
$4	105	95	85	75	65	55	45	30	0
$5	110	100	90	90	70	60	50	40	30
$6	115	110	105	100	95	90	85	80	60
$7	115	110	105	100	95	90	85	80	60
$8	115	110	105	100	95	90	85	80	60
$9	115	110	105	100	95	90	85	80	60
$10	115	110	105	100	95	90	85	80	60

Table 8. Western North Dakota medium productivity (31-50 bu/acre).

Wheat price	Cost cents per pound N 20	30	40	50	60	70	80	90	100
	Gross optimal N								
$3	125	120	110	100	90	80	60	0	0
$4	125	125	120	110	100	90	80	70	50
$5	130	130	125	120	110	100	90	80	70
$6	135	135	130	125	120	110	100	95	90
$7	140	135	130	125	120	110	100	95	90
$8	140	135	130	125	120	110	100	95	90
$9	140	135	130	125	120	110	100	95	90
$10	140	135	130	125	120	110	100	95	90

Table 9. Western North Dakota high productivity (>50 bu/acre).

Wheat price	Cost cents per pound N 20	30	40	50	60	70	80	90	100
	Gross optimal N								
$3	175	170	160	150	140	130	110	50	0
$4	175	175	170	160	150	140	130	120	100
$5	180	180	175	170	160	150	140	130	120
$6	185	185	180	175	170	160	150	145	140
$7	190	185	180	175	170	160	150	145	140
$8	190	185	180	175	170	160	150	145	140
$9	190	185	180	175	170	160	150	145	140
$10	190	185	180	175	170	160	150	145	140

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
Sugar beet	
Yellow leaves	0 lb N/acre
Yellow/green leaves	30 lb N/acre
Dark green leaves	80 lb N/acre

2nd 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 never should begin before Oct.1, and then only after soil temperatures measured at the 4-inch depth fall to 50 degrees between 8 and 10 a.m. Banded urea can be applied a week after this date and broadcast and incorporated urea should wait two weeks after the ammonia date.

Surface application of urea to no-till acres should be avoided in the spring. The risk of volatility of ammonia is too great if rain does not fall for several days. No-till wheat growers should explore ways to apply urea beneath the soil surface for greatest efficiency.

Liquid N sources, such as 28 percent nitrogen liquid fertilizer (commonly called 28 percent), also should be applied below the surface. If spring conditions prevent below-surface application, banding the 28 percent on the surface may delay volatilization several days compared with broadcast application.

Phosphate

The phosphate (P) recommendation currently is related to soil test P and yield potential. 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 most when P costs are relatively high. With P_2O_5 at 30 cents/lb and lower, the profitability of applying P to wheat is positive at soil test levels 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 profitably at a higher cost.

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 to many bushels 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.

Potassium

The potassium (K) recommendations have changed. Finding responses to K when soil test K levels are greater than 100 parts per million (ppm) is difficult. 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 displayed in Table 14.

Sulfur

Sulfur (S) is becoming more important than potassium or chloride in the state as a third major nutrient. Environmental regulations on fossil fuel emissions have put more stringent restrictions on sulfur emissions in recent years. This has resulted in less sulfur through rainfall.

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/acre of 28 percent mixed with 10 gallons/acre of water over the wheat in the cool of the day. Some leaf burning will result. 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 ½ percent protein increase has been achieved using this method. Use of low rates of slow-release N products before or after anthesis has not been shown to increase grain protein effectively.

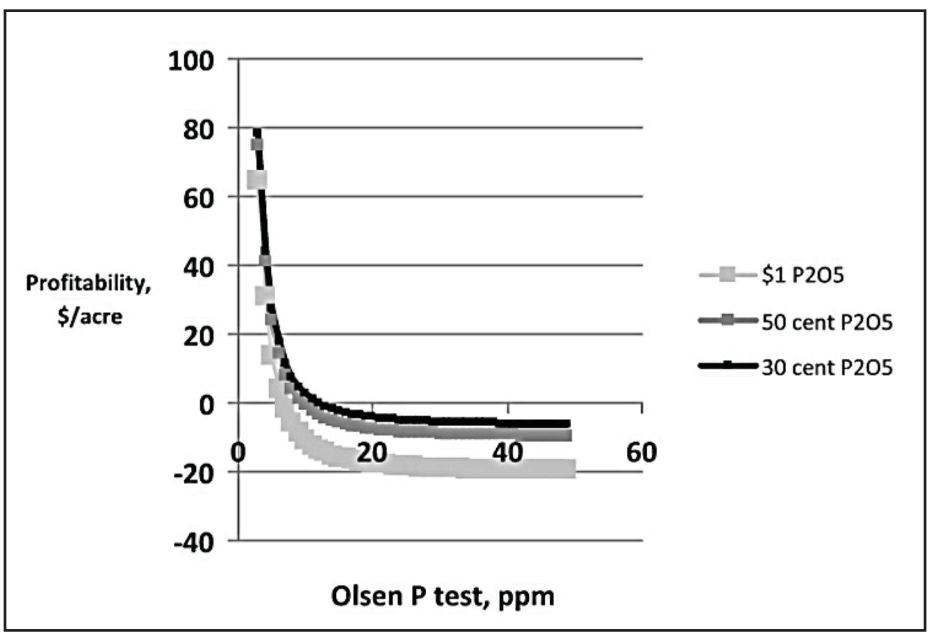

Figure 3. Profitability of using P for $6/bu wheat with P_2O_5 at 30 cents/lb, 50 cents/lb and $1/lb. From Halvorson (1978).

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

Yield potential, bu/acre	Soil test phosphorus, ppm VL 0-3	L 4-7	M 8-11	H 12-15	VH 16+
	Pounds P_2O_5/acre				
40	39	28	17	15	15*
60	59	42	26	15	15
80	78	56	35	15	15
100	98	70	43	17	15

Olsen P recommendations = (1.071-0.067STP)YP, where STP is soil test P and YP is yield potential.

* 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 Deibert, 1986). SU=seedbed utilization.

Planter opener type	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 Deibert, 1986).

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			lb N/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

Table 14. Potassium recommendations.

Soil test K > 100 ppm, no additional K required. KCl (0-0-60-50Cl) may be applied if Cl levels are low.

Soil test K 100 ppm or less, apply 50 lb/acre KCl (30 lb/acre K_2O)

The sulfur soil test is not a good predictor of possible sulfur deficiency. A more useful method to determine whether soils within a field likely will be S deficient is to consider which soils are sandy loam or coarser textured with less than 3 percent organic matter on higher landscape positions. If soils with these properties are present, review fall and spring rainfall conditions. If the fall and/or early spring seasons received normal to greater than normal rainfall or greater than normal winter snow, then the stage is set for possible sulfur deficiency and pre-emptive spring fertilizer application should include a soluble sulfur fertilizer.

Ammonium sulfate at rates of about 10 lb S/acre or gypsum at 20 lb S/acre would be excellent sources of sulfur. Elemental sulfur, even premium bentonite-blended forms, would not be nearly as useful in correcting a deficiency. Composite-blended granules of phosphate fertilizers that include sulfur could be used, but rates need to be high enough to supply the 10 lb S/acre needed as the ammonium sulfate portion of the fertilizer, or the application should be supplemented with a sulfate containing fertilizer.

Copper

Increases in yield and decreases in fusarium head blight (scab) have been documented in North Dakota (Franzen et al., 2008) with copper (Cu) application. The responses to copper were seen mostly on low organic matter, sandy soils. However, only about 15 percent 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 copper on loam soils or heavier or in soils between 3 percent and 8 percent organic matter provides no benefit. An application of copper sulfate at a rate of 5 lb Cu/acre will last many years.

Chloride

Chloride (Cl) 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 bu/acre. Studies in consecutive years investigating varietal responses to chloride provided inconsistent results. Yield increases from chloride arise from increased resistance to certain root and leaf diseases and an increase in kernel size. The critical level of chloride is 40 lb/acre in the surface 2 feet of soil. If the soil test is less than 40 lb Cl/acre, fertilizing with 5-10 lb Cl/acre with or near the seed at planting should supply the crop sufficiently for the year.

Other nutrients

No evidence has been found that supplemental zinc, iron, manganese or boron are required in North Dakota. Although numerous reports in the U.S. and around the world indicate these nutrients are required as fertilizer, our soils apparently supply enough and our wheat is adapted to our soils, so these nutrients do not need to be supplied artificially.

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