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EC143

Fertilizing Winter Wheat

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Introduction

This publication discusses soil testing, recommended fertilizer rates (including timing and placement) and residual fertilizer effects for winter wheat fertilization. It also includes worksheets to calculate recommended phosphorus rates for various application methods. Management practices that provide an adequate, but not excessive, supply of plant nutrients are essential for optimal yields of high quality winter wheat.

Determining Nutrient Need

Profitable winter wheat production often requires nitrogen (N) and phosphorus (P) fertilization in Nebraska, when there is adequate moisture. Other nutrients may be needed for some fields, but most Nebraska soils supply adequate nutrients other than N and P. In drought years, higher nitrogen rates can decrease yields. Soil test results are needed to optimize fertilizer use.

Soil Testing

Soil testing, the foundation of nutrient management in winter wheat, characterizes soil nutrient availability. Recommended fertilizers can then be applied to ensure optimal nutrition for the crop.

Information on proper soil sampling is provided in NebGuide G1740, *Guidelines for Soil Sampling* found at *http://www.ianrpubs.unl.ed/sendIt/g1740.pdf*. Soil samples from the surface (0 to 8 inches) or tillage layer should be analyzed for organic matter, pH, and other nutrients including nitrate.

Collect composite cores from at least 15 points in the field from areas measuring 40 acres or less. More than one set of samples may be necessary, if parts of the field differ due to the previous crop or soil characteristics such as slope, color, or texture. Complete soil testing is recommended every three to five years. However, soil testing for nitrate-nitrogen (NO_3-N) is recommended before planting each wheat crop.

Deeper soil samples are necessary for the most accurate prediction of nitrogen needs. Samples should include an upper soil or tillage-layer sample (0 to 8 inches) and a sample from 8 to 36 or 48 inches with at least 6 to 8 samples taken from a 40-acre area.

Nitrogen Recommendations

Most winter wheat grown in Nebraska requires nitrogen fertilization for profitable production. This is true for virtually all soils in Nebraska where wheat is commonly grown unless there is a large carryover of nitrate-N.

Residual soil nitrate can be measured effectively with a soil test of the root zone. While the depth of the root zone for wheat is often five to six feet or more, most available nitrogen affecting yield is in the top three or four feet of soil. Sampling less than three feet for residual nitrate can reduce the accuracy of the nitrogen fertilizer recommendation and adjusting N recommendations from samples less than two feet deep is not recommended.

The optimum fertilizer nitrogen rate for winter wheat (with a maximum rate of 100 lb of nitrogen per acre for dryland, and 150 lb of nitrogen per acre irrigated) can be calculated with the following equation or by using *Table I*.

Nitrogen Rate (lbs/acre) = ((N Price / Wheat Price) + (NO_3-N/68.7) - 0.235)*-725

Where:

- N Price is dollars per lb of fertilizer nitrogen,
- Wheat Price is in dollars per bushel of wheat

NO_3-N is the average parts per million (ppm) nitrate-nitrogen in the top three or four feet.

If a soil sample is not taken, an average soil nitrate level of 5 ppm of nitrate-nitrogen can be used.

Table I. Nitrogen fertilizer recommendations for wheat.

Wheat Price ($/bu)	*$3.50*			*$4.50*			*$5.50*			*$6.50*		
Fertilizer Price $/lb of N	*$0.25*	*$0.50*	*$0.75*	*$0.25*	*$0.50*	*$0.75*	*$0.25*	*$0.50*	*$0.75*	*$0.25*	*$0.50*	*$0.75*
Soil test NO_3-N ppm	*Nitrogen Application Rate – pounds of N per acre*											
2	100	45	0	110	70	30	115	85	50	120	95	65
4	75	25	0	90	50	10	95	60	30	100	75	45
6	55	0	0	65	25	0	75	40	10	80	50	25
8	35	0	0	45	0	0	55	20	0	60	30	10
10	15	0	0	25	0	0	30	0	0	40	10	0
12	0	0	0	0	0	0	10	0	0	15	0	0

Figure 1. Applicator for dual application of ammonia and 10-34-0.

Example: A field has a soil test value of 5 ppm residual nitrate-nitrogen in a 3-foot soil profile. The nitrogen costs $0.40 per lb and the wheat crop will sell for $5.00 per bushel.

The nitrogen fertilizer requirement is calculated as follows:

Nitrogen need (lb N/acre) = ((0.40/5.00) + (5/68.7)-0.235)*-725

Nitrogen need = 60 lb N/acre

Recommended nitrogen rates are adequate for dryland yields across the state unless producers expect yields above 75 bushels per acre above which an additional 20 lb of nitrogen per acre should be applied.

When to Apply Nitrogen

Nitrogen applications have a high probability of increasing yield when soil nitrogen availability is low in relation to yield potential, but nitrogen fertilizer application can cause yield depression, mainly under dry conditions.

Yield depressions have occurred more often with fall applications than with spring topdressing applications. Fall applications tend to stimulate increased vegetative growth that depletes the soil water and may increase susceptibility to disease. Yield depressions associated with fall application of nitrogen are uncommon and should not be used as a basis for not applying nitrogen to wheat.

If yield depression is a concern, especially in western Nebraska, spring topdressing is recommended. Spring topdressing allows the producer to evaluate yield potential based on plant stands and soil moisture. Some fall-applied N (10-20 lb/acre) should be applied to promote growth for cover and competition with weeds.

Topdressing the remaining N has a significant advantage over applying all N in the fall. It helps the producer avoid investing in a wheat crop that may have low yield potential and should be completed prior to jointing. With nitrogen applications made after jointing, yield response is decreased, but grain protein content generally shows an increase compared to non-fertilized wheat.

Yield decreases due to nitrogen application also can occur on soils high in available nitrogen. When available nitrogen is too high, lodging often results, especially with high soil moisture in the spring. This emphasizes the importance of soil tests to determine soil nitrogen availability.

Sources of Nitrogen for Wheat

All common nitrogen fertilizer sources are similarly effective, including urea (46-0-0), urea-ammonium nitrate (32-0-0 or 28-0-0), and anhydrous ammonia (82-0-0), when properly applied. Nitrogen sources vary in their susceptibility to volatilization or gaseous loss as ammonia to the atmosphere. Incorporation of fertilizer (mechanical, rainfall, or irrigation) soon after application should provide equal effectiveness of sources.

Anhydrous ammonia is the most economical source of nitrogen, especially under normal tillage. However, if applied with standard knife applicators, the increased power requirements will add to application costs. This makes the lower ammonia price less advantageous compared to other nitrogen sources.

Newer ammonia applicators with coulters allow narrower knife spacing (15 inches) and also operate at shallower depths, greatly reducing power requirements. Depending on local pricing, ammonia application rates must be more than 40 lb of nitrogen per acre to be more economical than other nitrogen sources. In western fallow areas, ammonia is generally a good source if it is applied early in the fallow period to avoid soil drying prior to seeding.

Fertilizing for Grain Protein

Nebraska wheat has traditionally been high in protein content and quality, desirable characteristics for the baking industry. Nitrogen availability directly affects grain protein. With high soil nitrogen, grain protein is often 13 percent or higher, depending on yield levels. If soil nitrogen is low, grain protein tends to decrease as grain yield increases.

Since grain protein reflects soil nitrogen availability, it can reflect when wheat yield will increase with applied nitrogen. A grain protein level of 12 percent to 13 percent, with an average yield, indicates adequate nitrogen. If grain protein is in the 10 to 11 percent range, however, yield response to nitrogen is very probable.

University of Nebraska–Lincoln nitrogen fertilizer recommendations for wheat will generally produce grain protein above 12 percent. If higher grain protein is your goal, about 20 lb per acre additional nitrogen will need to be topdressed in the spring for each one percent increase in grain protein desired, up to a maximum of 40 lbs N per acre.

Fertilizing With Nitrogen Following High Yields

For most wheat grown in wheat-fallow or wheat-summer crop-fallow systems, producers have sufficient time for straw decomposition before the next wheat crop, if favorable soil moisture and temperature conditions exist.

Continuous wheat cropping is another consideration. This is not a recommended practice, because of disease and insect concerns, but it is done in some areas.

A producer planting wheat following above-average grain yields, may need increased nitrogen fertilizer due to increased nitrogen removal by the previous crop and because the increased straw requires additional N for decomposition.

Straw yields increase about 0.35 tons for each 10-bushel-per-acre increase in grain yields for semidwarf varieties and 0.45 tons for taller varieties. Straw only contains about 10 lb of nitrogen per ton.

Wheat following grain yields of 70 bushels per acre or more may require an additional 20 lb of N per acre for proper straw decomposition to avoid nitrogen deficiency from N immobilization. This N deficiency usually does not express itself until the next spring during the wheat's rapid growth.

If these conditions exist, additional N can be applied when straw is tilled before planting or the additional N could be added during rapid vegetative growth early the following spring.

Phosphorus Recommendations

Wheat responds to applied phosphorus (P) more than other major Nebraska grain crops. Soil test levels of phosphorus must be higher for wheat than for corn, grain sorghum, or soybeans.

Research indicates that phosphorus mainly increases tillering in the fall, which increases the number of heads and grain yield. To a lesser extent, phosphorus increases seed size and kernel number in the head.

Because of the effect of phosphorus on wheat rooting, winterkill is often associated with low soil phosphorus. Phosphorus deficiencies also result in delayed maturity, which is clearly visible on eroded and high pH soils with low availability of soil phosphorus.

Figure 2. Row-applying 10-34-0 at planting.

Areas of green wheat among mature wheat also are good indicators of phosphorus deficiency.

Optimum Phosphorus Rate for Row or Dual Placement

The UNL equation for phosphorus is based on soil test value, P application method, yield goal, phosphorus fertilizer price, and wheat price. Calculate the optimum fertilizer phosphorus rate for winter wheat using the following equations or by using *Worksheets 1* or *2* and *Tables II* through *VI*. An Excel® spreadsheet found at *http://soilfertility.unl.edu* also can be used.

Bray-1 P Test:

P_2O_5 rate (lb/acre) = (-9.98 - 2.38 x LN(Bray-1P) + 4.39 x LN YG)/(P Price/Wheat Price)

Olsen P Test:

P_2O_5 rate (lb/acre) = (-9.98 - 2.38 x LN(OlsenP*1.5) + 4.39 x LN YG)/(P Price/Wheat Price)

Optimum Phosphorus Rate for Broadcast Application

Bray-1 P Test:

P_2O_5 rate (lb/acre) = (17.13 - 3.21 x LN (Bray-1P) + 2.89 x LN YG - 9.81 x LN pH)/(P Price/Wheat Price)

Olsen P Test:

P_2O_5 rate (lb/acre) = (17.13 - 3.21 x LN (OlsenP*1.5) + 2.89 x LN YG - 9.81 x LN pH)/(P Price/Wheat Price)

In the equation, LN is the natural logarithm,

Bray-1P is the soil phosphorus test (ppm)
YG stands for yield goal in bushels per acre,

pH is soil pH,
P Price is dollars per lb of P_2O_5,
Wheat Price is in dollars per bushel of wheat

Several soil extractants are now used by commercial soil-testing laboratories to determine available P. Most research has been conducted by calibrating Bray-1 P with corn response.

The authors suggest using the following equations to convert results using other extractants to a "Bray-1 P equivalent" to be used in making a P recommendation.

For Mehlich 2: Bray-1 P = 0.9 * Mehlich II
For Mehlich 3: Bray-1 P = 0.85 * Mehlich III
For Olsen P: Bray-1 P = 1.5 * Olsen P

Phosphorus Application Methods

Three basic methods of phosphorus application can be used for wheat:

- Applying directly with the seed
- Broadcasting and incorporating prior to seeding or
- Dual placement, which is applying ammonium polyphosphate liquid (10-34-0) together with anhydrous ammonia prior to seeding

With new air seeders, air distribution of fertilizer, and precision ammonia applicators available, producers can find many variations of these three application schemes. For example, a producer using different kinds of tillage and placement shovels, sweeps, or a no-till seeding system can place nitrogen and phosphorus fertilizers either under, or slightly to the side of, the seed row.

Seed rows also may vary greatly in width, where the seed may be spread out over several inches under a sweep or seeded in a narrow slot.

These variations greatly influence fertilizer-seed contact which may affect seed germination. The normal ammonium superphosphates (11-52-0, MAP or 18-46-0, DAP) generally have little effect on wheat stands because of their low salt index, the lower fertilizer concentration associated with narrow rows (7- to 10-inch vs. 14-inch), and the generally high rates of seeding used with modern wheat varieties. The seeding mechanism for applying phosphorus fertilizer with the seed (or in bands) is not critical unless the producer applies additional nitrogen at the same time. If you apply large amounts of nitrogen (over 15 to 30 lb of nitrogen per acre, depending on row spacing), fertilizer nitrogen must be separated from the seed or stand losses may result. This is accomplished with some types of air seeders.

Experiments in Nebraska have shown that dual-placed phosphorus performs similarly to seed-applied phosphorus, so the recommendation is the same for both application methods. While dual-placed phosphorus often results in somewhat less uniform wheat growth than seed-applied phosphorus, harvest yields have been similar for the two application methods.

Greater wheat growth variability associated with dual-placed phosphorus results from delayed root contact due to the greater distance from the row that phosphorus is placed, compared to seed application. This mainly occurs on soils testing very low in P.

This difference in time of root-to-phosphorus contact normally does not affect yield when wheat is seeded at the optimum seeding date; however, if wheat is seeded late without time for adequate root growth, the seed application method is superior.

Knife spacing for dual placement should be no greater than 15 inches. Wider spacing of nitrogen and phosphorus bands can result in variable plant height and may reduce yield. The normal ammonia application depth of 5 to 7 inches is also a good depth for phosphorus application. Double tubes on the shank for ammonia delivery and liquid fertilizer phosphorus are required.

Residual Phosphorus

When fertilizer phosphorus is applied, only 10 to 30 percent is absorbed by the wheat. The remaining 70 to 90 percent of the applied phosphorus remains in the soil as residual phosphorus. This residual phosphorus begins slowly reverting to insoluble and less available P forms. Less than 25 to 30 percent of residual phosphorus is generally found in the following year's soil tests for phosphorus when the phosphorus is broadcasted and mixed with the soil.

Studies have shown that residual phosphorus availability can increase significantly when it is knifed-in below tillage depth. Undisturbed bands may provide some phosphorus for several years, but the primary effect occurs during the year following application. Therefore, residual phosphorus from banding is most effective in continuous cropping systems and less effective in winter wheat-fallow systems because of the two-year period between phosphorus application and seeding of the next wheat crop.

Worksheet 1: Phosphate Fertilizer Requirement for Dual or Row Application

1) Soil test value: Bray-P1 ____________ ppm........................ Factor 1 (from *Table II*): ____________

OR OR OR

Olsen P ____________ ppm........................ Factor 1 (from *Table II*): ____________

2) Yield Goal: ____________ bu/acre................... Factor 2 (from *Table III*): ____________

3) Add Factor 1 and Factor 2 ____________

If result is negative, STOP; NO fertilization is required.

4) Price per bushel of wheat $____________

5) Price per lb of P_2O_5 ____________

6) Divide Line 4 by Line 5 ____________

7) Multiply result of Line 3 by the result of Line 6. ____________

Result of Line 7 is the amount of fertilizer (pounds of P_2O_5/acre) required.

Table II. Conversion factor for soil test value.

Bray-P1	*Olsen P*	*Factor 1*	*Bray-P1*	*Olsen P*	*Factor 1*
1.5	1.0	-10.95	16.0	10.7	-16.58
2.0	1.3	-11.63	17.0	11.3	-16.72
3.0	2.0	-12.59	18.0	12.0	-16.86
4.0	2.7	-13.28	19.0	12.7	-16.99
5.0	3.3	-13.81	20.0	13.3	-17.11
6.0	4.0	-14.24	21.0	14.0	-17.23
7.0	4.7	-14.61	22.0	14.7	-17.34
8.0	5.3	-14.93	23.0	15.3	-17.44
9.0	6.0	-15.21	24.0	16.0	-17.54
10.0	6.7	-15.46	25.0	16.7	-17.64
11.0	7.3	-15.69	26.0	17.3	-17.73
12.0	8.0	-15.89	27.0	18.0	-17.82
13.0	8.7	-16.08	28.0	18.7	-17.91
14.0	9.3	-16.26	29.0	19.3	-17.99
15.0	10.0	-16.43	30.0	20.0	-18.07

Table III. Conversion factor for yield goal.

Yield goal	*Factor 2*	*Yield goal*	*Factor 2*
30	14.93	80	19.24
35	15.61	85	19.50
40	16.19	90	19.75
45	16.71	95	19.99
50	17.17	100	20.22
55	17.59	105	20.43
60	17.97	110	20.64
65	18.33	115	20.83
70	18.65	120	21.02
75	18.95		

Worksheet 2: Phosphate Fertilizer Requirement for Broadcast Application

1) Soil test value: Bray-P1 ____________ pm.......................... Factor 3 (from *Table IV*): ____________

   OR

   OlsenP ____________ ppm........................ Factor 3 (from *Table IV*): ____________

2) Yield Goal: ____________ bu/acre................... Factor 4 (from *Table V*): ____________

3) Soil pH: ____________ .... Factor 5 (from *Table VI*): ____________

4) Add Factor 3 and Factor 4 and Factor 5 ____________

   If result is negative, STOP; NO fertilization is required.

5) Price per bushel of wheat $____________

6) Price per lb of P_2O_5 $____________

7) Divide Line 5 by Line 6 ____________

8) Multiply result of Line 4 by the result of Line 7 ____________

Result of Line 8 is the amount of fertilizer (pounds of P_2O_5/acre) required.

Table IV: Conversion factor for soil test value.

Bray-P1	*Olsen*	*Factor 3*	*Bray-P1*	*Olsen*	*Factor 3*
1.1	0.7	16.82	16.0	10.7	8.23
2.0	1.3	14.90	17.0	11.3	8.04
3.0	2.0	14.60	18.0	12.0	7.85
4.0	2.7	12.68	19.0	12.7	7.68
5.0	3.3	11.96	20.0	13.3	7.51
6.0	4.0	11.38	21.0	14.0	7.36
7.0	4.7	10.88	22.0	14.7	7.21
8.0	5.3	10.45	23.0	15.3	7.07
9.0	6.0	10.08	24.0	16.0	6.93
10.0	6.7	9.75	25.0	16.7	6.80
11.0	7.3	9.43	26.0	17.3	6.67
12.0	8.0	9.15	27.0	18.0	6.55
13.0	8.7	8.90	28.0	18.7	6.43
14.0	9.3	8.66	29.0	19.3	6.32
15.0	10.0	8.44	30.0	20.0	6.21

Table V. Conversion factor for yield goal.

Yield goal	*Factor 4*	*Yield goal*	*Factor 4*
30	9.83	80	12.66
35	10.27	85	12.84
40	10.66	90	13.00
45	11.00	95	13.16
50	11.31	100	13.31
55	11.58	105	13.45
60	11.83	110	13.58
65	12.06	115	13.71
70	12.28	120	13.84
75	12.48		

Table VI. Conversion factor for soil pH.

pH	*Factor 5*
6	-17.58
6.2	-17.90
6.4	-18.21
6.6	-18.51
6.8	-18.81
7	-19.09
7.2	-19.37
7.4	-19.63
7.6	-19.90
7.8	-20.15
8	-20.40
8.2	-20.64
8.4	-20.88
8.6	-21.11

Example for Worksheet 1:

Phosphate Fertilizer Requirement for Dual or Row Application

A grower has a field with the following soil test value: Bray-P1: 10.0 ppm. His yield goal is 60 bushels per acre. He will pay $0.40 per lb of P_2O_5 and plans to sell the wheat crop for $4.50 per bushel.

1)	Soil test value: Bray-P1:	10.0	ppm........................	Factor 1 (from *Table II*):	-15.46
2)	Yield Goal:	60	bu/acre...................	Factor 2 (from *Table III*):	17.97
3)	Add Factor 1 and Factor 2: (If result is negative, STOP; NO fertilization is required).				2.51
4)	Price per bushel of wheat:				$4.50
5)	Price per lb of P_2O_5:				$0.40/lb
6)	Divide Line 4 by Line 5:				11.25
7)	Multiply result of Line 3 by the result of Line 6: (2.51*11.25) =				28.2

Result of Line 7 is the amount of fertilizer (pounds of P_2O_5/acre) required.

Example for Worksheet 2:

Phosphate Fertilizer Requirement for Broadcast Application

A grower has a field with the following soil test value: Olsen P: 4.0 ppm, soil pH 7.4. His yield goal is 60 bushels per acre. He will pay $0.35 per lb of P_2O_5 and plans to sell the wheat crop for $4.25 per bushel.

1)	Soil test value:				
	OlsenP:	4.0	ppm........................	Factor 3 (from *Table IV*):	11.38
2)	Yield Goal:	60	bu/acre...................	Factor 4 (from *Table V*):	11.83
3)	Soil pH:	7.4	....	Factor 5 (from *Table VI*):	-19.63
4)	Add Factor 3 and Factor 4 and Factor 5: (If result is negative, STOP; NO fertilization is required.				3.58
5)	Price per bushel of wheat:				$4.25
6)	Price per lb of P_2O_5:				$0.35/lb
7)	Divide Line 5 by Line 6:				12
8)	Multiply result of Line 4 by the result of Line 7: (3.58*12) =				43

Result of Line 8 is the amount of fertilizer (pounds of P_2O_5/acre) required.

Potassium Recommendations

Most Nebraska soils have enough potassium (K) for maximum wheat production. The plant must have adequate potassium nutrition to ensure efficient water use within the plant. Early symptoms of potassium deficiency include uniform chlorosis on older plant tissue. Leaves eventually become streaked with yellow or appear scorched, bronzed, or blighted along their edges.

Some experiments have shown apparent yield increases with potassium fertilization, but the increases have not been predictable and may have been the result of abnormal weather conditions, disease, or some indirect effect (chloride effect on foliar disease) other than a direct potassium response.

Potassium recommendations based on soil tests are shown in *Table VII*. It is rare for potassium to be recommended for wheat grown on Nebraska soils because most soils in wheat growing areas contain more than 150 ppm potassium.

Table VII. Potassium fertilizer recommendations.

Potassium soil test level (Exchangeable potassium, ppm)	*Potash application rate (lb K_2O/A)*
0-40	40
40-74	30
75-124	20
125-150	0
>150	0

Other Nutrients

Zinc

When soil zinc (Zn) levels are less than 0.4 ppm (DTPA test), wheat may respond to Zn fertilization. Usually it's not economical to broadcast 10 or 15 lb of zinc per acre from Zn sulfate to increase the soil test level unless producers are irrigating or producing other high-Zn requiring crops.

If the soil test is very low in zinc, row-applied 10-34-0 + 1 percent Zn is an excellent way to provide a small amount of zinc to correct potential deficiency. Zn-ammonia complexes can be cold-mixed with 10-34-0 to provide Zn and are often more economical than chelated Zn sources. One-half to one lb of zinc per acre is usually sufficient.

Sulfur

Most fine-textured soils in Nebraska have adequate amounts of organic matter and/or residual sulfate sulfur (S) deeper in the soil for maximum wheat yield. The exception may be sandy soils, especially irrigated sandy soils.

If sulfur is required on a sandy soil, a **broadcast rate** of 10 to 15 lb S/acre should be sufficient. Irrigated wheat on sandy soils with low organic matter and low sulfate levels in the irrigation water may require up to 20 lb S/acre.

If 10-34-0 is row-applied at planting, ammonium thiosulfate (12-0-0-26S) should not be mixed with the phosphate. Thiosulfate can severely injure wheat seedlings and drastically reduce stand.

Chloride

Experiments conducted in western Nebraska on dryland winter wheat showed little response to chloride even though many soils contained low chloride based on guidelines developed from South Dakota research. At this time, the authors do not recommend chloride fertilization for winter wheat.

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