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Fertilizer Suggestions for Corn

Charles A. Shapiro, Richard B. Ferguson, Gary W. Hergert, and Charles S. Wortmann, Extension Soils Specialists; Daniel T. Walters, Professor of Agronomy and Horticulture

Fertilizer nutrient requirements for corn are based on expected yield and nutrient levels in the soil. This revision contains slight changes to the nitrogen (N) recommendation equation and the addition of cost adjustment and timing factors for the calculation of the recommended N rate. In place of a table for phosphorus (P) recommendations, a graph of recommended rates based on soil test P is presented.

Nutrient Needs

Crop production in Nebraska typically requires (N) fertilization to supplement what is available from the soil. After N, phosphorus (P) is the nutrient most likely to be deficient for profitable corn production.

For corn after corn, annually test for residual nitrate in the soil profile in spring (0 - 4 feet) to fine-tune your N recommendation. Soil nitrate sampling is generally not needed for corn grown after soybean unless the fields have a recent manure history. To determine P, potassium (K) and micronutrient needs and the level of soil organic matter, collect soil samples from a depth of 0 - 8 inches every three to five years in the fall. Most Nebraska soils supply adequate amounts of K, sulfur, zinc, and iron, but on some soils the corn crop will benefit from applying one or more of these nutrients. Calcium, magnesium, boron, chlorine, copper, manganese, and molybdenum are seldom, if ever, deficient for corn production in Nebraska. The complete University of Nebraska nutrient recommendations for all crops are available at *soiltest.unl.edu*.

Nitrogen Requirement

Estimates of fertilizer N needed for corn are based on expected yield, the amount of residual soil nitrate-nitrogen (NO_3-N), soil organic matter, other N sources, timing of application and price of fertilizer. *Table I* shows the results of the University of Nebraska N recommendation equation for 1, 2, and 3 percent organic matter and several yield expectations and soil N levels. The N rates in *Table I* are not adjusted for other N credits listed in the complete equation.

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Table I. Nitrogen fertilizer recommendations based on expected yield with adjustments for soil nitrate-nitrogen (NO_3-N) and soil organic matter.

Soil Nitrate	*Yield Goal bu/ac*							
ppm	*60*	*90*	*120*	*150*	*180*	*210*	*240*	*270*
	Organic matter 1% **Recommended N rate based on soil N, yield goal and soil organic matter (lb N/acre)**							
1	90	120	155	185	220	250	280	315
3	75	105	140	170	200	235	265	295
6	50	80	115	145	180	210	240	275
9	25	60	90	120	155	185	215	250
12	5	35	65	100	130	160	195	225
18	0	0	20	50	80	115	145	175
24	0	0	0	0	35	65	95	130
	60	**90**	**120**	**150**	**180**	**210**	**240**	**270**
	Organic matter 2%							
1	80	110	135	165	195	220	250	275
3	65	95	120	150	175	205	230	260
6	40	70	95	125	155	180	210	235
9	20	45	75	100	130	155	185	210
12	0	20	50	75	105	130	160	185
18	0	0	0	30	55	85	110	140
24	0	0	0	0	10	35	65	90
	60	**90**	**120**	**150**	**180**	**210**	**240**	**270**
	Organic matter 3%							
1	75	95	120	145	165	190	215	240
3	60	80	105	130	150	175	200	220
6	35	55	80	105	125	150	175	200
9	10	35	55	80	105	125	150	175
12	0	10	35	55	80	105	125	150
18	0	0	0	10	30	55	80	100
24	0	0	0	0	0	5	30	55

The N recommendation for corn grain is:

N need (lb/ac) =
[35 + (1.2 x EY) - (8 x NO_3-N ppm) - (0.14 x EY x OM) - other N credits] x $Price_{adj}$ x $Timing_{adj}$

where: EY = expected yield (bu/ac)
NO_3-N ppm = average nitrate-N concentration in the root zone (2-4 foot depth) in parts per million
OM = percent organic matter
Other N credits include N from legumes, manure, other organic materials, and from irrigation water
$Price_{adj}$ = adjustment factor for prices of corn and N
$Timing_{adj}$ = adjustment factor for fall, spring and split applications

The expected yield should be about 105 percent of the five-year yield average (see NebGuide G481, *Setting a Realistic Yield Goal*). A higher yield goal may be appropriate if management improvements are expected to result in increased yield.

The N recommendation equation for corn silage is:

N need (lb/ac) =
[35 + (7.5 x EY_s) - (8 x NO_3-N ppm) - (0.85 x EY_s x OM) - other N credits] x $Price_{adj}$ x $Timing_{adj}$

where: EY_S = expected silage yield in tons per acre and NO_3-N, OM, N credits, and adjustment factors are the same as those listed above.

Optimal N rates are sensitive to wide fluctuations in fertilizer and corn prices. Research conducted from 2002 to 2004 provides the basis for economic adjustments to the N recommendation equation, and is summarized in papers available at *soilfertility.unl.edu*. The price factor in the N equation ($Price_{adj}$) is based on the diminishing effect of increasing N rate on corn yields. As N becomes less expensive relative to corn price, more N per bushel yield increase can be profitably applied. In *Table II*, read down from the corn price/bu to the price that is appropriate for the cost of N to get $Price_{adj}$. The ratio has a floor of 4:1 and a cap of 12:1; often corn and N prices result in ratios near 8:1. $Price_{adj}$ is applied after the other calculations are made. A spreadsheet for these calculations, with supporting documentation, is available at *soilfertility.unl.edu*.

The timing adjustment factor ($Timing_{adj}$ *Table III*) is used to adjust for either fall or split application, with spring preplant application as the reference.

Table II. Price adjustment factors ($Price_{adj}$) adjusting the N recommendation for corn ($/bu) and fertilizer ($/lb) prices. Use price adjustment factor in equation.

Nitrogen Price ($/lb)	*Corn Price ($/bu)*						
	3.00	*4.00*	*5.00*	*6.00*	*7.00*	*8.00*	*9.00*
	-------------- Price adjustment factor --------------						
0.30	1.10	1.19					
0.60	0.79	0.91	1.02	1.10	1.16		
0.90	0.63	0.74	0.83	0.91	0.99	1.05	1.10
1.20	0.55	0.63	0.71	0.79	0.85	0.91	0.97

Note: Do not use with a Corn:N price ratio > 12 or < 4.
Price adjustment factor = 0.263 + (0.1256*Corn:N) - (0.00421*(Corn:N)^2)

Table III. Timing adjustment factors ($Timing_{adj}$) and definitions for adjusting calculated N rate.

Timing	*Definition*	*$Timing_{adj}$ Factor*
Split (BMP)	At least 30 percent of N applied by sidedress and fertigation N	0.95
Mostly pre-plant	Less than 30 percent sidedress and fertigation N and preplant N>fall N	1.00
Mostly fall	Mostly fall applied N and less than 30 percent sidedress and fertigation N	1.05

Nitrogen Adjustment for Soil Nitrate-N

Corn will use soil nitrate-N remaining in the rooting zone from the previous year. This nitrogen should be credited in the calculated N recommendation. The average nitrate-N concentration (in parts per million: ppm) in the root zone (or the depth-weighted concentration) is considered in the UNL nitrogen recommendation equation and is averaged across several soil depths as illustrated in *Table IV*. Soil nitrate-N can be estimated by sampling soils to a minimum depth of 2 feet, but is better estimated from samples collected to a 3- or 4-foot depth. For every ppm of depth-weighted average nitrate-N concentration to a 4-foot depth, the recommended N need is reduced by eight pounds per acre. This credits about 50 to 55 percent of the soil nitrate-N as equivalent to fertilizer N. Some soil testing laboratories may report estimates of all or some fraction of nitrate-N in pounds per acre.

When soil test results for nitrate-N are not available, a default value of 3.6 ppm is used for medium/fine textured and 1.9 ppm for sandy soils to calculate the N recommendation. To avoid over-crediting soil nitrate when shallower soil samples are taken, the default nitrate values for unsampled depths are 3 ppm for medium/fine textured and 1.5 ppm for sandy soils.

Table IV. An example calculation of mean depth-weighted soil nitrate-nitrogen concentration across several soil depths.

Soil layer, inches	*Thickness, inches*	*Nitrate-N, ppm*	*Calculations for soil layer*
0-8	8	15	8 x 15 =120
8-24	16	10	16 x 10 =160
24-48	24	3	24 x 3 = 72
Total	48		352
Weighted average ppm			352/48 = 7.3 ppm

Note: to convert from lb N/ac to ppm, the default soil density can be assumed to be 3.6 M lb soil/ac-ft.

If root growth is restricted to less than 2 feet due to a high water table, a hardpan, or a layer of gravel, rock or shale, residual nitrate is estimated for the effective rooting depth only rather than for the 4-foot depth. When the root zone is less than 2 feet, use zero ppm nitrate for the depth without soil to determine average nitrate ppm concentration. If the example in *Table IV* is for shallow soil over gravel at 24 inches, it would have a weighted average concentration of 5.8 ((352-72)/48) ppm since we would use zero rather than 3 ppm in the lower 24 inches.

Nitrogen Adjustment for Soil Organic Matter

Nitrogen is released as ammonium- and nitrate-N from organic matter in the soil through mineralization. Mineralization is a microbial process that is favored by conditions favorable to high corn yield; thus, the estimated credit for N from organic matter is related to expected yield. When a soil test for organic matter is not available, one percent organic matter is assumed for sandy soils and soils in the Panhandle, and 2 percent is assumed for other soils. The maximum soil organic matter content used in the algorithm is capped at 3 percent organic matter since few Nebraska soils above this level were represented in the database used to develop the equation.

Nitrogen Adjustment for Legumes, Manure, Other Organic Materials, and Irrigation Water

Preceding legume crops result in improved N supply to the corn crop because legume crop residues decompose faster than cereal crop residues and cause less soil and fertilizer N immobilization or tie-up. When corn follows a legume in rotation, the N rates (*Table I*) are reduced by the legume N credit *(Table V)*.

Table V. Estimated nitrogen credit from legumes and other crops.

	N Fertilizer Reduction (lb/acre)	
Legume Crop	*Medium and Fine Textured Soils*	*Sandy Soils*
Soybean	45	35
Dry bean	25	25
Alfalfa (70-100% stand, >4 plants/ft^2)	150	100
Alfalfa (30-69% stand, 1.5-4 plants/ft^2)	120	70
Alfalfa (0-29% stand, <1.5 plants/ft^2)	90	40
Sweet clover and red clover	80% of credit allowed for alfalfa	
Sugar beets	50	50

Soybeans are credited for 45 lbs of N per acre on non-sandy soils and 35 on sandy soils unless the yield was less than 30 bu/ac. For yields less than 30 bu/ac, credit 1 lb of N per bushel harvested. Soybeans are good scavengers of soil nitrate; therefore, soil nitrate levels after soybean harvest are often low, in the range of 3 to 4 ppm nitrate-N. Deep soil sampling for nitrate-N is recommended if organic amendments were applied within the previous two years or if the soybean crop yield was poor due to hail, weather or insect damage, or if soybeans were fertilized with N.

When manure is applied in a rotation that includes corn, recommended rates of N should be reduced according to the source of manure, the amount applied, and the method of application. See NebGuide G1335 *Determining Crop-Available Nutrients from Manure,* (*www.ianrpubs.unl.edu/sendIt/g1335.pdf*). The preplant soil nitrate test does not estimate future manure N availability.

Irrigation water often contains a significant amount of nitrate-N that is readily available to corn. When the amount of N supplied in irrigation water exceeds 15 lb N per acre it should be deducted from the recommended N (*Table I*). For each foot of effective irrigation water applied, one ppm nitrate-N in water is equal to 2.7 lb N per acre. Irrigation amounts vary from year to year and the N credit for irrigation should be based on 80 percent of the average amount applied over a three-year period. Based on long-term conditions, reasonable average applications for different areas of the state would be 6 inches in eastern Nebraska, 9 inches in central Nebraska, 12 inches in west central Nebraska, and 15 inches in western Nebraska.

Timing, Method, and Form of Nitrogen Application

Nitrogen fertilizer may be applied at different times including fall, spring preplant, planting time, sidedress or in irrigation water. Research has shown that fall applications are generally less efficient than growing season applications because of the increased risk of N loss from either leaching or denitrification. Multiple applications of N are usually more efficient than single large doses. This is especially true on sandy soils that are prone to leaching. Fertilizer N is most efficiently used when some is applied near the period of rapid N uptake which begins about the eighth leaf stage (V8). Application of N after tasseling should be avoided unless N deficiency is obvious or rainfall has delayed fertigation.

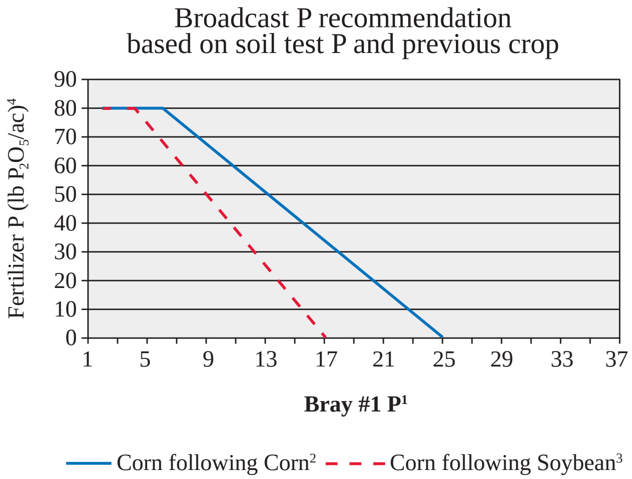
Fall application of N is not recommended on sandy soils. On very sandy soils it is desirable to apply most of the N as sidedress or with multiple applications of irrigation water after corn is 1 foot tall. Up to one-third of the planned N can be applied at or before planting to prevent early season N deficiency on sandy soils and soils low in organic matter. The timing adjustment factor reflects these considerations in the N equations (*Table III*). Fall application of nitrate (NO_3) forms of fertilizer is discouraged due to risk of substantial losses by leaching and denitrification.

Phosphorus Fertilization

Several soil extractants are now used by commercial soil testing laboratories to determine available P. Most research has been conducted on calibrating Bray-1 P with corn response. The authors suggest 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 = 0.9 * Mehlich II
For Mehlich 3:	Bray-1 = 0.85 * Mehlich III
For Olsen P:	Bray-1 = 1.5 * Olsen P

Research indicates yield increases are expected from P applications when corn is grown in rotation with soybeans when soil test levels are below 10 ppm by the Bray-1 and Mehlich-3 P soil tests, or 7 ppm by the Olsen P soil test (also known as the sodium bicarbonate P test) *(Figure 1)*. Under continuous corn, research indicates that there is a good probability of corn yield increase from P fertilization when soil tests are equal to or below 20 ppm Bray-1 P. For soil tests greater than 25 ppm Bray-1 P, yield increases are unlikely. Use of starter P will both help maintain soil P and provide early season nutrients but yield increases at soil tests of 25 ppm Bray-1 P or higher are unlikely. Application of P on a crop removal basis (0.33 lb P_2O_5/bu) when Bray-1 P is below 20 ppm is likely to be a slightly less profitable alternative that will commonly result in increased soil test P (stover removal is about 4 lbs P_2O_5/ton). When soils are greater than 25 ppm Bray-1 P or 15 ppm Olsen P phosphorus application is not needed. With variations in P level within fields, it is important to identify low testing areas. For fields with substantial variability in soil P, site-specific P application is recommended. Other soil tests can be converted to Bray-1 P values based on the formula given above. Use the continuous corn recommendation for P when corn follows crops other than soybean.



1. Bray P-1 for acid and neutral soils. For other extractants use the formulas in the text to calculate a "Bray-1 P" equivalent.
2. The following equation is graphed above for continuous corn:
   If Bray-1 P <= 25 ppm: P-rate (lb P_2O_5/ac) = (25 - Bray-1 P) x 4; maximum rate = 80 lb P_2O_5/ac
   If Bray-1 P > 25 ppm: P-rate (lb P_2O_5/ac) = 0
   Bray-1 P = Bray-1 P (ppm) in 0-8 inch depth
3. The following equation is graphed above for corn following soybeans:
   If Bray-1 P <= 17 ppm: P-rate (lb P_2O_5/ac) = (17 - Bray-1 P) x 6; maximum rate = 80 lb P_2O_5/ac
   If Bray-1 P > 17 ppm: P-rate (lb P_2O_5/ac) = 0
4. Apply half the broadcast P rate when banding preplant or beside the row at planting.

Figure 1. Phosphorus recommendation based on Bray-1 P soil test level.

Phosphorus Application Methods

Phosphorus fertilizers can be applied broadcast prior to planting or by placing the fertilizer in bands in the root zone. Incorporating P into the soil results in more effective use and less potential for loss through runoff. Tillage associated with reforming ridges in ridge-plant systems incorporates fertilizer adequately for efficient use. Surface-applied P is generally efficiently used if there is sufficient residue cover to maintain moisture on the soil surface. When there is, residue and moisture roots proliferate and can utilize surface-applied P.

Application of P fertilizer in bands is usually more efficient than broadcast application, especially when soil P levels are very low. Use half the rate recommended in *Figure 1* when banding. Fertilizer P can be applied in preplant bands or banded beside the row, over the row, or in the furrow when corn is planted. Preplant banding with anhydrous ammonia (dual-placement) and placement in strip tillage are effective application methods.

Potassium Fertilization

Most Nebraska soils are capable of supplying enough potassium for excellent corn yields, but soil K deficiency can occur. Tests of 0-8 inch soil samples are useful in determining K fertilizer needs for corn *(Table VI)*.

Table VI. Potassium fertilizer suggestions.

Potassium Soil Test, ppm K	*Relative Level*	*Amount to Apply Annually (K_2O), lb/ac*		
		Broadcast[1]		**Row[2]**
0 to 40	Very Low (VL)	120	plus	20
41 to 74	Low (L)	80	plus	10
75 to 124	Medium (M)	40	or	10
125 to 150	High (H)	0		0
Greater than 150	Very High (VH)	0		0

Potassium test - exchangeable K
[1]The following equation provides an alternative to using table values:
K_2O (lb/ac) = 125 – soil test (ppm) K; if soil test K < 125.
[2]Banded beside seed row but not with the seed.
[3]When soil test levels are above 100 ppm the probability of a yield response to fertilizer K is very low. Consider the value of corn and the cost of K before deciding to apply K expecting little chance of profitable response if the price ratio of a bushel of corn to a pound of K is less than 8 (for example $4.00/bu corn and $ 0.50/lb of K_2O).

Sulfur Fertilization

Nebraska soils generally supply adequate sulfur (S) for excellent corn production. Only sandy soils that are low in organic matter are likely to need added S. Sulfur application on medium to fine texture soils may result in early greening of leaves in cool weather but is unlikely to increase yields. The ability of soils to supply S to plants varies greatly in Nebraska. The need for S also depends on the S content of irrigation water. The S content of irrigation water is generally low in the Sandhills but is usually adequate to meet the needs of crops irrigated with groundwater elsewhere in the state. Guidelines for broadcast or row applications of S are given in *Table VII*.

Table VII. Sulfur fertilizer recommendations (sandy soils only).

Sulfur Soil Test ppm SO_4-S	*Amount to Apply Annually (S), lb/ac*		
	Soil Organic Matter 1% or less		*Soil Organic Matter Greater than 1%*
Irrigation water with less than 6 ppm SO_4-S			
	Broadcast	*Row[1]*	*Row[1]*
Less than 6	20	10	5
6 - less than 8	10	5	0
8 and greater	0	0	0
Irrigation water with 6 or greater ppm SO_4-S			
Less than 6	10	5	0
6 - less than 8	10	5	0
8 and greater	0	0	0

Sulfur test - $Ca(H_2PO_4)_2$ extraction
[1]Applied in a band next to row but not with seed

Sulfur must be in the sulfate form to be used by plants; thus, elemental S must be oxidized to the sulfate form to be utilized. Where S is applied preplant on very sandy soils, one-half of the applied S should be finely ground elemental S and the rest sulfate S. Elemental S can be granulated or flaked with a binding agent, but prilled S is rarely effective. Applying some elemental S at planting reduces leaching losses in sands during wet springs and allows adequate time for oxidation to sulfate. Band application is the most effective method of applying S. When S is applied in a band at planting, use sulfate or thiosulfate-S as the oxidation process is not rapid enough for elemental S to be effective. Ammonium thiosulfate (12-0-0-26S) also is effective, but should NOT be placed with the seed because of the potential for poor seed germination. Ammonium thiosulfate is an excellent source when injected into irrigation water for sprinkler application and can provide S in-season if a deficiency develops.

Zinc Fertilization

Zinc deficiency in corn occurs most often where subsoil is exposed on soils leveled for irrigation. In western Nebraska calcareous soils that are low in organic matter or of sandy texture are more likely to show a need for zinc. Soil zinc can be easily raised to adequate levels by broadcasting zinc fertilizer, usually zinc sulfate (*Table VIII)*. Periodic soil testing to an 8-in depth is suggested to assess zinc levels in soils. Zinc applied in a band beside the row also is effective, provided about 10 lb of N is placed in the same band.

Table VIII. Zinc fertilizer recommendations

Zinc Soil Test Level		*Amount to Apply (Zn), lb/ac*[1]			
DTPA Extraction	*Relative Level*	*Calcareous Soils*[2]		*Noncalcareous Soils*	
ppm Zn		Broadcast	Band	Broadcast	Band
0 to 0.4	Low (L)	10	2	5	2
0.41 to 0.8	Medium (M)	5	1	3	1
> 0.8	High (H)	0	0	0	0

[1]Rates are for inorganic forms of zinc such as zinc sulfate.
[2]Calcareous soils defined as soils with moderate to excess lime.

Iron Fertilization

Symptoms of iron chlorosis, observed as interveinal yellow striping on corn leaves, may occur on highly calcareous or saline-sodic soils with pH levels above 7.8.

Correction of iron chlorosis requires several strategies. First, select corn hybrids that have tolerance to chlorosis as this may be adequate in overcoming iron problems. If chlorosis persists, iron fertilizers may need to be applied. Current research shows the most effective treatment for correcting high pH chlorosis in corn requires an at-planting seed-row application of 50 - 100 lb of ferrous sulfate heptahydrate ($FeSO_4 \cdot 7H_2O$) per acre. This treatment costs $18-$35 per acre (2009 prices) depending on product cost and requires dry fertilizer application equipment on the planter.

A second approach is to apply a stable iron chelate (FeEDDHA) with the seed as a liquid. At least 2.5 - 4 lb of FeEDDHA per acre is required. Chlorosis correction from FeEDDHA has not been as effective as that of $FeSO_4 \cdot 7H_2O$ in research at North Platte and the chelate is more expensive ($35-$55/a). The FeEDDHA works well for correcting soybean chlorosis on high pH soils, but because of differences in iron uptake chemistry between grasses and legumes, it is less effective on corn.

Foliar sprays using ferrous sulfate or FeEDDHA are not always effective in producing significant yield responses. Treatment needs to begin as soon as chlorosis first becomes visible and repeated every 7 to 10 days until newly emerged leaves remain green. Spray must be directed over the row to be effective. A standard application rate is 20 gallons per acre of a 1 percent iron sulfate solution.

Lime Suggestions

Corn is less sensitive than legumes to acid soils. Where corn is grown continuously or with other grain crops, lime application is advised when the soil pH is 5.5 or less, except in the central and western parts of the state where the surface soil may be acid and lower depths of the soil are calcareous. If subsoil samples from 8 - 16 inches show pH below 5.5, liming should be considered. Actual lime rates are determined by a buffer pH test. More specific and detailed recommendations are given in NebGuide G1504.

Where corn is irrigated with groundwater, sufficient lime in the water may maintain a satisfactory soil pH level. Before applying lime on irrigated fields, soil pH change should be monitored for three to five years to determine if the soil pH is declining. If subsoil samples from 8 to 16 inches show pH below 5.5, liming should be considered. Since liming is an expensive practice and can only be economical on a long-term basis, it is prudent to lime some areas and observe the results before making a large investment in lime.

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