EXTENSION

CROP INPUTS AND COST OF PRODUCTION WORKSHOP

SAUNDERS COUNTY

NOVEMBER 11
2-4 p.m.

EASTERN NEBRASKA RESEARCH, EXTENSION, AND EDUCATION CENTER

1071 COUNTY ROAD G

ITHACA, NEB.

The UNL Corn Nitrogen Calculator for Nebraska

Revision Date: 10/19/21

Farm:
Agronomist:
Date:

Enter N management programs to consider	Time of application	Proportion % of total N	N source for each	N content %	Price $/ton	Appl. cost $/acre
Split	Fall		1 AA	82		
change names in boxes	Pre-plant & starter	66	2 AN	34	$735	$5.50
	Sidedress	34	2 AN	34	$735	$7.00
	Fertigation		4 UAN 28	28	$400	$7.00
Pre-plant	Fall		1 AA	82		
	Pre-plant & starter	80	1 AA	82	$820	$18.00
	Sidedress		5 UAN 32	32		
	Fertigation	20	4 UAN 28	28	$400	$7.00
Fall	Fall	100	1 AA	82	$820	$18.00
	Pre-plant & starter		1 AA	82		
	Sidedress		4 UAN 28	28		
	Fertigation		4 UAN 28	28		

Enter short names in the column headers below (#1 to #4)

	Enter field-specific information in columns E to H			1 Example	#2	#3	#4
1	Yield goal	5-yr avg. yield + 5-10%	bu/acre	220			
2	Soil texture			Med./Fine			
3	Soil organic matter (OM)	in 0-8" depth	%	3.0			
4	Soil test nitrate-N	Effective rooting depth	inches	48			
		Soil layers sampled	no.	2 Layers			
		Layer 1 bottom	inches	8			
		Layer 2 bottom	inches	24			
	select nitrate unit in box	Layer 3 bottom	inches				
	ppm	Layer 1 nitrate	ppm	1.6			
		Layer 2 nitrate	ppm	1.6			
		Layer 3 nitrate	ppm				
5	Previous crop			02 Soybean			
6	Irrigation	Water amount	inches	0			
		Water nitrate-N	ppm	5			
7	Manure	Type		01 Beef solid			
		Terms (unit for application)		Tons/acre			
		Amount (tons or 1000 gal/acre)		0			
		Ammonium N	lb/unit	4			
		Organic N	lb/unit	11			
		Year applied		Current			
		Application method		10 Spr, no inc.			
8	Nitrogen management program			1 Split			
9	Expected corn value		$/bu	$6.00	$5.00	$5.00	$5.00
10	N applied since harvest		lb/acre	0			

do not enter anything below

	UNL N recommendation		Unit	1 Example	#2	#3	#4
A	N algorithm components	Crop N requirement	lb/acre	299	Yield goal?	Yield goal?	Yield goal?
		SOM credit	lb/acre	92	OM?	OM?	OM?
		Soil nitrate-N credit	lb/acre	16	Depth?	Depth?	Depth?
		Legume N credit	lb/acre	45	Prev. crop?	Prev. crop?	Prev. crop?
		Irrigation N credit	lb/acre	0	Water?	Water?	Water?
		Manure N credit	lb/acre	0	Manure?	Manure?	Manure?
B	**Recom. N amount (unadjusted)**		**lb/acre**	**145**	**#VALUE!**	**#VALUE!**	**#VALUE!**
C	Average nitrogen price		$/lb N	$1.08	N progr.?	N progr.?	N progr.?
D	Corn price : N price ratio			5.6	#VALUE!	#VALUE!	#VALUE!
E	**Recom. N amount (adjusted for time and prices)**		**lb/acre**	**115**	**#VALUE!**	**#VALUE!**	**#VALUE!**
F	Total N application cost		$/acre	$12.5	#N/A	#N/A	#N/A
G	Total cost of N fertilizer + N application		$/acre	$136.4	#VALUE!	#VALUE!	#VALUE!

https://cropwatch.unl.edu/soils

Corn Phosphorus Rate Calculator

Enter results from Phosphorus Test

5 ppm

Phosphorus Test Used

- (•) Bray-1
- ( ) Mehlich II
- ( ) Mehlich III
- ( ) Olson P

5

What was grown the previous year(s)?

Previous Crop

- ( ) Corn
- (•) Soybeans
- ( ) Other Crop

How often is phosphorus applied? Every year

What were previous yields?

Corn grain		bu/acre
Stover	3	tons/acre (if harvested)
Soybean grain		bu/acre

0 72

P_2O_5 Application Rate 72 lb/acre

Credits: Charles A. Shapiro, Richard B. Ferguson, Charles S. Wortmann, Bijesh Maharjan, and Brian Krienke

Contact: Charles Wortmann, cwortmann2@unl.edu

https://go.unl.edu/corn-p-rate-calc

Soil Test Phosphorus Value Interpretations in the Region

By Nathan Mueller, Water and Integrated Cropping Systems Extension Educator for Saline, Jefferson, and Gage counties

Table 1. Soil test phosphorus interpretations for corn at 180 bu/acre yield goal

Entity	Soil Test Method	Depth (inches)	Categories or Interpretation				
			Very Low	Low	Medium	High	Very High
UNL[a]	Bray-P1 (ppm)	8	5	10	15	20	25
	P_20_5 Rate (lbs/acre)		***72***	***53***	***26***	***0***	***0***
KSU[b]	Bray-P1 (ppm)	6	0-5	5-10	10-15	15-20	20+
	P_20_5 Rate (lbs/acre)		***75***	***55***	***30***	***15***	***0***
ISU[c]	Bray-P1 (ppm)	6	0-8	9-15	16-20	21-30	31+
	P_20_5 Rate (lbs/acre)		***100***	***75***	***28***	***0***	***0***
SDSU[d]	Bray-P1 (ppm)	6	0-5 (5)	6-10 (10)	11-15 (15)	16-20 (20)	21+ (25)
	P_20_5 Rate (lbs/acre)		***95***	***63***	***32***	***0***	***0***
Ward Labs[e]	Bray-P1 (ppm)	6	0-5 (5)	6-12 (10)	13-25 (15)	26-50 (26)	51+
	P_20_5 Rate (lbs/acre)		**87**	**67**	**53**	**34**	**0**

a, No categories, equation based recommendation only. Corn after soybeans (60 bu/ac), fertilizer P applied every year – Used the new Excel P Calculator

b, Sufficiency approach. Starter P fertilizer may still be suggested when soil test P is 20 ppm

c, P rate not adjusted by yield goal

d, SDSU P Fert Rate = (0.7 – (0.035 x Bray P1)) x Yield goal

e, Ward Labs P equation

Sources

- UNL Nutrient Management Suggestions for Corn - https://extensionpublications.unl.edu/assets/pdf/ec117.pdf
- K-State Soil Test Interpretations and Fertilizer Recommendations - https://bookstore.ksre.ksu.edu/pubs/MF2586.pdf
- ISU A General Guide for Crop Nutrient and Limestone Recommendations in Iowa - https://store.extension.iastate.edu/product/5232
- SDSU Fertilizer Recommendations Guide - https://extension.sdstate.edu/sites/default/files/2019-03/P-00039_0.pdf
- WARDguide - https://www.wardlab.com/wp-content/uploads/2021/08/WARDGUIDE-Master-Updated-8.19.21.pdf

Table 1. Soil test phosphorus interpretations for soybean at 60 bu/acre yield goal							
	Soil Test	Depth	Categories or Interpretation				
Entity	Method	(inches)	Very Low	Low	Medium	High	Very High
UNL[a]	Bray-P1 (ppm)	8	0-5	6-8	9-12	>12	
	P_20_5 Rate (lbs/acre)		***65***	***40***	***20***	***0***	
KSU[b]	Bray-P1 (ppm)	6	0-5	5-10	10-15	15-20	20+
	P_20_5 Rate (lbs/acre)		***75***	***55***	***30***	***15***	***0***
ISU[c]	Bray-P1 (ppm)	6	0-8	9-15	16-20	21-30	31+
	P_20_5 Rate (lbs/acre)		***80***	***60***	***40***	***0***	***0***
SDSU[d]	Bray-P1 (ppm)	6	0-5 (5)	6-10 (10)	11-15 (15)	16-20 (20)	21+ (25)
	P_20_5 Rate (lbs/acre)		***63***	***33***	***3***	***0***	***0***
Ward Labs[e]	Bray-P1 (ppm)	6 or 8	0-5 (5)	6-12 (10)	13-25 (15)	26-50 (26)	51+
	P_20_5 Rate (lbs/acre)		**61**	**47**	**37**	**23**	**0**

a, 4 interpretation categories, different than the current UNL corn P fertilizer recommendations
b, Sufficiency approach. Starter P fertilizer not in direct contact with see may still be suggested when soil test P is 20 ppm
c, P rate not adjusted by yield goal
d, SDSU P Fert Rate = (1.55 – (0.10 x Bray-P1)) x Yield goal
e, Ward Labs P equation

Sources

- UNL Fertilizer Recommendations for Soybean - https://extensionpublications.unl.edu/assets/pdf/g859.pdf
- K-State Soil Test Interpretations and Fertilizer Recommendations - https://bookstore.ksre.ksu.edu/pubs/MF2586.pdf
- ISU A General Guide for Crop Nutrient and Limestone Recommendations in Iowa - https://store.extension.iastate.edu/product/5232
- SDSU Fertilizer Recommendations Guide - https://extension.sdstate.edu/sites/default/files/2019-03/P-00039_0.pdf
- WARDguide - https://www.wardlab.com/wp-content/uploads/2021/08/WARDGUIDE-Master-Updated-8.19.21.pdf

Please publish the following news columns in your edition of Wednesday, Dec. 9, 2020. Thank you!

Dec. 4, 2020

Crop Tech Cafe
By Nathan Mueller
Cropping Systems Extension Educator
Saline, Jefferson, and Gage counties

Phosphorus Management Proficiency: Continuous Corn Research Part 1

Last week I wrote about phosphorus (P) fertility philosophies or approaches. This week I am writing about Nebraska research that compared those phosphorus fertilizer approaches. This research was published in the 2018 Soil Science Society of America Journal by UNL faculty Wortmann, Shapiro, Shaver, and Mainz. One of the objectives of their research was to determine if another fertilizer P management approach was superior to the currently recommended UNL sufficiency approach for continuous corn production.

The research was conducted from 2011 to 2016 in Dixon, Saunders, and Lincoln counties in Nebraska. Dixon County near Concord was a rainfed site on Nora silty clay loam soil with an initial soil test P of 10 ppm. Saunders County near Mead was a pivot-irrigated site on Yutan silty clay loam soil with an initial soil test P of 6 ppm. Lincoln County near North Platte was a pivot-irrigated site on Cozad silt loam soil with an initial soil test P of 14 ppm. The experimental design was continuous corn with two different tillage systems, tillage with annual tandem disk and no-till at each site. Within each tillage system, there were five P treatments or approaches: no applied P, P applied according to UNL recommendation for continuous corn, P applied to replace P removal in the previous grain harvest, build/maintain soil test P at 25 ppm, and build/maintain soil test P at 35 ppm. Each P treatment or approach was replicated four times within each tillage system and the same plots were maintained for the 6-year study at all three sites.

Continuous corn yields from the five different P treatments were not significantly different between tillage systems. The average corn yields by P treatment across years, locations, and tillage system were 154 bu/ac (no P), 163 bu/ac (UNL P rec), 169 bu/ac (replace P removal), 166 bu/ac (maintain 25 ppm soil test P), 170 bu/ac (maintain 35 ppm soil test P). The corn yield was statistically the same for replace P removal, maintain 25 ppm soil test P, and maintain 35 ppm soil test P approaches. Meaning that the 1 to 3 bushel per differences are not likely due to the three different P approaches. However, the UNL recommendation yielded 3.3% less than replacing P removal in the previous grain harvest and the maintaining the soil test P at 35 ppm.

The amount of P fertilizer rate applied over the 6 years was quite different between the approaches. For example at the Saunders County site, cumulative total P_20_5 applied was approximately 250 lbs/ac for UNL P recommendation, 260 lbs/ac for replacing P in grain harvest, 355 lbs/ac for build/maintain at 25 ppm, and 611 lbs/ac for build/maintain at 35 ppm. Assuming $0.45 per pound P_20_5 cost, replacing P removed in grain harvest cost $117 per acre while the build/maintain soil test P at 35 ppm cost $275 acre. Overall, the best management approach for continuous corn production in this 6-year study in Nebraska was replacing P removed in grain harvest each year. We will dive into more details in part 2 next week.

Contact me with questions or suggest topics for me to write about in regards to phosphorus management at nathan.mueller@unl.edu or 402-821-1722. Know your crop, know your tech, know your bottom line at croptechcafe.org.

Fertilizer Approach	Yield	Lbs P205 applied per year (Total over 6 years/6)	Profit (Yield difference * corn price) - (Fertilizr rate * price)
No P	154	0	0.00
UNL P rec	163	41.67	12.83
Replace P removal	169	43.33	42.74
Maintain 25 ppm	166	59.17	14.16
Maintain 35 ppm	170	101.83	0.13

MAP ($/ton)	Corn Price ($/bu)
850	5.21

Soil Test Potassium Value Interpretations in the Region

By Nathan Mueller, Water and Integrated Cropping Systems Extension Educator for Saline, Jefferson, and Gage counties

Table 1. Soil test potassium interpretations for corn at 180 bu/acre yield goal							
	Soil Test	Depth	Categories or Interpretation				
Entity	Method	(inches)	Very Low	Low	Medium	High	Very High
UNL[a]	AA* (ppm)	8	0-40	41-74	75-124	125-150	150+
	$K_2$0 Rate (lbs/acre)		***120***	***80***	***40***	***0***	***0***
KSU[b]	AA* (ppm)	6	0-40	40-80	80-120	120-130	130+
	$K_2$0 Rate (lbs/acre)		***95***	***60***	***25***	***15***	***0***
ISU[c]	AA* (ppm)	6	0-120	121-160	161-200	201-240	240+
	$K_2$0 Rate (lbs/acre)		***130***	***90***	***40***	***0***	***0***
SDSU[d]	AA* (ppm)	6	0-40 (40)	41-80 (60)	81-120 (120)	121-160 (150)	161+ (200)
	$K_2$0 Rate (lbs/acre)		***157***	***131***	***52***	***13***	***0***
Ward Labs[e]	AA* (ppm)	6	0-40 (40)	41-80 (60)	81-120 (120)	121-200 (150)	200+
	$K_2$0 Rate (lbs/acre)		**97**	**76**	**40**	**30**	**0**

*AA = Ammonium Acetate extraction method using dry soil
a, Sufficiency approach
b, Sufficiency approach
c, Updated recommendations in 2013, dry test, fine-texture soils
d, SDSU Corn K Fert Rate = (1.166 – (0.0073 x STK)) x Yield goal
e, Ward Labs K equation

Sources

- UNL Nutrient Management Suggestions for Corn - https://extensionpublications.unl.edu/assets/pdf/ec117.pdf
- K-State Soil Test Interpretations and Fertilizer Recommendations - https://bookstore.ksre.ksu.edu/pubs/MF2586.pdf
- ISU A General Guide for Crop Nutrient and Limestone Recommendations in Iowa - https://store.extension.iastate.edu/product/5232
- SDSU Fertilizer Recommendations Guide - https://extension.sdstate.edu/sites/default/files/2019-03/P-00039_0.pdf
- WARDguide - https://www.wardlab.com/wp-content/uploads/2021/08/WARDGUIDE-Master-Updated-8.19.21.pdf

Table 1. Soil test potassium interpretations for soybean at 60 bu/acre yield goal							
	Soil Test	Depth	Categories or Interpretation				
Entity	Method	(inches)	Very Low	Low	Medium	High	Very High
UNL[a]	AA* (ppm)	8	0-40	41-74	75-124	>124	
	K_20 Rate (lbs/acre)		***60***	***40***	***20***	***0***	
KSU[b]	AA* (ppm)	6	0-40	40-80	80-120	120-130	130+
	K_20 Rate (lbs/acre)		***85***	***55***	***25***	***15***	***0***
ISU[c]	AA* (ppm)	6	0-120	121-160	161-200	201-240	240+
	K_20 Rate (lbs/acre)		***120***	***90***	***66***	***0***	***0***
SDSU[d]	AA* (ppm)	6	0-40 (40)	41-80 (60)	81-120 (120)	121-160 (150)	161+ (200)
	K_20 Rate (lbs/acre)		***88***	***66***	***0***	***0***	***0***
Ward Labs[e]	AA* (ppm)	6	0-40 (40)	41-80 (60)	81-120 (120)	121-200 (150)	200+
	K_20 Rate (lbs/acre)		**95**	**75**	**40**	**31**	**0**

a, Sufficiency approach, 4 interpretation categories
b, Sufficiency approach
c, Updated recommendations in 2013, dry test, fine-texture soils
d, SDSU Soybean K Fert Rate = (2.2 – (0.0183 x STK)) x Yield goal
e, Adjusted rate above standard recommendation based on 35 bu/ac at 6.5 lbs K_2O/10 bu.

Sources

- UNL Fertilizer Recommendations for Soybean - https://extensionpublications.unl.edu/assets/pdf/g859.pdf
- K-State Soil Test Interpretations and Fertilizer Recommendations - https://bookstore.ksre.ksu.edu/pubs/MF2586.pdf
- ISU A General Guide for Crop Nutrient and Limestone Recommendations in Iowa - https://store.extension.iastate.edu/product/5232
- SDSU Fertilizer Recommendations Guide - https://extension.sdstate.edu/sites/default/files/2019-03/P-00039_0.pdf
- WARDguide - https://www.wardlab.com/wp-content/uploads/2021/08/WARDGUIDE-Master-Updated-8.19.21.pdf

Soil Test Zinc Value Interpretations in the Region

By Nathan Mueller, Water and Integrated Cropping Systems Extension Educator for Saline, Jefferson, and Gage counties

Table 1. Soil test zinc interpretations for corn

Entity	Soil Test Method	Depth (inches)	Categories or Interpretation				
			Very Low	Low	Medium	High	Very High
UNL[a]	DPTA (ppm)	8		0-0.4	0.41-0.8	0.8+	
		Zn Rate (lbs/acre)		***5***	***3***	***0***	
KSU[b]	DPTA (ppm)	6	0.1*	0.3*	0.6*	0.9*	1.2*
		Zn Rate (lbs/acre)	***10***	***8***	***5***	***1***	***0***
ISU[c]	DPTA (ppm)	6		0-0.4	0.5-0.8	0.9+	
		Zn Rate (lbs/acre)		***10***	***5***	***0***	
SDSU[d]	DPTA (ppm)	6	0-0.25	0.26-0.50	0.51-0.75	0.76-1.00	1.01+
		Zn Rate (lbs/acre)	***10***	***10***	***5***	***0***	***0***
Ward Labs[e]	DPTA (ppm)	6		0-0.25	0.26-0.50	0.51-1.00	1.01+
		Zn Rate (lbs/acre)		**8-10**	**6-8**	**1-5**	**0**

a, Non-calcareous soils example (changes for calcareous soils), only 3 categories
b*, Equation Zn Rate = 11.5 – (11.25 x ppm DTPA Zn), if greater than 1 ppm then not recommended
c, Only 3 categories
d, 5 categories
e, 4 categories

Sources

- UNL Nutrient Management Suggestions for Corn - https://extensionpublications.unl.edu/assets/pdf/ec117.pdf
- K-State Soil Test Interpretations and Fertilizer Recommendations - https://bookstore.ksre.ksu.edu/pubs/MF2586.pdf
- ISU A General Guide for Crop Nutrient and Limestone Recommendations in Iowa - https://store.extension.iastate.edu/product/5232
- SDSU Fertilizer Recommendations Guide - https://extension.sdstate.edu/sites/default/files/2019-03/P-00039_0.pdf
- WARDguide - https://www.wardlab.com/wp-content/uploads/2021/08/WARDGUIDE-Master-Updated-8.19.21.pdf

Table 1. Soil test zinc interpretations for soybeans – Broadcast rates							
Entity	Soil Test Method	Depth (inches)	Categories or Interpretation				
			Very Low	Low	Medium	High	Very High
UNL[a]	DPTA (ppm)	8		0-0.4	0.4-0.8	0.8+	
		Zn Rate (lbs/acre)		***5***	***0***	***0***	
KSU[b]	DPTA (ppm)	6					
		Zn Rate (lbs/acre)					
ISU[c]	DPTA (ppm)	6					
		Zn Rate (lbs/acre)					
SDSU[d]	DPTA (ppm)	6					
		Zn Rate (lbs/acre)					
Ward Labs[e]	DPTA (ppm)	6		0-0.25	0.26-0.50	0.51-1.00	1.01+
		Zn Rate (lbs/acre)		**8-10**	**6-8**	**0-2**	**0**

a, Non-calcareous soils example (changes for calcareous soils), only 3 categories
b, Not recommended
c, Not recommended
d, Not recommended
e, 4 categories

Sources

- UNL Fertilizer Recommendations for Soybean - https://extensionpublications.unl.edu/assets/pdf/g859.pdf
- K-State Soil Test Interpretations and Fertilizer Recommendations - https://bookstore.ksre.ksu.edu/pubs/MF2586.pdf
- ISU A General Guide for Crop Nutrient and Limestone Recommendations in Iowa - https://store.extension.iastate.edu/product/5232
- SDSU Fertilizer Recommendations Guide - https://extension.sdstate.edu/sites/default/files/2019-03/P-00039_0.pdf
- WARDguide - https://www.wardlab.com/wp-content/uploads/2021/08/WARDGUIDE-Master-Updated-8.19.21.pdf

EC117
April 2019

Nutrient Management Suggestions for Corn

Charles A. Shapiro, Emeritus Professor of Agronomy and Horticulture;
Richard B. Ferguson, Charles S. Wortmann, and
Bijesh Maharjan, Extension Soils Specialists; Brian Krienke, Extension Soils Educator

Fertilizer nutrient requirements for corn are based on expected yield and soil nutrient availability. The preplant nitrogen (N) recommendation equation, with adjustment for fertilizer cost and time of application, is retained from the previous edition of this publication. Suggestions for in-season nitrogen decisions are briefly outlined. The major change is providing a phosphorus (P) recommendation based on yield history with an implied intent to build and maintain soil test P above the critical level, which has not changed.

Nutrient Needs

Crop production in Nebraska typically requires nitrogen (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. Criteria for other nutrients are given, but the need varies across the state.

With overall improved management by corn producers in Nebraska, the likelihood of significant levels of residual nitrate in fields has declined. While deep sampling to account for residual nitrate in fields is still encouraged as a way to fine-tune N fertilizer recommendations, the contribution of residual nitrate to the subsequent crop, or as a risk to groundwater quality, has declined from what was more common in the 1980s and 1990s. This is especially the case for corn-soybean rotation systems. We encourage deep sampling for nitrate in circumstances where elevated nitrate is expected. Such situations might include recent manure applications, large fall or late season fertilization and subsequent above normal precipitation, drought damage, hail damage, and compromised crops due to pests or other mishaps.

Soil nitrate sampling generally is not needed for corn grown after soybean or other legume unless the fields have a recent manure history. Sampling to 4 ft for residual nitrate will provide the most accurate recommendations, but a minimum sample depth of 2 ft is acceptable. To determine P, potassium (K) and micronutrient needs, and soil organic matter content, collect soil samples from a depth of 0 to 8 inches every three to five years in the fall (http://extensionpubs.unl.edu/publication/9000016364877/guidelines-for-soil-sampling/). Most Nebraska soils supply adequate amounts of potassium, 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 and toxicities may occur with overapplication. The complete University of Nebraska–Lincoln nutrient recommendations for all crops are available at http://extensionpubs.unl.edu/publication/9000016363764/nutrient-management-for-agronomic-crops-in-nebraska/ and up-to-date nutrient management information at https://cropwatch.unl.edu/tags/nutrient-management.

Nitrogen Requirement

Our recommendations for fertilizer N are based on expected yield, the amount of residual soil nitrate-N (NO_3-N), soil organic matter, other N sources, timing of application, and price of fertilizer. This remains an option and is useful in planning and financial budgeting. Alternative N management is suggested for improved fertilizer use efficiency and to maintain or increase profit. These written guidelines are complemented by a downloadable Excel spreadsheet for N rate calculation (https://cropwatch.unl.edu/soils/software). Look for the Corn Nitrogen Recommendations Calculator. The N recommendation equation has proven to be very accurate for profit maximization on average, but the economic optimum

N rate varies by year and application of about 60 percent of the fertilizer N in-season in response to crop needs should be considered (see section on N timing).

The N recommendation for corn grain (lb/ac) =

$$[35 + (1.2 \times EY) - (8 \times NO_3\text{-N ppm}) - (0.14 \times EY \times OM) - \text{other N credits}] \times Price_{adj} \times Timing_{adj}$$

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 soil organic matter (with a minimum of 0.5 and a 3 percent maximum)

Other N credits include N from previous legume crop, manure and other organic material applied, and irrigation water N.

$Price_{adj}$ = 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 (lb/ac) =

$$[35 + (7.5 \times EY_s) - (8 \times NO_3\text{-N ppm}) - (0.85 \times EY_s \times OM) - \text{other N credits}] \times Price_{adj} \times Timing_{adj}$$

where: EY_S = expected silage yield in t/ac 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 https://agronomy.unl.edu/nitrogen. The price factor in the N equation ($Price_{adj}$ Price adjustment factor = 0.263 + (0.1256*Corn:N) – (0.00421* $(Corn:N)^2$) is based on the diminishing effect of increasing N rate on corn yields (as N is increased there is less yield increase per unit of N applied). As N becomes less expensive relative to corn price, more N per bushel can be profitably applied, but special consideration should be placed on minimizing N loss.

Figure 1 is a graph of the price adjustment equation cited above with the range of price ratios and resulting adjustment. Read across the horizontal axis for the corn price: N price ratio that is appropriate for the cost of N and find the $Price_{adj}$ on the vertical axis. We restrict the range of price adjustment to between ratios of 4:1 to 12:1, to avoid situations of inadequate or excessive N application with extreme corn or N price situations. Most often, the ratio is around 8:1. $Price_{adj}$ is applied after the other calculations are made. The previously mentioned spreadsheet https://cropwatch.unl.edu/soils/software provides these calculations, with supporting documentation.

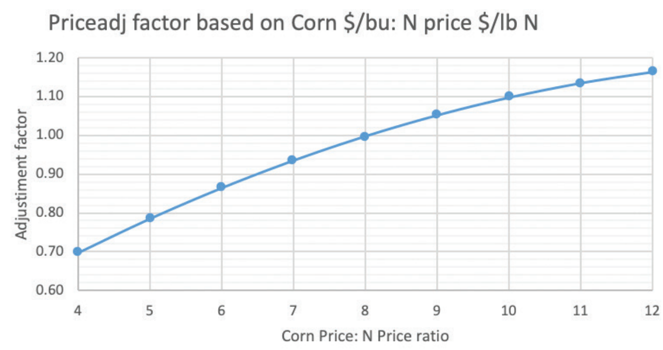


Figure 1. Price adjustment factor based on the Corn Price in U.S. dollars, $/Nitrogen (lb of actual N in $).
Note: Adjustment factor for situations where Corn: N price ratio is between 4 and 12.
Price adjustment factor = 0.263 + (0.1256*Corn:N) – (0.00421* $(Corn:N)^2$)
Example corn price ratio: when corn is $3.00/bu and nitrogen is $ 0.50/lb N = 3/0.5 = 6

Nitrogen Adjustment for Soil Nitrate-N

Corn will use soil nitrate-N remaining in the rooting zone from the previous year. This residual nitrate-N should be credited in calculation of N rates. The average nitrate-N concentration (in parts per million: ppm) in the root zone (or the depth-weighted concentration) is considered in the university's N recommendation equation and is averaged across several soil depths. Soil nitrate-N can be estimated by sampling soil with a single 0–2 foot sample. A default value for the 2 foot depth of 3.0 ppm is suggested for medium and fine textured soils and 1.5 ppm for sandy soils.

The depth-weighted average is then calculated as the sum of the nitrate-N concentration for 0–2 ft depth soil sample plus 3.0 (which is the assumed nitrate-N concentration below 2 ft) divided by 2. For example, if there was 5.0 ppm nitrate-N for the 0–2 ft depth, then the depth-weighted average = (5.0 + 3.0)/2 = 4.0 ppm. The recommended N need is reduced by 8 lb/ac for each ppm of the average nitrate-N concentration for the 0–4 foot depth (e.g. 4.0 × 8 = 32 lb/ac N credit). This credits about 50 to 55 percent of the residual soil nitrate-N as equivalent to fertilizer N. Some soil testing laboratories may report estimates of all or some fraction of nitrate-N in lb/ac rather than ppm. When soil test results for nitrate-N are not available, a default value of 3.6 ppm for the 0–4 foot depth is used for medium/fine textured and 1.9 ppm for sandy soils to calculate N rates.

Table I. Estimated N credit from legumes and other crops for medium/fine textured soil and coarse soils.

Legume Crop	*Fertilizer-N reduction by soil texture (lb/acre)*	
	Fine–Medium[1]	*Coarse*[2]
Soybean	45	35
Dry bean	25	25
Alfalfa (70–100% stand, >4 plants/ft²)	150	100
Alfalfa (30–69% stand, 1.5–4 plants/ft²)	120	70
Alfalfa (0–29% stand, <1.5 plants/ft²)	90	40
Sweet clover and red clover	80% of credit allowed for alfalfa	
Sugar beets	50	50

[1]All textural classes except those defined under coarse textured
[2]Includes sand, loamy sand, and sandy loam

If soil samples indicate greater than 15 ppm in the top 2 ft, it is likely that the horizons below are greater than the 3 ppm assumed. Further testing might be warranted to determine the nitrate level in the 2–4 ft depths.

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.

Nitrogen Adjustment for Soil Organic Matter

Nitrogen is released as ammonium-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, 1 percent organic matter is assumed for coarse 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 Credits 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 are reduced by the legume N credit *(Table I)*.

The soybean credit of 35 lb/ac N for coarse soils is a revision based on recent research in Holt County unless soybean yield was less than 30 bu/ac when the credit is 1 lb of N per bushel harvested. Soybeans are good scavengers of soil nitrate; therefore, residual soil nitrate-N after soybean harvest is often between 3 to 4 ppm nitrate-N. Soil sampling for nitrate-N following soybean is only 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.

Soybeans do not add N directly to the soil. In most cases, soybean doesn't leave a positive soil N balance. On average 55 percent of soybean N uptake is from the air and 45 percent from the soil. Soybean scavenges soil nitrate efficiently and does not add N to the soil. The apparent N credit from soybean is due to greater availability of mineralized soil N. High C:N ratio residue from a preceding corn crop will immobilize mineralized soil N during residue decomposition, making it unavailable for crop use. Low C:N ratio residue from a soybean crop immobilizes less mineralized soil N, leaving it more available for the following crop. The recommended credits were established empirically through the findings that corn needs less N when grown in rotation with soybeans.

When manure is applied in a rotation that includes corn, the recommended rates of N should be reduced according to the manure type and its N content, the amount applied, and the method of application. See NebGuide G1335 *Determining Crop-Available Nutrients from Manure*. The preplant soil nitrate test does not estimate future manure N availability.

Deposition of ammonium-N can be big credit near an animal feeding operation. It can be more than 100 lb/ac N/yr near to the operation but likely to drop off to less than 50 lb/ac within a mile or more but the amount is poorly estimated. If less than 75 lb/ac N is applied preplant, ammonium-N deposition can be accounted for by using a crop canopy sensor to direct an in-season N application rate.

Irrigation water often contains a significant amount of nitrate-N that is readily available to corn. When the season total amount of N supplied in irrigation water exceeds 15 lb N per acre it should be deducted from the recommended N. 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 the three-year average irrigation amount up to the corn R3 (milk) stage. Overall, in Nebraska 65 percent of the total irrigation amount is applied by August 1. Long term, average amounts of irrigation are estimated to be 8 in/yr in eastern Nebraska, 9 in/yr in central Nebraska, 12 in/yr in west central Nebraska, and 20 in/yr at the western Nebraska border with Wyoming (simplified from Sharma and Irmak, 2012).

Table II. Timing adjustment factors ($Timing_{adj}$) and definitions for adjusting calculated N rate for fine-medium textured soil and coarse texture soils.

Timing	*Definition*	*$Timing_{adj}$ Factor by soil texture*	
		Fine-Medium[1]	*Coarse*[2]
Split (BMP)	At least 30 percent of N applied by sidedress and fertigation N	0.95	1.00 (when >60% in-season)
Mostly pre-plant	Less than 30 percent sidedress and fertigation N and preplant N>fall N	1.00	Do not apply
Mostly fall	Mostly fall applied N and less than 30 percent sidedress and fertigation N	1.05	Do not apply

[1]All textural classes except those defined under coarse textured
[2]Includes sand, loamy sand and sandy loam

Nitrogen Application Timing

Timing, placement, rate and form of N applied determines efficiency and profitability. Managing N is similar to managing risk exposure. For example, fall applications are generally less efficient than in-season applications because of the increased risk of N loss from either leaching or denitrification associated with excessive rainfall, hence the 1.05 factor in our recommendations *(Table II)*. Multiple applications of N are usually more efficient than single large doses since it minimizes the amount of N exposed to loss while meeting crop demand, especially for coarse soils.

Fertilizer N is most efficiently used when most is applied near the beginning of rapid N uptake or about the eighth leaf stage (V8). Applications as late as R2 may have a profitable yield response to N but applying N after R3 is not recommended. On very sandy soils, 67 percent or more of N should be applied in-season such as with multiple fertigation applications after corn is 1 foot tall *(Table II)*. Up to 33 percent of the planned N may be applied pre- or at planting to ensure adequate early N availability. Crop sensors or remote imagery can be used to determine the sidedress N rate.

Phosphorus Fertilization

Several soil P tests are used by commercial laboratories to determine P availability. Most research has been conducted on calibrating Bray-1 P with corn response. The following equations can be used to convert results from a soil test to a "Bray-1 P equivalent":

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

Soil P availability is commonly managed by either the deficiency correction (DC) or the build and maintain approach. Nebraska and most Midwestern states use DC, which determines P rates according to the difference between the field's soil test P and a critical level, and above which there is a small probability of response. The build and maintain approach to P management is to build soil P availability to a targeted level that is above the DC critical level and to maintain it at that level.

Results of diverse studies have validated DC for corn in Nebraska although results from the mid-2000s indicated a need for a higher critical level if the previous crop was corn (Bray-1 P 20 ppm) rather than soybean (Bray-1 P 15 ppm). See *Figure 2*. Band application of starter fertilizer P is very efficient for meeting crop P needs, especially for early growth, but yield increases at Bray-1 P above 20 ppm are unlikely. Our recommendations are for the least cost and most likely to be profitable combination. Land ownership and other considerations may influence specific decisions on a field.

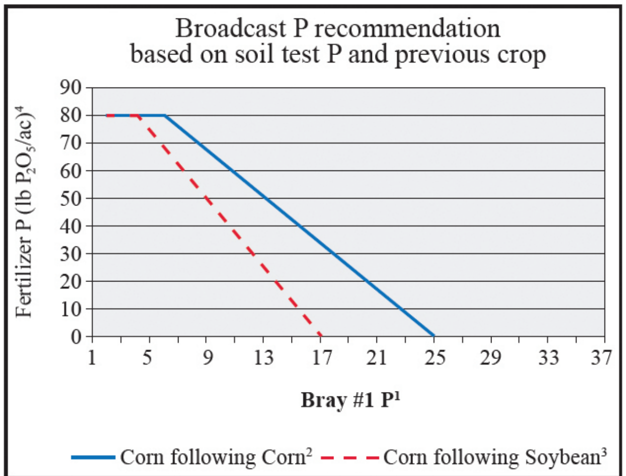
For current corn grain yields of 220 bu/acre or greater, it is important to apply adequate fertilizer P to meet crop demand without excessively mining soil P resources. Therefore, when Bray-P is less than 20 ppm for corn after corn (C/C) or 15 ppm for corn after soybean (C/S) (if the soil test is other than Bray-P convert with above formulas), the recommendation is to apply P according to the highest rate determined from two options (download Excel fertilizer P_2O_5 rate calculator):

Option 1: The P rate equals harvest P removal if Bray-1 P <20 ppm for C/C or <15 ppm for C/S. For C/C, if Bray-1 P is between 20–25 ppm, and for C/S if Bray-1 P 15–20 ppm, apply at 50% of these rates.

a. For corn after corn, P_2O_5 rate (lb/ac) = 0.33 × bu grain.
b. For corn after corn with grain and stover harvest, P_2O_5 rate (lb/ac) = 0.33 × bu grain + 4 × ton of stover harvested.
c. For corn after soybean, P_2O_5 rate (lb/ac) = 0.88 lb × bu soybean grain harvested.
d. If all fertilizer P is applied only previous to corn for both the corn and soybean years, and no stover is removed (grain harvest only): P_2O_5 rate = 0.33 × bu/ac corn grain + 0.88 lb × bu soybean grain.

For example, with the corn-soybean rotation with stover removal and one application in two years, and with Bray-1 P <15 ppm:

- Corn yield: 220 bu/ac corn



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 2. Broadcast P recommendation based on soil test P and the previous crop.

- Corn stover removed: 3 tons/ac
- Soybean yield: 75 bu/ac
- P_2O_5 rate (lb/ac) = 0.33 ×220 bu/ac corn grain + 4 × 3 t of corn stover + 0.88 lb × 75 bu/ac soybean grain
- P_2O_5 rate = 151 lb P_2O_5 /ac.

Option 1 is expected to increase Bray-1 P in the 0–8 inch soil depth. When Bray-1 P is >20 ppm, P rates should be reduced to less than harvest P removal to maintain Bray-1 P at near 20 ppm. No P should be applied if Bray-1 P is >25 ppm. This avoids sacrifice of profit for maintenance of excessive soil P availability while reducing the potential for P loss to water bodies due to runoff and erosion. If Bray-1 P is above the maintenance level of 15 or 20 ppm and less than 25 ppm, apply at 50 percent of removal and retest the soil after four years to adjust the annual rates.

Option 1 is expected to supply sufficient P to avoid yield loss on areas of the field with very low Bray-1 P but would over-apply on areas of the field with unusually high Bray-1 P. If Bray-1 P has been built to >20 ppm, P application could be reduced or skipped for a year if P costs are exceptionally high P, but application on a harvest P removal basis should be resumed within one or two years.

Option 2: For average yield of <150 bu/ac (< 50 lbs P_2O_5 removal) or Bray-1 P <7 ppm, Option 1 may apply less P than needed. The P rate should be calculated with the following formula (*Figure 2*)

a. (25 – Bray-1 P) * 4 for corn following corn or crops other than soybean; or
b. (17 – Bray-1 P) * 6 for corn following soybean.
c. Apply P according to option 2 if it gives a higher P rate than option 1.

Variable rate P application with Option 1 should be based on yield maps or mean yields for management zones of the previous one or two harvests, coupled with grid soil sample results to avoid unneeded application on parts of the field with Bray-1 P >20 ppm. Variable P rate application for Option 2 should be based on grid or management zone soil sampling results.

Phosphorus Application Methods

Phosphorus fertilizers can be broadcast prior to planting or by placing the fertilizer in bands in the root zone. Tillage and P incorporation do not affect corn response to applied P while tillage increases the potential for P loss in runoff and erosion. Crop residue cover with reduced evaporation of soil water allows root proliferation at the soil surface for surface-applied P uptake.

Application of P fertilizer in bands is usually more efficient in the short term than broadcast application when soil P levels are low. Use half the recommended rate 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 also effective application methods. However, as described in the P rate discussion, as soil P levels decrease below the critical level, P at removal rates may be necessary to maintain the critical level.

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 III)*.

Sulfur Fertilization

Nebraska soils generally supply adequate sulfur (S) for excellent corn production. Corn yield increase due to S application is expected only on coarse soils that are low in organic matter. Sulfur application on medium to fine texture

Table III. 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[3]	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).

Table IV. Sulfur fertilizer recommendations (coarse[1] soils only).

Sulfur Soil Test ppm SO⁴-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[2]*	*Row[2]*
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]Includes sand, loamy sand, and sandy loam

[2]Applied in a band next to row but not with seed

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 IV*.

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 band-applied 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 deficiency symptoms occur. Gypsum is an excellent source of sulfate-S.

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 ammoniated zinc or zinc sulfate (*Table V*). Chelated zinc sources are more available and have efficiencies up to four times the mineral zinc sources. However, they are water-soluble and will not stay in the root zone as long as zinc sulfate. Periodic soil testing to an 8-inch 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.

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. In some instances, excessive soil nitrate can make chlorosis more severe.

Correction of iron chlorosis may require several practices. First, select hybrids that are tolerant to chlorosis as this may be adequate in overcoming iron problems. If chlorosis persists, iron fertilizer may need to be applied. Application at planting in the seed furrow of 50–100 lb of ferrous sulfate heptahydrate ($FeSO_4$•7H2O) per acre can be effective in correcting high pH induced iron chlorosis. This material is selling at around $90/ton (2019 prices) and would be a cost-effective amendment but 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. Based on research at WCREC (North Platte), chlorosis correction from FeDDHA ($4.50/acre) has not been as effective as that of FeSO4-7H2O ($3.60/acre). The FeEDDHA works well for correcting soybean

Table V. 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 and ammoniated zinc.
[2]Calcareous soils defined as soils with moderate to excess lime.

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 acidic and lower depths of the soil are calcareous. If subsoil samples from 8 to 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 *Lime Use for Soil Acidity Management*.

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, on leased land a discussion with the landowner about shared costs is reasonable.

Acknowledgment

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Lime Use for Soil Acidity Management

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Soil acidity can reduce crop productivity by directly affecting roots and changing the availability of essential nutrients and toxic elements. Liming can neutralize soil acidity, but several factors can affect the economic benefits of liming.

Most field crops perform best at a soil pH between 6.0 and 6.8. This pH range provides the best balance of available nutrients. When soil pH is below this range (*Figure 1*), some nutrients become less available (e.g., phosphorus, molybdenum). Some elements, such as manganese and aluminum, become toxic in highly acid soils (< 5.0). With continuous cropping, soil pH can decrease (i.e., increase in acidity) because of various factors, including crop removal and leaching of basic cations (i.e., calcium and magnesium), application of ammonia-based nitrogen fertilizers, and organic matter decomposition. Adding lime or other materials with liming properties can raise soil pH to the ideal range for crop production, create an environment for a healthy function of microbes, and increase the levels of calcium or magnesium.

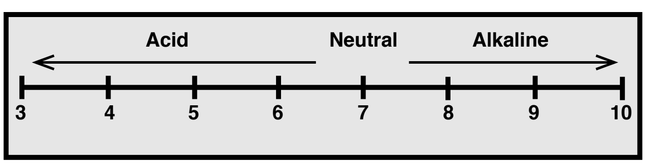

Figure 1. Range of soil pH.

Determining Lime Need

Soil acidity consists of active and reserve acidity. Most of the acid-causing elements (hydrogen and aluminum) are held by the cation exchange sites of the soil particles and organic matter. This is referred to as reserve acidity. Soils with large amounts of clay and organic matter have high potential for reserve acidity. Soil pH is a measure of active acidity, the hydrogen ion concentration in the soil solution. The higher the concentration of hydrogen ions in the soil solution, the lower the pH (i.e., greater acidity). The active acidity is present in the immediate environment of roots and microbes. The total acidity is the sum of the reserve and active acidity. Lime neutralizes both the active acidity and some of the reserve acidity. As active acidity is neutralized by the lime, reserve acidity is released into the soil solution, maintaining the active acidity or the pH. The ability of a soil to resist changes in pH is called buffering capacity and is largely due to the reserve acidity. More lime is required to neutralize acidity on a highly buffered soil compared to a less buffered soil (*Table I*).

Table I. Examples of approximate lime required to raise the pH of soils of different textural classes. (Source: *Nutrient Management for Agronomic Crops in Nebraska*, EC155, UNL Extension.)

Soil Texture	*CEC (meq/100 g)*	*Soil pH*	*Buffer pH*	*Lime rate (tons/acre)*
Loamy sand	6	5.6	6.8	1
Silt loam	14	5.5	6.6	2
Silty clay loam	24	5.6	6.2	4

University of Nebraska lime recommendations are based on raising soil pH to 6.5. When soil pH is less than 6.3, laboratories measure pH in a buffer solution that accounts for both active and reserve acidity. (Refer to NebGuide G1503, *Management Strategies to Reduce the Rate of Soil Acidification* for more details.) Buffer solution is composed of an acid and its salt, and can neutralize both high and low pH soils. The two types of buffer solutions used in Nebraska are the Woodruff and SMP, both at pH 7.0. Soils with a pH of less than 6.3 are added to the buffer solution and the pH of the soil-buffer mix is measured. The more the soil-buffer mix pH decreases below 7.0, the higher the reserve acidity and lime requirement of the soil. The Woodruff and SMP buffer solutions give similar results for most soils; however, the Woodruff buffer is preferred for sandy soils, and the SMP buffer is preferred when the soil is high in exchangeable aluminum.

University of Nebraska lime recommendations are based on liming material that has a 60 percent effective calcium carbonate equivalent (ECCE). Effective calcium carbonate equivalent is further discussed in the *Lime Quality* section. For each 0.1 pH buffer reading below 7.0, application of 1000 to 1200 lb/A of ag-lime (60 percent ECCE) is recommended to raise the soil pH to approximately 6.5 in the top 7 inches.

If lime ECCE is more or less than 60 percent, the rate is adjusted by multiplying the recommended rate by 60 and dividing by the actual ECCE (*Table II*). For example, if the recommended rate is 6,000 lbs (3 tons) per acre and the lime is 45 percent ECCE, then the lime rate is adjusted as:

Adjusted lime rate = Recommended lime rate x Adj. factor
6000 lb lime/A x 60 / 45 = 8000 lbs/A
or
6000 lb lime/A x 1.3 = 8000 lbs/A

Lime Quality and Materials

Lime Quality — Two factors determine the effectiveness (ECCE) of liming materials:

1. neutralizing value or purity, also referred to as calcium carbonate equivalent (CCE)
2. particle size or fineness of the liming material.

Table II. Rate adjustment for ECCE different than 60 percent. New application rate is determined by multiplying rate at 60 percent ECCE by the adjustment factor.

ECCE	*Adjustment Factor*
15	4.0
25	2.4
35	1.7
45	1.3
55	1.1
65	0.92
75	0.80
85	0.70
95	0.63

Table III. Calcium carbonate equivalent (CCE) of liming materials.

Material	*CCE%**
Pure calcite	100
Calcitic lime	75-100
Dolomitic lime	75-109
Hydrated lime	120-136
Burned lime	179
Pel-lime (finely ground ag-lime)	90-95
Fly ash**	43-44
Wood ash	30-70

* These values only consider the purity of the material, however the fineness also must be considered to determine the effectiveness of the lime (i.e., ECCE = CCE times fineness).

** Based on UNL research on ash from power plants in Nebraska. Fly ash CCE values and other chemical analyses should be done due to variation caused by source of coal, collection procedures and other factors.

The neutralizing value, or CCE, is the amount of acid on a weight basis that a given quantity of lime will neutralize acidity. It is expressed as a percentage of the neutralizing value of pure calcium carbonate or calcite (100 percent CCE). A lime that neutralizes 80 percent as much acid as pure calcium carbonate is said to have a CCE of 80. *Table III* shows the CCE of different liming materials.

Particle fineness is important for lime effectiveness. The neutralization effect is greater with small particles because of increased total surface area exposed to the soil acidity. Lime distribution in the soil also is important because the lime effect of a particle extends only about 1/8 inch. Two sieves, 8 and 60 mesh, are used to separate a sample into three particle sizes (*Figure 2*):

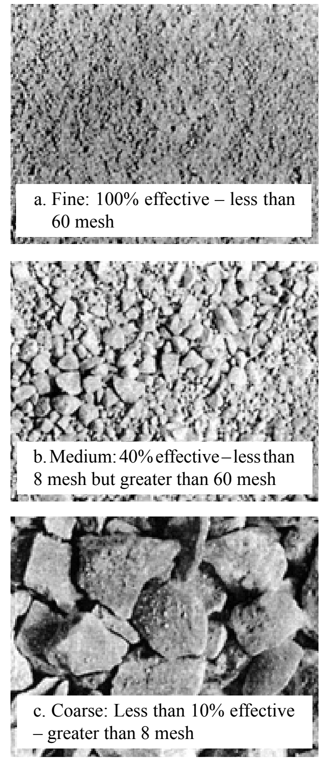

Figure 2. Ag-lime separated by sieving into three size ranges. (Mesh size equals openings per inch, e.g. 8 mesh equals 1/8-inch square sieve openings.

- less than 60 mesh — fine
- less than 8 mesh but greater than 60 mesh — medium
- greater than 8 mesh — coarse

The percentages of these three components are multiplied by factors of 1.0, 0.4, and 0.1 respectively, and added together to give the fineness factor. For example, if a liming material has a particle size distribution of 66 percent fine, 22 percent medium, and 12 percent coarse, the particle fineness of the material is calculated as:

Fineness = (66 x 1) + (22 x 0.4) + (12 x 0.1) = 76 percent

Effective calcium carbonate equivalent (ECCE) is the measure of the effectiveness of liming materials and is calculated as the product of the purity value (CCE) and the fineness value divided by 100. For example, if the purity is 80 percent and the fineness value is 75 percent, then:

ECCE = (80 x 75)/100 = 60 percent

Liming Materials (See *Table III*)

Ground limestone is the most common liming material and consists of calcium carbonate and magnesium carbonate.

Hydrated and burned (quick) limes are quick acting and have high ECCE, but are caustic and difficult to handle.

Pel-lime (granular lime) is finely ground lime material compressed into pellets or granules to reduce dust associated with very fine particle size. The pellets break down in water and the particles quickly disperse and neutralize soil acidity. Application rates are less than with ag-lime because the particles are finer.

Lime slurries, also called fluid lime and liquid lime, are pulverized limestone suspended with 30 to 50 percent water.

Sugar factory lime is very finely ground calcium carbonate used in the production of sugar from beets.

Basic slag or calcium silicate is a byproduct of the steel industry.

Fly ash is a byproduct of coal combustion. The chemical characteristics of fly ash depend on the source of the coal. Some coals have high sulfur content and can produce fly ash with low pH while others have lower sulfur content and have high calcium and magnesium contents.

Lime Application Considerations

Lime Application — Lime takes time to neutralize soil acidity. Often as much as six months may be needed before pH changes significantly. Neutralization will be quicker if particle size is small (less than 60 mesh) and the lime is well mixed with the soil. Typically, it will take two to three years to observe the full effect of ag-lime application on soil pH.

Lime recommendations are usually made to reach a target pH in the top 7 inches of soil. Under no-till systems, lime is surface applied and not mixed with the soil. Mixing eventually will occur because of lime falling into cracks, earthworm activity, soil disturbance with planting and other field operations, and irrigation and/or precipitation moving the lime slowly downward. Surface-applied lime in a no-till system has been found to move downward at about 1/2 inch per year on fine-textured soils. Several years are required to neutralize acidity below a 2-inch depth. Therefore, lime rates should be adjusted to 30 percent of the full rate since only the surface 2 to 3 inches of soil will be reacting with the lime. Periodic soil sampling in the 0-2, 2-4, and 4-8 inch ranges is the most reliable method to determine pH changes and lime requirement over time for no-till systems.

Cropping Systems and pH Threshold

The economic threshold for lime application depends on the most sensitive/responsive crop in the rotation. Soil pH thresholds for profitable response to lime application over a 5- to 10-year period are pH 6.0 for alfalfa-corn-soybean system; 5.6 to 5.8 for corn-soybean system, and 5.0 to 5.2 for continuous corn system. The pH thresholds are for the top 8 inches of soil with the assumption that the subsoil/ subsurface soil pH is 6.0 or greater than 6.0. (Acidification of the 8 to 24 inch subsoil is less common in Nebraska soils.)

Stratification of Soil pH

Soil pH stratification in the surface 8-inch depth should be considered when liming. Stratification of pH occurs especially in no-till sandy soils where anhydrous ammonia has been injected at a 4- to 8-inch depth for many years. At the depth of injection, an acidified layer is created due to hydrogen ions generated during the nitrification process (see NebGuide G1503).

This layer of acidity is difficult to correct under no-till systems because of slow movement of surface-applied lime. A single deep tillage to incorporate lime in the layer of acidity may be needed to alleviate the acidity problem. While there will be an added cost for the tillage operation and the loss of some of the no-till benefits, this may be more than offset by gains in productivity if a very acidic layer has developed. Sampling in layers of 0 to 2, 2 to 4, and 4 to 8 inches will help determine if tillage for lime incorporation is needed.

Site-specific or Variable Rate Application

Lime requirements vary within fields and can be mapped by grid soil sampling, on-the-go sampling and testing of the soil, or by sampling zones within fields. On-the-go sampling and testing may result in 20 to 50 times more samples compared with a two-acre grid sampling approach and does result in more detailed maps. However, broadcast lime application equipment generally does not allow sufficient control over lime placement to take good advantage of the more detailed application maps.

Management or sampling zones may be determined based on past crop and soil management, soil type and topographic position differences, manure application history, and yield differences, such as indicated by yield maps and remote images of the crop. Topographic position can imply differences in lime requirement. For example, for rolling cropland in southeast Nebraska, lime requirement was on average 21 percent more on hilltops and 16 percent less on bottomland, compared with hillsides.

After sampling by grids, on-the-go testing, or sampling zones, the results of the soil analysis need to be considered to determine if there is sufficient variation to justify variable rate or site-specific application.

Economic Considerations

The cost of liming soil to a depth of 6 to 8 inches should be considered an investment of five to 10 years. This is illustrated with an example from Washington County in a disk-tilled system where the initial soil pH was 5.5 and the cost of liming with ag-lime (60 percent ECCE) was $44 per acre (Nebraska Soybean and Feed Grains Profitability Project, Peterson and Hilgenkamp). Over 16 years, the total yield increase was 35 bu/ac for soybeans and 12 bu/ac for corn (*Figure 3*). Assuming soybean and corn prices of $10 and $4 per bushel, respectively, an initial liming cost of $44 per acre, and an interest rate of 5 percent, the average annual income was greater than the average annual expense by year four. In this case, 88 percent of the increase in profit came from increased soybean yield and only 12 percent from increased corn yield.

The economics of lime use on rented land needs special consideration. The increased yield of three or four harvests may be needed to break even on the costs of lime application (*Figure 3*). In some leases, the landowner may need to pay part or all of the cost of liming the field. Some leases stipulate that if a producer loses the lease, the landowner has to repay a portion of the producer's investment in lime. The framework for expected returns of liming will need to be considered when negotiating responsibility for the cost of lime application.

Pel-lime is expected to neutralize acidity sooner than ag-lime

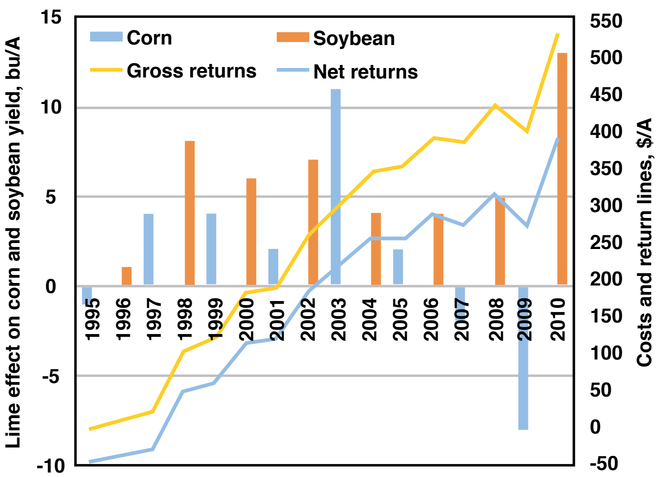

Figure 3. Cumulative lime effect with tillage (initial pH of 5.5; liming cost of $44/ac). (From Nebraska On-farm Research Network, 2014.)

but the long-term effectiveness of the two products in neutralizing acidity depends on their ECCE. Applying 1500 lb/ac of 60 percent ECCE ag-lime eventually will have the same effect on soil acidity as 1000 lb/ac of 90 percent ECCE pel-lime. Pel-lime may have a special role in some situations, such as short-term neutralization of acidity in a band near the roots of soybean to improve nitrogen fixation and yield. Surface application of pel-lime to increase pH at the soil surface may improve the performance of specific herbicides. Cost difference, however, is a major consideration when choosing between pel-lime and ag-lime.

Current recommendations are to apply enough lime to raise soil pH to about 6.5. This is well above the economic threshold for pH-induced yield loss for most Nebraska crops. Applying, for example, less than the recommended rate should be sufficient to maintain soil pH above the economic threshold for more than five years. A second application can be made several years later when soil pH again approaches the threshold level. The economic advantage of split application of lime depends on the reduction in interest cost compared to the cost of split-application. The lime source proximity and transportation costs also must be considered with a split application.

Summary

Several factors need to be considered for profitable lime use:

- Zonation of fields based on differences in management history, soil texture, soil type and topographic position should be considered in sampling for lime requirements.
- Threshold pH levels will differ for various crop rotations.
- Optimal liming practices differ for no-till and tilled conditions.
- It may take five to 10 years after application to recover the cost of liming.
- Product cost relative to ECCE is the major factor when comparing liming materials.
- Split application of a recommended amount of lime, with the second application several years later, may be more economical than applying all at once.

Additional Resources

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