Crop and Soil Responses to Rates of Lime: 35-Year Summary

RFR-A1948

Ken Pecinovsky, farm superintendent
Brian Lang, extension agronomist

Introduction

Soil pH is one of the most important soil characteristics of crop production. The pH is the negative logarithm of the hydrogen ion activity of a soil. For each unit increase in pH, there is a 10 times change in acidity. A pH of 5 is 10 times more acidic than a pH of 6, and 100 times more acidic than a pH of 7. A soil pH greater than 7 is called alkaline or basic. A soil pH less than 7 is called acidic.

When soil test results show pH is too acidic for optimum crop production, a limestone application is recommended to raise the soil pH to an optimum level. Iowa State University (ISU) provides limestone recommendations for Iowa soils in publication PM1688, *A General Guide for Crop Nutrient and Limestone Recommendations in Iowa.* Recommendations are given for corn, soybean, alfalfa, and pasture when the soil pH falls below 6.5, 6.5, 6.9, and 6.0, respectively.

Certain soils in Iowa are naturally acidic, although others acidify over time from environmental and crop production influences. Other soils in Iowa are naturally alkaline and will never require lime. The availability and uptake of essential plant elements is influenced by soil pH. Acidic soils can reduce the availability of calcium (Ca), magnesium (Mg), and potassium (K), and with further acidity reduce the availability of other elements (Figure 1). Alkaline soils can reduce the availability of phosphorous (P), boron (B), iron (Fe), manganese (Mn), and other elements. For example, Fe chlorosis is a notable problem in soybean production on the highly alkaline (calcareous) soils in north central Iowa.

This 35-yr research trial was designed to evaluate the effects of limestone applications on soil pH for a corn-soybean rotation that was either under, adequately, or over limed according to ISU recommendations.

Materials and Methods

A corn/soybean rotation was grown on a Kenyon loam soil at the ISU Northeast Research and Demonstration Farm in Nashua, Iowa. The soil pH was 5.5 at the start of the trial in 1984. In May 1984, a one-time application of limestone from a local quarry was applied at rates of 0; 1,000; 2,000; 4,000; 8,000; 12,000; and 16,000 lb/acre of effective calcium carbonate equivalent (ECCE). The ECCE is an expression of aglime effectiveness based on the combined effect of chemical purity and fineness of grind of the limestone. Tillage followed the lime applications. The trial design was a randomized complete block with four replications. Individual plots were 1,000 sq ft.

Each corn year pollination dates were recorded. After corn harvest, soil samples were collected periodically throughout the 35 years of the trial to a depth of 6 inches in each plot and analyzed to determine soil pH, available P, exchangeable K, Ca, Mg, and zinc.

Results and Discussion

Soils. Table 1 provides the soil pH level at the start of the trial in 1984, and periodic soil pH test results with corresponding corn and soybean yields. Where no limestone applications were made, the soil acidity declined only slightly from an initial 5.5 pH to 5.25 determined in 2004 and 2019. With higher initial limestone rate treatments, soil

pH increased to different levels over time before declining. Initial change in soil pH occurred within the first year and resulted in improved corn and soybean yields. Soil pH response to rates of 1,000 to 4,000 lb/acre limestone peaked around 1987 and rates of 6,000 lb/acre or greater peaked around 1990, with soil pH slowly declining afterwards (Figure 2). For corn and soybean production, ISU suggests maintaining soil pH levels between 6.0 to 6.5 by applying recommended rates of limestone based on soil tests taken every two to four years.

Crops. The yield responses for corn in 2019 and soybean in 2018 are provided in Table 2. Average corn and soybean yield for early, mid, and late periods of the trial are provided in Table 3. In general, a soil pH of around 6.0 or greater improved grain yields for both crops. Increased soil pH also shortened time to corn pollination by one to two days and lowered corn grain moisture at harvest by about 1 percent (Table 3). Soybean grain moisture at harvest was generally unaffected by soil acidity (Table 3) and similar results for other years. Data from this trial and other limestone trials suggest a critical soil pH range for corn and soybean is about 6.0 to 6.2. Below this range response to lime is likely to improve yield. However, this critical level has varied some with individual sites depending on subsoil acidity and other soil characteristics. Based on these trials, soil testing should be a standard practice to determine soil pH and make appropriate adjustments, if needed, through limestone applications.

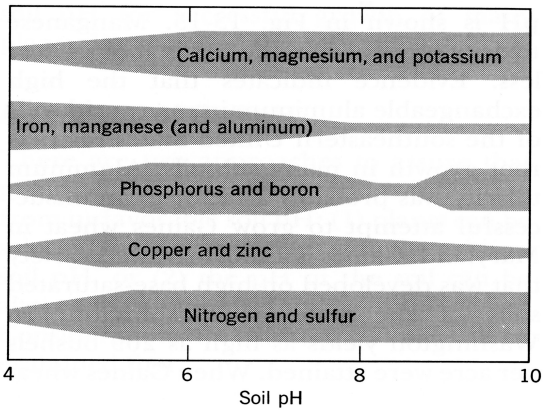

Figure 1. General relationship between soil pH and availability of plant nutrients. The wider the bar, the more available the nutrient.

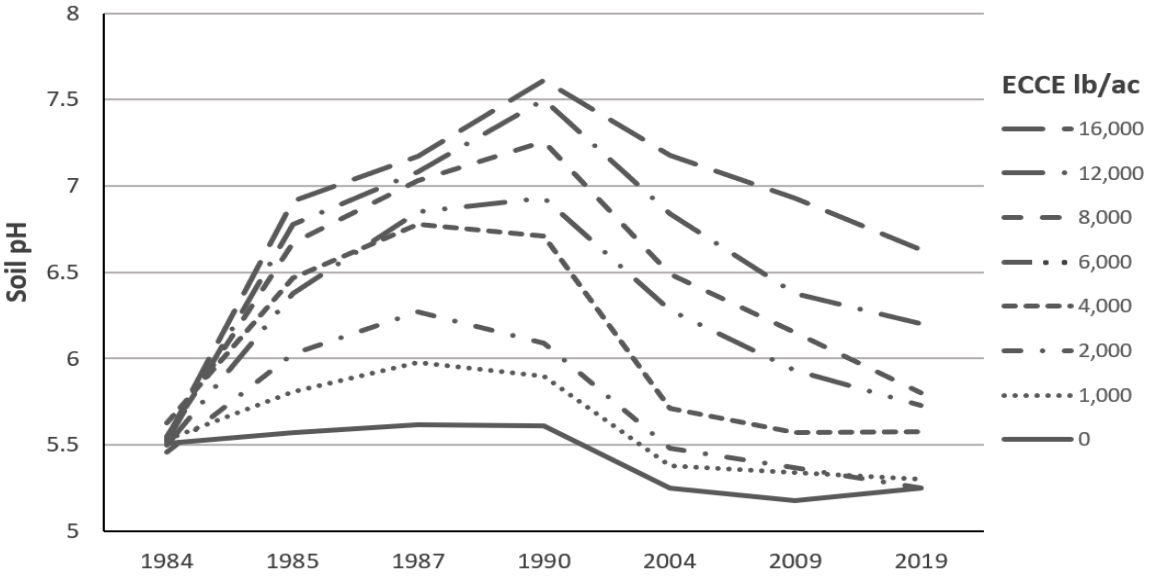

Figure 2. One-time application of limestone rates applied in 1984 as lb/acre of ECCE, and subsequent soil pH levels during the 35-yr trial.

Table 1. Soil pH levels at the start of the trial in 1984 and periodic soil pH test results with corresponding corn and soybean yields through 2019.

ECCE	1984 soil pH	1985 soil pH	1985 corn	1986 soybean	1990 soil pH	1990 soybean	1991 corn	2004 soil pH	2004 soybean	2005 corn	2009 soil pH	2009 corn	2010 soybean	2019 soil pH	2018 soybean	2019 corn
lb/ac			bu/ac	bu/ac		bu/ac	bu/ac		bu/ac	bu/ac		bu/ac	bu/ac		bu/ac	bu/ac
0	5.51	5.57	146.3	42.9	5.61	60.5	165.0	5.25	59.6	208.5	5.18	217.7	65.1	5.25	66.6	235.2
1,000	5.53	5.81	157.0	49.0	5.90	61.4	161.7	5.38	60.1	206.0	5.34	224.8	68.6	5.30	69.2	231.0
2,000	5.46	6.03	153.8	51.2	6.09	61.5	165.6	5.48	61.7	213.4	5.37	222.6	68.5	5.25	68.8	227.8
4,000	5.63	6.47	156.3	52.0	6.71	65.5	167.8	5.71	61.3	213.3	5.57	228.7	69.5	5.58	68.3	244.1
6,000	5.50	6.38	155.8	53.0	6.93	64.0	165.3	6.28	62.0	218.2	5.93	238.3	69.3	5.73	71.3	241.6
8,000	5.55	6.67	152.2	52.8	7.26	61.4	170.7	6.49	61.3	214.3	6.15	245.0	71.3	5.80	72.4	247.8
12,000	5.52	6.78	151.9	52.7	7.50	64.3	164.0	6.84	60.5	214.1	6.38	241.1	71.9	6.20	69.6	251.9
16,000	5.54	6.91	151.0	51.2	7.61	63.6	169.0	7.18	58.6	216.9	6.93	250.2	71.4	6.63	71.2	253.1

Table 2. Fall 2019 soil test for pH, secondary and micronutrients, 2019 corn yield, grain moisture, and pollination date, and 2018 soybean grain yield.

		Corn			Soybean		Secondary and micronutrients							
ECCE	soil pH	yield	moisture	pollination	yield	moisture	Mg	Ca	Zn	Mn	Cu	Fe	B	S
lb/ac		bu/ac	%	date	bu/ac	%	ppm							
0	5.25	235.3 ab	22.3 a	23-July	66.6 a	11.3 a	134	1335	0.4	10.4	0.40	63.6	0.3	5.3
1,000	5.30	231.0 a	22.6 a	22-July	69.2 bc	11.4 a	143	1451	0.5	9.7	0.40	61.9	0.3	5.5
2,000	5.25	227.8 a	22.2 a	22-July	68.8 ab	11.3 a	139	1368	0.4	8.9	0.40	58.0	0.3	4.5
4,000	5.58	244.1 c	21.6 ab	23-July	68.3 ab	11.5 a	157	1441	0.5	7.3	0.43	53.0	0.2	4.3
6,000	5.73	241.6 bc	21.9 ab	22-July	71.3 cd	11.5 a	179	1530	0.6	7.0	0.43	49.8	0.2	4.3
8,000	5.80	247.8 cd	21.8 ab	22-July	72.4 d	11.4 a	199	1685	0.5	6.7	0.43	44.5	0.2	4.0
12,000	6.20	251.9 d	21.3 b	21-July	69.6 bc	11.4 a	244	1908	0.7	4.7	0.40	36.8	0.3	4.0
16,000	6.63	253.1 d	21.1 b	21-July	71.2 cd	11.4 a	272	1979	0.8	2.8	0.38	26.1	0.3	3.5
$LSD_{0.05}$		7.6	0.9		2.3	0.4								

Table 3. Average corn and soybean grain yield, corn grain harvest moisture, and corn pollination date for early (1985-1998), mid (1999-2010), and late (2011-2019) periods of the trial.

	Average corn grain yield			Average corn grain moisture			Average corn pollination date			Average soybean grain yield		
ECCE	1985-1998	1999-2010	2011-2019	1985-1998	1999-2010	2011-2019	1986-1998	1999-2010	2011-2019	1986-1998	1999-2010	2011-2019
lb/ac	bu/ac			%			date			bu/ac		
0	139.0	180.5	231.8	22.3	21.2	21.1	23-July	22-July	24-July	48.6	58.8	61.9
1,000	140.9	182.7	230.2	22.2	20.9	20.9	23-July	22-July	24-July	51.2	60.5	62.6
2,000	143.4	181.3	231.4	22.1	21.0	21.0	23-July	21-July	24-July	51.4	60.7	62.5
4,000	144.6	184.7	236.6	21.8	20.8	20.6	23-July	21-July	24-July	53.9	62.0	63.8
6,000	144.3	188.3	236.4	21.9	20.4	20.7	23-July	21-July	23-July	54.3	61.6	64.8
8,000	145.7	192.2	239.0	21.6	20.3	20.6	22-July	20-July	23-July	53.6	62.0	64.9
12,000	145.6	192.3	240.4	21.8	20.2	20.2	22-July	20-July	22-July	53.9	61.5	64.3
16,000	145.7	195.7	238.0	21.9	20.1	19.9	22-July	20-July	22-July	63.1	60.9	64.5