Soil pH and Liming Needs in Minnesota

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Nutrient Management Conference
Feb. 9, 2016, Morton MN

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Outline

- pH and liming basics
  - pH determination, terminology and lime requirement suggestions for Minnesota
- Crop and soil responses to liming in Minnesota
- Response data from other states with similar climate and soils

pH

- Water pH is a measure of the hydrogen ion concentration in the soil (active acidity).
- Buffer pH is a measurement of total soil acidity (active + reserve acidity).
- Reserve acidity is a measure of the buffering capacity of the soil.
- Soils with low buffering capacities (low CEC) usually have less total acidity than soils with high CEC if the pH is the same.

Ideal pH range

- pH of 7.0 is neutral, but few crops require a neutral pH.
- pH of 6.5 is best for crops like alfalfa, alsike clover, apple and asparagus (Group 1).
- pH of 6.0 is adequate for crops like corn, barley, canola, grass hay, oat, pea, soybean, sugar beet, sweet corn and wheat (Group 2).
- Many crops and plants like acid soils.
  - Potato, grass sod, blueberry and wild rice.

Source: Lime Needs in Minnesota, AG-FS-05956-C

Other benefits

- pH of 6.0 to 6.5 or higher provides an ideal environment for bacteria and microbial activity, also for nodulation on roots of legumes.
- Phosphorus availability in soils is greatest at pH of 6.0 to 6.5.

Source: Lime Needs in Minnesota, AG-FS-05956-C

pH and lime requirements

- pH is determined in the lab from a soil sample to a fixed depth (**6-8 inch depth**).
- pH is taken from a 1:1 mixture of soil and water (water pH).
- If water pH is less than 6.0, then a buffer solution is added to the soil/water mixture and another pH reading is taken (buffer pH).
- U of M currently uses the Sikora buffer

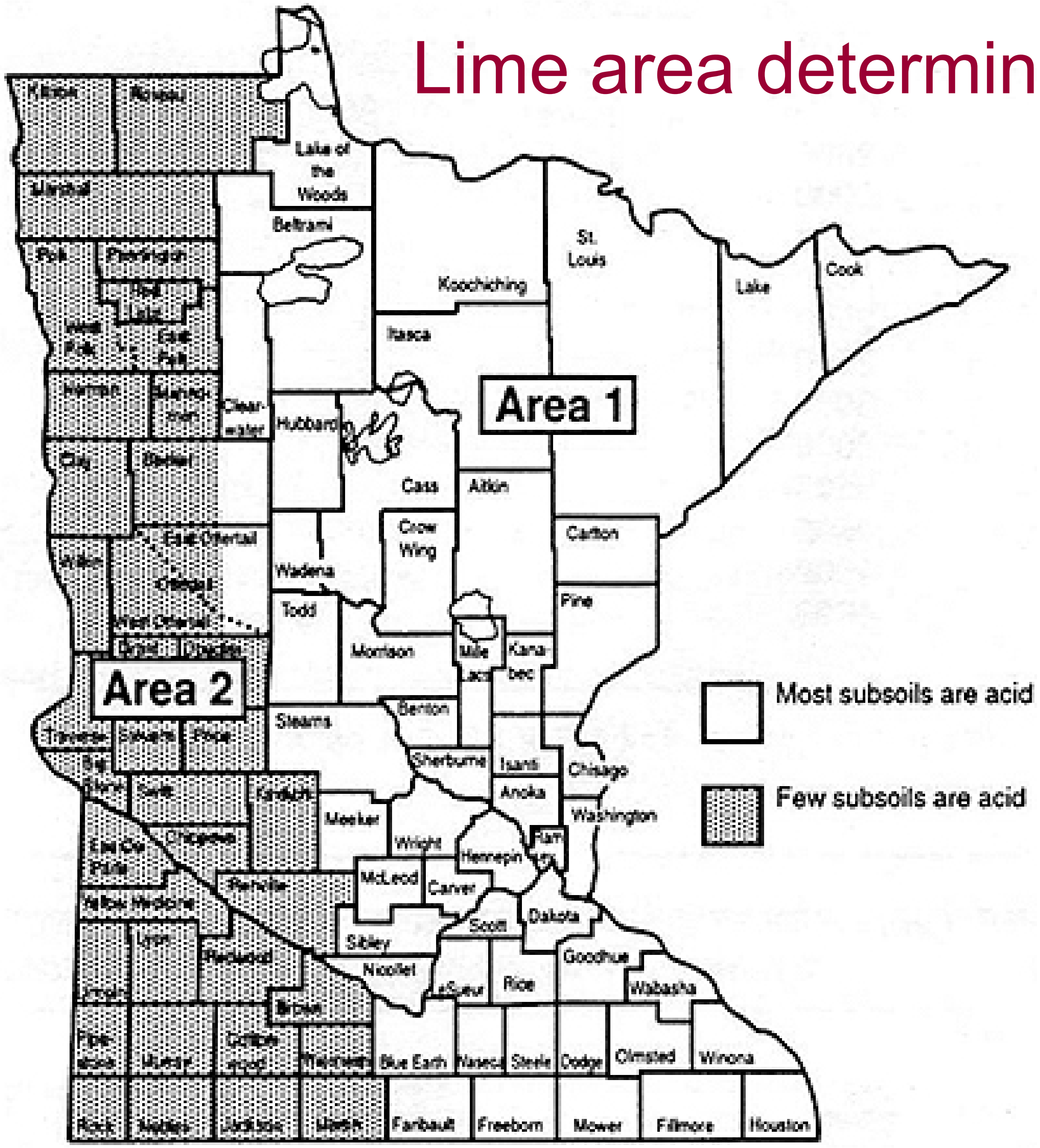
Source: Lime Needs in Minnesota, AG-FS-05956-C

Lime requirement

- Lime requirement in Minnesota is determined from water or buffer pH and a lime area designation.
- A lime requirement is calibrated to raise the water pH to a desired “target pH”

Source: Lime Needs in Minnesota, AG-FS-05956-C

Lime area determination

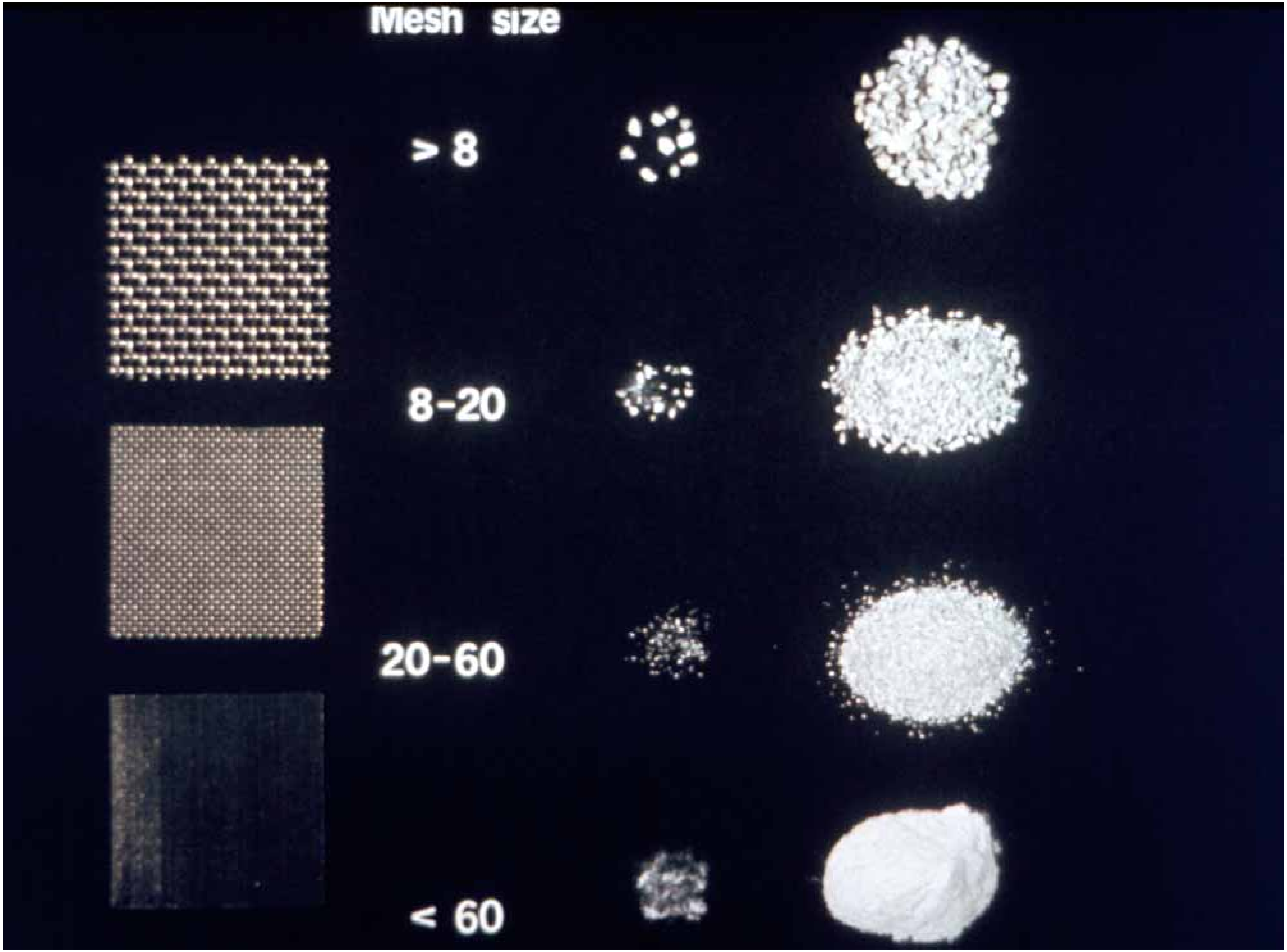


Lime area determination

- Factors that affect subsoil pH
  - Parent material – glacial till, loess, alluvial, outwash
    - Free calcium carbonates
  - Native vegetation – forest vs prairie
  - Rainfall and climate
  - Internal drainage

What determines the quality of a liming material?

- Purity
  - Calcium carbonate equivalent (CCE)
  - Determined by a lab
- Fineness
  - Particle size
  - Dry sieve analysis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Summary of Minnesota terminology

- Effective neutralizing power (ENP)
  – Lime suggestions are in lb of ENP/acre
- Total Neutralizing Power (TNP) = CCE
  – Calcium carbonate equivalent (CCE)
- Fineness index (FI) = total fineness efficiency
- % ENP of a lime material =
  – %TNP × FI × % dry matter = % ENP

Source: FS-05956-C

Table 1. Lime suggestions for mineral soils when the soil pH is less than 6.0. The rates suggested should raise the pH to 6.0 or 6.5.

Sikora	Targe pH 6.0			Target pH 6.5	
Buffer	Area 1	Area 2		Area 1	Area 2
Index	ENP	ENP		ENP	ENP
	-------------------- lb/ac --------------------				
6.8	2000	0		3000	2000
6.6	2000	0		4000	2000
6.4	3000	2000		5000	2500
6.2	4000	2000		6000	3000
6.0	5000	2500		7000	3500
5.8	6000	3000		8000	4000
5.6	7000	3500		9000	4500

Adapted from FS-05956, Kaiser et al., 2011

Table 2. Lime suggestions for mineral soils when the Sikora Buffer Test is not used (soil pH > 6.0). The rates suggested should raise the pH to 6.5.

Soil Water pH		Area 1 ENP	Area 2 ENP
		------------ lb/ac	------------
6.5		0	0
6.4		2000	0
6.3		2000	0
6.2		3000	0
6.1		3000	0
6.0		3000	2000

From FS-05956, Kaiser et al., 2011

ne Analysis Results ×

www.mda.state.mn.us/licensing/licensetypes/limeprogram/aglimeanalysisresults.aspx

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Ag-Lime Analysis Results

The analysis results are provided as an educational/information component of the MDA's ag-lime program. The analysis results were submitted by ag-lime Producers either per samples analyzed by the University of Minnesota Soil Testing Laboratory or by Producers certified by the MDA to analyze their own ag-lime products. Use the Minimum Pounds of Effective Neutralizing Power per Ton (Min. Lbs. ENP/Ton) quality rating to determine ag-lime recommendations/application rates. Questions? Contact the MDA at 651-201-6275.

Production/Storage Site Name or Address	Site Location	Product Description	Ag-Lime Type	Date of Analysis	% Passing #8 Sieve	% Passing #20 Sieve	% Passing #60 Sieve	Fineness Index (FI)	%CCE	%ENP	%Moisture	Min. Lbs. ENP/Ton
Aggregate Industries, Eagan, MN, 651-683-8131												
Larson Quarry	MN-Washington	2011 Production Ag-Lime	Quarry	12/7/2011	93	71	53	68	93	63	7	1180
Larson Quarry	MN-Washington	Old Stockpile Ag-Lime	Quarry	12/7/2011	90	68	49	65	92	60	5	1136
Larson Quarry	MN-Washington	Old Stockpile Ag-Lime	Quarry	2/6/2012	92	69	51	66	92	61	5	1165
Larson Quarry	MN-Washington	2012 Production Aglime	Quarry	05/18/2012	89	66	48	63	96	61	3	1186

ne Analysis Results

www.mda.state.mn.us/licensing/licensetypes/limeprogram/aglimeanalysisresults.aspx

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Larson Quarry	MN-Washington	2012 Production Aglime	Quarry	05/18/2012	89	66	48	63	96	61	3	1186
Larson Quarry	MN-Washington	Cyclone Lime	Quarry	12/07/2011	100	100	87	95	88	84	5	1588
Larson Quarry	MN-Washington	2011 Production Aglime	Quarry	02/06/2012	93	73	54	70	93	65	5	1230
Larson Quarry	MN-Washington	2011 Production Aglime	Quarry	8/31/2012	93	73	54	69	93	65	5	1230
American Crystal Sugar Company, Moorhead, MN, 218-236-4304												
American Crystal Sugar Company - East Grand Forks, MN	MN-Polk	Sugarbeet BP Lime @ Press	Industrial By-Product	10/22/2012	100	100	100	100	79	79	30	1093
American Crystal Sugar Company - East Grand Forks, MN	MN-Polk	Sugarbeet BP Lime - Stockpile	Industrial By-Product	10/22/2012	100	100	100	100	78	78	31	1069
American Crystal Sugar Company - Moorhead, MN	MN-Clay	Sugarbeet BP Lime - Press	Industrial By-Product	10/11/2012	100	100	100	100	75	75	29	1072
American Crystal Sugar Company - Moorhead, MN	MN-Clay	Sugarbeet BP Lime - Stockpile	Industrial By-Product	10/11/2012	100	100	100	100	72	72	30	1011
American Crystal Sugar Company - Hillsboro, ND	ND-Traill	Sugarbeet BP Lime - Stockpile	Industrial By-Product	10/10/2012	100	100	100	100	75	75	34	992
American Crystal Sugar Company - Hillsboro, ND	ND-Traill	Sugarbeet BP Lime - Press	Industrial By-Product	10/10/2012	100	100	100	100	76	76	38	938
American Crystal Sugar Company - Crookston, MN	MN-Polk	Sugarbeet BP Lime	Industrial By-Product	10/10/2012	100	100	100	100	77	77	29	1094

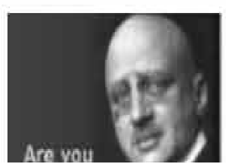
www.extension.umn.edu/agriculture/nutrient-management/index.html

Nutrient Management

- Nutrient/Lime Guidelines
- Crop Calculators
- Soil and Plant Sampling
- Manure Management
- Non-traditional Amendments
- Historic Blue Books
- Nitrogen
- Phosphorus
- Potassium
- Secondary Macronutrients (Ca, Mg, S)
- Micronutrients
- Fertilizer Management

Nutrient management research focuses on helping farmers and ag professionals optimize crop production using appropriate nutrient inputs while minimizing effects on the environment.

- Nutrient Management Team



Nitrogen Smart: Fundamentals

A new training program for producers presents the fundamentals for maximizing economic return on nitrogen investments while minimizing

Corn, Soybean and Alfalfa Response to Dolomitic and Calcitic (Pell) Lime

Gyles Randall and Jeff Vetsch
University of Minnesota
Southern Research and Outreach Center

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Situation

- Intensive “grid” soil sampling has identified soils with surface soil pH values normally considered to be below optimum for soybean production.
- Site-specific management allows these soils to be treated (limed) independently of high pH soils in the same field.

Materials and Methods.

- Established at SROC (Waseca) in August 1998.
- Nicollet clay loam soil (glacial till parent material)
- Initially a corn–soybean rotation, alfalfa established spring 2002.
- Plots are 15 ft. wide by 28 ft. long.
- Initial soil (0-6 inch) water pH = 5.4, buffer 6.0.
  - LR for pH 6.0 = 5,000 lb ENP or 7,000 lb for 6.5 (alfalfa)
- Lime materials broadcast (by hand) and incorporated 4 inches deep with a roto-tiller before growing corn and soybean.
- Effective neutralizing power (ENP) was 1030 and 1800 lb/ton for dolomite and calcite (**pell lime**), respectively.

Treatments (1998-2006) Old prices

Lime Source	Rate, T/A	ENP, lb/A	Applied	Cost, $/A*
Control	0.0	0	None	0
Dolomite	0.5	515	8/98 & 10/00	12
Dolomite	2.0	2,060	8/98 & 10/00	50
Dolomite	4.0	4,120	8/98 & 10/00	99
Dolomite	6.0	6,180	8/98 & 10/00	149
Dolomite	10.0	10,300	8/98 & 10/00	248
Calcite (pell)	0.2	360	8/98 & 10/00	49
Calcite (pell)	0.5	900	8/98 & 10/00	109
Calcite (pell)	1.0	1,800	8/98 & 10/00	209
Calcite (pell)	0.2	360	Annually	196
$CaSO_4$ (gypsum)	0.2	0	Annually	228
$CaCl_2$ (salt)	0.2	0	8/98 & 10/00	NA

* Product costs were $12.40/T applied (hauling 20 miles) for dolomite and $100 and $120/T for pell lime and gypsum, respectively, plus $4.5/application.

2013 Pricing.

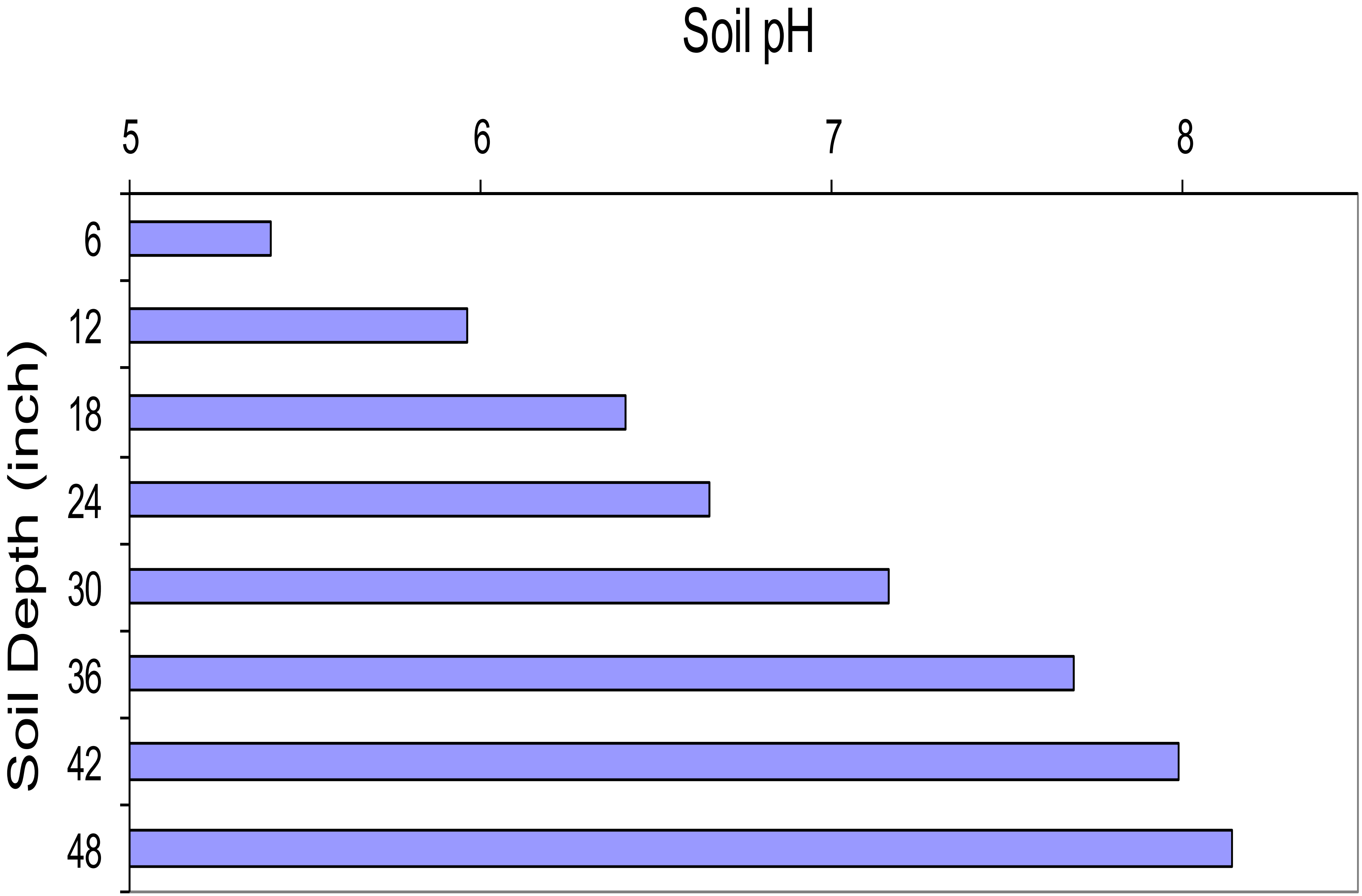
- Current prices reflect differences in transportation costs and product quality.
  - Dolomite (ENP) ≈ 1,000, price ranges from \$25/T for Blue Earth Co. to \$40/T for Redwood Co.
  - Calcite (ENP) ≈ 1,600, price ranges from \$40/T for Blue Earth Co. to \$60/T for Redwood Co.

Treatments (1998-2006) 2013 prices

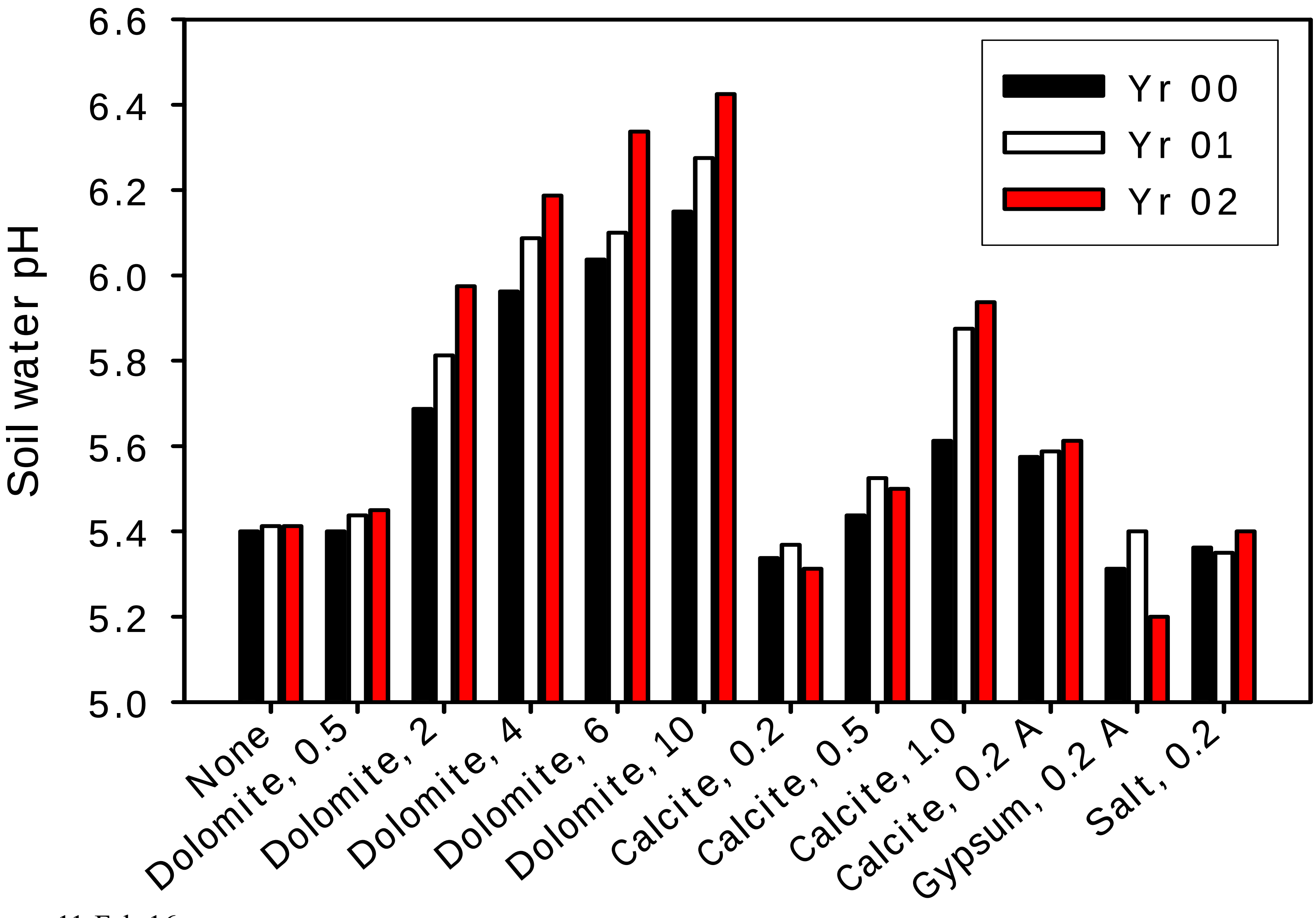
Lime Source	Rate (T/A)	Applied	Cost ($/A)*
Control	0.0	None	0
Dolomite	0.5	8/98 & 10/00	30
Dolomite	2.0	8/98 & 10/00	120
Dolomite	4.0	8/98 & 10/00	240
Dolomite	6.0	8/98 & 10/00	360
Dolomite	10.0	8/98 & 10/00	600
Calcite (pell)	0.2	8/98 & 10/00	~120
Calcite (pell)	0.5	8/98 & 10/00	~300
Calcite (pell)	1.0	8/98 & 10/00	~600
Calcite (pell)	0.2	Annually	~420
$CaSO_4$ (gypsum)	0.2	Annually	~500
$CaCl_2$ (salt)	0.2	8/98 & 10/00	NA

* Product costs were $30/T applied (Waseca from Kasota, hauling 20 miles) for dolomite and $300 and $350/T for pell lime and gypsum, respectively.

Soil profile pH, Nicollet soil, 1998



Soil pH as affected by liming.



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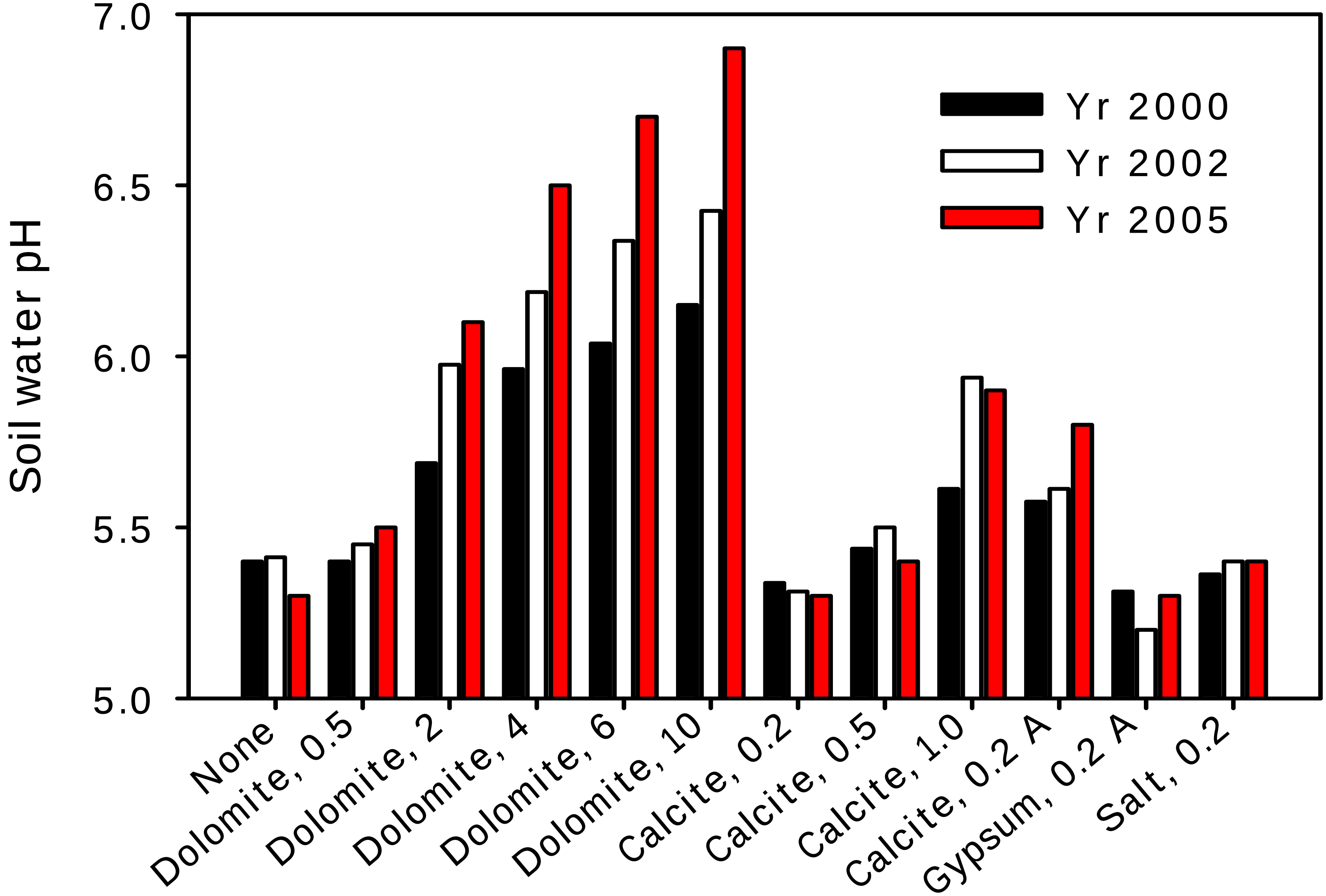
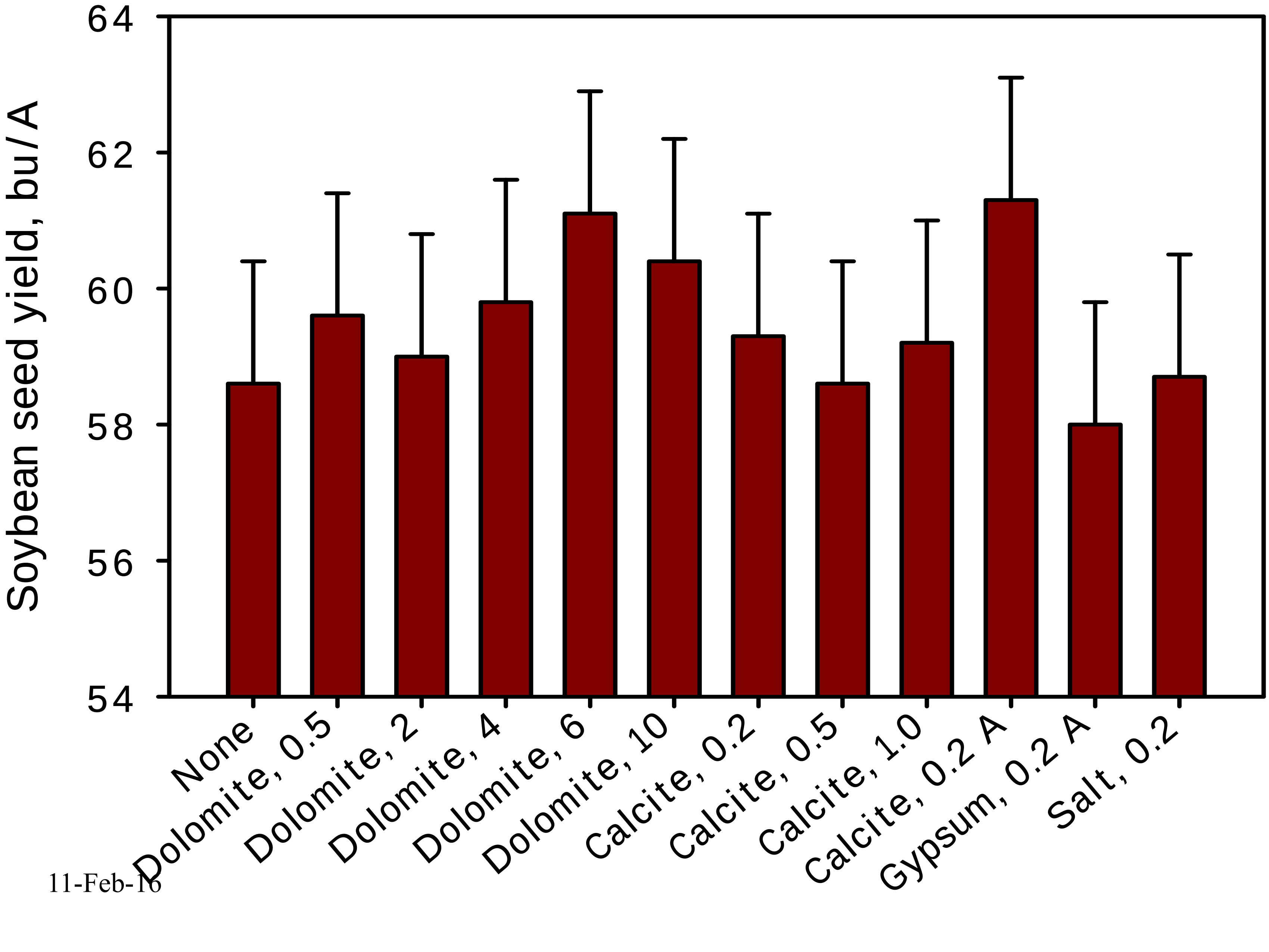
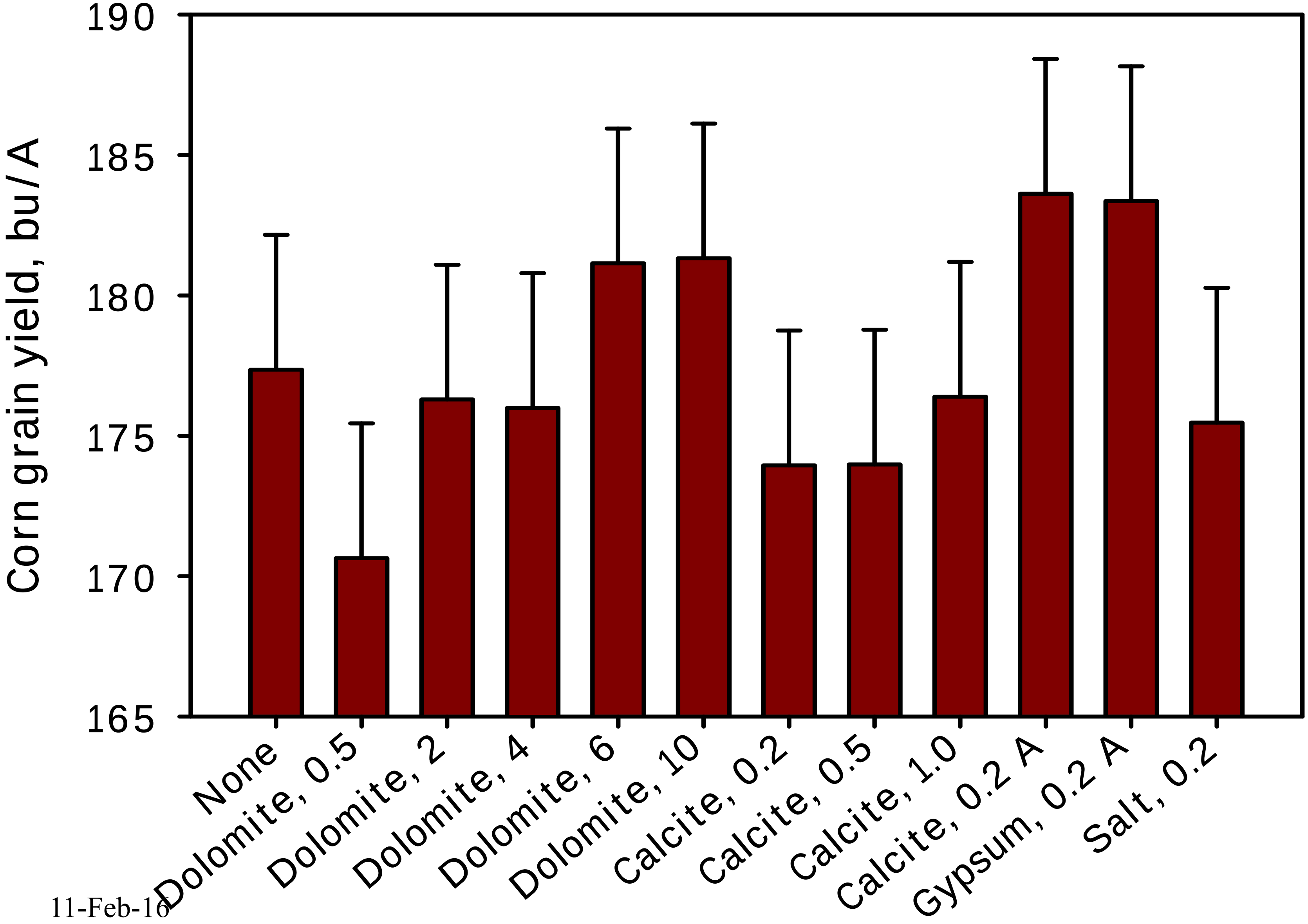


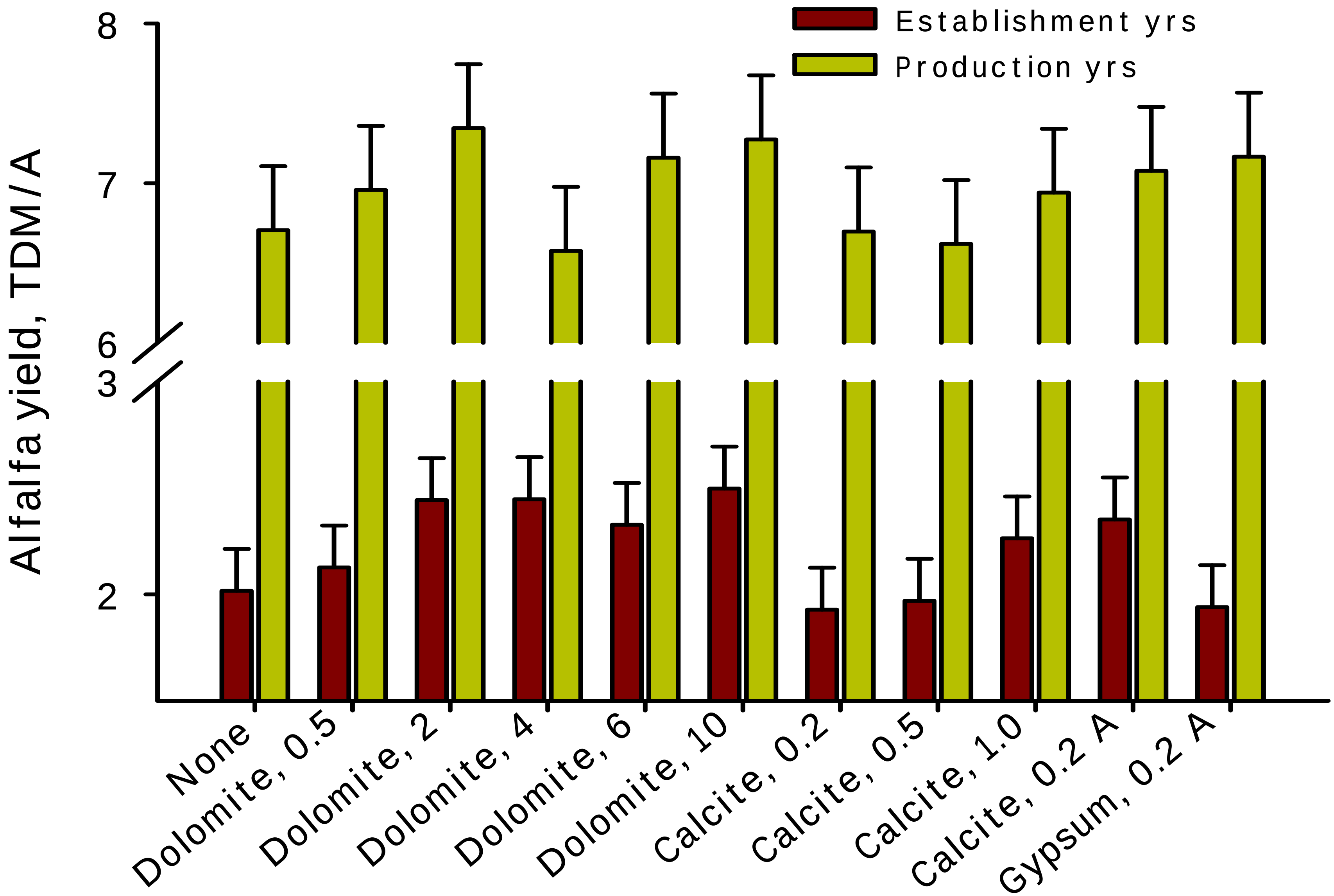
Soybean yield (5-yr avg.) as affected by liming.



Corn yield (6-yr avg.) as affected by liming.



Alfalfa yield as affected by liming.



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Economic return (1998-2006) old prices.

Treatment	Input Cost	Gross Income Over Control *		
		Soybeans	Corn	Alfalfa
Source, rate (T/A), apl.	$/A	---------	$/acre	----------
Dolomite, 0.5, 2x	12	28	-106	102
Dolomite, 2, 2x	50	13	-17	291
Dolomite, 4, 2x	99	34	-22	50
Dolomite, 6, 2x	149	72	60	208
Dolomite, 10, 2x	248	53	63	280
Calcite, 0.2, 2x	49	21	-54	-21
Calcite, 0.5, 2x	109	0	-53	-37
Calcite, 1.0, 2x	209	16	-15	126
Calcite, 0.2, Annual	196	79	99	188
Gypsum, 0.2, Annual	228	-17	95	128

* Gross income = treatment yield – check x crop value ($5.80, 2.63 and 105 for soybean, corn, and alfalfa, respectively).

Economic return (1998-2006) 2013 prices.

Treatment	Input Cost	Gross Income Over Control *		
		Soybeans	Corn	Alfalfa
Source, rate (T/A), apl.	$/A	---------	$/acre	----------
Dolomite, 0.5, 2x	30	64	-282	293
Dolomite, 2, 2x	120	29	-45	831
Dolomite, 4, 2x	240	76	-57	142
Dolomite, 6, 2x	360	161	159	595
Dolomite, 10, 2x	600	119	167	800
Calcite, 0.2, 2x	120	46	-143	-61
Calcite, 0.5, 2x	300	0	-142	-106
Calcite, 1.0, 2x	600	37	-40	359
Calcite, 0.2, Annual	420	177	263	536
Gypsum, 0.2, Annual	500	-38	252	367

* Gross income = treatment yield – check x crop value ($13, $7 and $300 for soybean, corn, and alfalfa, respectively).

Results: pH

- In July of 2000, soil pH in the surface 6 inches was increased from 5.4 to 6.2 with dolomitic lime rates up to 10 T/A.
- By July of 2002, two applications of lime increased pH from 5.4 to 6.4 (10 T/A dolomite) and 5.4 to 5.9 (1 T/A calcite).
- By July of 2005, two applications of lime increased pH from 5.4 to 6.9 (10 T/A dolomite) and 5.4 to 5.9 (1 T/A calcite).

Results: Soybean yield

- Lime treatments increased soybean yields in 2 of 5 site years and the 5-yr average.
- The 6 T/A rates of dolomite applied twice and the 0.2 T/A rate of calcite applied annually increased soybean yields about 2.5 bu/A compared with the control.

Results: Corn yield

- Significant differences among treatments were found in 4 of 6 site years and the 6-yr average.
- The 6 and 10 T/A rates of dolomite applied twice resulted in corn yields 4 bu/A greater than the control [not statistically significant at (0.10)].
- The 0.2 T/A rate of calcite and gypsum applied annually increased corn yields 8 and 7 bu/A, respectively, compared with the control.

Results: Alfalfa yield

- Lime treatments increased alfalfa yields in establishment years and in 1 of 3 production years and for the 3 production-year average.
- Generally, lower rates of dolomite (2, 4, and 6 T/A) applied twice were adequate to increase both establishment years and production years alfalfa yield.
- Calcite applied twice and annually at 1 and 0.2 T/A, respectively increased alfalfa yields in establishment years.

Results: Economic return (old)

- The small yield increases found for corn and soybean in this experiment would NOT result in a return on investment based on the input costs of these treatments, using our assumptions.
- These data suggest that alfalfa would provide a return on investment for lower rates of dolomitic lime but not calcitic lime.

Results: Economic return (2013)

- The small yield increases found for corn and soybean in this experiment would NOT result in a return on investment based on the input costs of these treatments, using our assumptions.
  - However, select treatments would break even.
- These data suggest that alfalfa would provide a return on investment for most dolomitic rates.

Conclusion: Waseca study

- These data showed the importance of long-term studies for pH and liming:
  - Corn and soybean yield responses were small and generally would not have given a ROI.
  - Alfalfa consistently responded to liming.
  - Clearly showed a yield response to sulfur.

Iowa Studies: Mallarino and Pagani

- On-farm studies (43 site-yrs)
- Rates 0 and 3 ton/ac of ECCE.
- Plot size 0.3 to 0.5 ac.
- Corn and soybean.
- Same fields for up to 4 yr.

ww.agronext.iastate.edu/soilfertility/info/Mallarino_LimeOnFarm_ICM-2011.pdf

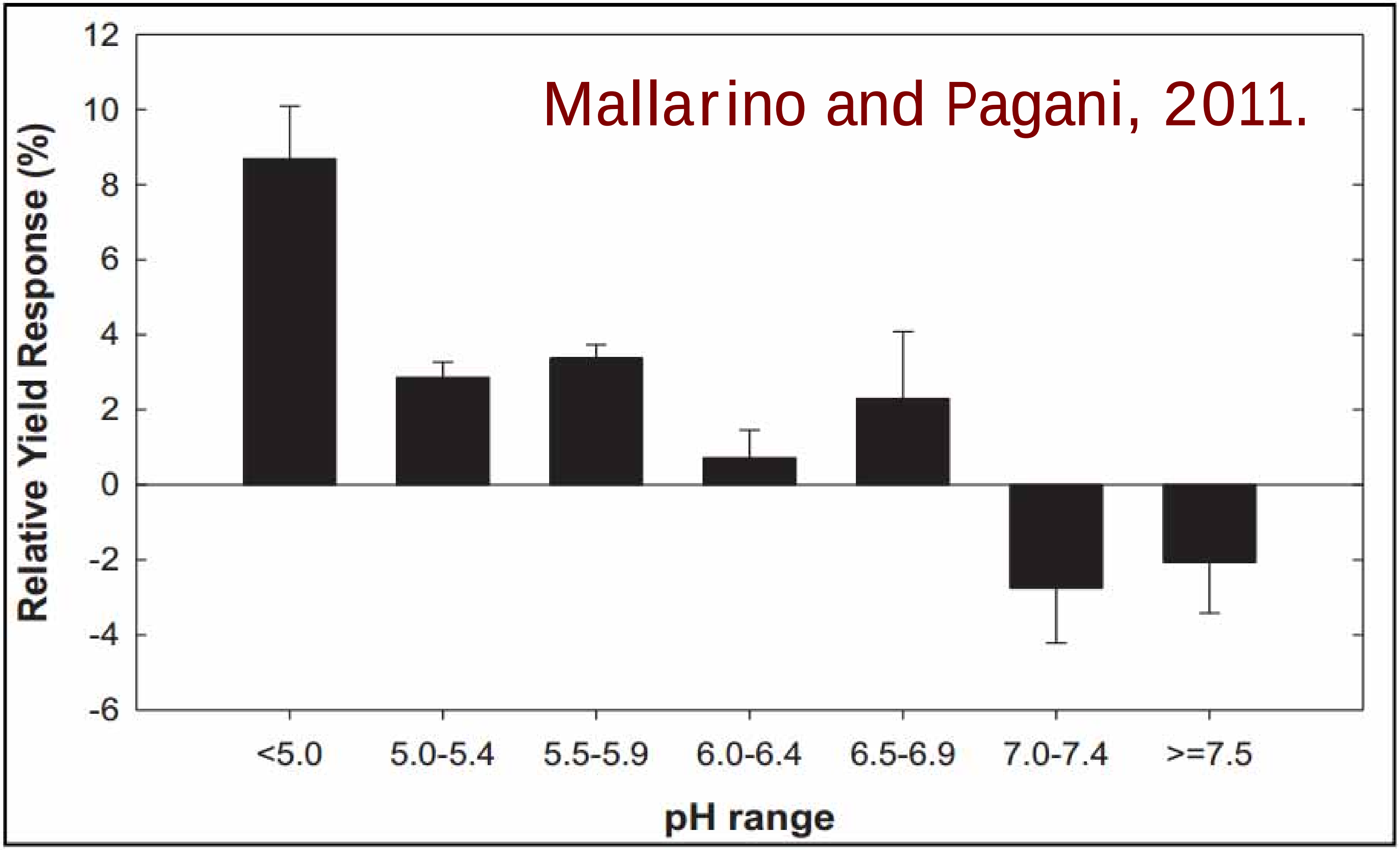

Figure 4. Relative grain yield response (combined corn and soybean) to 3 ton ECCE/acre summarized by soil pH across all strip trials and years (43 site-years). Lines represent standard errors.

Iowa Studies: Mallarino and Pagani

- Averaged across 43 site-yrs there were large corn and soybean yield responses for pH ranges up to 5.9, smaller and barely significant responses for ranges 6.0 to 6.9 and small yield decrease at higher pH values (Fig. 4).

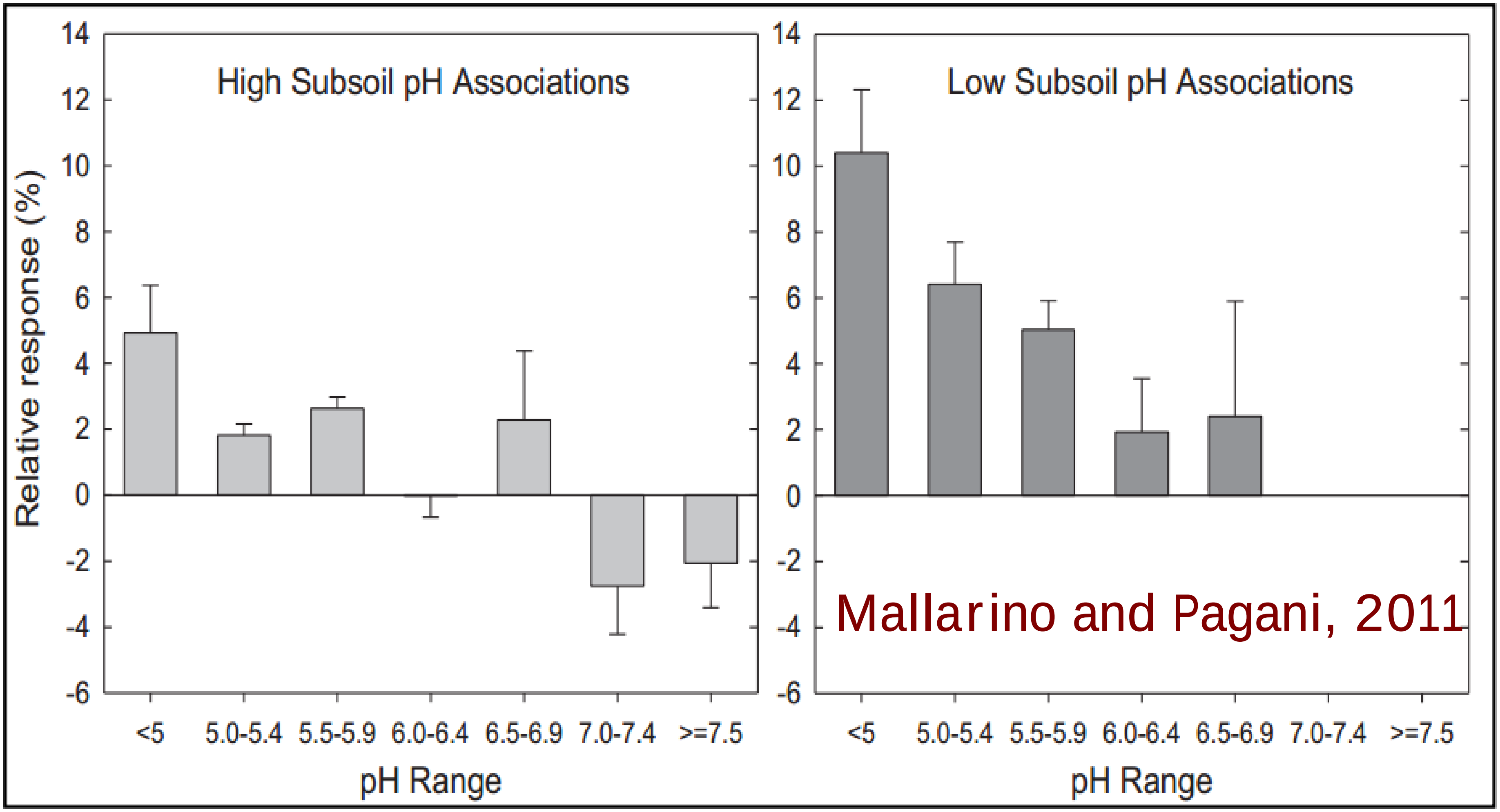

Figure 6. Relative yield response (combined for corn and soybean) to 3 ton ECCE/acre according to pH for soil associations areas with or without high-pH subsoil (lines represent standard errors).

Iowa Studies: Mallarino and Pagani

- Fields with high pH subsoil, had a large yield increase with liming on very acid pH surface soils (pH < 5.0), smaller but significant increases up to pH 5.9 and no significant or consistent increases from pH 6.0 to 6.9 (Fig. 6)
- For low subsoil pH fields, large yield responses were found up to pH 5.9, smaller but significant up to pH 6.4 and no increase for higher pH values.

onext.iastate.edu/soilfertility/info/Mallarino_LimeOnFarm_ICM-2011.pdf

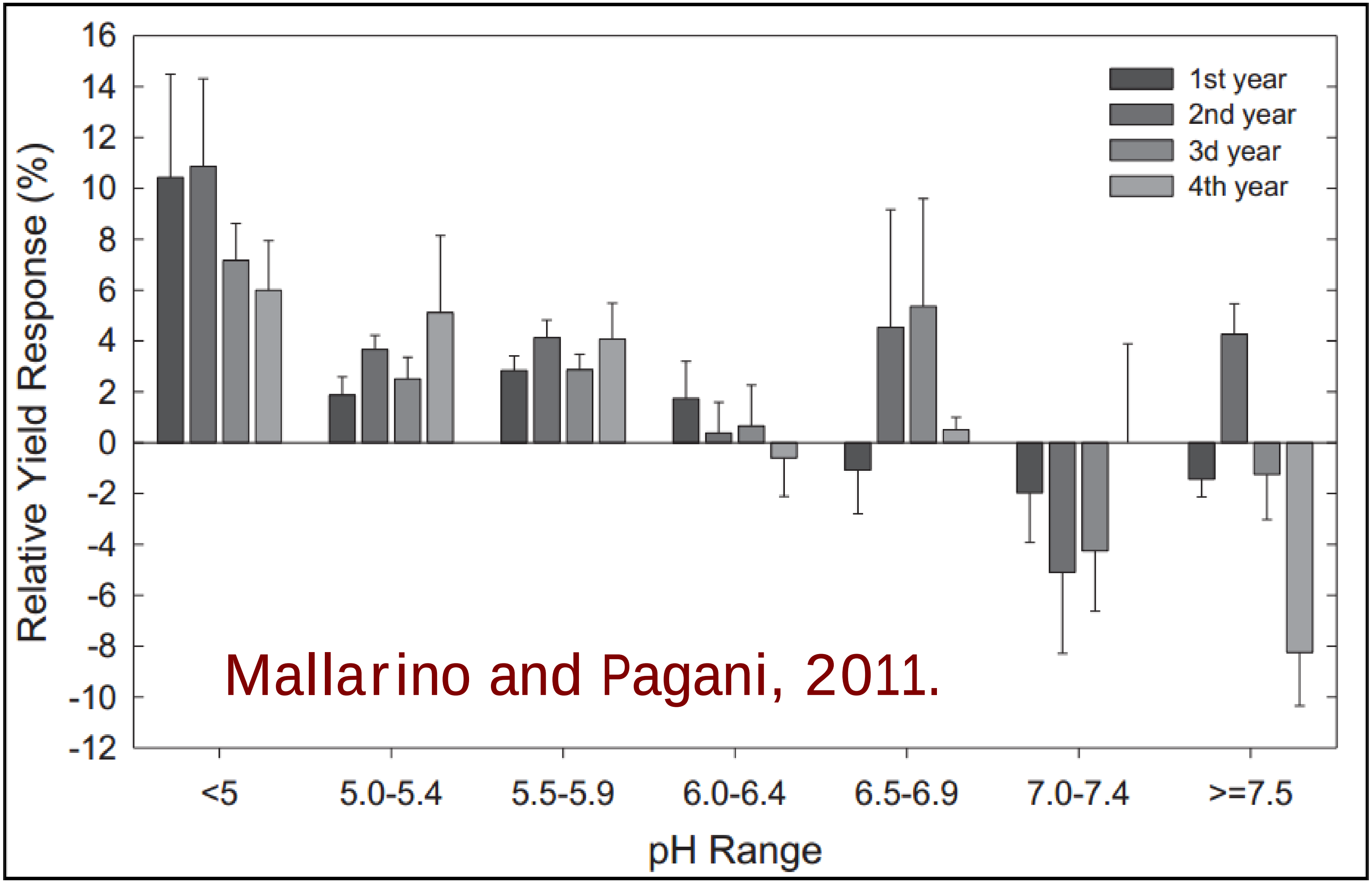

Figure 5. Relative grain yield response (combined corn and soybean) to 3 ton ECCE/acre summarized by soil pH across all strip trials for each sampling year after liming (43 site-years). Lines represent standard errors.

Michigan study (Pierce and Warncke, 2000)

	Durand (loamy glacial till)			Plainwell (glacial outwash)		
	Corn	Corn	Soybean	Corn	Corn	Soybean
LR treatment	1995	1996	1997	1995	1996	1997
100 ft grid	137	143	39	108	135	43
200 ft grid	137	146	42	99	129	42
300 ft grid	138	146	38	114	133	45
Sm. plot	138	152	41	111	139	43
Control	137	140	30	109	135	42
LSD (0.05):	NS	NS	4	NS	NS	NS

Michigan study (Pierce and Warncke, 2000)

- Corn yields did not respond to liming.
  - Yield levels in study were < what's typical of southern MN.
- Soybean yields responded when pH < 5.9 and response increased linearly as pH decreased.
- "Lime requirement (LR) interpolations (maps) consistently underestimated and were not correlated with LR measured on each plot"
  - Grid based interpolation maps were on 0.2, 0.9 and 2.1 acres grids.

Wisconsin study (Laboski and Peters, 2006)

Target soil pH	Corn silage yield	
	Marshfield	Spooner
	-- ton DM/acre --	
4.7 - 4.8	5.59	5.88
5.2 - 5.3	5.94	6.48
5.7 - 5.8	6.10	6.35
6.2 - 6.3	6.52	7.66
6.7 - 6.8	6.43	7.00
LSD:0.05	0.83	0.85

Conclusions

- Corn yield responses to liming occur, especially at water pH values < 5.4; however, they often do not give a ROI.
- Soybean yield responses are more common but may be small 2 to 3 bu/ac.
- Alfalfa generally responds to lime applications when soil tests recommend liming.
- Glacial till soils are highly buffered, therefore have a slower pH response when limed.

Contact info

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