Basic Principles of Liming

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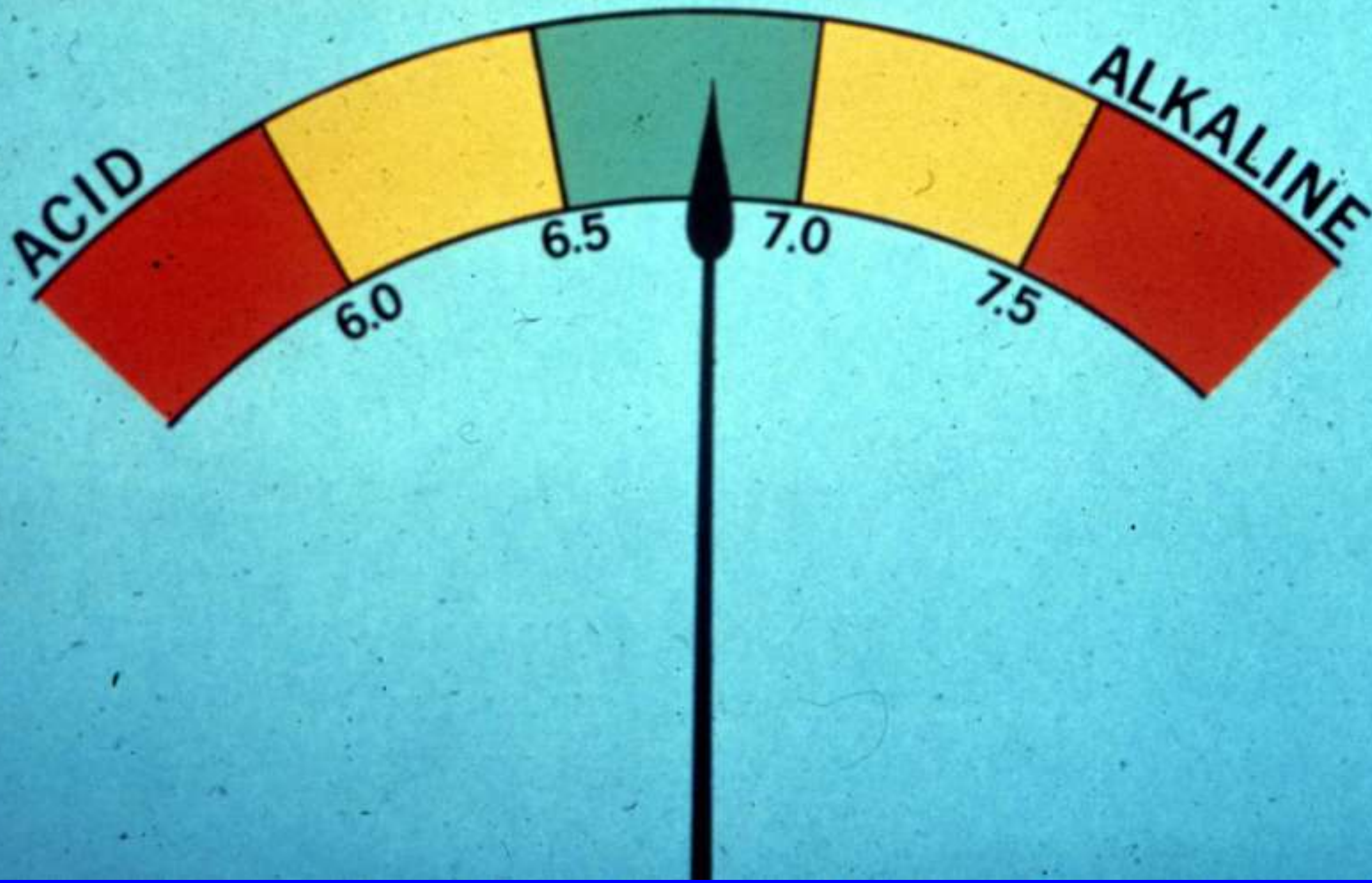
UW Soil Science Department

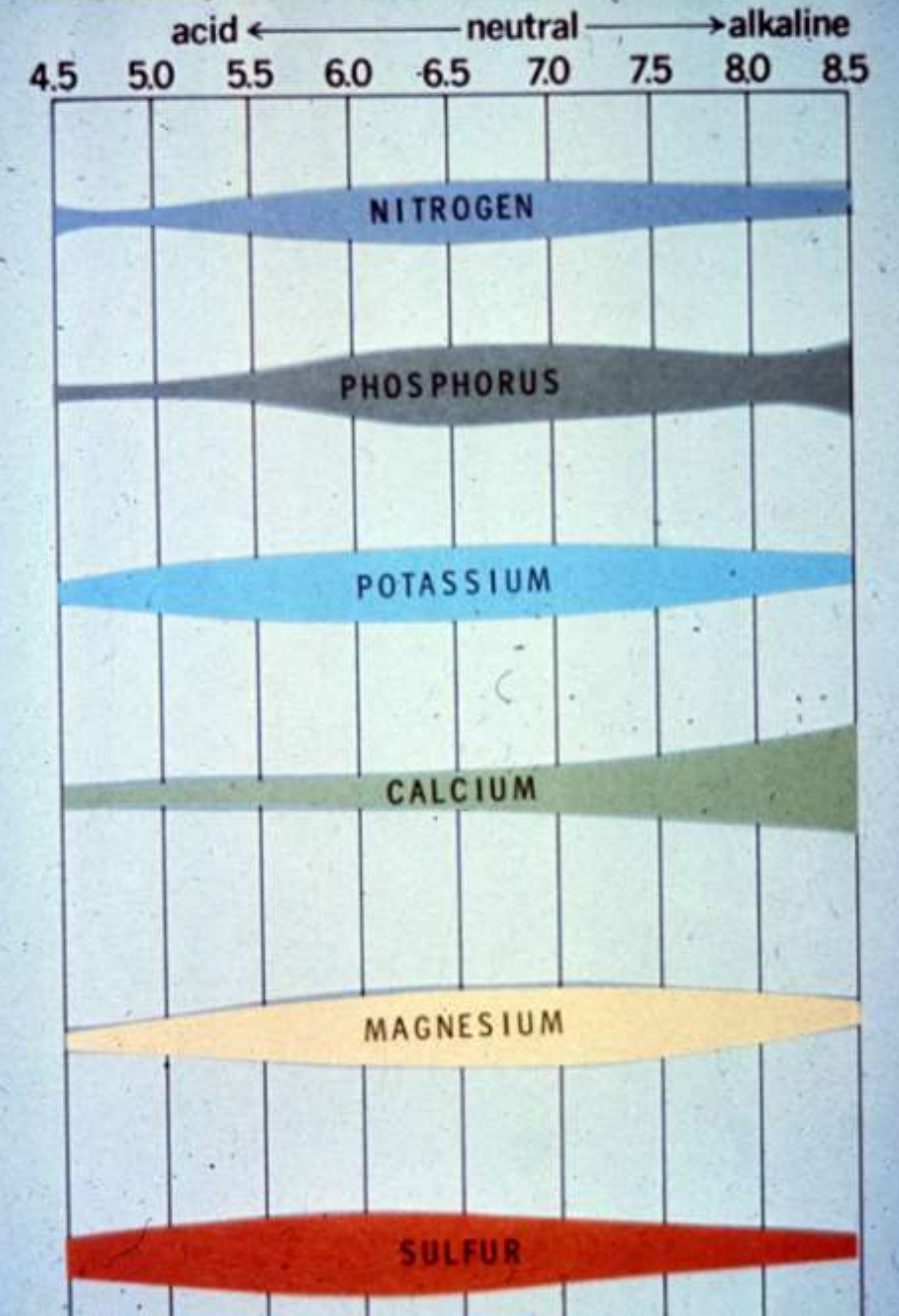
What is soil pH?

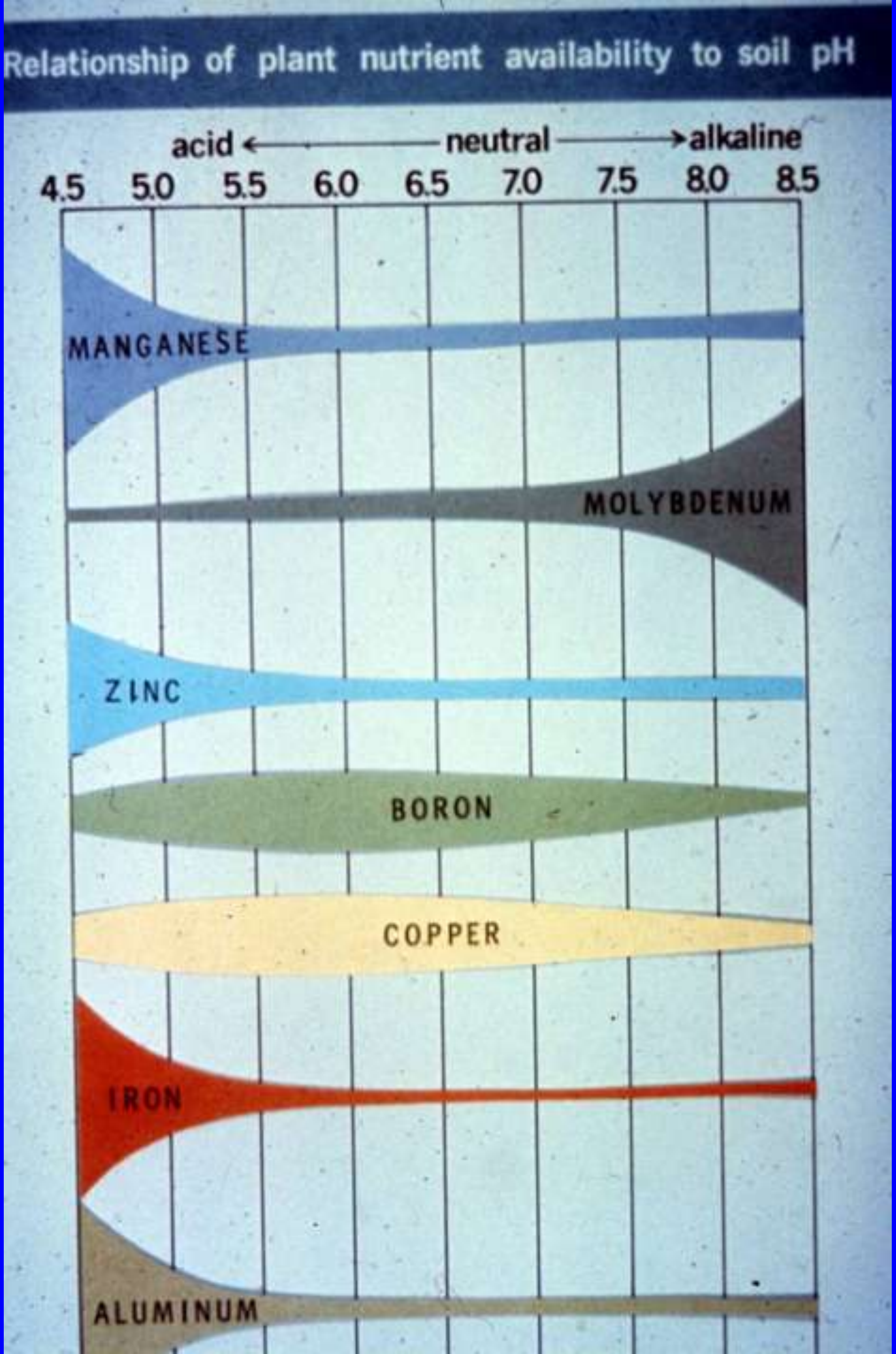


Soil pH affects many chemical and physical reactions in soil

- Availability of most essential elements
- Activity of microorganisms
- Ability of soil to hold cations
- Solubility of non-essential elements such as heavy metals
- Herbicide performance

Relationship of plant nutrient availability to soil pH





Relationship of plant nutrient availability to soil pH
acid
neutral
alkaline
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
MANGANESE
MOLYBDENUM
ZINC
BORON
COPPER
IRON
ALUMINUM

What factors determine the lime needs of a soil

- Soil pH – determined by soil test
- Buffer pH – determined by soil test

Buffer pH
Organic matter

Soil pH

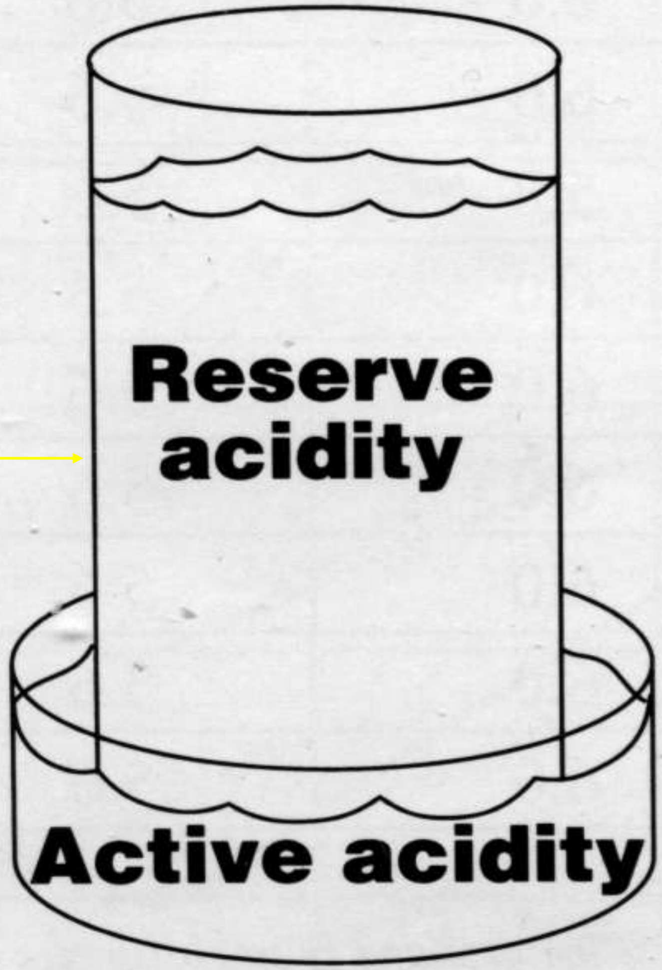
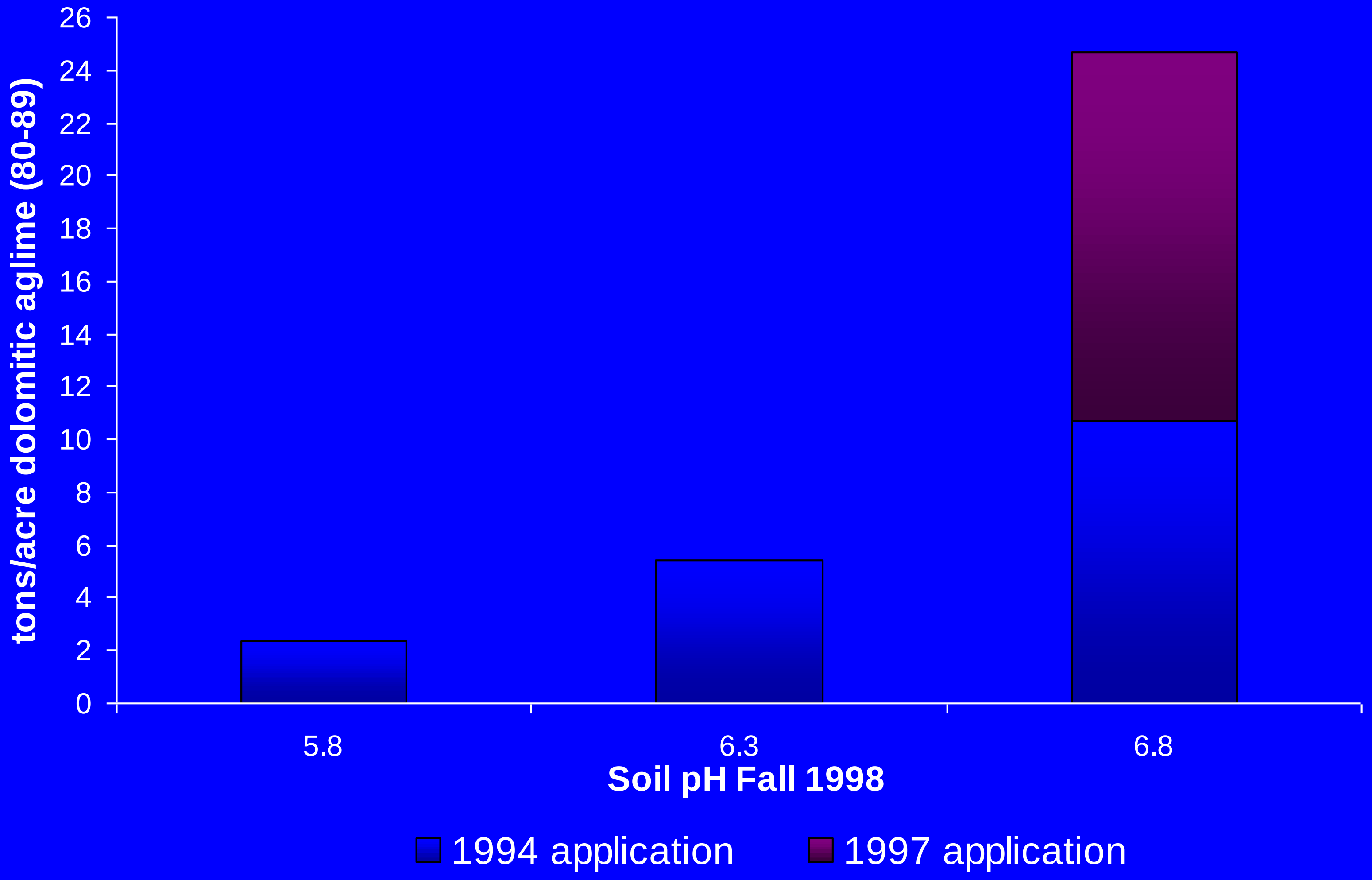


Figure 6-2. Active and reserve acidity in soil compared with a poultry watering fountain.

Figure 3. Aglime rates required to reach target pH - Marshfield, WI.

Initial pH = 5.3



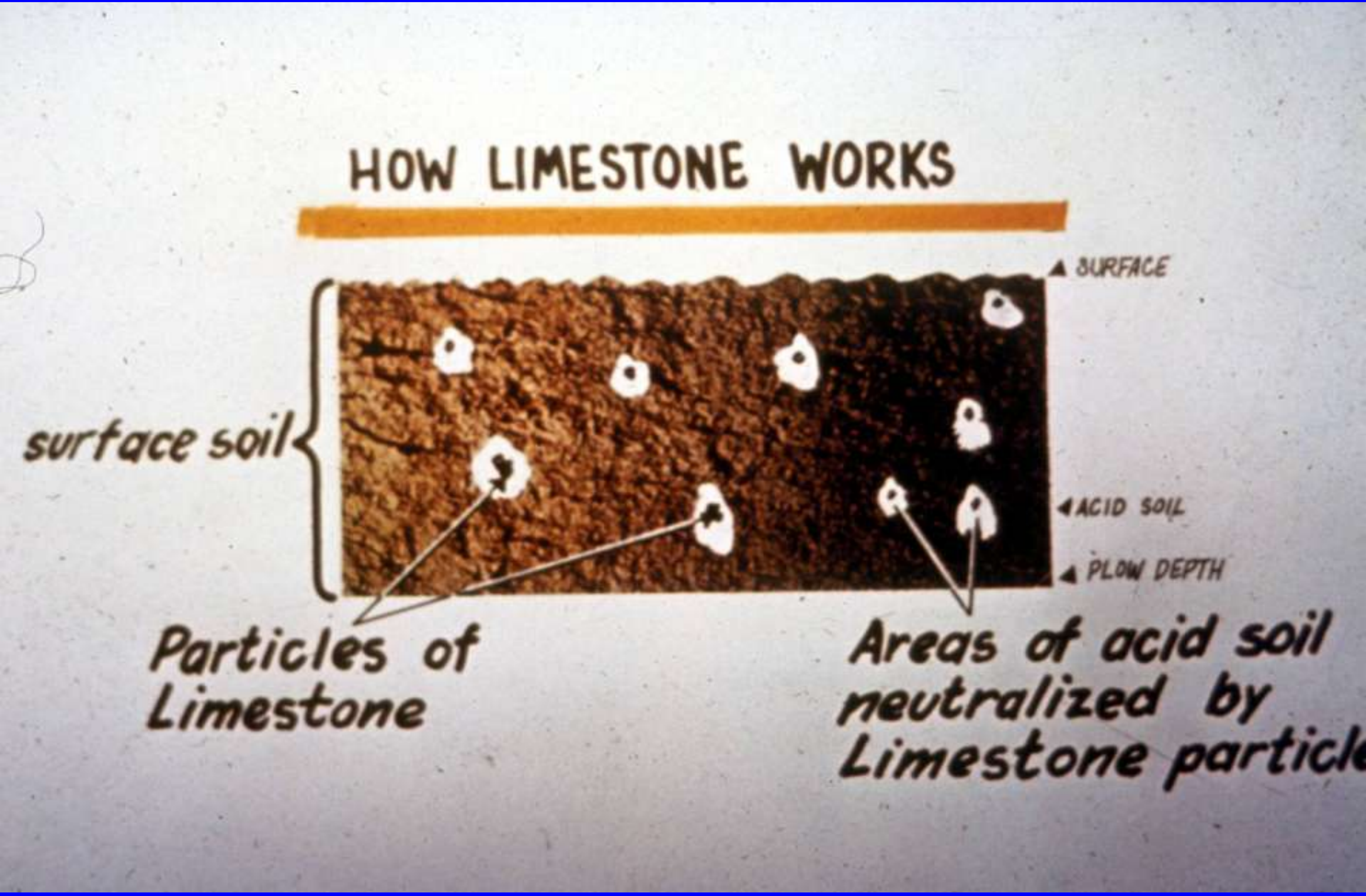
What factors determine the lime needs of a soil

- Soil pH – determined by soil test
- Buffer pH – determined by soil test
- Organic matter level – determined by soil test
- Target pH – determined by crop rotation
  - Lime requirement for a target pH of 6.8 = 2.0(1.64(6.8-pH)(OM-0.07)-0.046(SMP))

Target pH

- Alfalfa – 6.8
- Corn – 6.0
- Oats – 5.8
- Red Clover – 6.3
- Soybean – 6.3
- Pasture – 6.0

Mixing is Critical in Determining the Effectiveness of a Lime Application



HOW LIMESTONE WORKS
SURFACE
surface soil
ACID SOIL
PLOW DEPTH
Particles of Limestone
Areas of acid soil neutralized by Limestone particle

Incorporation is critical

Table 4. Changes in soil pH as a function of time and soil amendment added to a Withee silt loam

		Months				
Amendment	**Rate**	**0**	**2**	**10**	**26**	**48**
	ton/a	soil pH				
None	0	5.0	5.0	4.8	5.1	5.1
Aglime (90-99)	1	5.0	5.0	5.1	5.2	5.4
	2	5.0	5.1	5.1	5.4	5.4
	4	5.0	5.2	5.4	5.9	5.9
	16	5.0	5.8	6.2	6.7	6.9
Papermill lime sludge	3	5.0	5.8	6.0	5.8	6.0
	10	5.8	6.8	6.8	7.0	7.2

Primary tillage performed annually. Maximum pH reached at 48 months; thereafter, pH declined. Peters and Schulte, Univ. of Wis., unpublished data.

Figure 1. Long-term trends in soil pH, Hancock ARS

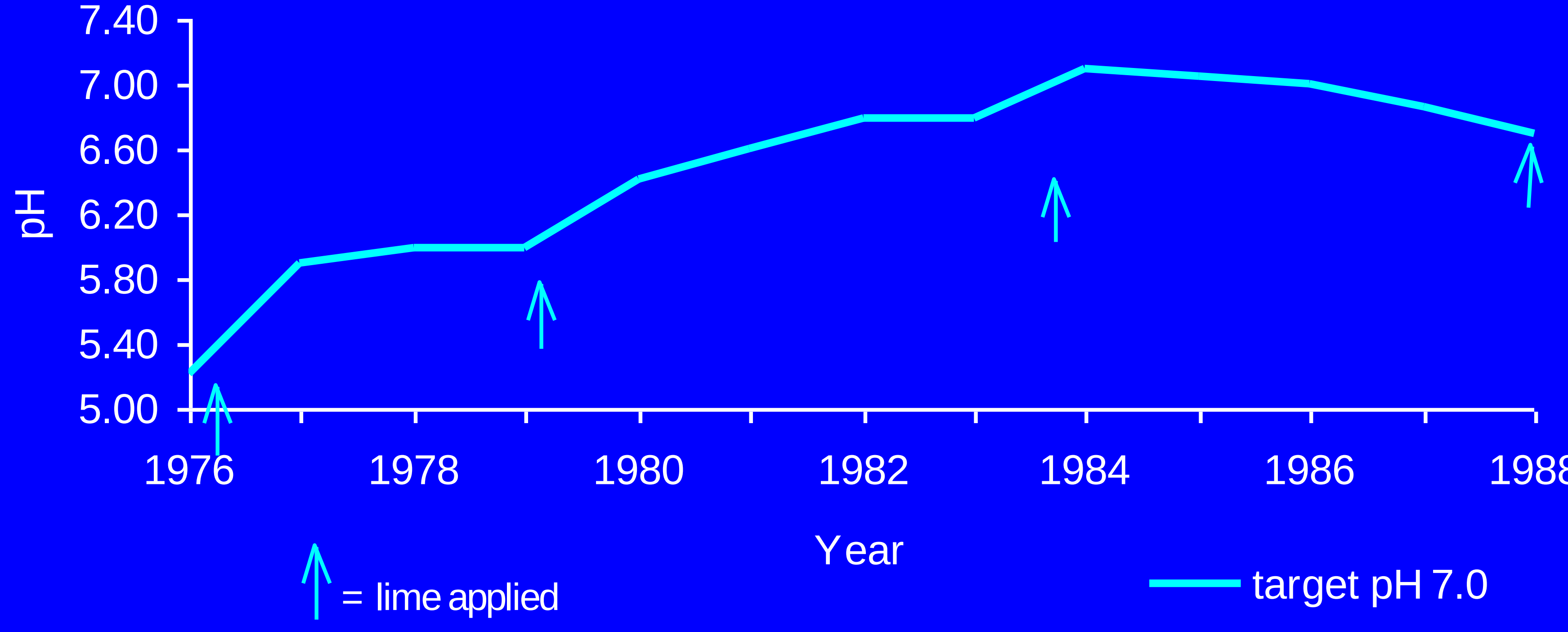
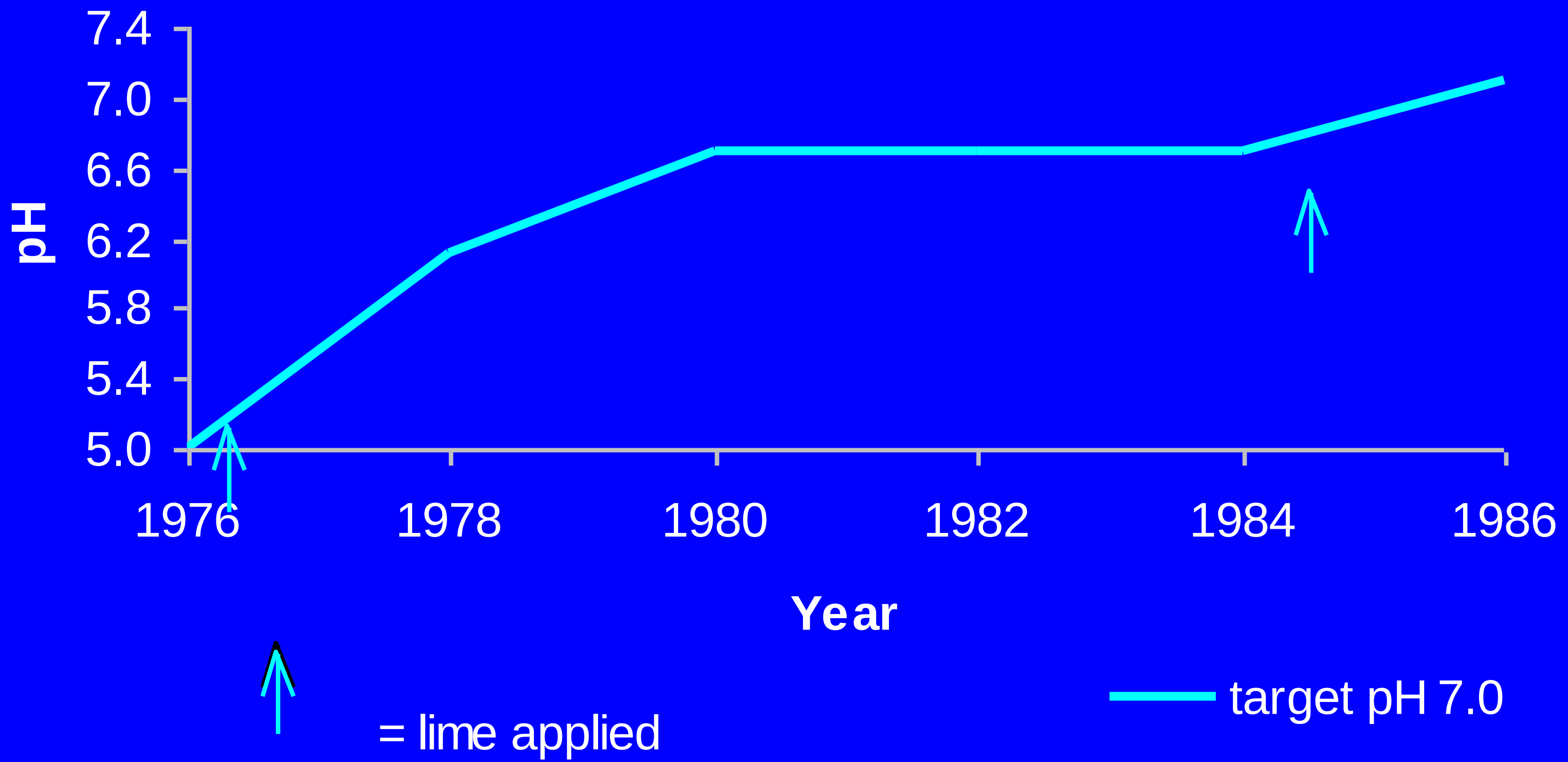


Figure 2. Long-term trends in soil pH, Marshfield ARS

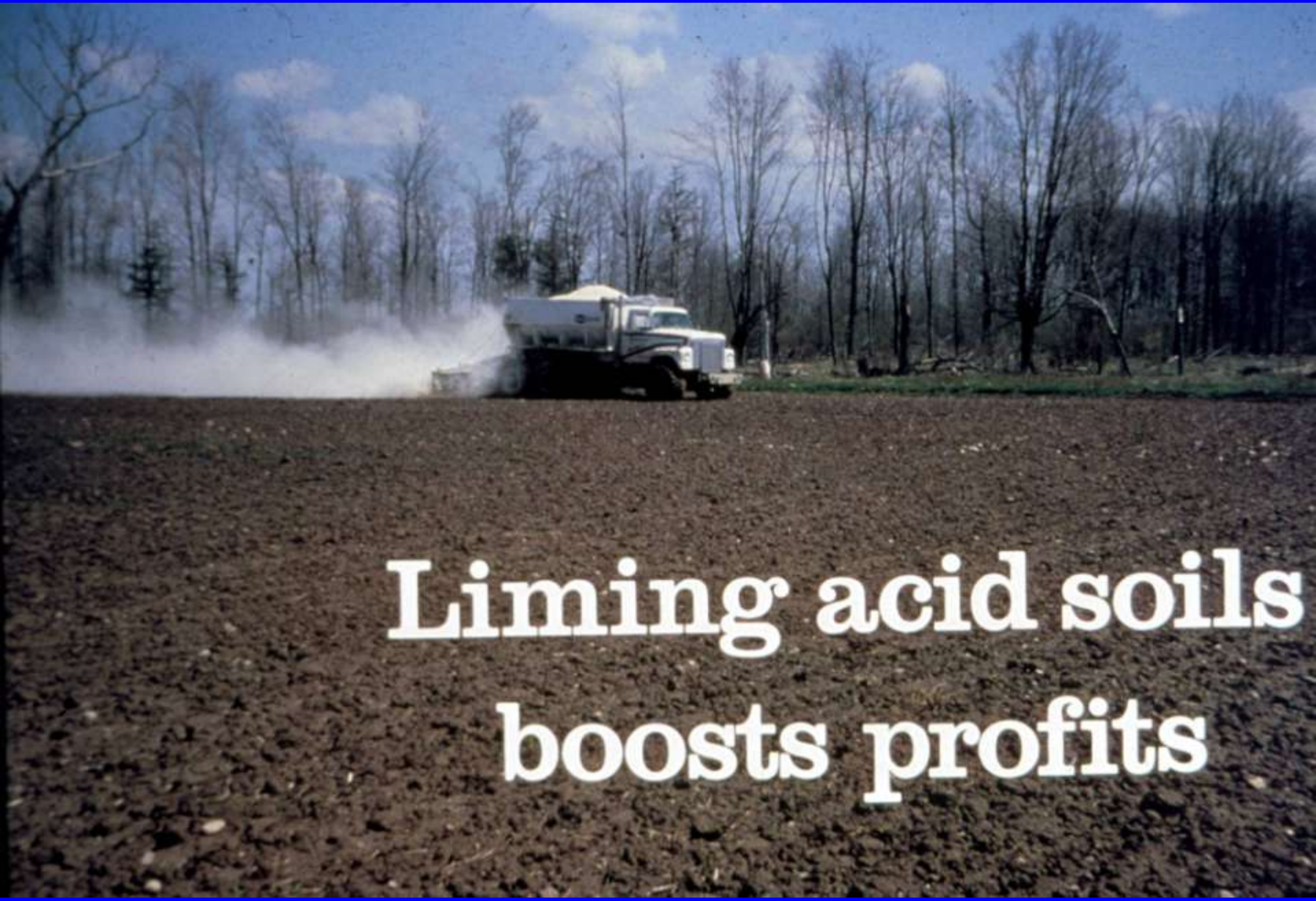


Depth of tillage affects the lime requirement of soils

Tillage depth (inches)	Factor used to adjust lime recommendations for depth of tillage
<7.1	1.00
7.1–8.0	1.15
8.1–9.0	1.31
>9.0	1.46

When should I apply lime?

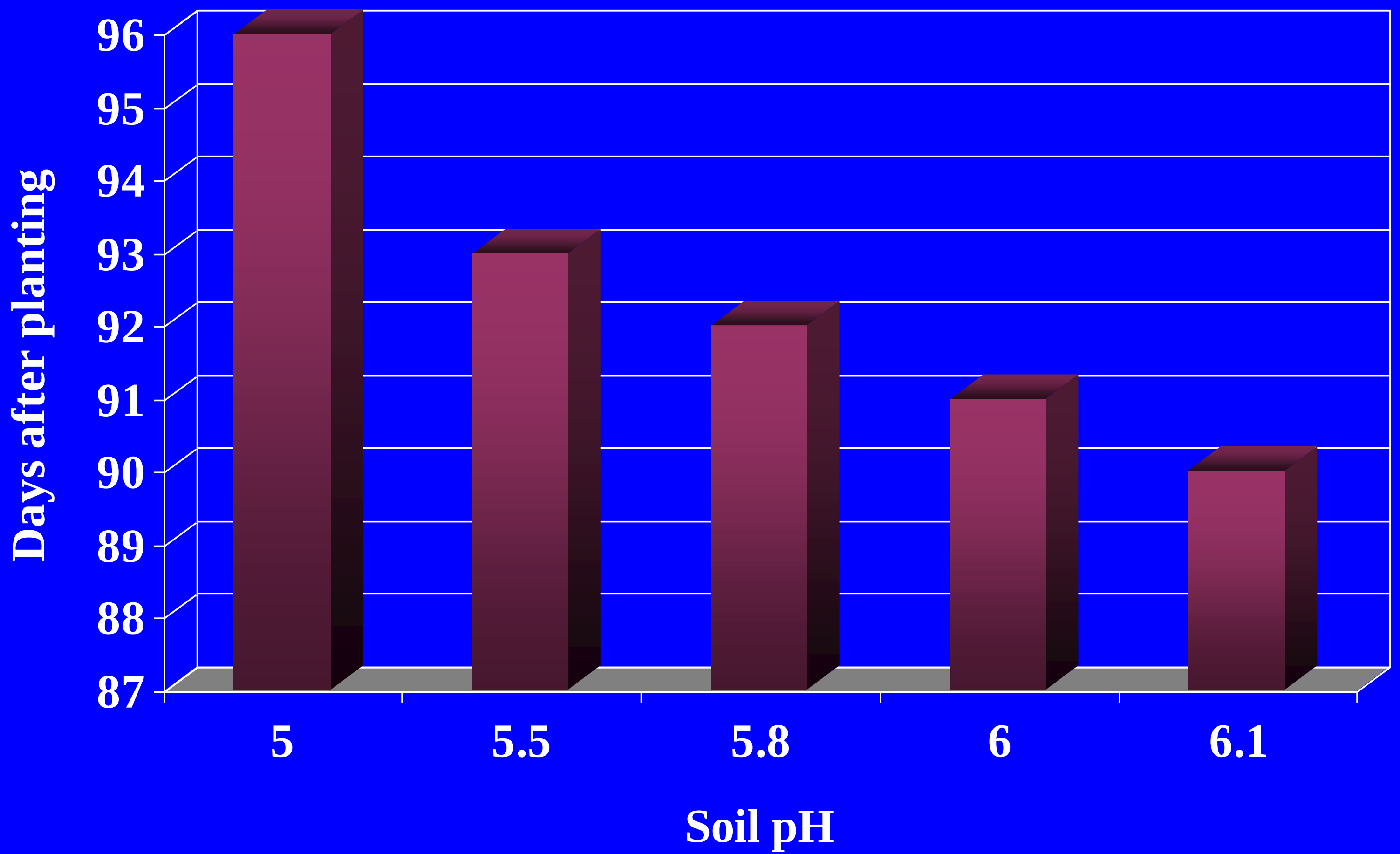

Any time you can


Liming acid soils
boosts profits

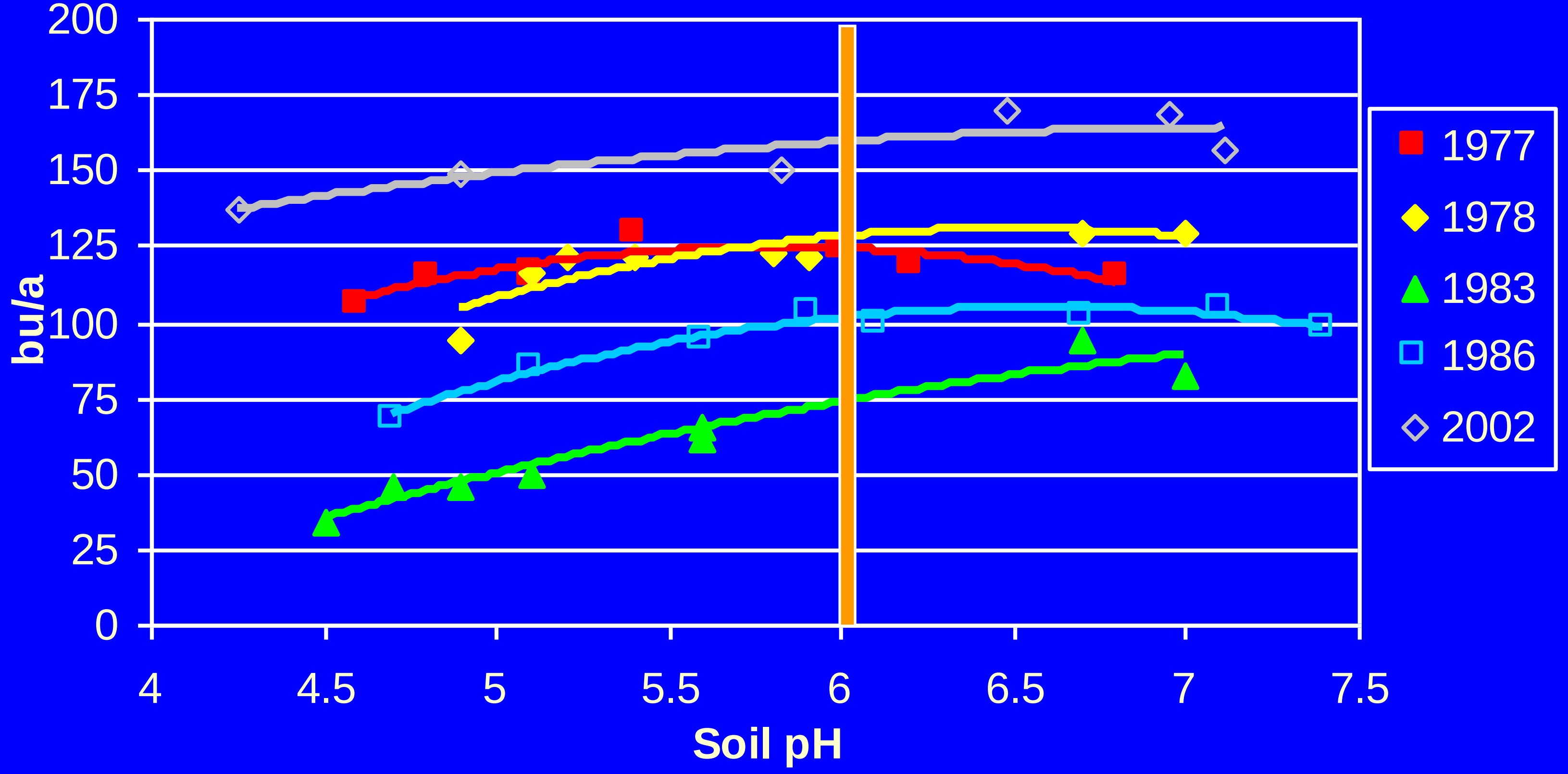

pH on Corn


HANCOCK
PLOT 1
PH 4.5
6/29/77

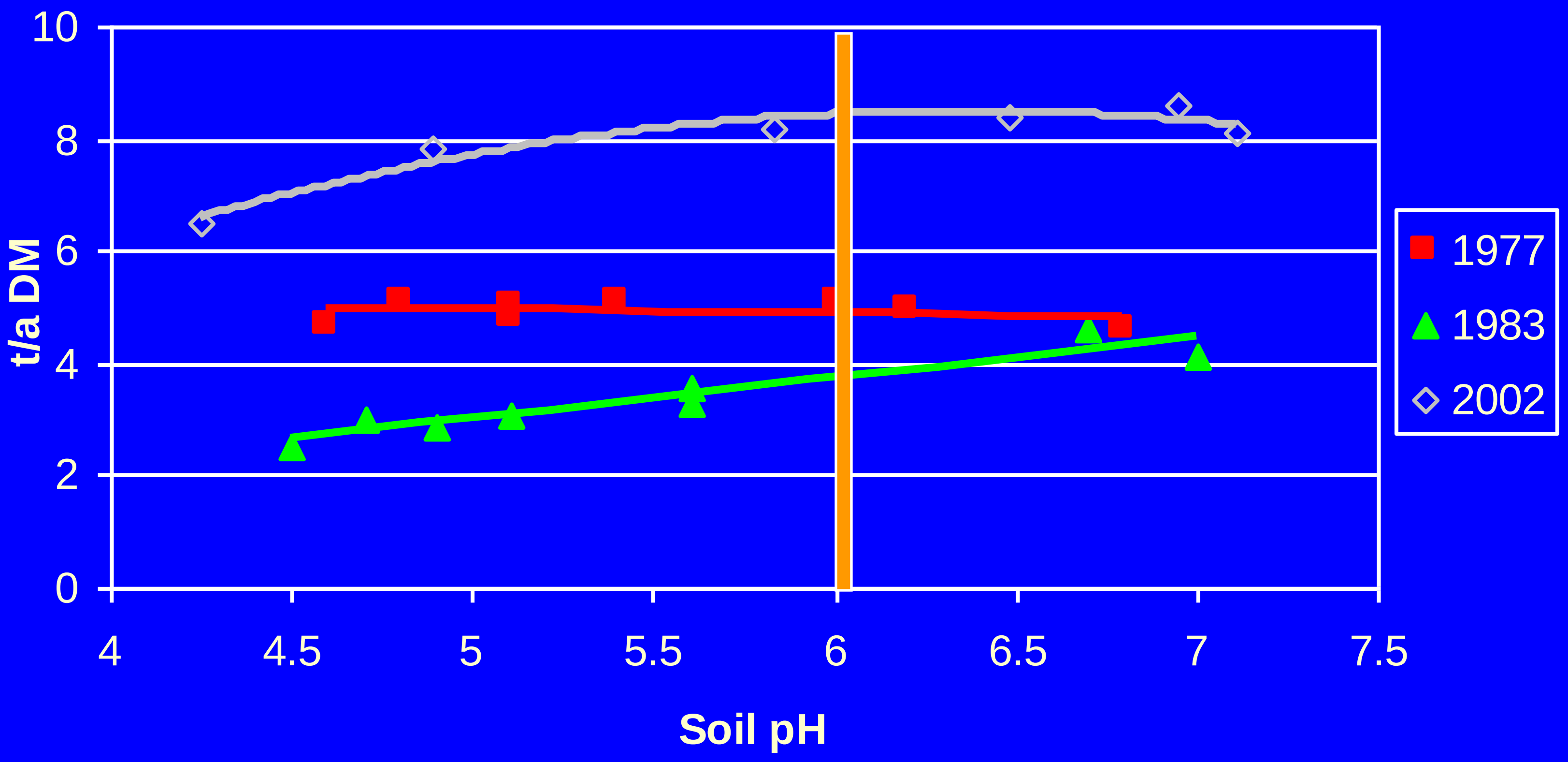
Date of silking as affected by pH



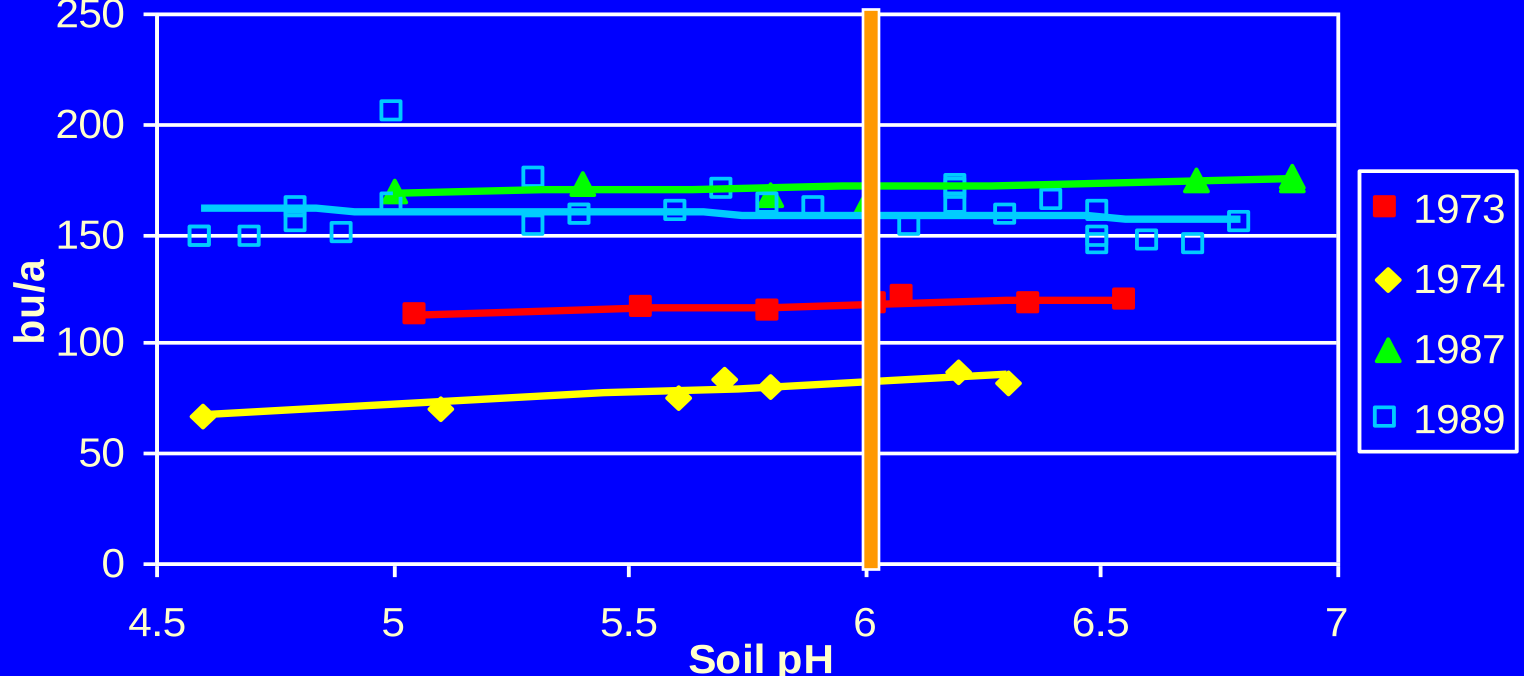
Marshfield Grain



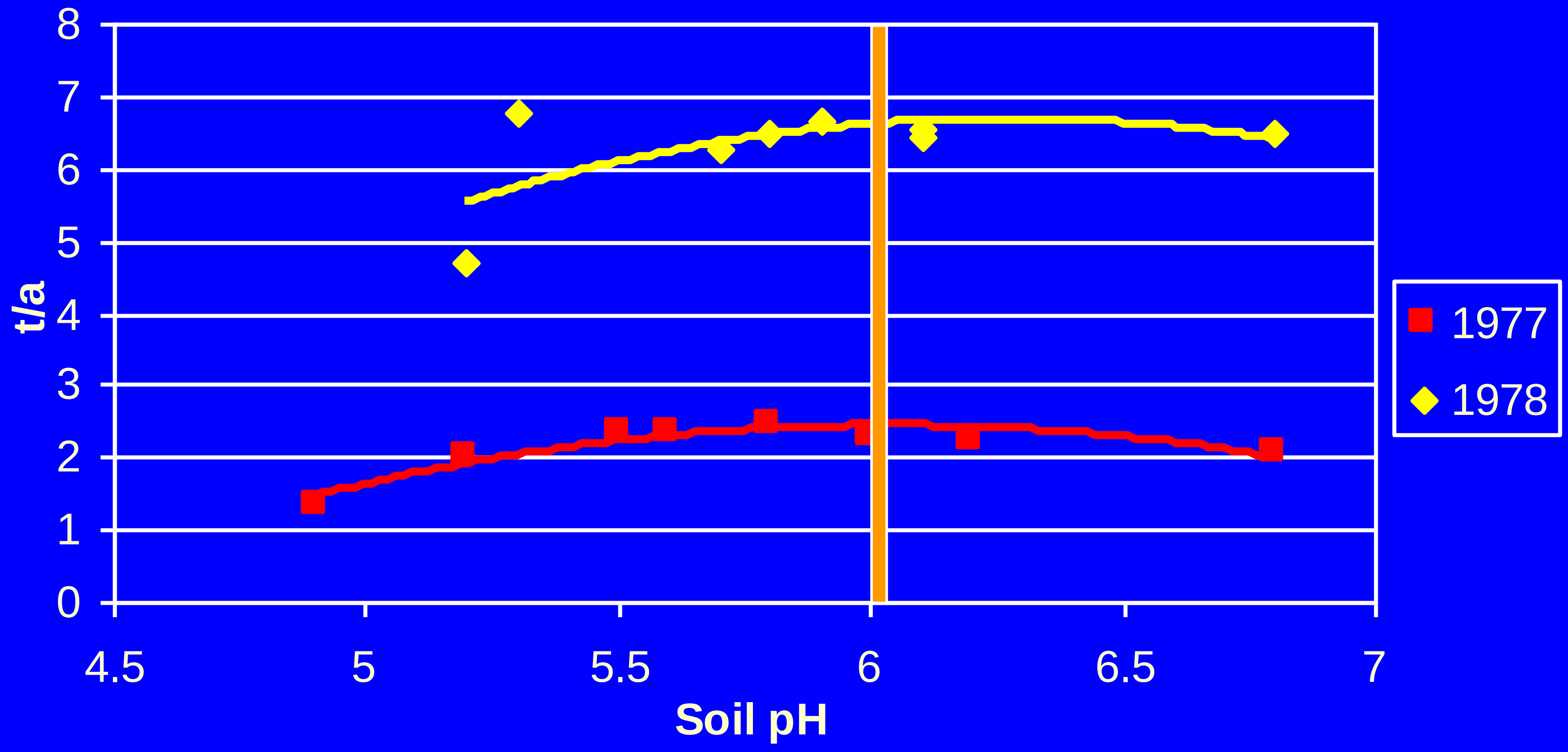
Marshfield Silage



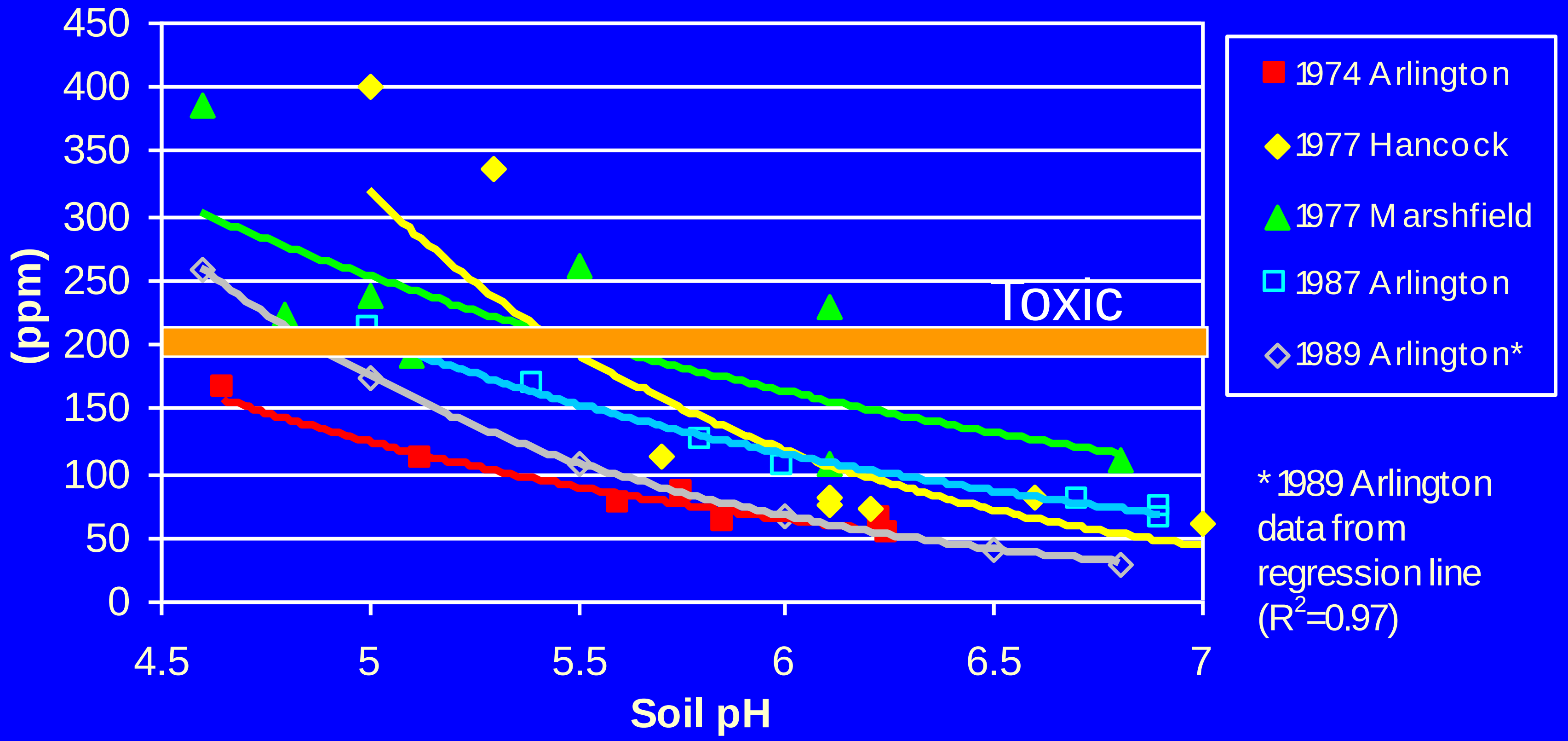
Arlington Grain



Hancock Sweet Corn



Earleaf Mn content at silking

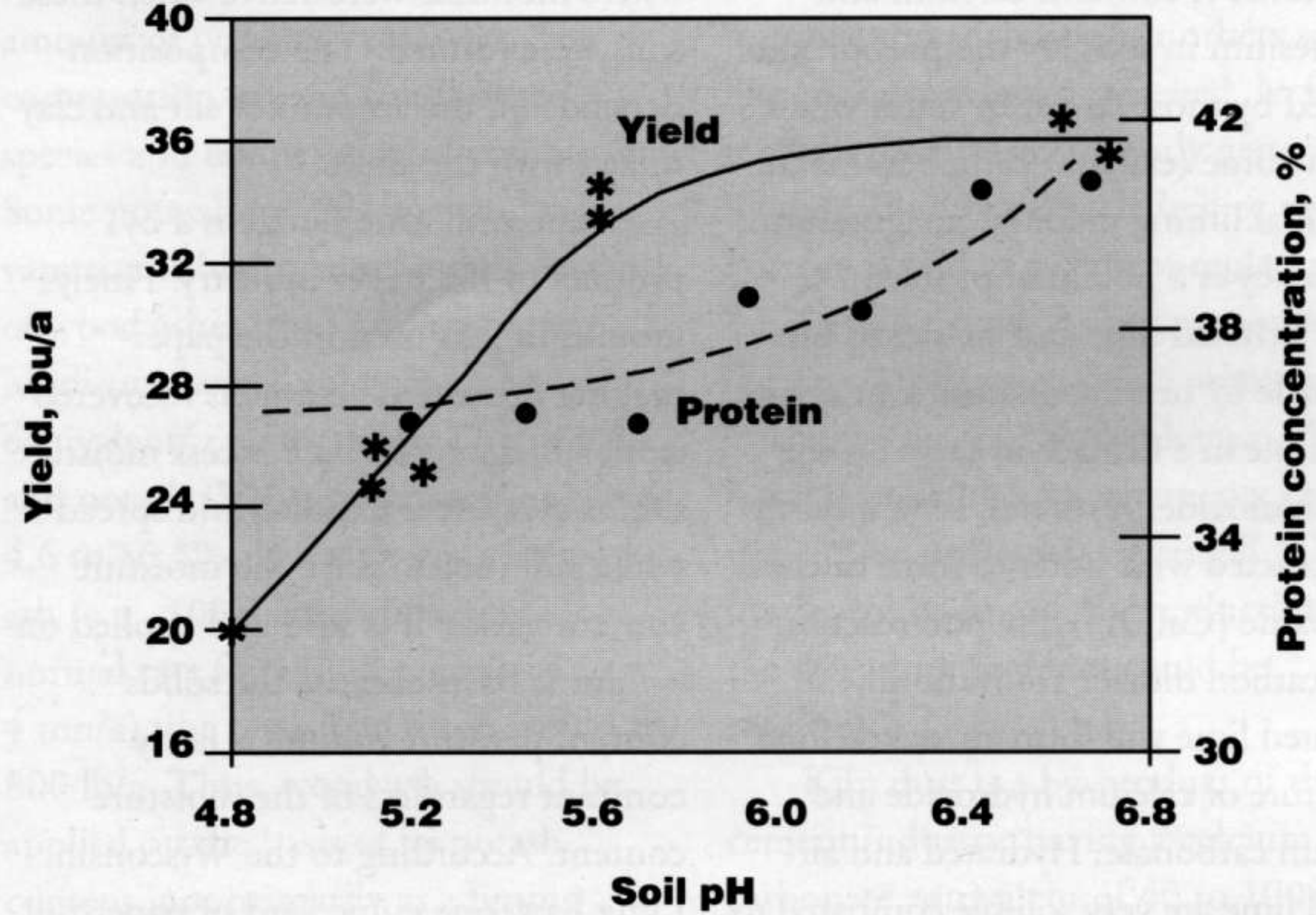


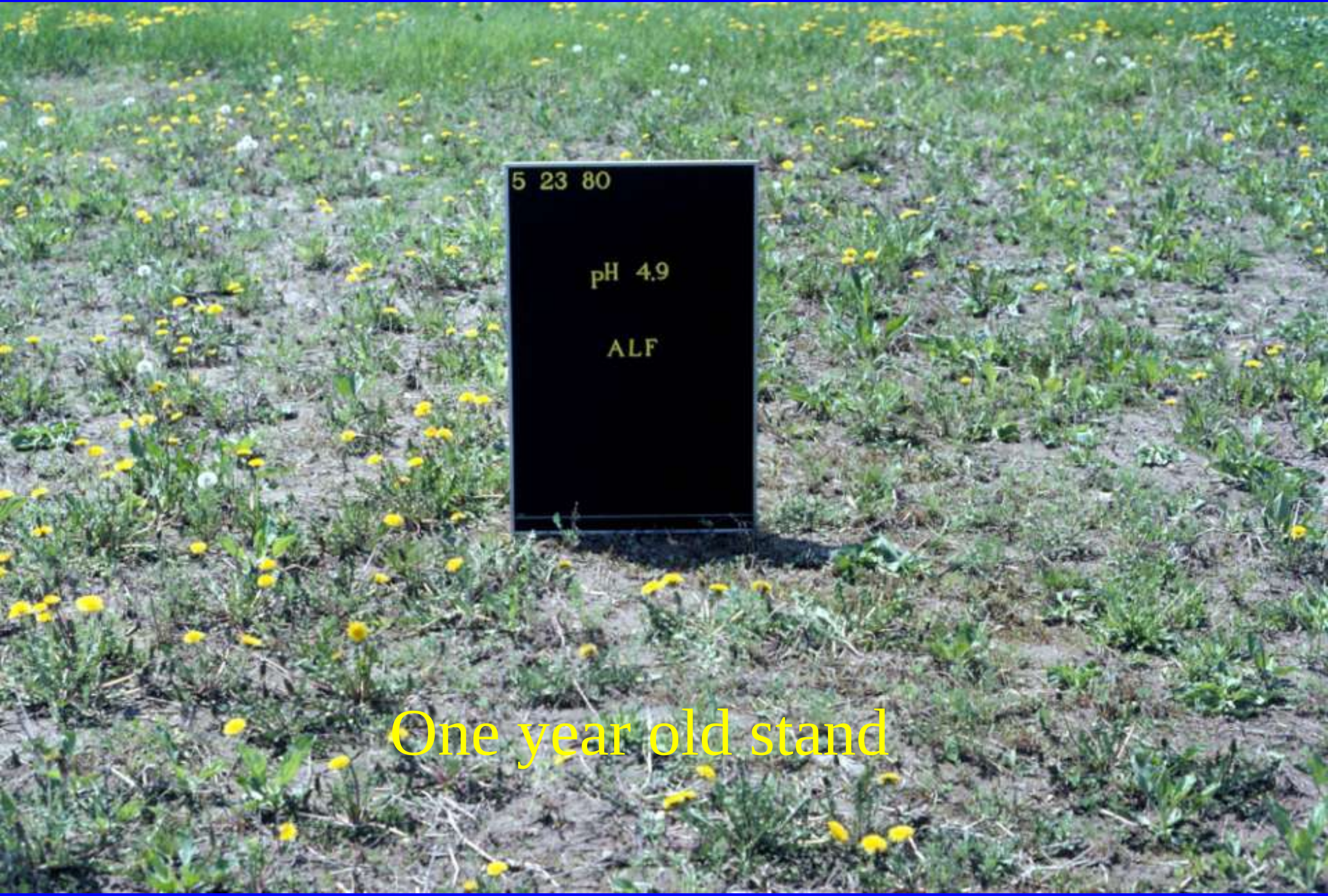
Summary of corn response to liming

- Central and northern silt loam and sandy loam soils show little yield benefit to liming above pH 6.5
- Influence on maturity may be a factor on somewhat poorly drained soils
- Little response seen on the sandy soils or the southern silt loams– Mn toxicity is less of a concern on these soils

Soil pH Effect on Soybeans

Figure 6-6. Effect of soil pH on soybean yield and protein (Marshfield, WI). *Source: Gritton et al., 1985. Proc. 1985. Fert., Aglime & Pest Mgmt. Conf. 24:43–48.*

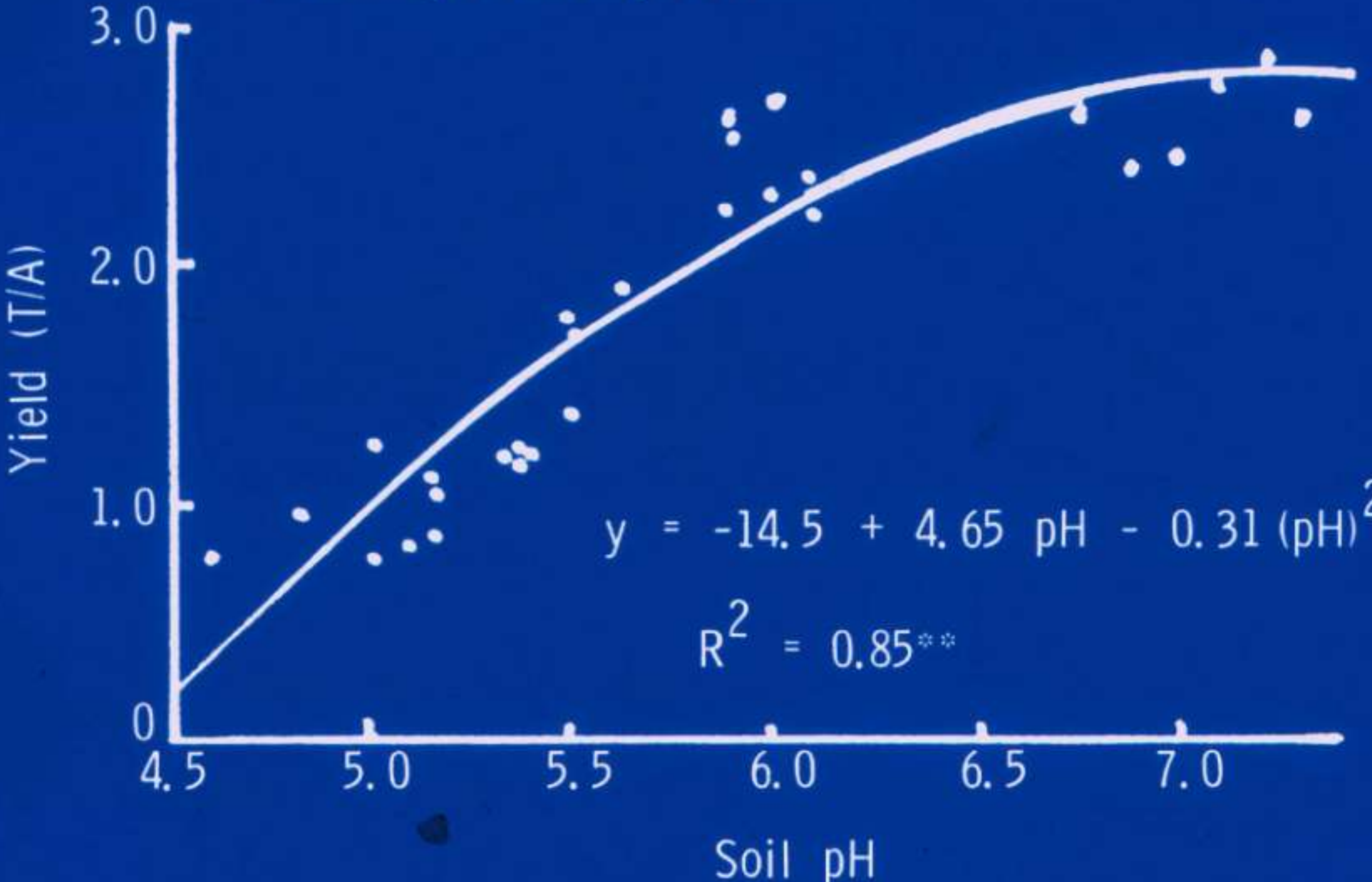




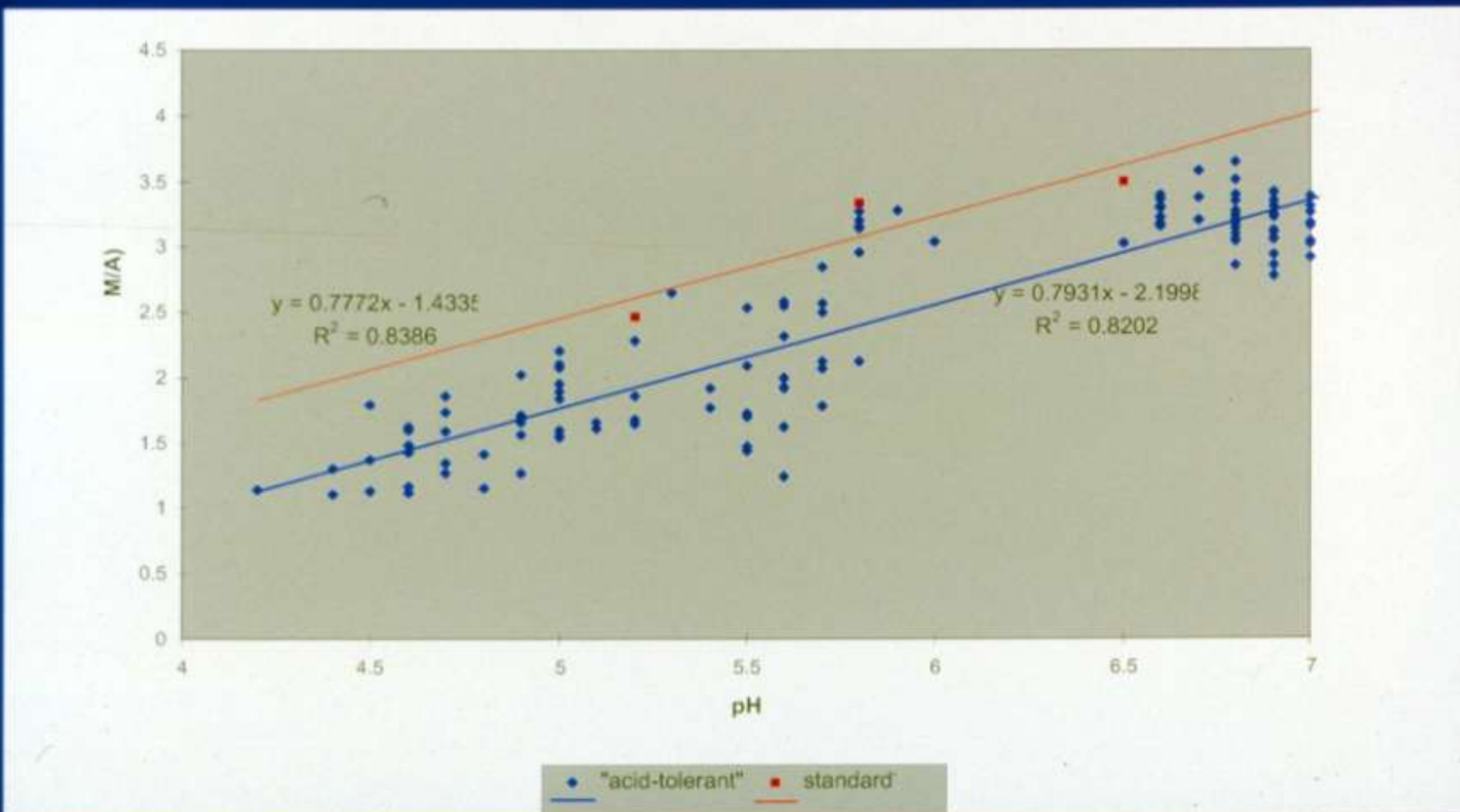
One year old stand

One year old stand

Effect of soil pH on avg. alfalfa yields at Marshfield (avg. of 1980-1981; sum of 2 cuttings each year).

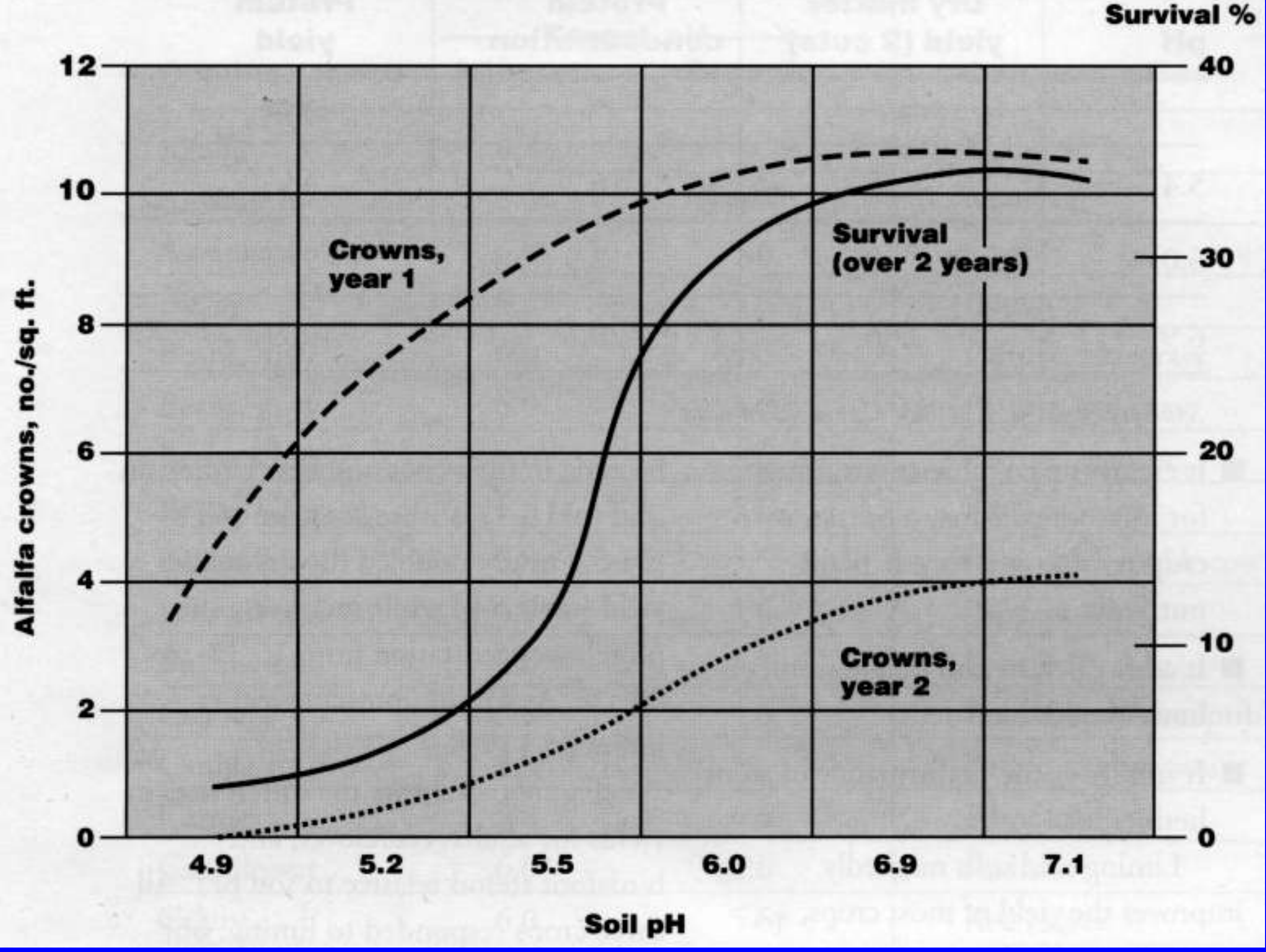


Yield of "acid tolerant" vs. standard varieties, second year after establishment, Spooner.



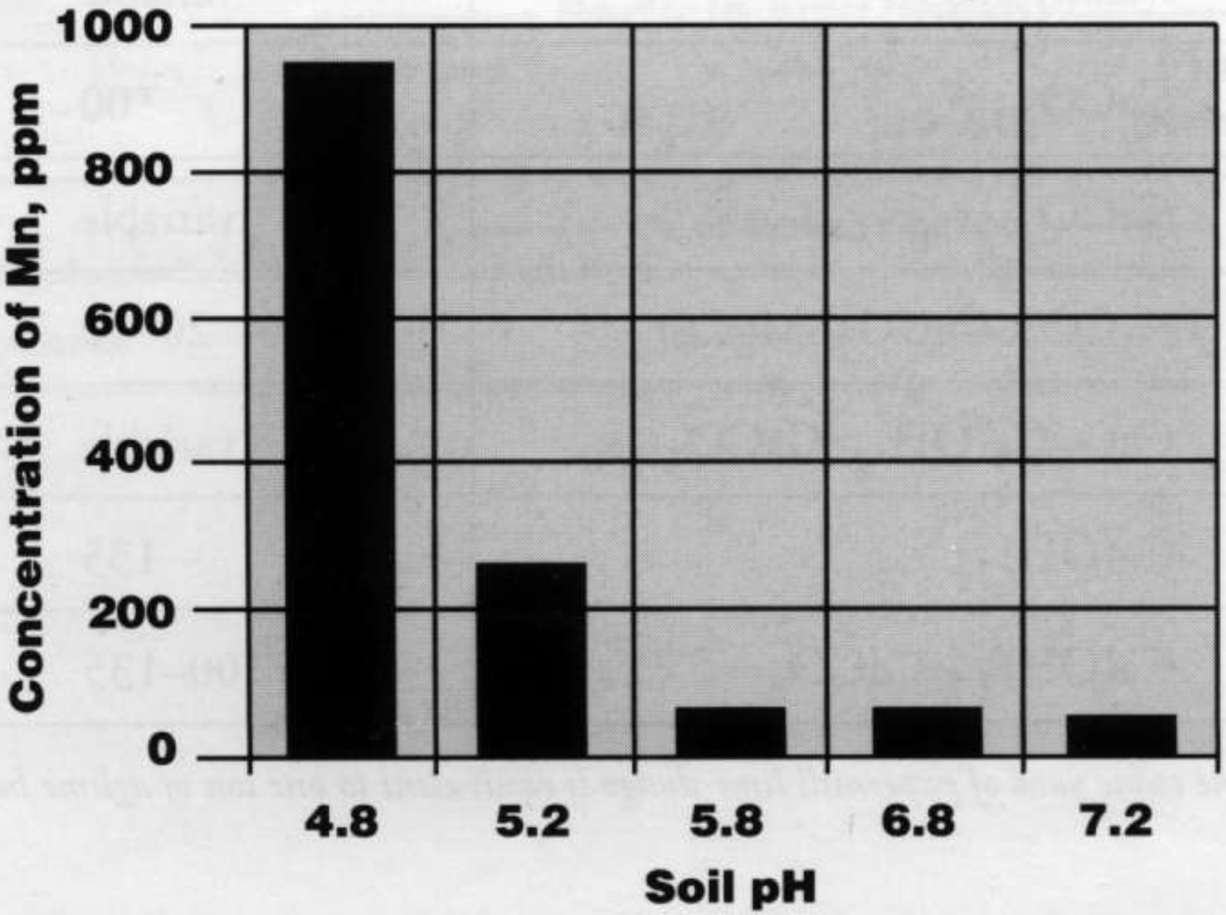
pH Influence on Alfalfa Stand

Figure 6-4. Effect of soil pH on establishment and persistence of alfalfa in Withee silt loam (Marshfield, WI). *Adapted from Proc. 1981 Fert., Aglime & Pest Mgmt Conf. 20:77–85*



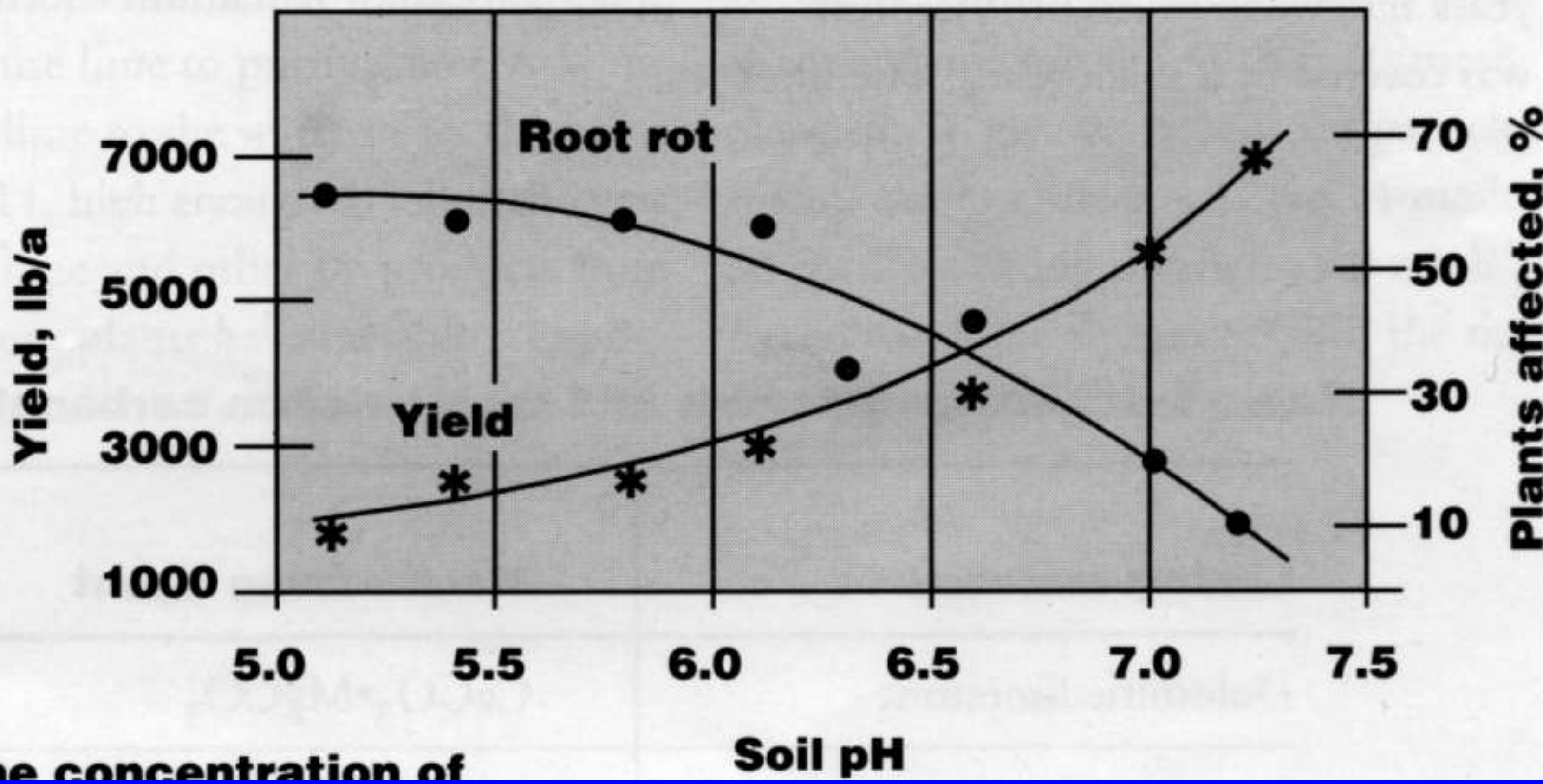
Mn toxicity at low pH levels

Figure 6-8. The influence of soil pH on the concentration of manganese in alfalfa tissue (Marshfield, WI). *Source: Schulte, E.E. 1982. Unpublished data.*



Soil pH influence on root rot of Snapbeans

Figure 6-7. Relationship between soil pH, snapbean yield, and root rot (Hancock, WI). *Source: Schulte, E.E. 1987. Proc. Processing Crops Conf. Dept. of Hort., UW-Madison.*

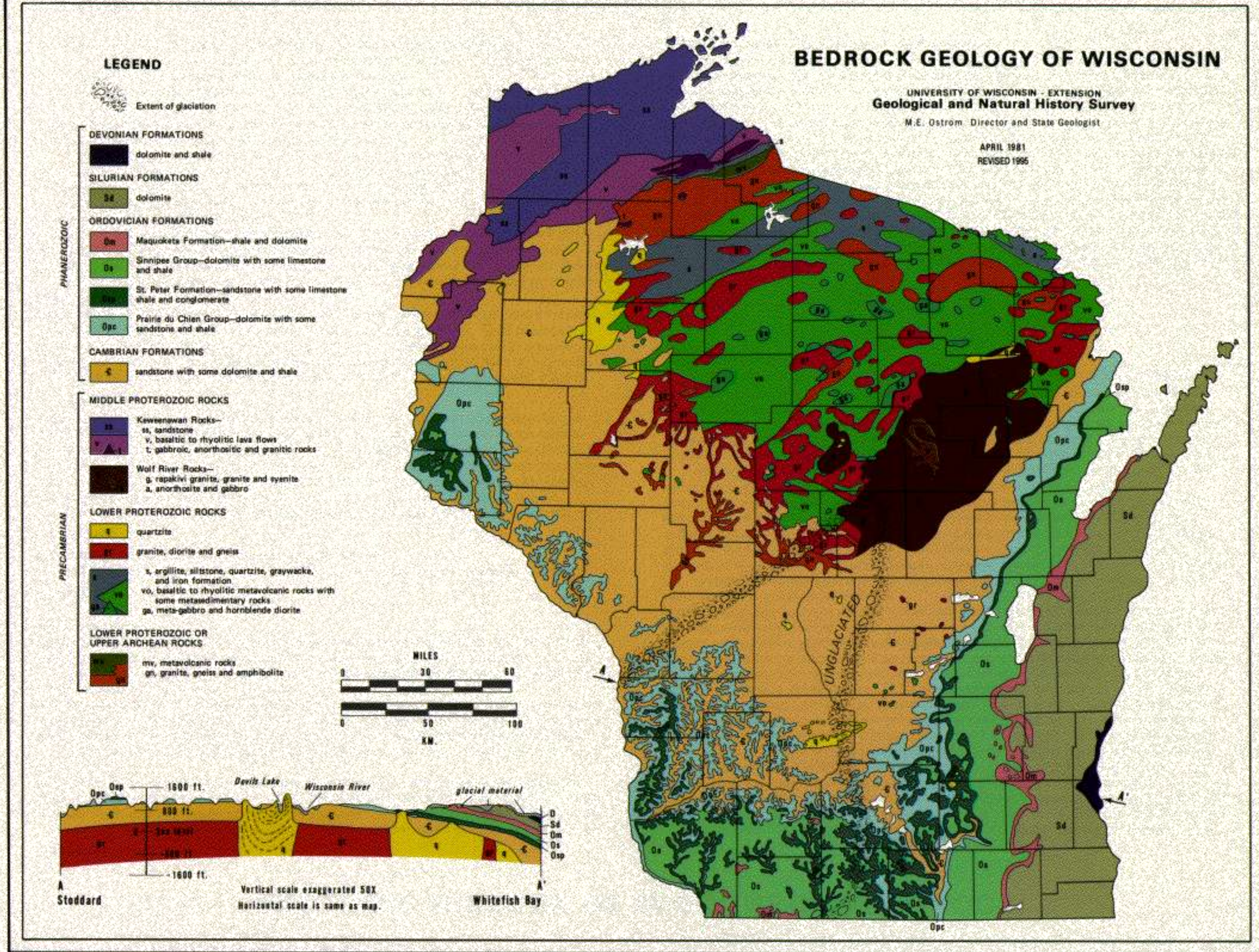


he concentration of

How does the soil become acid?

Causes of soil acidification

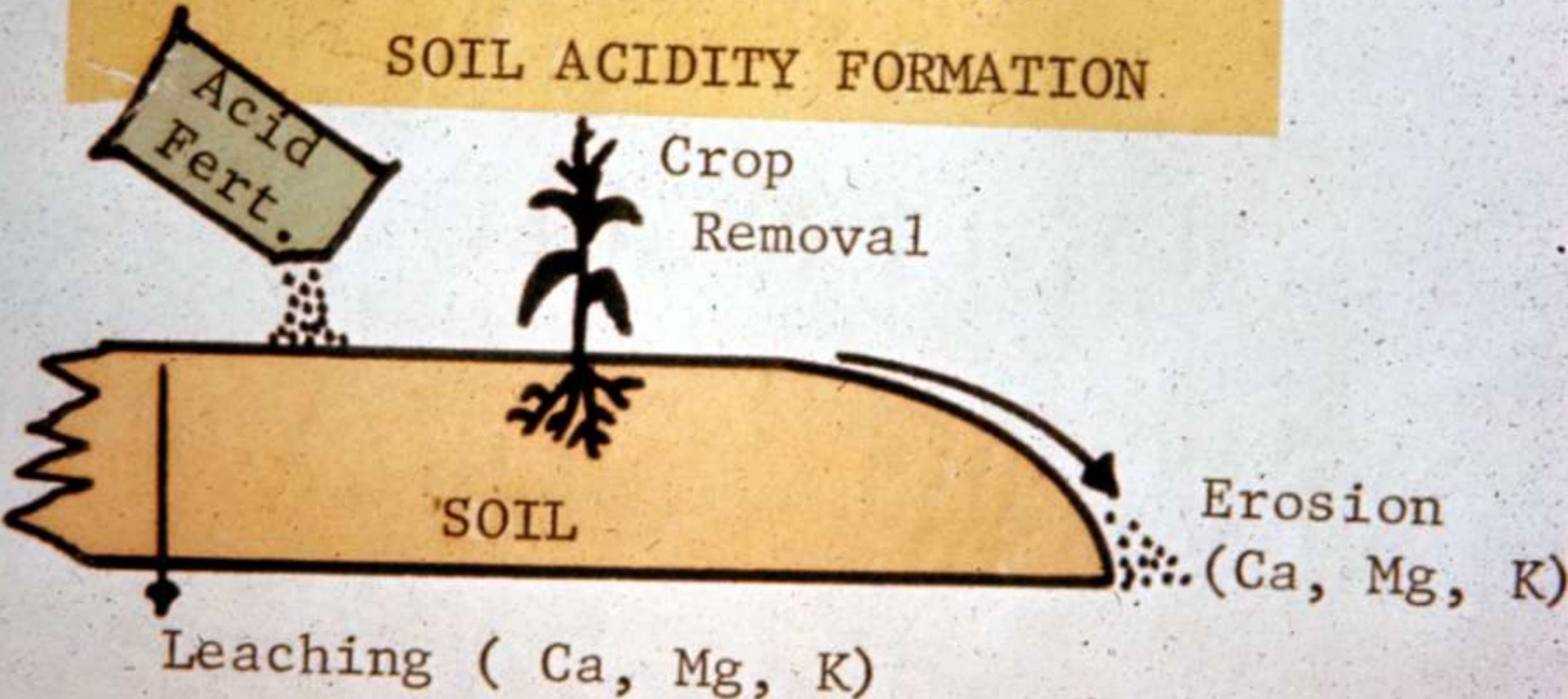
- Acidic parent material


BEDROCK GEOLOGY OF WISCONSIN
UNIVERSITY OF WISCONSIN - EXTENSION
Geological and Natural History Survey
M.E. Ostrom Director and State Geologist
APRIL 1981
REVISED 1995
LEGEND
Extent of glaciation
PHANEROZOIC
DEVONIAN FORMATIONS
dolomite and shale
SILURIAN FORMATIONS
Sd dolomite
ORDOVICIAN FORMATIONS
Om Maquoketa Formation—shale and dolomite
Os Sinnipee Group—dolomite with some limestone and shale
Osp St. Peter Formation—sandstone with some limestone shale and conglomerate
Opc Prairie du Chien Group—dolomite with some sandstone and shale
CAMBRIAN FORMATIONS
€ sandstone with some dolomite and shale
PRECAMBRIAN
MIDDLE PROTEROZOIC ROCKS
Keweenawan Rocks—
ss, sandstone
v, basaltic to rhyolitic lava flows
t, gabbroic, anorthositic and granitic rocks
Wolf River Rocks—
g, rapakivi granite, granite and syenite
a, anorthosite and gabbro
LOWER PROTEROZOIC ROCKS
q quartzite
gr granite, diorite and gneiss
s, argillite, siltstone, quartzite, graywacke, and iron formation
vo, basaltic to rhyolitic metavolcanic rocks with some metasedimentary rocks
ga, meta-gabbro and hornblende diorite
LOWER PROTEROZOIC OR UPPER ARCHEAN ROCKS
mv, metavolcanic rocks
gn, granite, gneiss and amphibolite
MILES
0 30 60
0 50 100
KM.
UNGLACIATED
A
A'
Opc
Os
Sd
Om
Osp
1600 ft.
800 ft.
Sea level
-800 ft.
-1600 ft.
Devils Lake
Wisconsin River
glacial material
D
A
Stoddard
A'
Whitefish Bay
Vertical scale exaggerated 50X
Horizontal scale is same as map.

Causes of soil acidification

- Acidic parent material
- Leaching of basic cations
- Crop removal of cations

FACTORS AFFECTING SOIL ACIDITY FORMATION



-U.T. Ext. Agron. Dept.-

Aglime required to replace basic cations in several crops

Crop	Yield	Aglime Required
Corn grain	150 bu/a	25 lb/a
Corn silage	8 ton/a	250 lb/a
Soybean	45 bu/a	125 lb/a
Alfalfa	4 ton/a	685 lb/a

E.E. Schulte and L.M. Walsh. Management of Wisconsin Soils.

Causes of soil acidification

- Acidic parent material
- Leaching of basic cations
- Crop removal of cations
- Use of Nitrogen fertilizers

Acid forming fertilizers

- $2NH_4 + 4O_2 \rightarrow 2NO_3 + 2H_2O + 4H^+$

Aglime required to neutralize acid forming N fertilizers

Nitrogen source	Pounds of aglime needed per pound of Nitrogen[1]
Ammonium sulfate	7.5
Diammonium phosphate	7.5
Anhydrous ammonia	5
Urea	5
Solutions (28% - 41% N)	4
Ammonium nitrate	4

[1]Approximation

Table 3. Effect of nitrogen on soil pH.

Nitrogen Application (lbs/acre/year)*	Soil pH
0	6.1
40	6.1
80	6.0
120	6.0
160	5.8
200	5.7

* Nitrogen application occurred each year for 5 years.

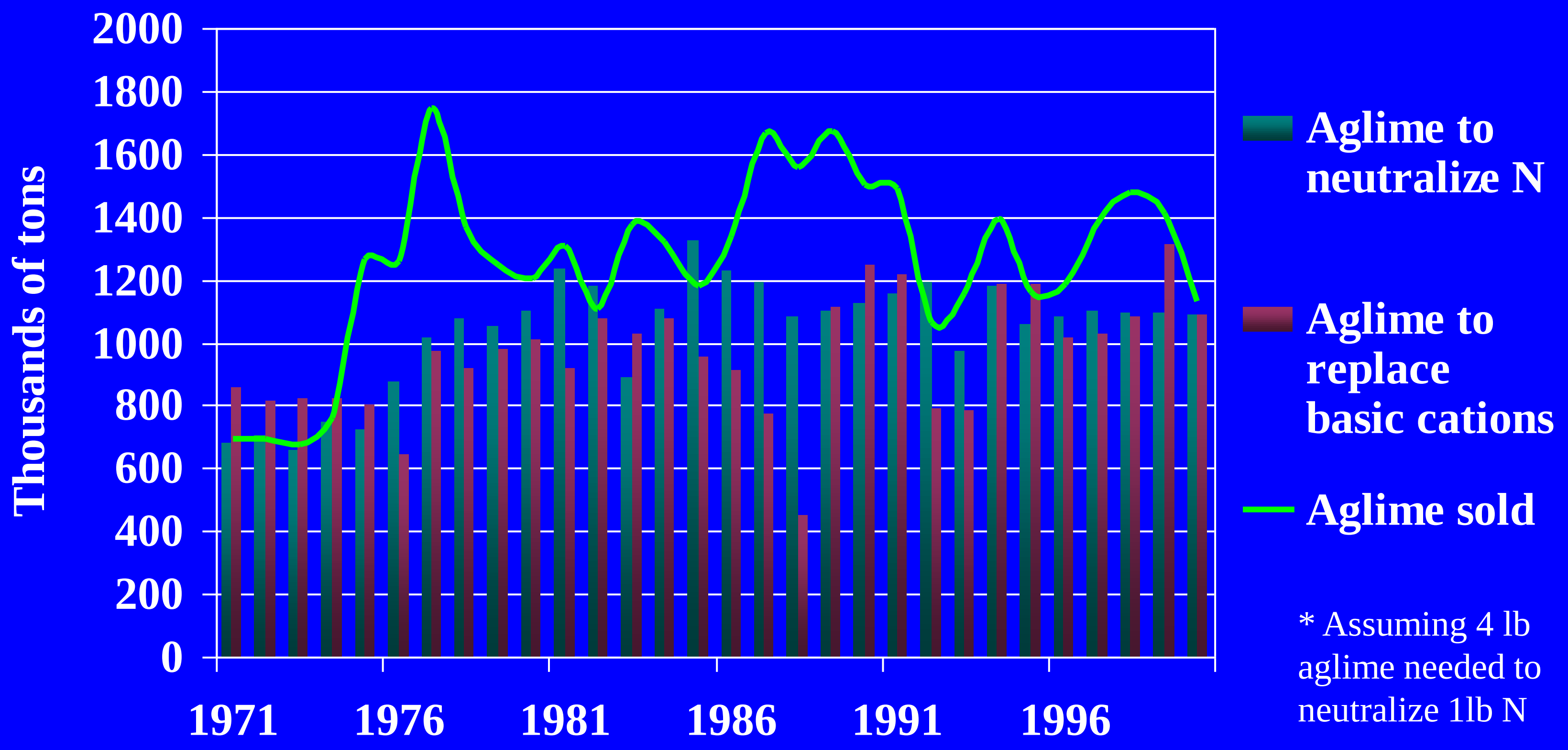
Table 4. Aglime balance in Wisconsin

Year	Aglime required to Neutralize N*	Aglime required to replace basic cations removed annually**	Aglime Sold
	------------------------------	Thousand tons	------------------------------
1982	1,180	1,194	1,109
1985	1,325	1,055	1,182
1990	1,124	895	1,504
1995	1,056	663	1,161

* 4 pounds aglime/lb N.

** Corn grain silage and alfalfa areas only

Aglime required for cation replacement and soil neutralizing*



* Assuming 4 lb aglime needed to neutralize 1lb N

Summary

- Annual lime sales are about equivalent in neutralizing power to acidity inputs from manure and fertilizer N
- Annual lime additions are keeping up with crop removal of basic cations

Causes of Soil Acidification

- Acidic parent material
- Leaching of basic cations
- Crop removal of cations
- Use of nitrogen fertilizers
- Other- Acid rain, industrial emissions internal combustion engines, etc.

Summary of factors in determining lime needs for a soil

- Soil texture
- Parent material
- Agricultural factors - soil pH decline
  - N fertilizer and manure
  - Crop removal and leaching of bases
  - Cropping and management practices

Is all lime the same?

Choosing Between Liming Materials

- Consider the cost per acre to achieve the desired pH
  - The cheapest product may not be the best choice
  - Need to know the NI and cost per ton (spread) of the material

Choosing Between Liming Materials

- Example
  - 4 tons of 60-69 NI material at $13/ton results in a cost per acre of $52
  - 3 tons of 80-89 NI material at $16/ton results in a cost per acre of $48
  - The cheaper product may not always be the best buy

What is Ca:Mg ratio?

$$\frac{\text{Ca level}}{\text{Mg level}}$$

Origin of "low" Ca:Mg ratios

1. $\frac{\text{low Ca}}{\text{normal Mg}}$

2. $\frac{\text{normal Ca}}{\text{high Mg}}$

3. $\frac{\text{very low Ca}}{\text{low Mg}}$

Moser (1933) examined 8 NY soils

- No relationship between Ca:Mg and yield (barley, red clover, corn, timothy)
- Significant factor was exchangeable Ca levels

Hunter (1949) varied soil Ca:Mg from 1:4 to 32:1

- No effect on alfalfa yield
- No effect on lignin content
- High Mg increased P uptake
- High Ca increased Ca uptake and decreased Mg and K uptake
- Sum of cations remained constant

Bear et al., 1945 examined 20 NJ ag. soils

Concluded “ideal” soil exchange sites

- 65% Ca
- 10% Mg
- 5% K
- 20% H

W.A. Albrecht and students -- Several papers from 1937-1947

- No alfalfa nodules at pH 5.5 unless added Ca
- Adding Ca increased number more than raising pH
- N fixation affected by nutrients, not pH
- High yields increased when Ca variable

Artificial media

Few or no statistics

Claims for Creating High Soil Ca:Mg Ratios

- Improves soil structure
- Reduces weed populations
- Stimulates populations of earthworms and beneficial microorganisms
- Improves forage quality
- Excess soil Mg "ties up" and promotes leaching of other plant nutrients
- Better "balance" of soil nutrients
- Improved plant and animal health
- "Cows milk easier"

Ratio of exchangeable calcium to exchangeable magnesium in some Wisconsin soils

Soil	Ca:Mg ratio	Soil	Ca: Mg ratio
Antigo	4.0:1	Norden	8.1:1
Boone	1.0:1	Ontonagon	4.0:1
Dubuque	4.0:1	Pella	3.9:1
Fayette	6.3:1	Plainfield	6.1:1
Kewanee	3.1:1	Plano	3.3:1
Marathon	7.7:1	Withee	3.5:1

Ratio is expressed on pounds per acre exchangeable basis

Simson et al (1979) studies

- pH 6.8
- Theresa sil and Plainfield ls
- Added 0 - 7,700 lb/a gypsum or 0 - 15,400 lb/a Epsom salts
- Ca 425 - 1025 ppm
- Mg 120 - 195 ppm
- Ca:Mg 2.4 - 8.2

Effect of varying Ca:Mg ratios on alfalfa yield and plant nutrient levels

Soil	Theresa sil		Plainfield ls	
Ca:Mg	Plant Ca:Mg	Yield	Plant Ca:Mg	Yield
		T/a		T/a
2.4	2.15	3.31	2.48	4.14
3.4	2.36	3.31	3.32	4.35
4.8	2.87	3.40	3.35	4.12
8.2	3.29	3.22	3.64	4.35

selected data from Simson et al (1979)

Why no response to Ca:Mg inbalance

- Ca and Mg levels are relatively high in soil solution compared to plant uptake
- Plant K uptake is 2-4 times that of Ca and Mg
- Ca and Mg are supplied to roots by mass flow

Reid (1996) used 4 liming materials to create Ca:Mg ratios from 267:1 to 1:1

- 5 lime rates (0 to 15 T/a)
- all interactions
- planted to alfalfa and birdsfoot trefoil

Effect of lime rate and Ca:Mg ratios on total alfalfa or trefoil yields (1975-1979)

Ca:Mg Ratio	Lime Rate			Lime Rate		
	0	6 T/a	15 T/a	0	6 T/a	15 T/a
	----Alfalfa Yield (T/a)----			----Trefoil Yield (T/a)----		
1:1	1.2	11.2	11.9	4.2	8.4	9.3
3:1	1.2	10.9	12.2	4.4	7.9	9.4
10:1	0.9	11.1	11.0	3.9	8.0	8.9
19:1	1.0	11.7	12.0	4.3	7.8	8.9
41:1	1.2	11.5	11.6	3.3	7.5	8.9
267:1	2.9	11.1	11.2	3.8	8.2	8.6

W.S. Reid (1996), Cornell

Recent Wisconsin Experiments

- 3 locations (River Falls, Pine Bluff, Marshfield)
- Added gypsum, Epsom salts, dolomitic lime, calcitic lime or pelletized calcitic lime to achieve various soil pH and Ca:Mg ratios
- At Marshfield and River Falls superimposed annual gypsum and Epsom salts treatments
- Grew corn followed by alfalfa

Measured:

- Yields
- Forage quality
- Earth worms
- Alfalfa stand (weediness)
- Compaction

Relationship between selected soil test parameters and various experimental measures at Marshfield, 1993

Soil test parameter	Alfalfa yield	Alfalfa stand	Weeds	Alfalfa quality			Earthworms
				CP	ADF	NDF	
pH	**	NS	NS	*	NS	NS	NS
OM	**(-)	**(-)	*	*(-)	NS	NS	*
Exch Ca	NS	NS	NS	NS	NS	NS	NS
Exch Mg	NS	NS	NS	NS	NS	NS	NS
Exch K	**	**(-)	NS	NS	NS	NS	NS
Exch Ca+Mg+K	NS	NS	NS	NS	NS	NS	NS
Ca:Mg	NS	NS	NS	NS	NS	NS	NS

Schulte et al, 1995

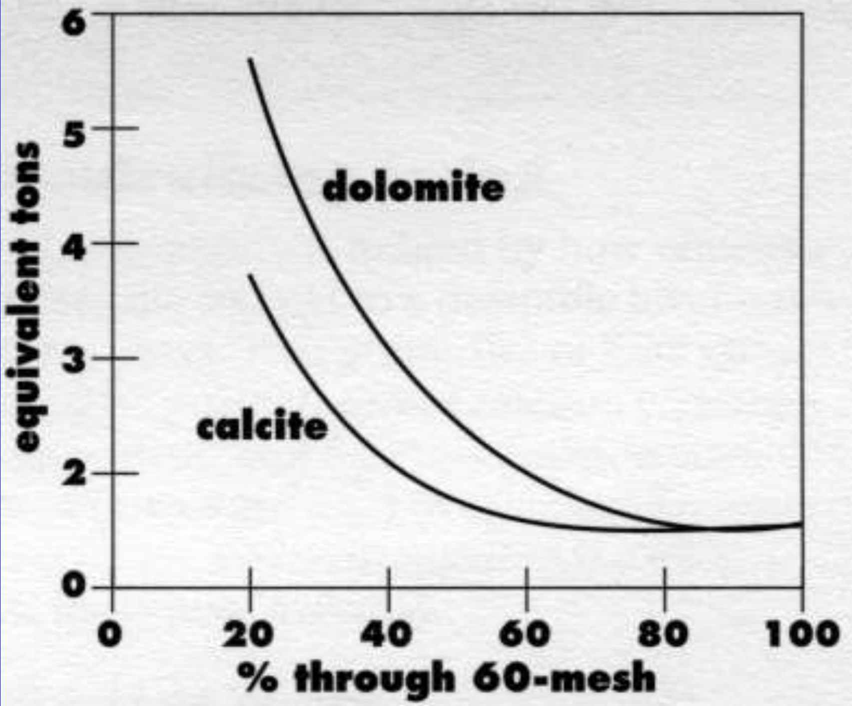
Relationship between selected soil test parameters and various experimental measures at River Falls, 1993

Soil test parameter	Alfalfa yield	Alfalfa stand	Weeds	Alfalfa quality			Earthworms
				CP	ADF	NDF	
pH	NS	**	*(-)	NS	NS	NS	NS
OM	NS	**(-)	NS	NS	NS	*(-)	NS
Exch Ca	NS	**(-)	NS	NS	NS	NS	NS
Exch Mg	NS	NS	NS	NS	NS	NS	NS
Exch K	NS	**(-)	NS	**	NS	NS	NS
Exch Ca+Mg+K	NS	**(-)	NS	NS	NS	NS	NS
Ca:Mg	NS	**(-)	NS	NS	NS	NS	NS

Schulte et al, 1995

Calcite vs. Dolomite

Figure 2. Influence of fineness of limestone on the relative effectiveness of calcitic and dolomitic limestone



Barber (1973). Reproduced with permission of the American Society of Agronomy, Inc.

Conclusions

- Alfalfa yield related to exchangeable K and soil pH, not Ca:Mg
- Neither Ca or Mg additions affected weeds
- Earthworms related to organic matter, not Ca:Mg
- Alfalfa quality related to pH and stand, not Ca:Mg
- No justification to use calcitic over dolomitic lime or adding extra Ca

NCR 103 Committee
NC Regional Publication 533
Soil Cation Ratios for Crop Production

Concerns

- Levels could be balanced but too low
- No field research to support concept

Concludes

"A sufficient supply of available cations is the most important consideration in making economic fertilizer recommendations"

Any questions?