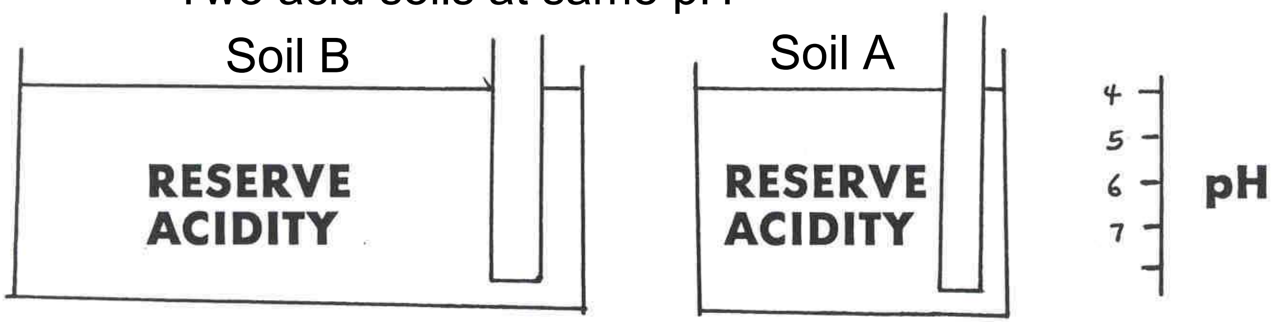
Buffering reprise

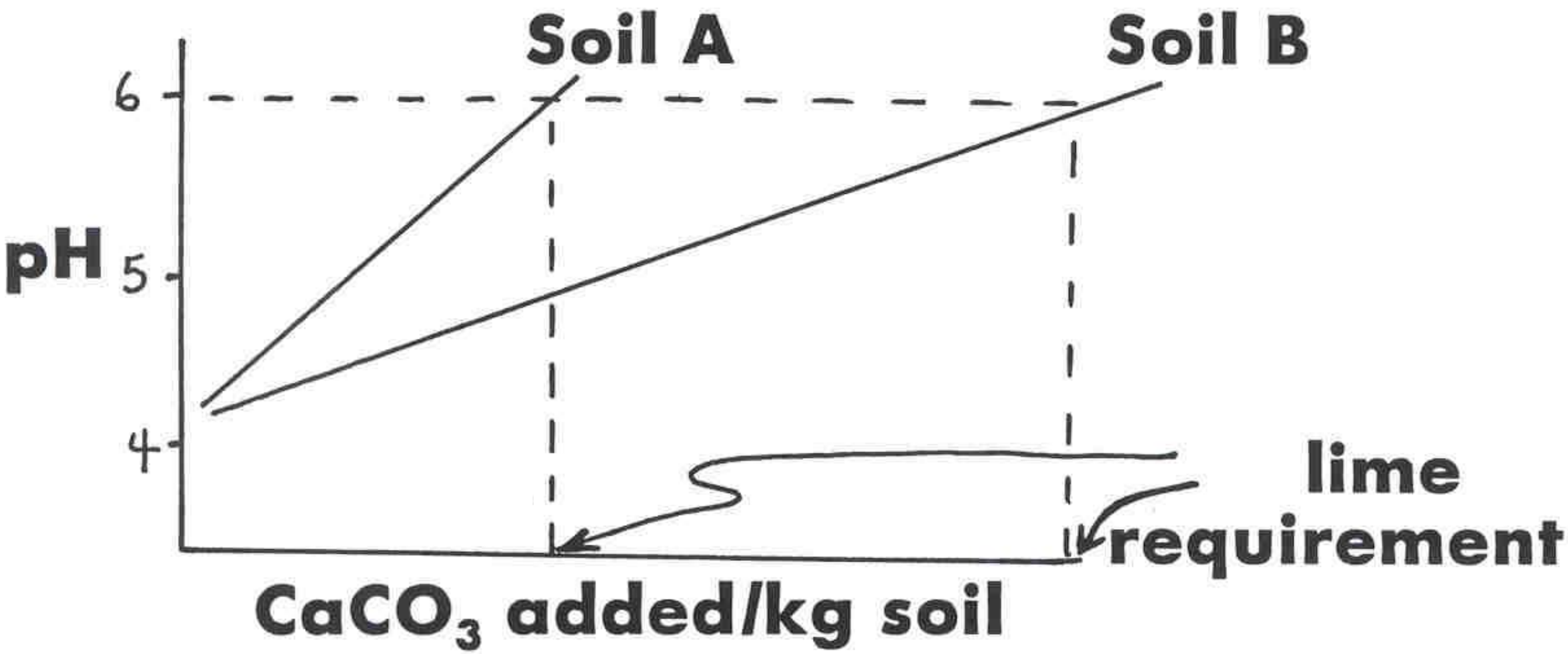
Two acid soils at same pH



WELL-BUFFERED

WEAKLY BUFFERED

BUFFER CAPACITY OF SOIL = capacity to release or neutralize Al, H
= amount of acid/base needed to bring about a specific shift in pH



Soil A
Soil B
6
pH
5
4
lime
requirement
$CaCO_3$ added/kg soil

While at high pH calcification acts as a buffering reaction to prevent high pH

At low pH it acts to raise the pH!

Liming Reaction

$$Ca^{2+} + 2(H^+ + HCO_3^-) \leftrightarrow 2H^+ + CaCO_3 + H_2O + CO_2$$

Remember all reactions are reversible

DIAGNOSIS OF LIME NEEDS

1. **LABORATORY -**

   Titrate soil to several pH values with lime. Interpolate lime requirement based on desired pH (usually 5-6).

2. **RULE OF THUMB**

   Based on soil texture, color (organic content)

Soil Texture	Amt. of Lime to Raise pH 4.5->5.5
Sand	1,000 kg/ha
Sandy loam	2,000
Clay loam	4,000
Organic soil (peat)	8,000

TABLE 9.4 Common Liming Materials: Their Composition and Use

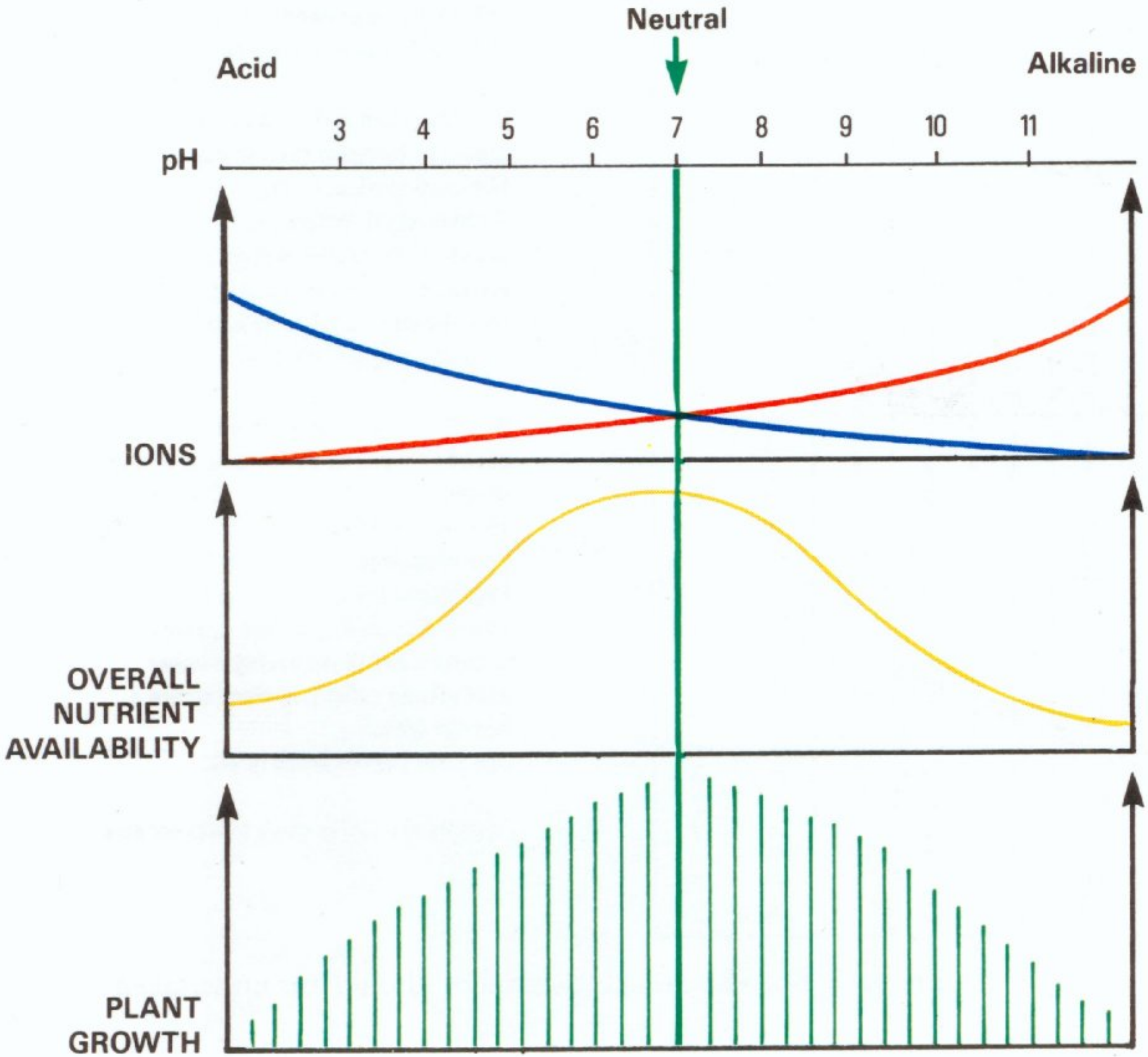
The two limestones are by far the most commonly used. Use of the other materials is largely dependent on the need for fast reaction, cost, and local availability. The relative amounts needed of the different materials can be judged by comparing the respective $CaCO_3$ equivalent values.

Common name of liming material	*Chemical formula (of pure materials)*	*% $CaCO_3$ equivalent*	*Comments on manufacture and use*
Calcitic limestone	$CaCO_3$	100	Natural rock ground to a fine powder. Low solubility; may be stored outdoors uncovered. Noncaustic, slow to react.
Dolomitic limestone	$CaMg(CO_3)_2$	95–108	Natural rock ground to a fine powder; somewhat slower reacting than calcitic limestone. Supplies Mg to plants.
Burned lime (oxide of lime)	CaO (+ MgO)[a]	178	Caustic, difficult to handle, fast acting, can burn foliage, expensive. Made by heating limestone. Protect from moisture.
Hydrated lime (hydroxide of lime)	$Ca(OH)_2$ (+ $Mg(OH)_2$)[a]	134	Even more caustic and more difficult to handle than CaO. Fast acting, can burn foliage, expensive. Made by slaking hot CaO with water. Protect from moisture.
Basic slag	$CaSiO_3$	70	By-product of pig-iron industry. Must be finely ground. Also contains 1–7%P.
Marl	$CaCO_3$	40–70	Usually mined from shallow coastal beds, dried, and ground before use. May be mixed with soil or peat.
Wood ashes	CaO, MgO, K_2O, $K(OH)$, etc.	40	Caustic, largely water-soluble, must be protected from water.
Misc. lime-containing by-products	Usually $CaCO_3$ with various impurities	20–100	Variable composition; test for toxic impurities.

[a] If made from dolomitic limestone.

Biological Effects of pH

- Plant Growth
- Nutrient Availability
- Deleterious Effects:
  - Aluminum Toxicity
  - Other Toxicities



Acidity in the soil is the result of a build up of positively charged hydrogen ions. This build up is registered on the logarithmic pH scale (blue).
The increase in calcium and/or magnesium ions as a result of liming is shown in red.

This has a definite effect on overall plant nutrient availability, the maximum availability to the plant being very near neutrality–pH7.

Plant growth follows very much the same pattern especially where a 'Lime Sensitive' crop is grown.

Plant Growth

DIRECT - foliage damage by acid precipitation (only in extreme cases)

- root damage by H^+ ions (only when $pH << 4$)

INDIRECT - usually more important

Al toxicity to root (stunting)
Ca deficiency to root & top
Mn toxicity to plant
(Mo deficiency)

TOLERANCE

- legumes are generally intolerant of acidity

- maize is fairly tolerant

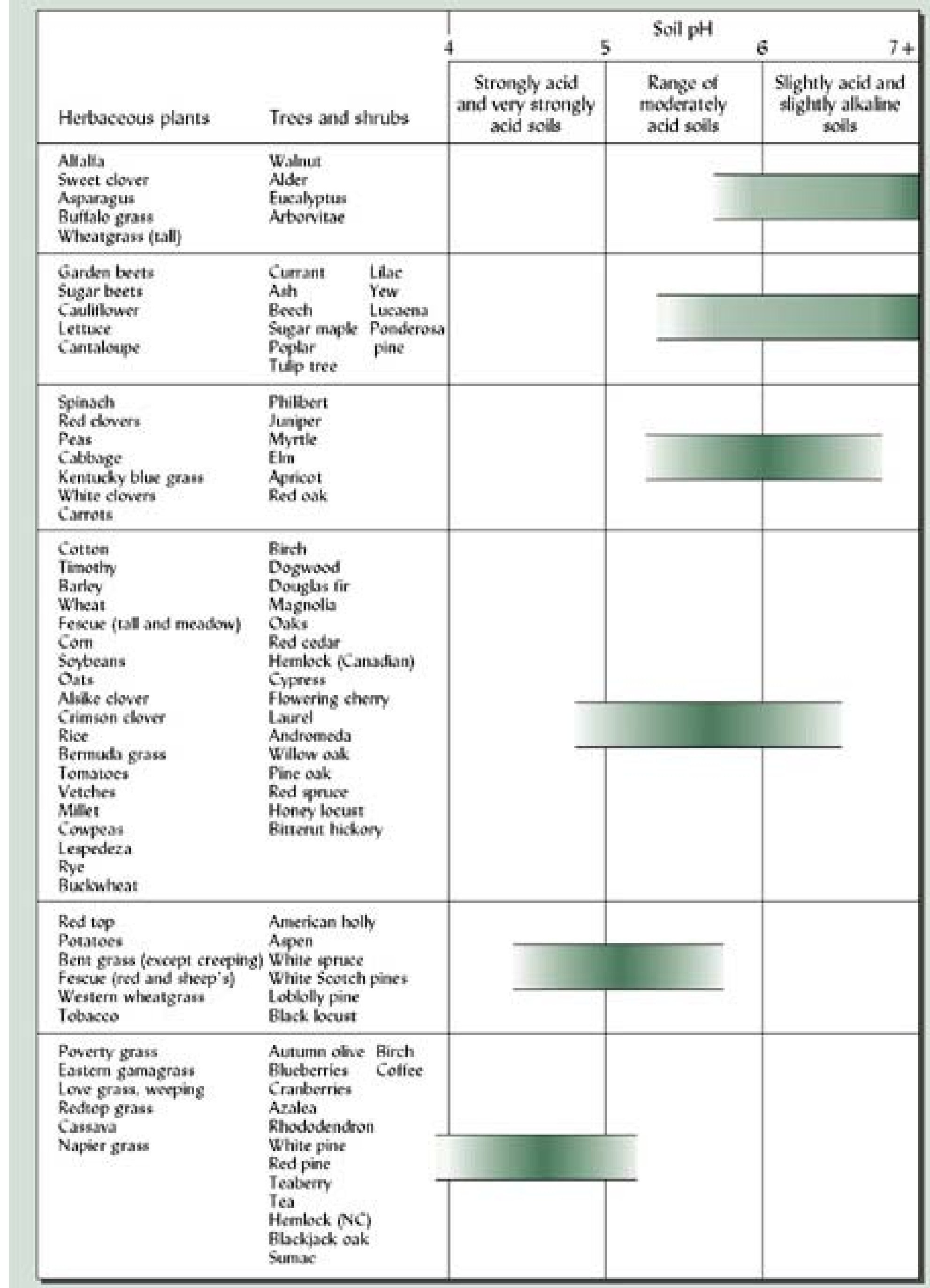
Plants vary considerably in their optimum pH growth range

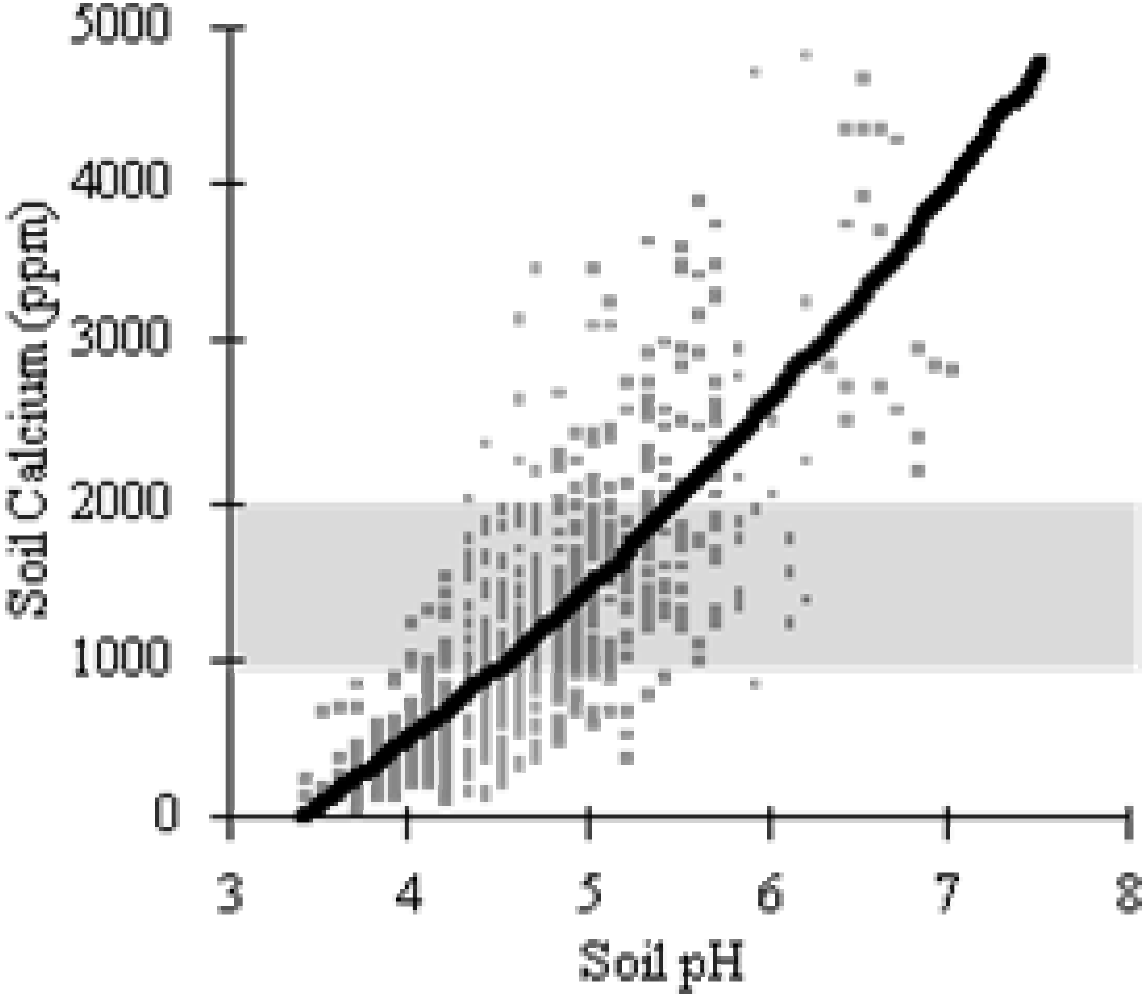
These ranges appear to be based on sensitivity to Al and their requirement for Ca

Species with high Ca nutrient needs require high pH's where more Ca is available

Species that have optimum ranges in the lower pH's, are typically forest species from humid regions and have developed tolerance for high [Al] and often require higher [Fe] which is more available at low pHs

Most cultivated crops grow well in soils with a slight acidity (5.5 to 7)





5000
4000
3000
2000
1000
0
Soil Calcium (ppm)
3
4
5
6
7
8
Soil pH

TABLE 9.3 Acid Soil Tolerance of Forest Plant Species as Suggested by Their Root Elongation Response to the Addition of Calcium Oxide to an Extremely Acid Soil

The soil, a Dystrudept in Pennsylvania, had an initial pH of 3.8 and a ratio of available Ca/Al of 0.24, a condition expected to induce aluminum toxicity even in many forest species. Adding 1 g of CaO to 180g of this soil raised the pH to 6.8 and the Ca/Al ratio to 15.5. Note that root growth in some species was reduced by the CaO addition, suggesting that the treated soil was overlimed with respect to the requirement of those acid-loving species.

Positive response to CaO (Al-sensitive)		*Negative or no response to CaO*	
Plant species	*Root response to CaO addition, %*	*Plant species*	*Root response to CaO addition, %*
Honey locust	+17	Black locust	0
White spruce	+40	Mountain laurel	−15
Grey dogwood	+41	Blueberry	−21
Red cedar	+46	Norway spruce	−31
Bitternut hickory	+52	Black birch	−47
Quaking aspen	+83	Chestnut oak	−52
Pin oak	+104	White pine	−53
Sugar maple	+150	Teaberry	−68

Data selected from Demchik, et al. (1999a).

Nutrient Availability

At low pH's (high acidity) the availability of macronutrients is limited.

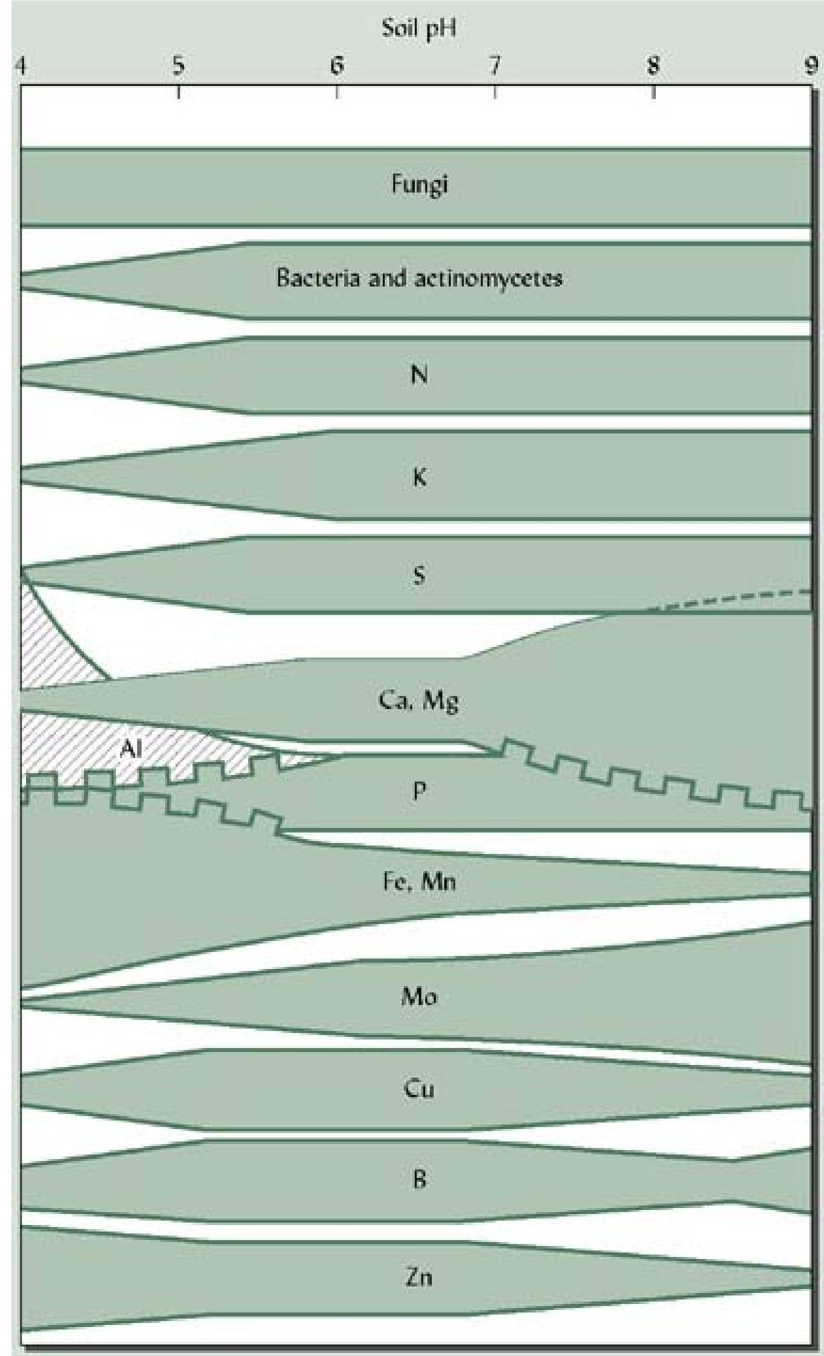
(Ca, Mg, K, P, N, and S)

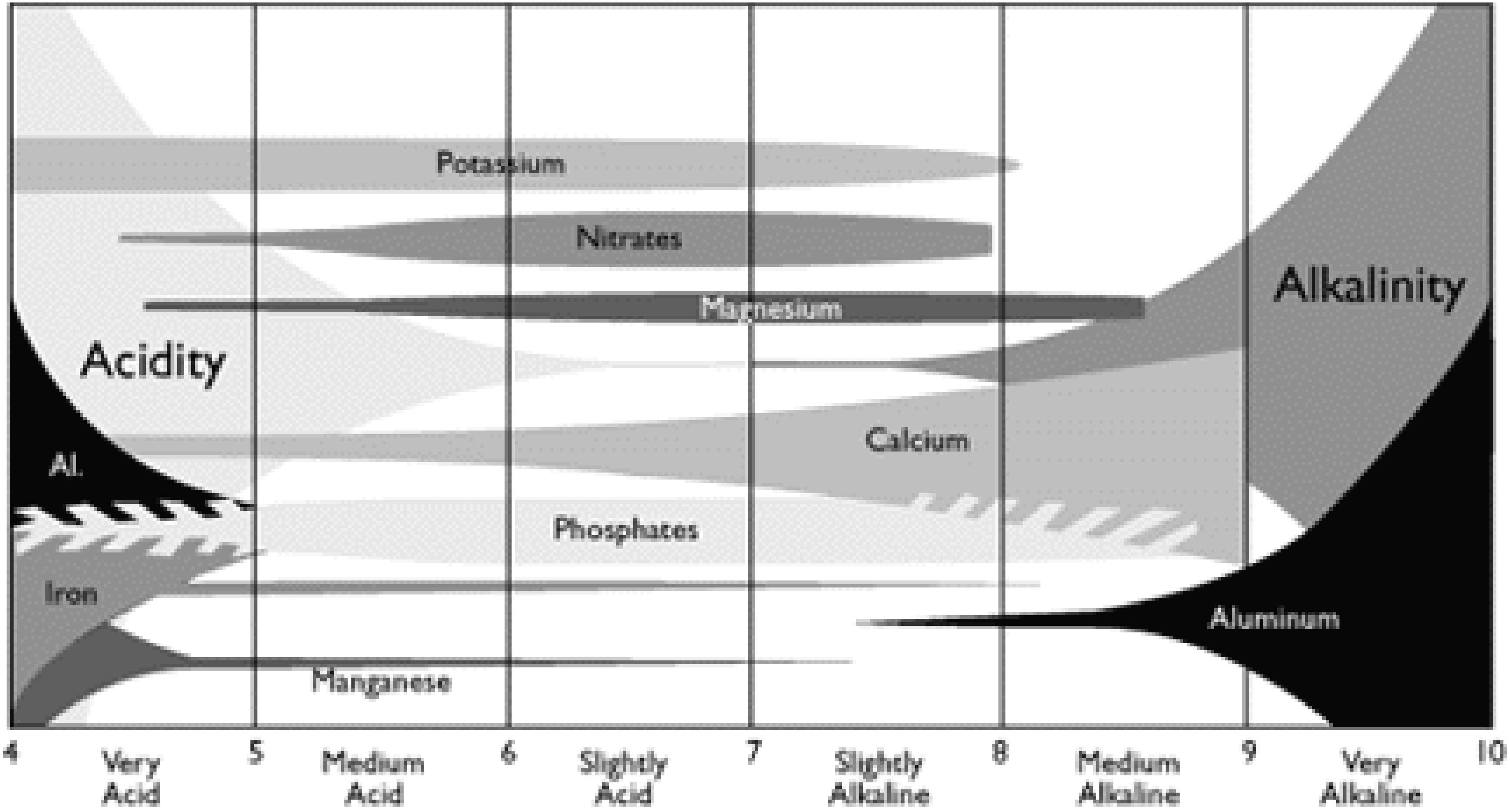
Yet at the same time the availability of most micronutrients increase.

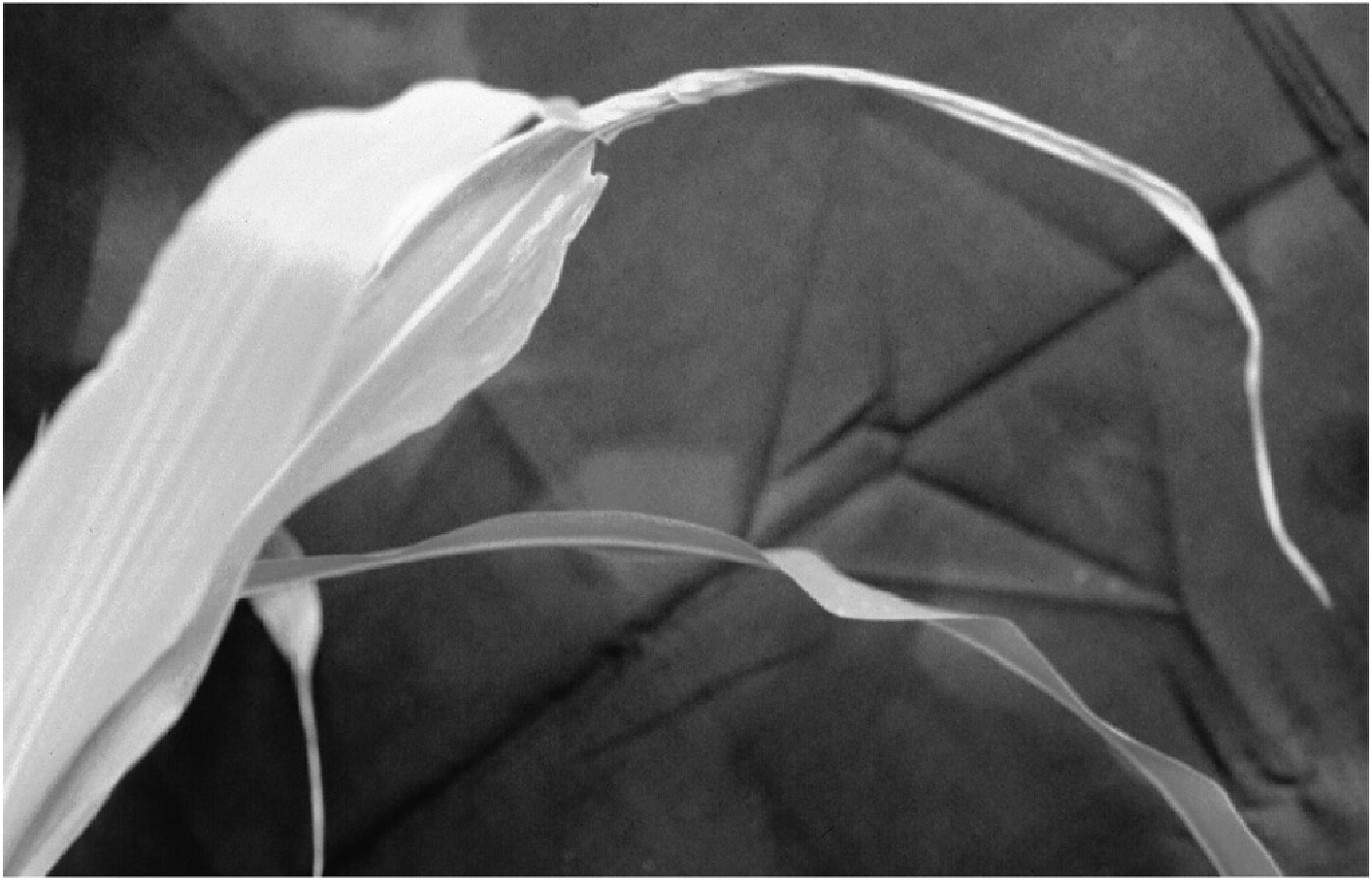
(Fe, Mn, Zn, Cu and Co)

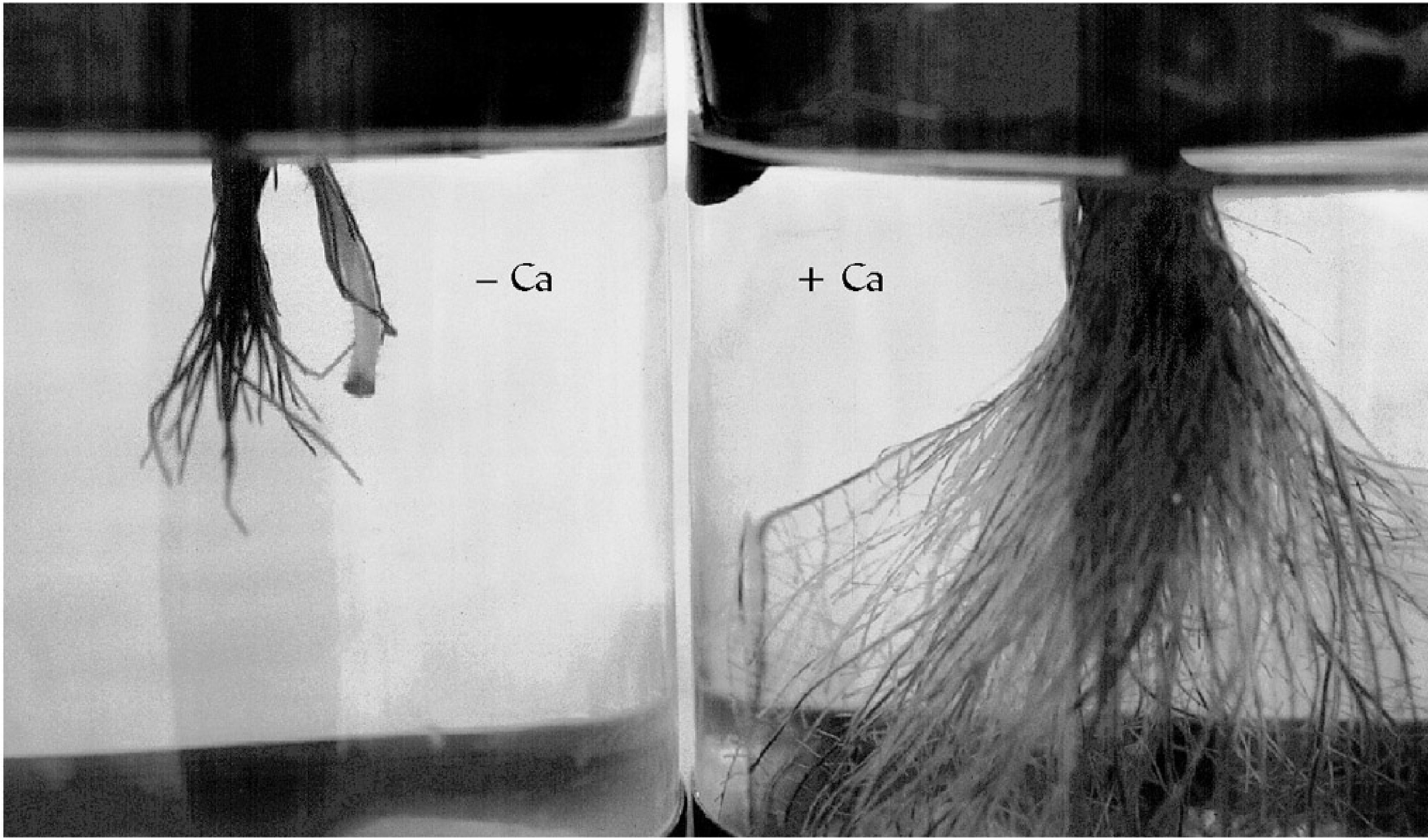
As a result, the optimum pH range for nutrient availability is

5.5 to 6.5




Potassium
Nitrates
Magnesium
Alkalinity
Acidity
Calcium
Al.
Phosphates
Iron
Aluminum
Manganese
4
Very Acid
5
Medium Acid
6
Slightly Acid
7
Slightly Alkaline
8
Medium Alkaline
9
Very Alkaline
10





– Ca
+ Ca

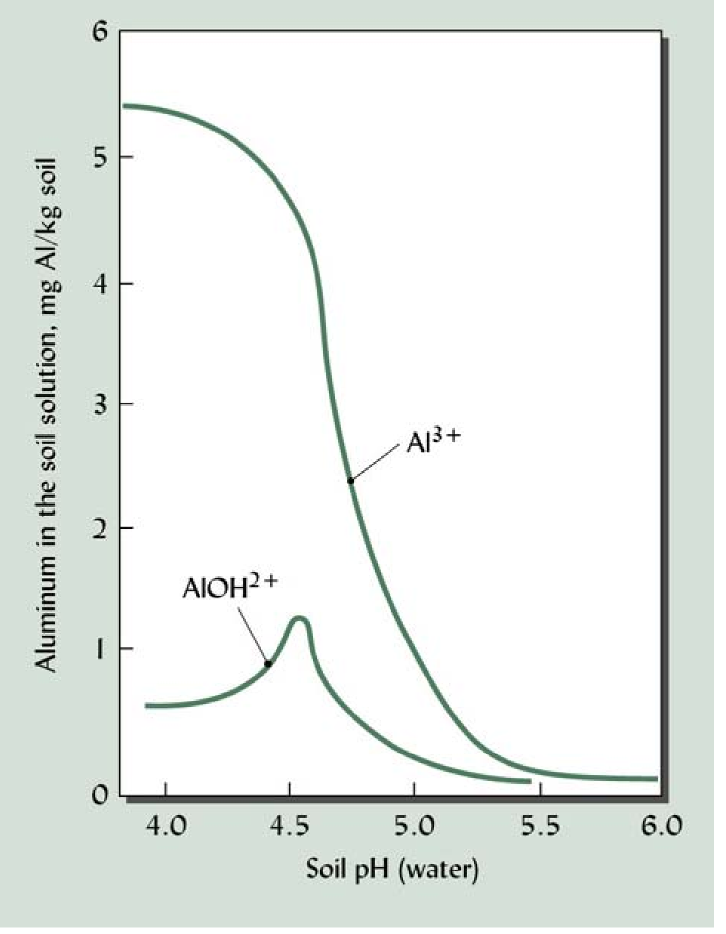
Aluminum Toxicity

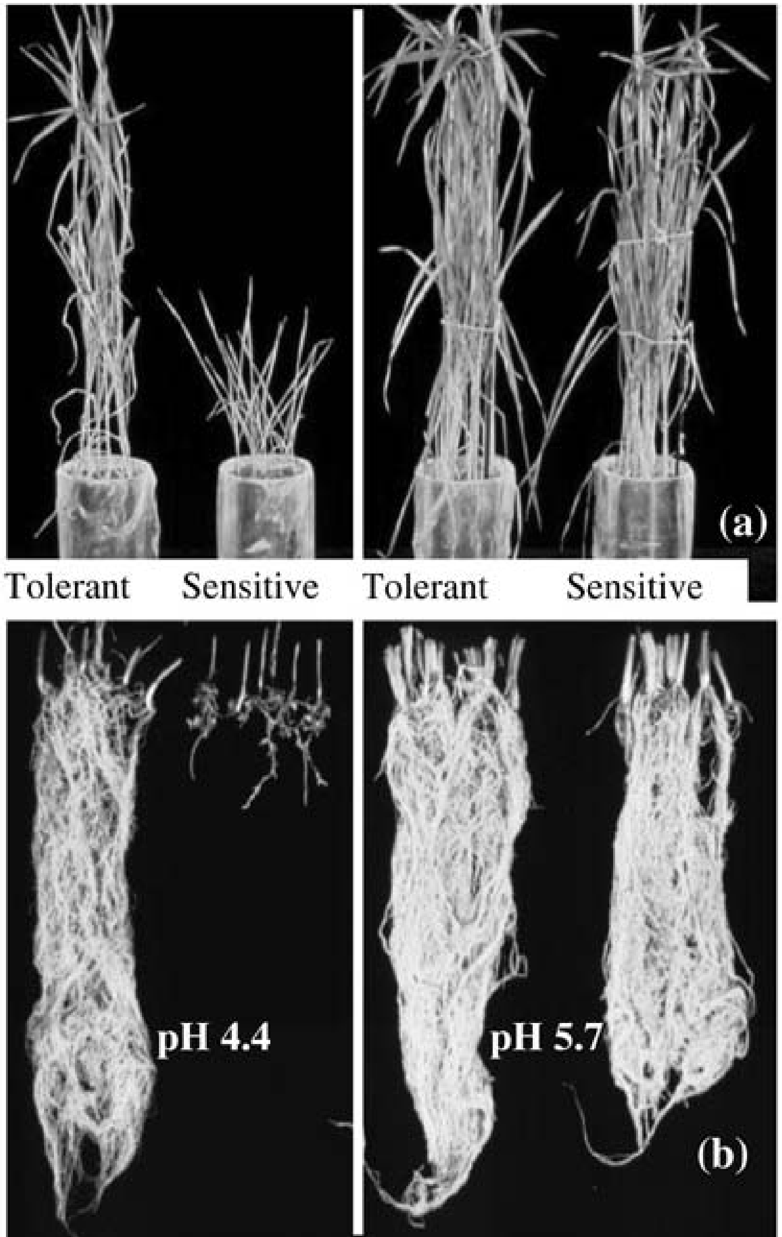
Most common severe problem associated with acid pH’s in soils

Plant and Bacteria populations are effected

> effects plants by (1) block Ca entrance into plants, (2) binds with P (in ATP) which inhibits energy transfer and genetic coding, and (3) restricts cell wall expansion

Rarely a problem above a pH of 5.2




(a)
Tolerant
Sensitive
Tolerant
Sensitive
pH 4.4
pH 5.7
(b)

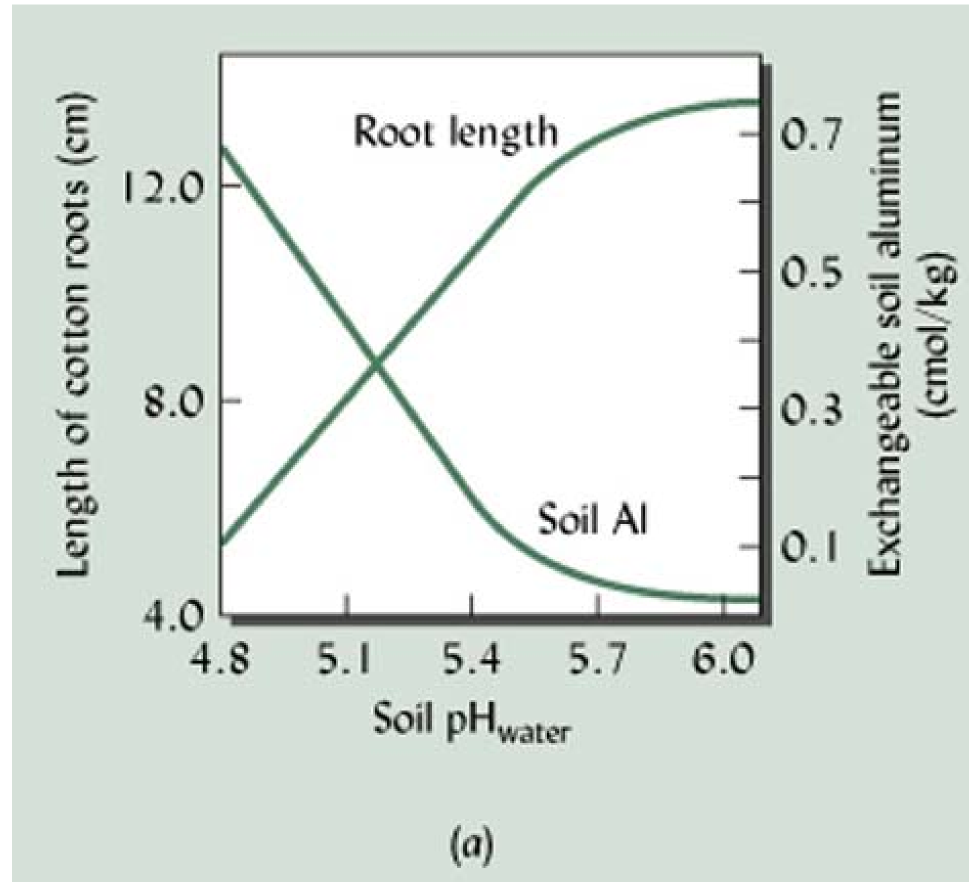
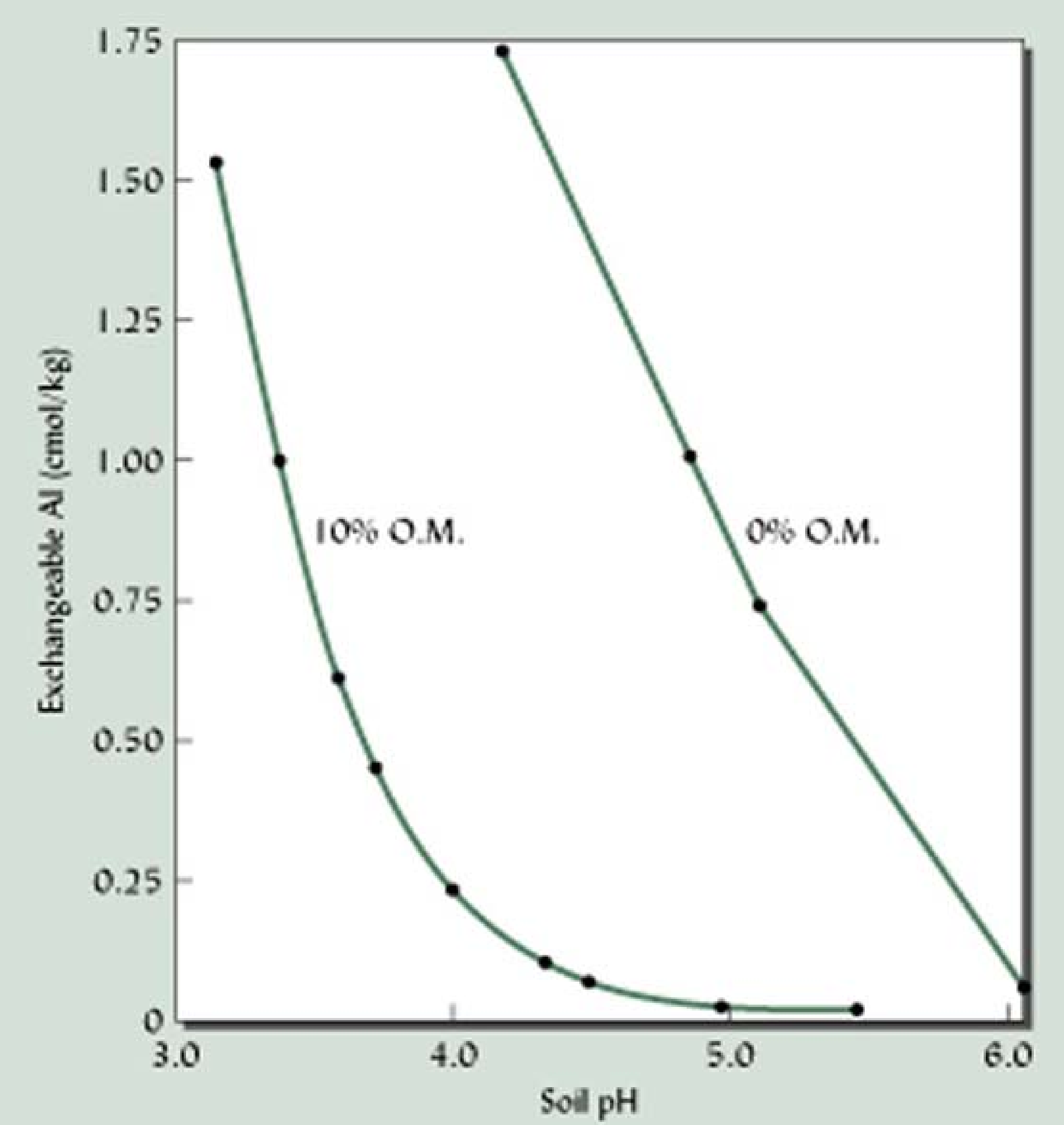

Root length
Soil Al
Length of cotton roots (cm)
Exchangeable soil aluminum (cmol/kg)
Soil pH water
4.0
8.0
12.0
0.1
0.3
0.5
0.7
4.8
5.1
5.4
5.7
6.0
(a)

TABLE 9.2 Relationship between Presence of Sugar Maple Seedlings under Mature Sugar Maples at Sites in Pennsylvania (Udepts) and Soil Properties Related to Acidity

No seedlings were present on sites with ratios of mol_c Ca/mol_c Al below 1.0 in the B horizon. Note that Al was most abundant in the low-organic-matter B horizons and Mn most abundant in the high-organic-matter O horizons. Data given are the averages for 18 forested sites dominated by overstory sugar maples.

		Exchangeable cations, mg/kg				
Seedlings present?	*Horizon*	*Mn*	*Ca*	*Al*	*Ca/Al, mol_c/mol_c*	*pH (water)*
No	O	188	2738	53	23.1	4.02
Yes	O	89	6371	38	74.1	4.45
No	A	59	1252	143	3.9	4.34
Yes	A	33	2755	142	8.5	4.58
No	B	15	305	279	0.5	4.62
Yes	B	8	1061	202	2.3	4.90

Data from Demchik, et al. (1999b). Ca/Al ratios recalculated to give units shown.

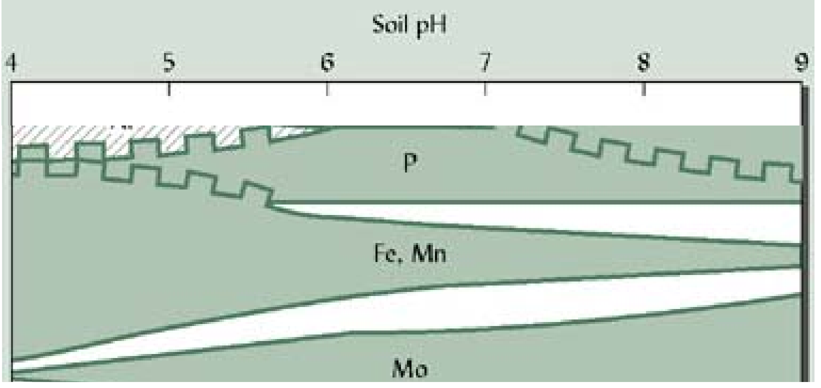


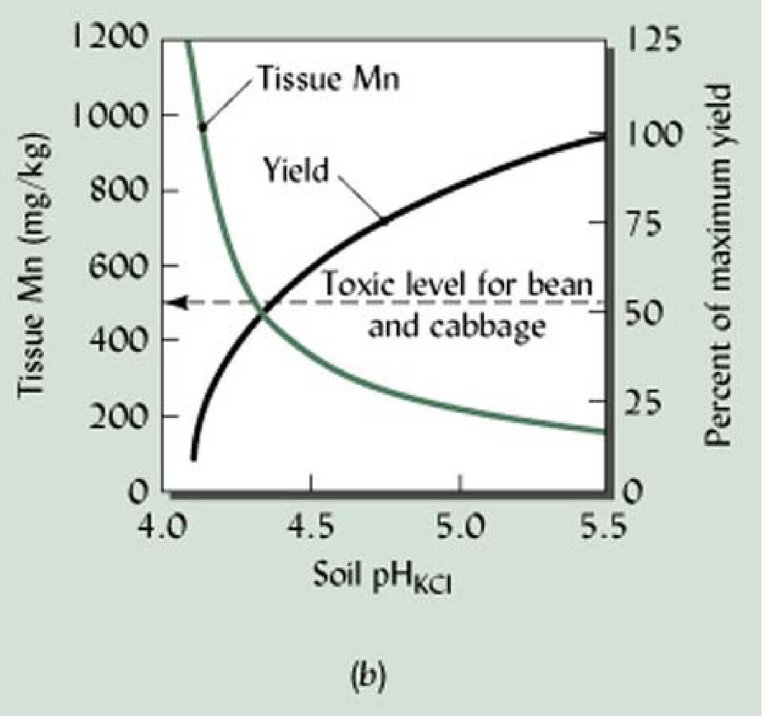
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
3.0
4.0
5.0
6.0
Exchangeable Al (cmol/kg)
Soil pH
10% O.M.
0% O.M.

Other Toxicities

Manganese Toxicity

it's a nutrient but,… can be toxic at pHs up to 5.6

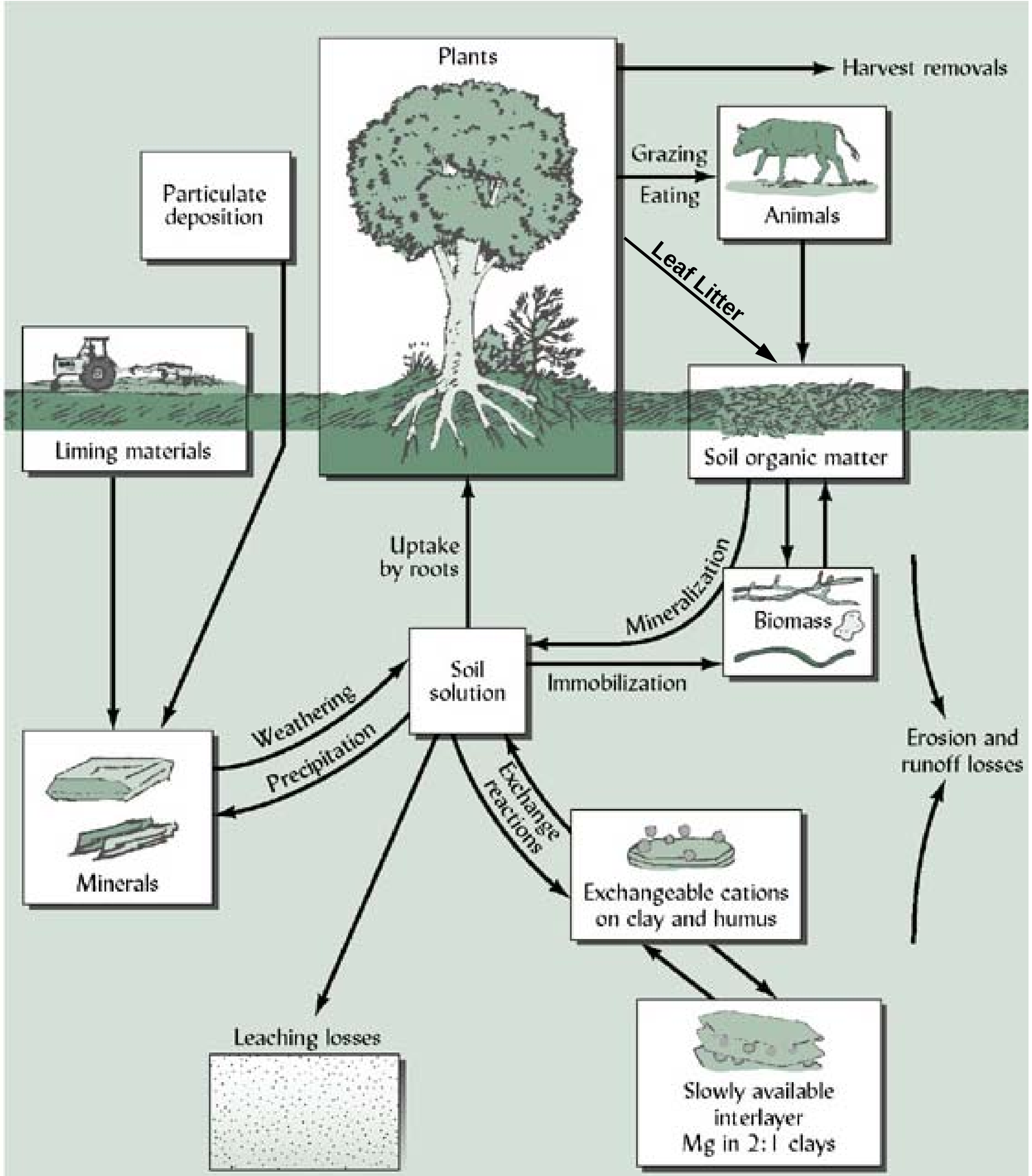




H^+ Toxicity

damages root membranes

kills beneficial microbes



Plants
Harvest removals
Grazing
Eating
Animals
Leaf Litter
Particulate deposition
Liming materials
Soil organic matter
Uptake by roots
Mineralization
Biomass
Soil solution
Immobilization
Weathering
Precipitation
Minerals
Exchange reactions
Erosion and runoff losses
Exchangeable cations on clay and humus
Leaching losses
Slowly available interlayer Mg in 2:1 clays