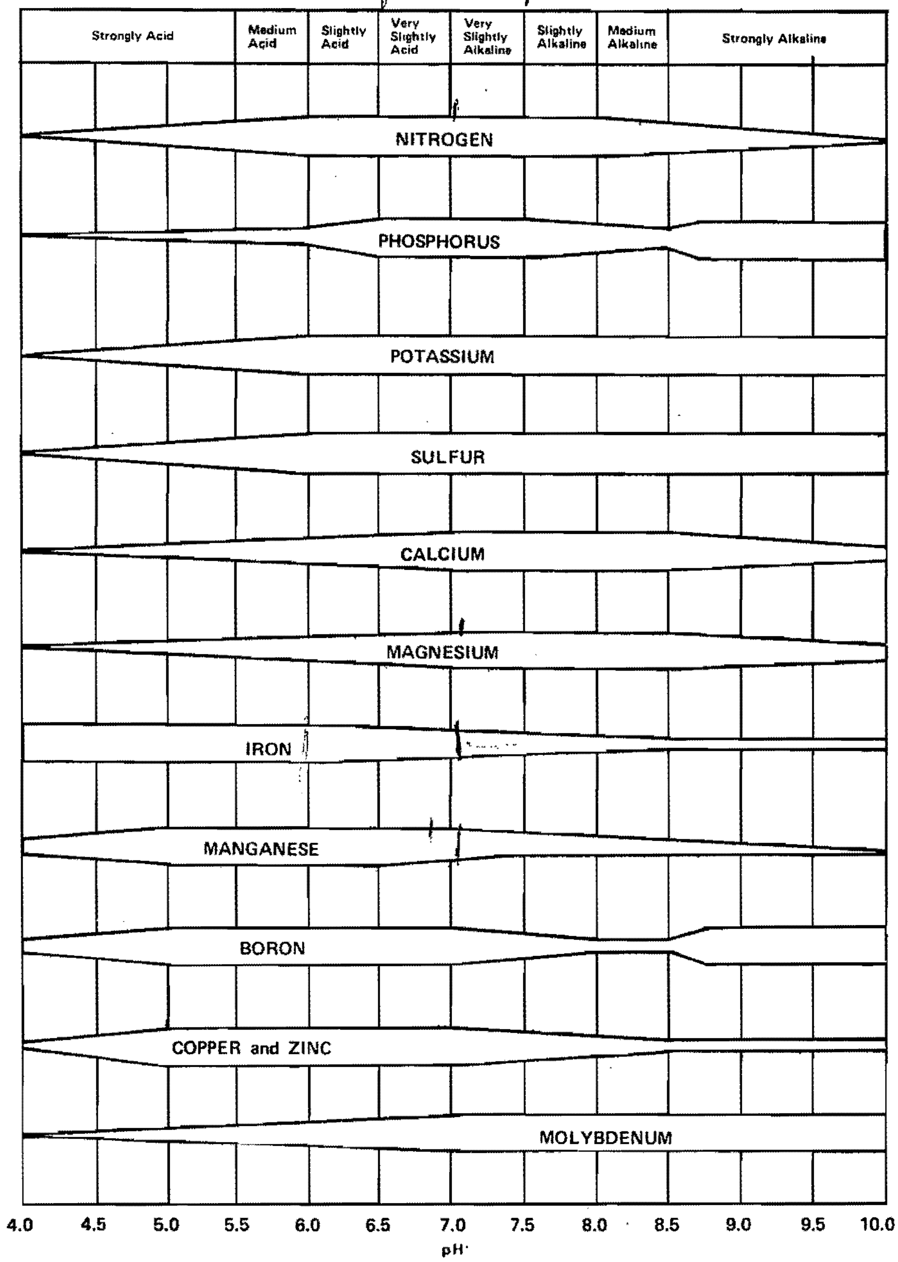
The Soil pH

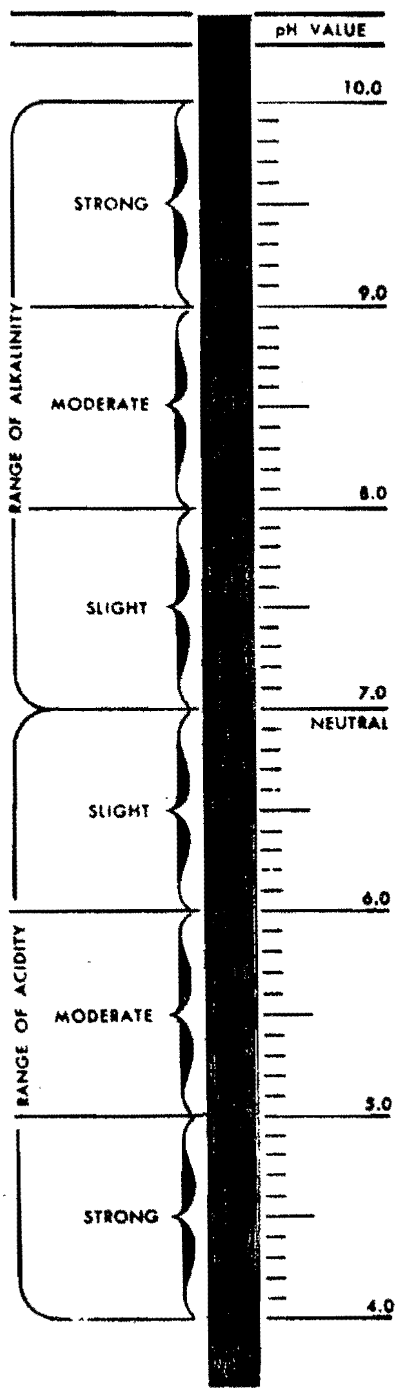
What is soil pH?
How Soil pH Affects the Availability of Soil Nutrients

How soil pH affects availability of plant nutrients

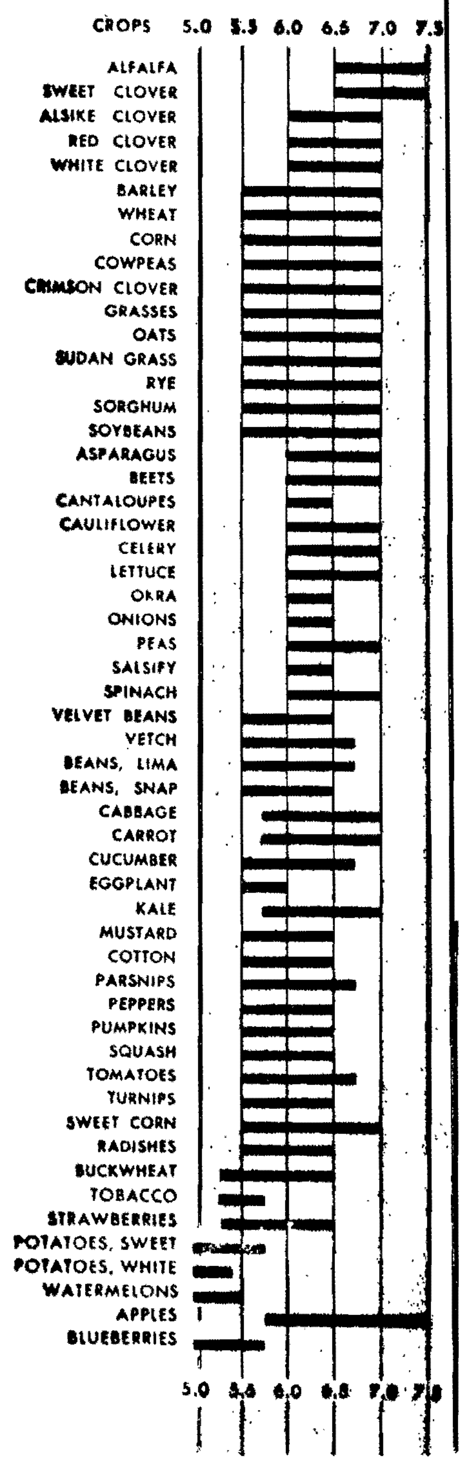


Availability of above nutrients to plants decreases as width of bar decreases.
Soil pH is a key factor in regulating nutrient supply.

pH SCALE FOR SOIL REACTION



SUITABLE pH RANGE FOR VARIOUS CROPS



NUTRIENT UPTAKE INTERFERENCE WITH EACH OTHER (Zn)

Note: Zn deficiency can be caused by 7 different factors. Follow the lines from Zinc to see what these 7 factors are.

Low N
High N

Low P
High P

Low K
High K

Low Ca
High Ca

Low Mg
High Mg

Low Mn
High Mn

Low Fe
High Fe

High Al

Low B
High B

Low Cu
High Cu

Low Zn
High Zn

Low pH
High pH

Poor Drainage

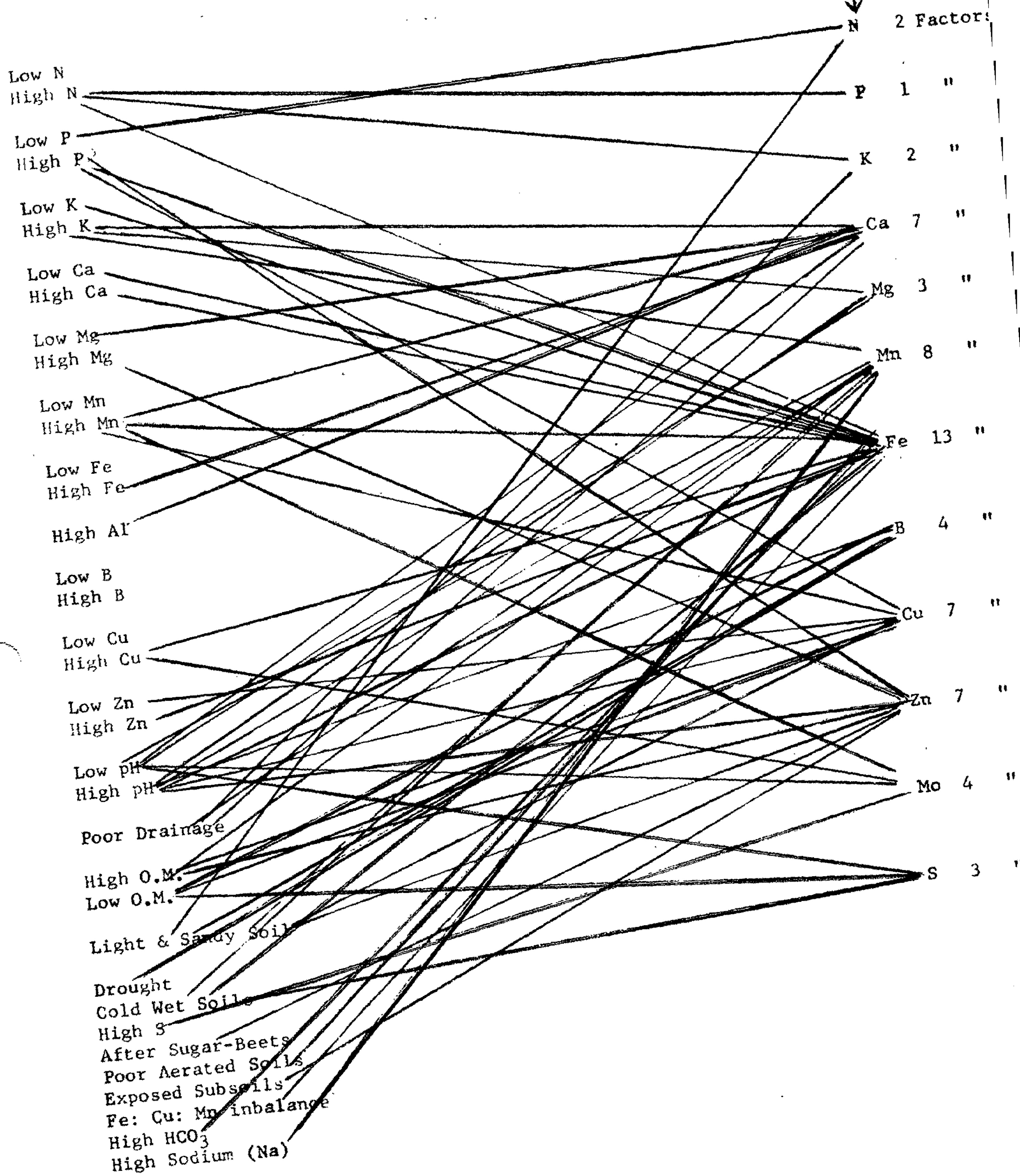
High O.M.
Low O.M.

Ligh & Sandy Soil

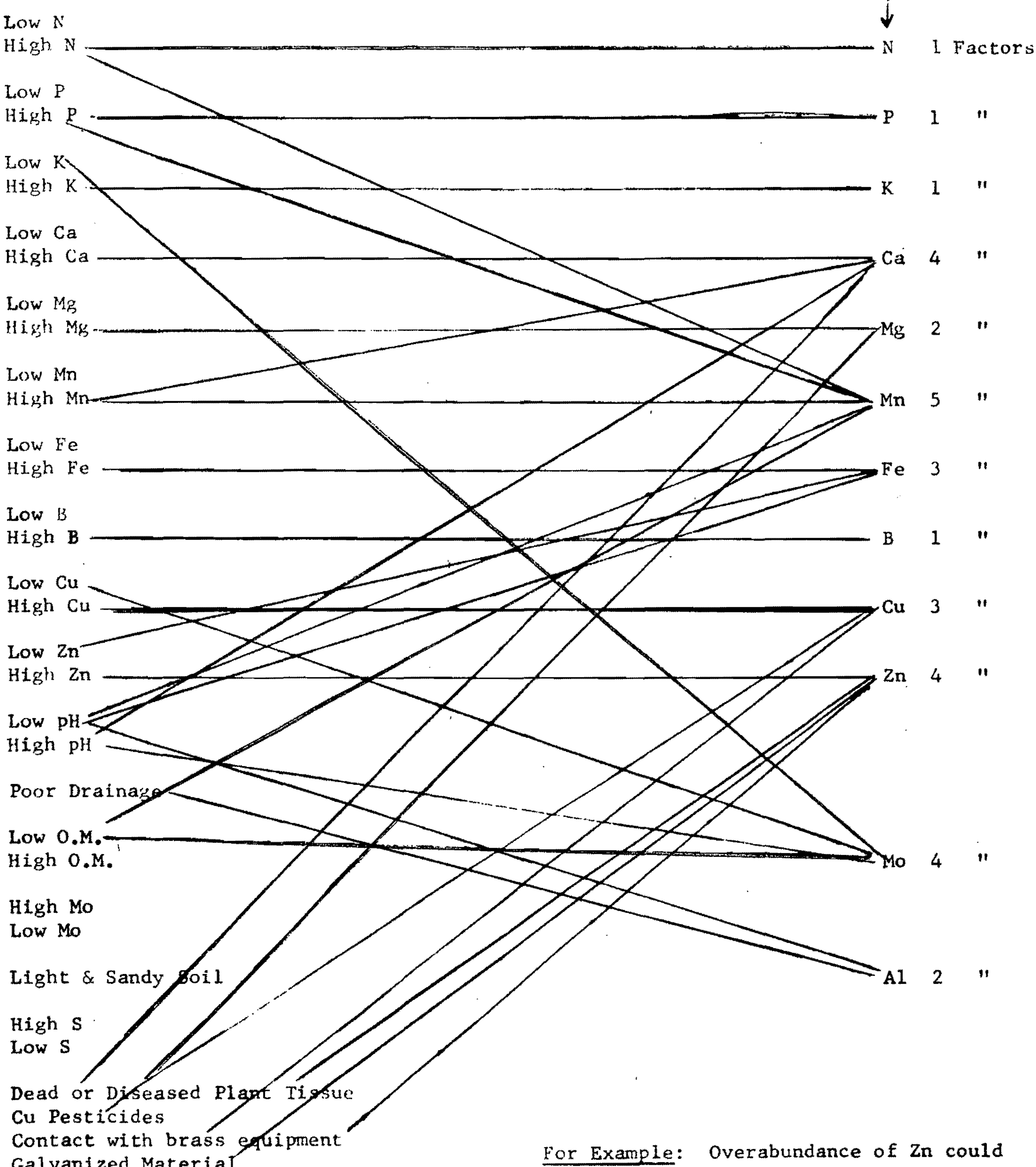
Drought
Cold Wet Soils
High S
After Sugar-Beets
Poor aerated Soils
Exposed Subsoils
Fe, Cu, Mn Imbalance
High HCO_3
High Sodium (Na)

	FACTORS
N	2
P	1
K	2
Ca	7
Mg	3
Mn	8
Fe	13
B	4
Cu	7
Zn	7
Mo	4
S	3

NUTRIENT UPTAKE INTERFERENCE WITH EACH OTHER (Deficiencies)



NUTRIENT UPTAKE INTERFERENCE WITH EACH OTHER (Toxicities)



For Example: Overabundance of Zn could be caused by 1) application of a highly soluble zinc source (e.g. sulfate + chelates carriers); 2) Dead or diseased plant tissues 3) foliar spraying of plants by using galvanized equipment; 4) Contact of zinc source with brass (brass nozzles).

What Is Soil
&
Textural Classifications

Chart showing the percentages of clay (below 0.002 mm.), silt (0.002 to 0.5 mm.), and sand (0.05 to 2.0 mm.) in the basic soil textural classes used by the U. S. Department of Agriculture.

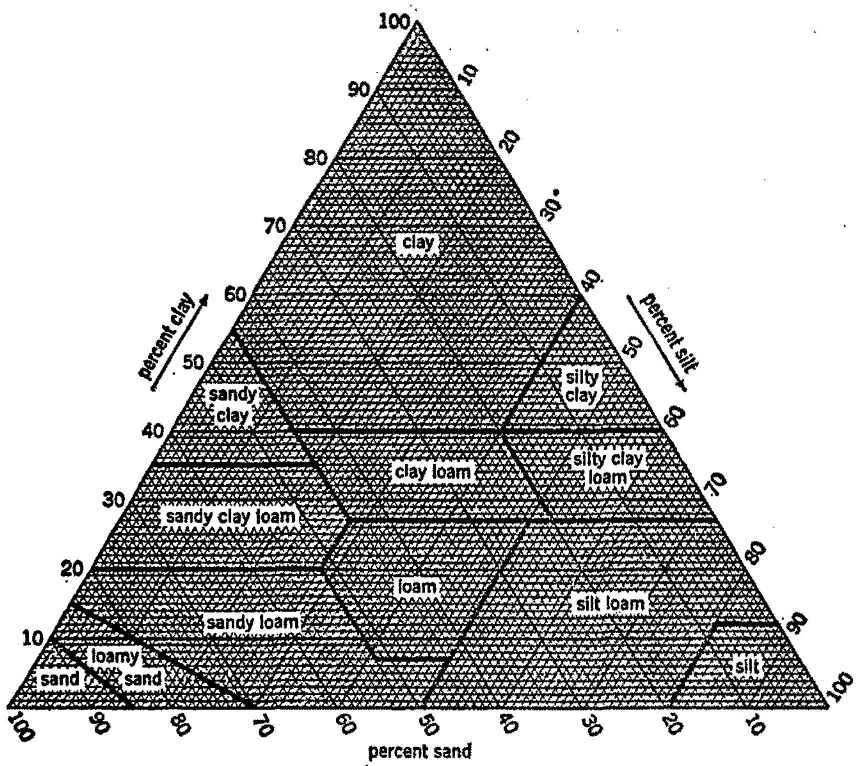
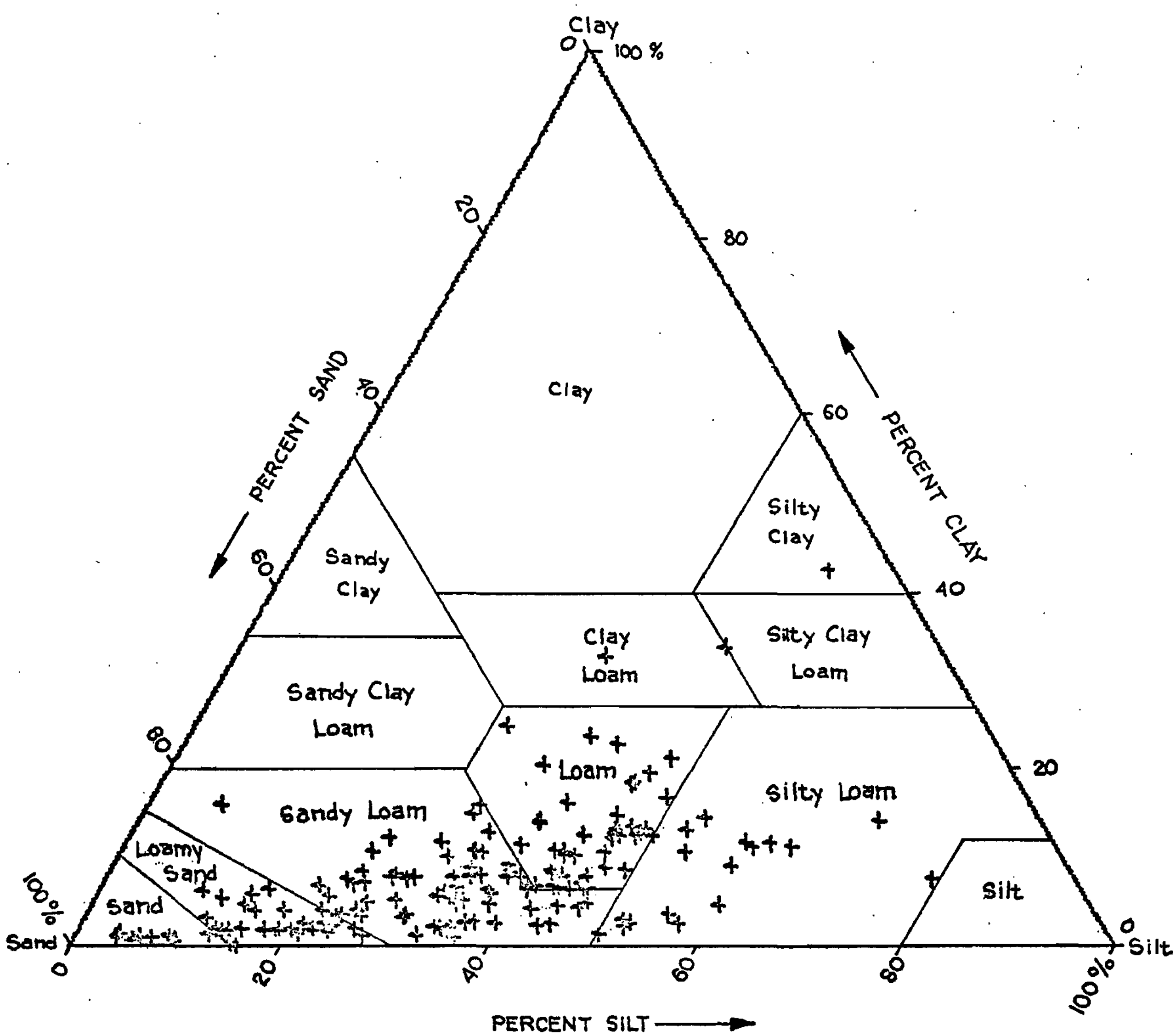


Figure 1



Plotted on U. S. Department of Agriculture

Textural Classification Chart

The Soil Nutrients
&
The Limiting Factors That Determines The Success or Failure In Establishing Vegetation or Crops

1.0 INTRODUCTION

The capacity of a soil to supply existing or establishing vegetation with all the elements necessary for sustained and optimum growth is defined as the fertility level of a soil. These essential elements must be present in both usable forms to plants and in concentrations optimum for growth. In addition, there must be a proper balance among the concentrations of the soluble nutrients in the soil.

Seventeen elements have been demonstrated to be essential for plant growth and are as follows:

*Essential Elements Used in Relative Large Amounts		**Essential Elements Used in Relative Small Amounts	
Carbon (C)	Potassium (K)	Iron (Fe)	Copper (Cu)
Hydrogen (H)	Calcium (Ca)	Manganese (Mn)	Zinc (Zn)
Oxygen (O)	Magnesium (Mg)	Boron (B)	Chlorine (Cl)
Nitrogen (N)	Sulfur (S)	Molybdenum (Mo)	Cobalt (Co)
Phosphorus (P)			

*Implies that a plant cannot grow without these elements.

**As an example, two pounds of Zn are just as important as 100 pounds of N or 150 pounds of phosphate.

Of these 17 elements, carbon, hydrogen and oxygen are supplied by air and water, and all other elements must be supplied and maintained within the soil. Factors responsible for maintaining an adequate supply of nutrients at the root surface include weathering of mineral, deposition from the atmosphere, application of minerals and nutrient seepage from other areas.

APPENDIX I - CHEMICAL SYMBOLS USED

B = Boron and Boron Frit Fertilizer

$Na_2B_2O_3$ = Sodium borate

Ca = Calcium

$CaSO_4$ = Calcium sulfate

Cu = Copper

$CuSO_4$ = Copper sulfate

CuO = Copper oxide

Fe = Iron

K = Potassium

K_2O = Potassium oxide

KCl = Potassium chloride

KNO_3 = Potassium nitrate

Mg = Magnesium

$MgSO_4$ = Magnesium sulfate

Mn = Manganese

$MnSO_4$ = Manganese sulfate

MnO = Manganous oxide

Mo = Molybdenum

Na_2MoO_4 = Sodium molybdate

Na = Sodium

N = Nitrogen

NO_3 = Nitrate

NH_2CONH_2 = Urea

NH_4 = Ammonium

NH_4NO_3 = Ammonium Nitrate

$NH_4H_2PO_4$ = Monoammonium phosphate

$(NH_4)_2HPO_4$ = Diammonium phosphate

NH_4SO_4 = Ammonium sulfate

P = Phosphorus

P_2O_5 = Phosphorus pentoxide

S = Sulfur

Zn = Zinc

$ZnSO_4$ = Zinc sulfate

ZnO = Zinc oxide

To prescribe proper fertilization formulations and application rates for a given soil, consideration must be given to the analysis of the total nutrient spectrum. This analysis includes evaluation of environmental conditions, such as temperature and moisture (which influence the availability and balance of plant nutrients in the soil), the factors which affect the plant's ability to absorb nutrients, the presence of primary secondary and trace elements and of micronutrient interactions.

2.0 FACTORS AFFECTING THE PLANT'S ABILITY TO ABSORB NUTRIENTS

2.1 Oxygen Concentration in the Soil Atmosphere

The energy required for nutrient uptake from soil to plant is generated by the process of respiration in the plant roots, therefore poor aeration inhibits absorption of most nutrients (14, 29). The respiration process depends on a supply of oxygen in the soil atmosphere for all but aquatic plants.

2.2 Soil Temperature

Nutrient absorption is related to metabolic activity, the rate of which is temperature dependent. A greater solution concentration of a nutrient is required for a maximum growth rate in cold soils than in warm soils (57). This is particularly true of phosphorus which is an essential element necessary for plant growth in relative large amounts.

2.3 Antagonistic Reactions Affecting Nutrient Uptake

Although normally the concentration of a nutrient at the root surface is probably the most critical factor affecting the rate of uptake, antagonistic reactions between ions can become deleterious if not properly controlled.

An example of an antagonistic reaction which causes growth depression is the addition of K to a soil which is low or borderline in Mg availability. The antagonic reaction of K on Mg uptake results in growth depression due to an induced Mg deficiency. This would happen even though the K concentration appears to be below the "toxic" limit and the Mg concentration appears to be adequate. Many examples of an ion antagonistic reaction have been validated (20, 24). In dealing with antagonistic ion reactions, the general rule is to maintain a proper "nutrient balance" and at the same time insure adequate amounts of the individual elements.

2.4 Toxic Substances

A toxic substance interferes with the metabolic process of a plant and consequently affects nutrient uptake. Such toxic substances may be due to a high concentration of Mn and Al in acid soils, soluble salts, excess of B, or high concentrations of heavy metals.

3.0 INTERPRETATION VARIABLES

3.1 Soil pH

Whether a soil is acid, neutral or basic greatly affects the solubility of numerous compounds, the relative bonding of ions to exchange site and the activity of various microorganisms (58, 59) and therefore, is an important determination.

The following three soil pH ranges are particularly valuable in soil analysis:

1) pH below 4 indicates the presence of free acids, generally derived from the oxidation of sulfides.

2) pH below 5.5 suggests the probable occurrence of exchangeable aluminum.

3) pH from 7.8 to 8.2 indicates an excess of calcium carbonate ($CaCO_3$).

The soil pH is an intensity factor analogous to air pressure in a tire. The lime requirement is a capacity factor analogous to the total air content of the tire, and just as a tractor tire may have the same pressure as a bicycle tire, but contains much more air, so may two soils of the same pH differ greatly in lime requirement. Because the ultimate goal of a fertilization program is to maintain the native condition, the pH may be left unchanged even though lime application under normal agricultural conditions would be required.

3.2 Organic Matter

The greater the concentration of organic matter in a soil, the more acidic ions can accumulate on the plant exchange sites, and therefore, the content of organic matter and lime requirements of soils are highly correlated (38).

3.3 Cation Exchange Capacity (CEC)

Based on an eight year study of the treatment of twenty soils, an ideal soil has the cation exchange complex saturation of 65%

Ca, 10% Mg, 5% K and approximately 20% H (8). It has been suggested that 75% Ca, 10% Mg and 2.5-5% K is best, but yields would be little affected if Ca ranged from 65-85%, Mg 6-12% and K 2-5% (30). Once these saturation ranges are reaches, the soil pH will be in a more favorable range, and adequate amounts of the basic cations will be provided and in reasonable balance with each other.

4.0 SOIL NUTRIENTS

4.1 Nitrogen

Nitrogen is a vitally important plant nutrient. It is absorbed by plants in the form of nitrate (NO_3), ammonium (NH_4) or urea (NH_2CONH_2). Regardless of the form in which it is absorbed, it is converted within the plant to reduced nitrogen (NH_2), complex organic compounds and ultimately into protein (44).

Crops all over the world are probably more often deficient in nitrogen than in any other element, and yet there is no well accepted method for testing soils for available N (17). This is partially due to the fact that 97% to 99% of N in a soil is present in very complex organic compounds which are not available to the plants. However, microbial decomposition of organic matter results in the slow conversion of N to the inorganic forms which make it acceptable for plant absorption.

The rate at which the conversion takes place is dependent upon the rate of microbial decomposition, which is dependent upon temperature, moisture, aeration, the type of organic matter, pH conditions and other factors such as the C:N ratio. Because the primary form of available N, nitrate nitrogen (NO_3), is subject to leaching, denitrification and immobilization by microorganisms, the availability rate may be further curtailed (17).

4.2 Phosphorus

Phosphorus occurs in quantities much smaller than nitrogen and potassium in most plants. It is a constituent of nucleic acid, phytin, phospholipids and is a factor in increased root growth. Phosphate forms in the soil are sparingly soluble compounds with divalent and trivalent cations. It is absorbed as a primary orthophosphate (H_2PO_4) and to a lesser degree as a secondary orthophosphate (HPO_4).

Studies indicate that the P is absorbed by plants only from the soil solution (4) and calculations show that for normal plant growth and P uptake to occur, the soil solution must be renewed several times each day during the growing season. Factors involved in the renewal of the soil solution are the amount of P which can be solubilized, its degree of solubility and the rate of its diffusion from the solid to the plant root surface (4).

4.3 Potassium

The third major element, potassium, is absorbed as potassium ion, K^+. Unlike nitrogen and phosphorus, potassium does not form an integral part of a plant, but serves a catalystic function. It is essential to the following plant physiological functions:

1) Carbohydrate metabolism and translocation of starch

2) Nitrogen metabolism and protein synthesis

3) Control and regulation of the functions of various other essential elements

4) Neutralization of organic salts

5) Activation of various enzymes

6) Promotion of meristematic tissue growth

7) Adjustment of stomatal movement and water regulation (18)

Generally only a small part, less than 1%, of the total potassium is in exchangeable form, and much smaller amounts are in soil solution. The results of intensive cropping conditions are highly correlated with the level of exchangeable K (18).

4.4 Calcium

Calcium, absorbed as Ca^{++}, is a secondary element required by all plants. Calcium is considered to be important in the formation of the middle lamellae of plant cells and also in the synthesis of calcium pectate within the plant. It also affects protein synthesis because it enhances the uptake of nitrate nitrogen and is associated with the function of certain enzymes (44, 63).

The total exchangeable and non-exchangeable calcium in the soil is usually less than the total potassium and magnesium combined.

4.5 Magnesium

Magnesium, absorbed in the ionic state Mg^{++}, is the only nucleus (mineral constituent) of the chlorophyll molecule. Therefore, the importance of Mg is obvious, because without chlorophyll the green plant will fail to carry on the vital process of photosynthesis. Also, Mg appears to be related to phosphorus metabolism and is considered to be a key factor in the activation of a number of plant enzymes (44).

According to a number of investigators, soil pH has a diverse effect upon the availability of Mg and therefore, it is recommended that Mg saturation should exceed 10% (1, 21, 35, 37, 62).

4.6 Sulfur

The important functions of sulfur in plant growth and metabolism are as follows:

1) Required in the synthesis of amino acids
2) Activation of proteolytic enzymes
3) Constituent of certain vitamins
4) Increases the oil content of a plant
5) Contributes to cold resistance (44)

Sulfur is absorbed by plants almost exclusively as a sulfate ion (SO_4), however, small amounts can be absorbed through plant leaves as sulfur dioxide (SO_2). Generally, crops require approximately the same amount of S as P. Investigators have found that the average yield of forage crops remove 15 to 35 kg of S per hectar which is equal to 13.2 to 30.8 lbs/acre.

In many ways, the microbial mineralization - immobilization cycle of S, resembles that of N, and the C:N:S ratio of the organic fraction of soils is approximately 125:10:1.2 (26). However, during the decomposition of organic matter, the proportionate release of nitrate to sulfur is not always in that ratio (25).

4.7 Boron

Although boron is absorbed in very small quantities, it has the following effects on plant function:

1) Functions in carbohydrate metabolism
2) Sugars move within the plant in a boron-sugar complex
3) Boron influences cell development by controlling the formation of polysaccharides
4) Functions in pectin synthesis
5) Functions as a guard against polymerization of sugars at the sites of sugar synthesis (44)

Boron is absorbed in one or more of its ionic forms such as $B_4O_7^{=}$, $H_2BO_3^-$, $HBO_3^{=}$ or $BO_3^{=}$. Favorable crop responses to the application of B fertilizer have been reported in 41 states in the U.S.A. (10) and from many countries (54). Toxic levels were also frequently encountered as a result of excessive B fertilizer application.

4.8 Iron

Iron, which may be absorbed in an ionic form or as complex organic salts (chelates), affects the following plant functions:

1) Activates at least 3 enzymatic systems
2) Participates in the chlorophyll production mechanism
3) Believed to be associated with the synthesis of chloroplastic protein
4) Is able to substitute molybdenum as a metal co-factor which is necessary to the functioning of nitrate reductase (44)

4.9 Manganese

Manganese is absorbed by plants as the manganous ion, M^{++}, and in molecular combinations with chelating agents such as EDTA. Manganese functions within a plant are as follows:

1) Activates enzymes associated with carbohydrate metabolism
2) Active in phosphorylation reactions
3) Functions in the citric acid cycle
4) Combines with other metals and contributes to activation of enzymes, especially phosphatase
5) Chemically functions in the chloroplast processes (44)

4.10 Copper

Copper is absorbed by plants as a cupric ion, Cu^{++}, and organic complexes such as EDTA (chelate). Copper has the following functions within a plant:

1) Activator of several enzymes
2) Plays an important role in the light reactions of plants
3) Controls excessive iron uptake, especially in the nodes of plants. This is particularly important because a heavy accumulation of iron will kill a growing plant and therefore, inclusion of copper on soils with high iron content is extremely important (44).

4.11 Zinc

Zinc is absorbed by plants in the ionic state, Zn^{++}, and as a molecular complex of such chelating agents as EDTA. Zinc functions in plants are as follows:

1) Metal activator of eleven enzymes

2) Contributes to sugar production (44)

4.12 Molybdenum

Molybdenum, absorbed as $MoO_4^{=}$, is important to the following plant functions:

1) Required in nitrate reduction and is important in other oxidation reduction processes (23)

2) Serves as a nutrient for nitrogen fixing bacteria within plant nodules.

3) Contributes to amino acid and protein synthesis (44)

Low Mo content within a plant contributes to accumulation of nitrates (NO_3) and an apparent lowering of the ascorbic acid oxidase activity (44). Deficiencies of Mo in crops have been reported from nearly every agricultural area in the world (36). Mo applications have become quite common as it is recognized as an essential and beneficial addition to crops (2, 3, 47).

The Mo content of soils has not been tested because all extraction reagents evaluated have proven unsuitable (6, 32, 33, 41).

4.13 Chlorine

Chlorine, absorbed as the Cl^-ion, function within a plant is not entirely understood but is believed to aid in the resistancy to diseases and general plant development (44).

Excessive application of Cl in the form of KCl, if not leached in time, can become toxic to both plant and/or seedling, and consequently must be carefully controlled where drainage problems exist.

Nutrient Deficiencies Cause Of A Deficiency Or Toxicity

5.0 MICRONUTRIENT INTERACTIONS

Adequate micronutrition of plants depends not only on the ability of the soil to supply the elements but also on the distribution of nutrients within the functional sites and nutrient mobility within the plant. Another factor in micronutrition is nutrition interactions which are defined as the influence, mutual or reciprocal, of one element upon another, or when elements combine to produce an added effect not generally produced by any one of them alone. Interactions occur between micronutrients as well as with some macronutrients (8, 12, 13, 14), and take place in the soil as well as within the plant. Interactions of micronutrients with other elements are well known and recognized as a problem source if not properly circumvented.

5.1 Zinc-Phosphorus

High application of phosphates can induce a zinc deficiency, and therefore, Zn application on deficient soils and on soils that contain high levels of P is necessary (5, 55, 60).

5.2 Zinc-Nitrogen

High application of nitrogen can induce a Zn deficiency identical to high P applications. Moderate nitrogen applications will alleviate the problem and accentuate the uptake of both P and Zn (40, 52).

5.3 Zinc-Iron

The metabolic functioning of calcium and iron in plants is connected with the supply of zinc (49).

5.4 Copper-Phosphate

Generally, heavy or prolonged use of phosphatic fertilizers may result in phosphate interactions with copper, and consequently inhibit Cu uptake.

5.5 Molybdenum-Phosphorus

Phosphorus is known to enhance the absorption and translocation of Mo plants (12, 13). It is also suspected that the P may stimulate Mo uptake because of the formation of a complex phosphomolybdate anion which is more rapidly absorbed by plants (6).

5.6 Molybdenum-Sulfur

In contrast to phosphates, the uptake of Mo by plants is reduced by available soil sulfate sulfur (SO_4) (56). This relationship between S and Mo necessitates care in using sulfur either alone or in fertilizer mixtures.

5.7 Zinc-Magnesium-Calcium

High rates of Mg or increase of pH by liming reduces the availability of Zn to plants (21, 60, 62).

5.8 Copper-Zinc

High application of Zn can induce a copper deficiency (28). This means that in areas where both copper and zinc are deficient, the rate of zinc must be carefully controlled.

NUTRIENT DEFICIENCIES

Often the causes are factors other than the presence or absence of the nutrients themselves. For instance; An Fe/Cu/Mn imbalance can tie up Iron (Fe) present in the soil and make it unavailable to plants; low organic matter can make several important micronutrients unavailable; poor drainage can be the cause of deficiencies in K, Ca, and Mn.

In preparing a Balanced Fertility Program for a customer, or in talking to the customer, the following Nutrient Deficiency Chart will prove to be an excellent immediate reference. It lists the deficiency conditions that are likely to arise, and the most likely causes for them.

NUTRIENT DEFICIENCY CHART **

DEFICIENCY OBSERVED													CAUSE OF DEFICIENCY
N	P	K	Ca	Mg	Mn*	Fe	B	Cu	Zn	Mo	S	Al	
													Low N
	x	x				x		x					High N
x													Low P
						x		x	x				High P
						x							Low K
			x	x									High K
						x							Low Ca
	x					x							High Ca
			x										Low Mg
									x				High Mg
													Low Mn
			x			x		x		x			High Mn
													Low Fe
	x		x		x								High Fe
			x										High Al
													Low B
													High B
													Low Cu
					x	x				x			High Cu
								x					Low Zn
					x	x		x					High Zn
			x	x	x								Low pH
	x			x	x	x	x	x	x				High pH
						x	x	x			x		Low Organic Matter
					x			x	x				High Organic Matter
		x	x		x								Poor Drainage
x					x		x	x	x		x		Light & Sandy Soil
					x		x						Drought
					x	x					x		Cold Wet Soils
						x							Fe: Cu: Mn Imbalance
										x			High S
						x							High Bicarbonates
									x				After Sugar Beets or Sweet Corn
					x								High Sodium
						x							Poor Aerated Soils
									x				Exposed Subsoils
						x							Area of Heavy Manuring
							x						Area of Heavy Rainfall

* Mn chelate application will further aggravate Mn deficiency

** Color pictures of deficiencies are shown in "Modern Crop Production", pages 221 to 230, inclusive.

NUTRIENT TOXICITY CHART

TOXICITY SYMPTONS													CAUSE
N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Mo	S	Al	
													Low N
x					x								High N
													Low P
	x				x								High P
										x			Low K
		x											High K
													Low Ca
			x										High Ca
													Low Mg
				x									High Mg
													Low Mn
			x		x								High Mn
													Low Fe
						x							High Fe
													Low B
							x						High B
										x			Low Cu
								x					High Cu
						x							Low Zn
									x				High Zn
					x	x						x	Low pH
			x							x			High pH
												x	Poor Drainage
					x					x			Low O.M.
													High O.M.
													Low Mo
										x			High Mo
													Light & Sandy Soil
													Low S
											x		High S
			x	x					x				Dead or Diseased Plant Tissue
								x					Cu Pesticides
								x	x				Contact with brass equipment
									x				Galvanized Material

How To Correct an Undesirable Soil pH

Lime ?
Gypsum?
Sulfates?

LIME — MAP AND INTERPRETATION

The field map below shows the pH for each sample. Figures on the charts for limestone needed are based on these assumptions:

1. A 9-inch depth of plowing. For each inch less, the limestone requirement may be reduced by 10 percent.
2. Typical-fineness limestone — 90 percent through 8-mesh. 60 percent through 30-mesh. 30 percent through 60-mesh.
3. A calcium carbonate equivalent (total neutralizing power) of 90 percent.

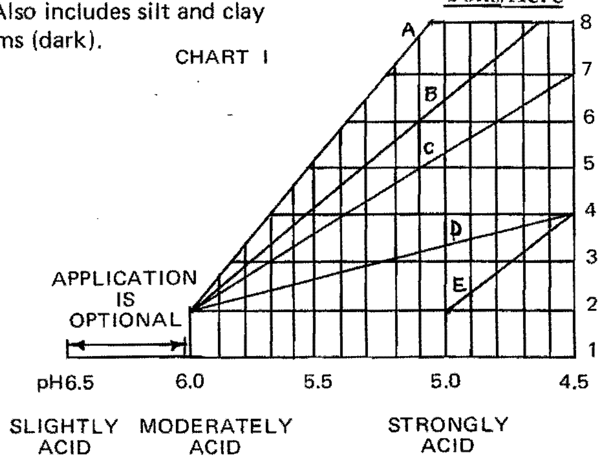
If these assumptions do not apply to your situation, adjust the limestone rate accordingly.

STEPS TO FOLLOW

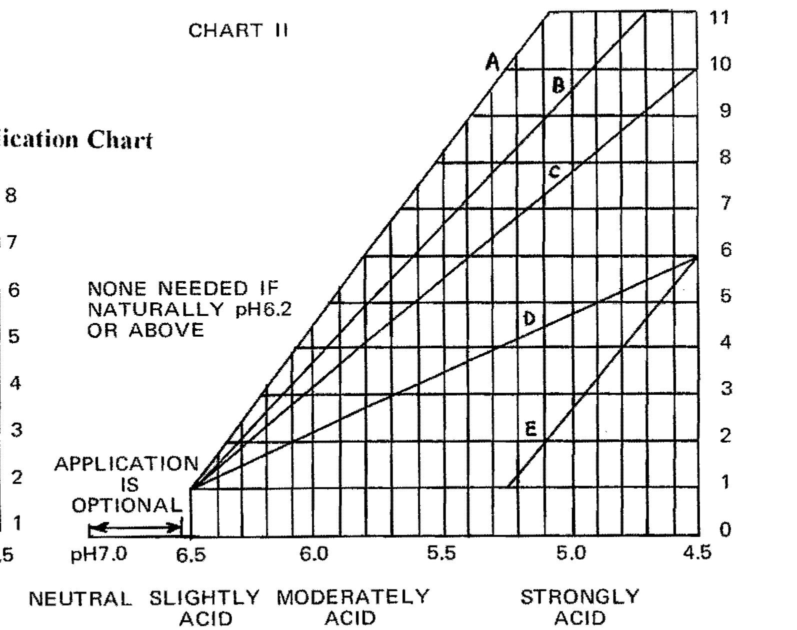
1. Use Chart I for grain systems and Chart II for alfalfa, clover, or lespedeza.
2. Decide which soil class fits your soil.
   - A. Silty clays and silty clay loams (dark).
   - B. Silty clays and silty clay loams (light and medium).*
   - C. Silt and clay loams (light and medium), sandy loams (dark), loams (dark and medium).
   - D. Loams (light), sandy loams (light and medium), sands.
   - E. Muck and peat.
3. Find your soil's pH along the bottom of the chart.
4. Follow up the vertical line until it intersects the diagonal line A, B, C, D, or E that fits your soil.
5. Read the suggested rate of application along the right side of the chart that your are using.

* Also includes silt and clay loams (dark).

General Lime Application Chart
Tons/Acre



Primarily for Legumes
Tons/Acre

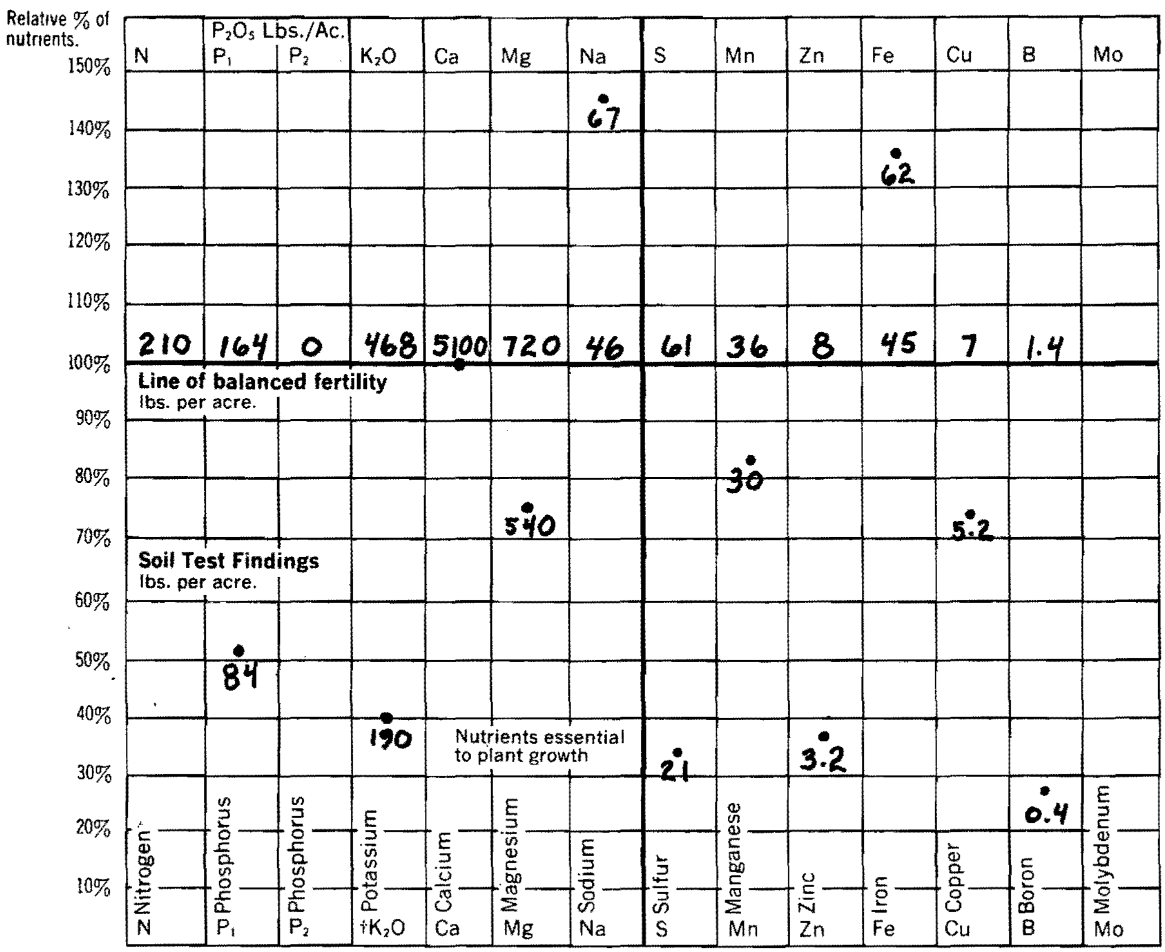


SOIL-ACIDITY MAP

Note: The original training manual goes from step # 1 through step # 14 . You are seeing step 13 & step 14 the final results.

EXAMPLE:

After Step 13, your example chart should look like this.



TAILORING RECOMMENDATIONS

As has been pointed out in Step 6 (Potassium), there will be occasions when extreme imbalances may require adjustments that may not be economically sound for the person you are talking to. When this happens relate what you know about the program, to what you know about the customer. What is the "breaking point" . . . in other words, what additional expenditure for fertilizer, will he consider? Now, with this in mind, take another look at your recommendations. While it may be wise to show him the ideal program, be prepared to offer an adjustment of it that he will be willing to accept. Basically, there are three different ways to adjust the program.

1. Make adjustments according to the crop to be grown. See following chart - "Crops which show greatest to least response to added nutrients". Where conditions are acceptable, suggest 50% of the rates for crops listed in the middle row, and eliminate recommendations for crops listed in the third row.
2. Point out to the customer that Balanced Fertility can be achieved by spreading the amount recommended, in excess of the amount needed for his yield goal, over a period of two or three years. Never, however, recommend less N, P, or K, than is needed for his yield goal, acording to your recommendation chart in the fertilizer sales manual.
3. Sit down with the customer and reassess his yield goal. Point out that a goal higher than 10–15% over last years yields is going to necessitate a major adjustment to fertility. Help him examine the investment/expected returns. This plan is particularly applicable to Postassium. Study the yield goal/Potassium level chart found in Step 6.

Balanced Fertility is a guide line to an ideal fertility program. It is up to you to determine what is, and is not, practical for the customer you are talking to . . . and then adjust the program for his particular situation. Regardless of the individual adjustments that may become necessary, Balanced Fertility gives you an agronomically sound program that no competitor can touch!

RECOMMENDATIONS

BLUE GRASS PASTURE

YIELD PERFORMANCE PER ACRE	*NITROGEN CODE LBS./ACRE			SOIL TEST REPORT P_2O_5 LBS./ACRE									SOIL TEST REPORT K_2O LBS./ACRE								
	1	2	3	VL 0–12	L 13–30	M 31–45	L_H 46–80	M_H 81–114	H 115–150	L_{VH} 151–186	M_{VH} 187–250	VH 251+	VL 0–100	L 101–180	M 181–250	L_H 251–360	M_H 361–579	H 580–798	L_{VH} 799–1017	M_{VH} 1018–1235	VH 1236–1454
LOW	100	110	120	170	120	80	70	60	50	40	30	20	170	120	100	80	60	40	0	0	0
AVERAGE	120	130	140		150	110	100	90	80	70	60	50		150	130	110	90	70	20	0	0
HIGH	140	150	160			140	130	120	110	100	90	80			160	140	110	100	40	20	0

(1) For an above average performance/acre a complete soil analysis is recommended.
(2) For high CEC or peat muck soils add extra 25 lbs. of both P_2O_5 and K_2O.
(3) For light sandy soils (less than 9% clay) deduct 20# of N, P_2O_5 and K_2O.
* DANGER All dry Nitrogen sources have a tendency to burn foliage
Apply only when grass is dry, or after cutting or grazing.

4. Apply nitrogen at 30–50 lbs./acre intervals after cutting.
1st application normally early spring.
2nd application normally in June.
3rd application normally in July.

30 Minutes
to
The Balanced Soil Fertility

Soil Nutrient Recommendations

Based On Soil Test For Major, Secondary & Trace Elements

RECOMMENDATIONS

BROME GRASS
FESCUE GRASS
ORCHARD GRASS - - - For HAY
RYE GRASS
WHEAT GRASS

YIELD PERFORMANCE PER ACRE	NITROGEN CODE LBS./ACRE			SOIL TEST REPORT P_2O_5 LBS./ACRE									SOIL TEST REPORT K_2O LBS./ACRE								
	1	2	3	VL 0–12	L 13–30	M 31–45	LH 46–80	MH 81–114	H 115–150	LVH 151–186	MVH 187–250	VH 251+	VL 0–100	L 101–180	M 181–250	LH 251–360	MH 361–579	H 580–798	LVH 799–1017	MVH 1018–1235	VH 1236–1454
LOW	80	100	50	200	160	120	60	40	20	5	0	0	200	180	160	120	60	40	20	10	0
AVERAGE	120	140	70		180	140	80	60	40	35	10	0		220	180	140	80	60	40	30	10
HIGH	160	180	90			160	100	80	60	45	30	10			200	160	100	80	60	50	30

(1) For an above average performance/acre a complete soil analysis is recommended.
(2) For high CEC or peat muck soils add extra 25 lbs. of both P_2O_5 and K_2O.
(3) For light sandy soils (less than 9% clay) deduct 20#of N, P_2O_5 and K_2O.

RECOMMENDATION TABLE
FOR TRACE (MICRO) AND SECONDARY ELEMENTS

RECOMMENDATIONS FOR: All States
CORN, SOYBEANS, AND OTHER LEGUMES AND GRASSES

Rate – – Pounds/Acre To Apply When Soil Test Is [1]

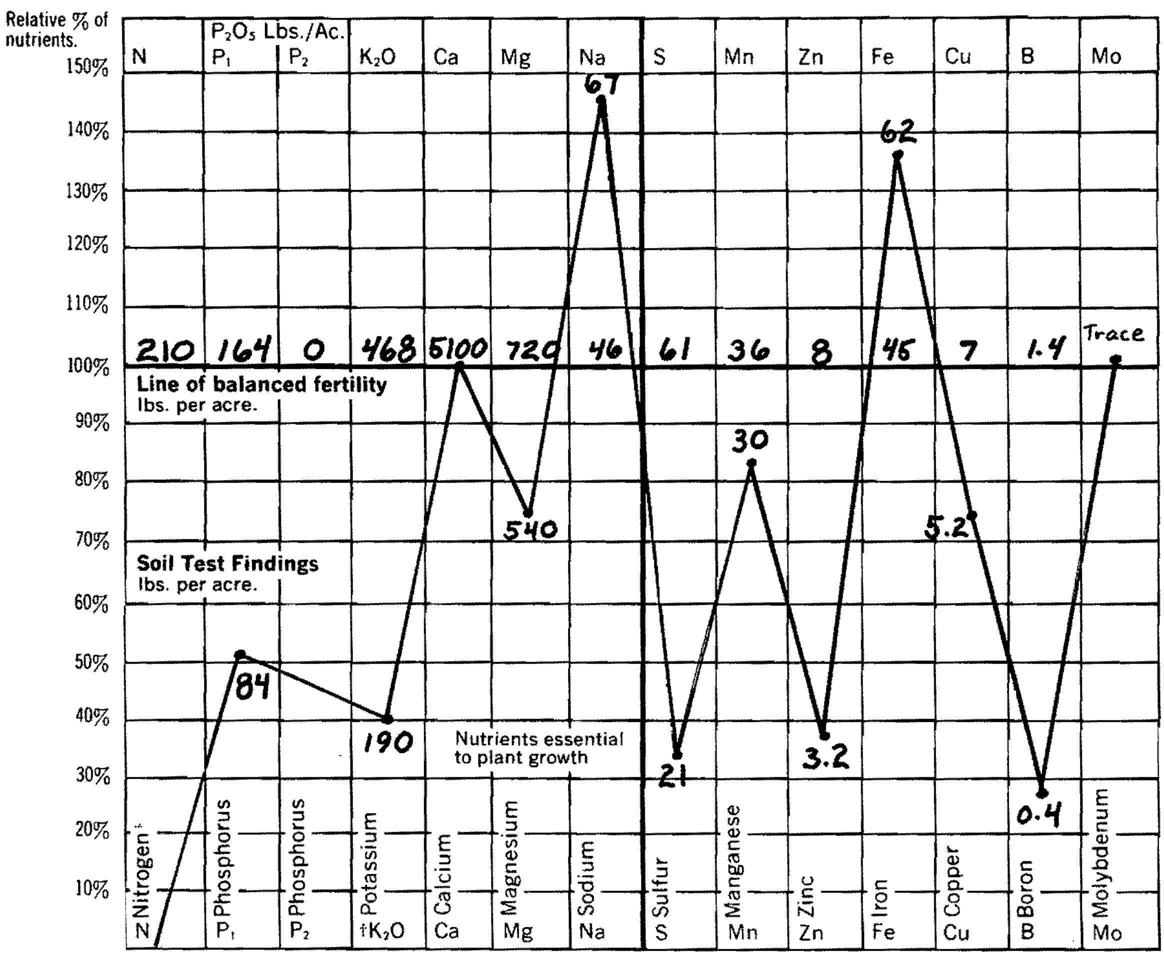
NUTRIENT	SOIL TYPE	Soil Test Lbs./Acre VL	L	M	H	VH
Zinc	Range →	0-3	4-10	11-20	21-35	35+
	Sand-Sandy Loam	5-4	4-3.5	3.5-2.5	2.5-1	1-0
	Silty & Clay Loams; Clays	7-5	5-4	4-2.5	2.5-1	1-0
	Peats & Mucks	10-7	7-5	5-3.5	3.5-2	2-0
Boron	Range →	0-0.5	0.6-1	2-3	3-6	6+
	Sand-Sandy Loam	1-.75	.75-.5	.5-.3	.3-.1	.1-0
	Silty & Clay Loams; Clays	1.25-1	1.0-.75	.75-.5	.5-.3	.3-.1
	Peats & Mucks	5-3	3-2	2-1	1-.75	.75-.25
Copper	Range →	0-2	3-5	6-10	11-20	20+
	Sand-Sandy Loam	2-1	2-1	2-1	1-.5	.5-0
	Silty & Clay Loams; Clays	5-3	3-2	2-1	1-.5	.5-0
	Peats & Mucks	8-6	6-4	3-2	2-1	1-0
Iron	Range →	0-8	9-20	21-33	34-45	45+
	Sand-Sandy Loam	5-4	4-3	3-2	2-1	1-0
	Silty & Clay Loams; Clays	6-5	5-4	4-3	3-2	2-1
	Peats & Mucks	8-7	6-5	5-4	4-3	3-1
Manganese	Range →	0-7	8-15	16-23	24-30	30+
	Sand-Sandy Loam	20-14	14-10	10-6	6-3	3-0
	Silty & Clay Loams; Clays	30-23	22-16	15-11	11-6	5-0
	Peats & Mucks	40-31	30-23	22-16	15-11	14-1
*Sulphur	Range →	0-10	11-25	26-35	36-50	50+
	Sand-Sandy Loam	52-44	43-32	31-18	17-8	7-0
	Silty & Clay Loams; Clays	60-49	48-35	34-21	20-11	10-0
	Peats & Mucks	73-62	61-49	48-35	36-19	18-0
Magnesium	Range →	0-100	101-250	251-400	401-800	800+
	Sand-Sandy Loam	22-17	16-13	12-7	6-2	1-0
	Silty & Clay Loams; Clays	25-20	19-16	15-9	8-3	2-0
	Peats & Mucks	31-26	25-20	19-15	14-9	8-0

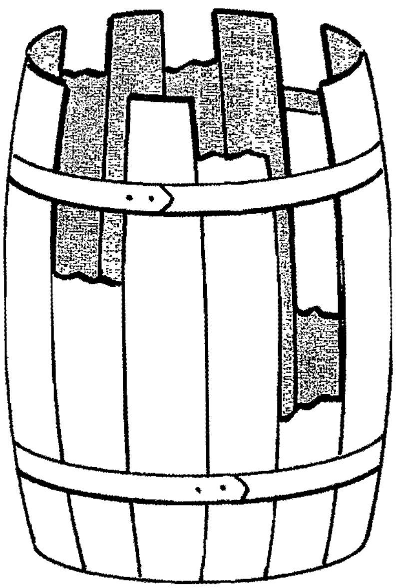
1 All recommendations given in lbs./acre **elemental.**
*For each 0.1% decrease in organic matter below 2% increase recommendation by 1 lb./acre **elemental.**

For Broadcast Application: double the rate if **fritted** or **chelated** material is used. Triple the rates if **sulfate** carriers are used. Quadruple the rate if oxide are used.

EXAMPLE:

After Step 14, your example chart should look like this.





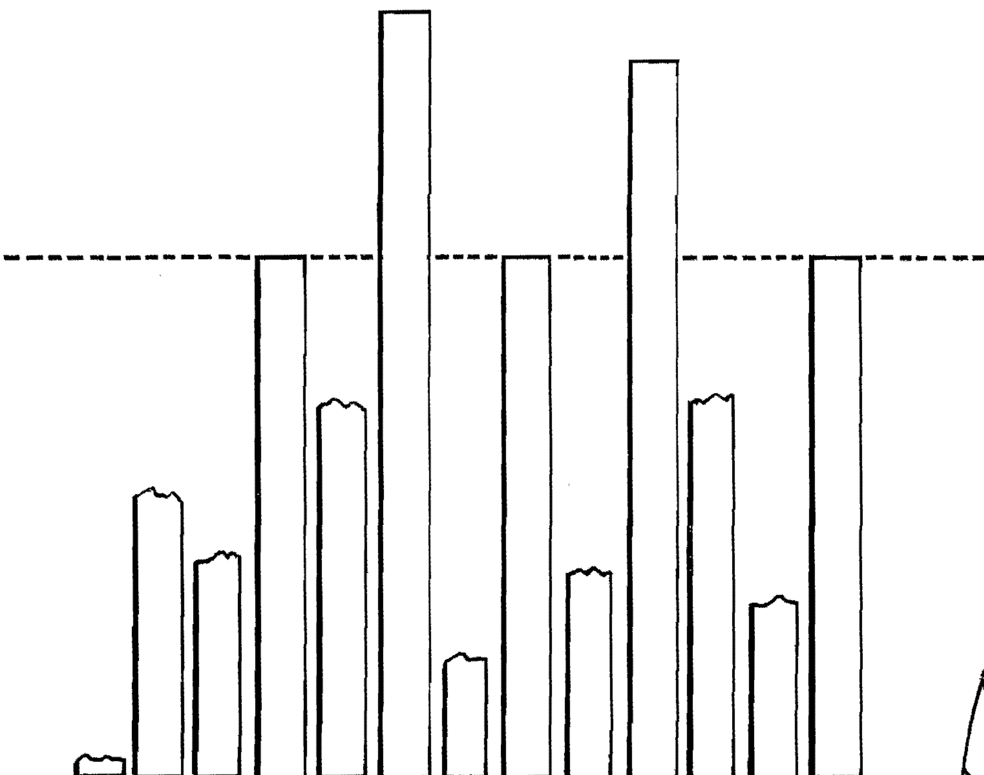
OKAY . . . NOW YOUR BALANCED

FERTILITY CHART IS COMPLETED.

WHAT DOES IT MEAN?

Think of a barrel with 13 staves . . . each stave representing one essential soil nutrient. Regardless of the size or condition of the other staves, the barrel will hold water only to the height of the shortest stave. No more. Similarly, soil will only produce yields to the limitation brought about by the nutrient in shortest supply.

Imagine the Balanced Fertility Chart that you just completed as a barrel opened and laid flat, with all staves showing. The Line of Balanced Fertility is the top of the barrel. The percentages of nutrients available represent the top of the staves.



. . . it means that you know precisely which staves are to be shortened, or lengthened, and by how much. It's a program that 'holds water'.

Yes, this comparison is oversimplified. But, we hope it clearly shows what the chart means, and also how easily 'just pouring on more fertilizer' can result in little more than a waste of money.