Back To Basics-Soil Fertility

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What is Soil?

A living dynamic resource that supports plant life.

Mineral particles, organic matter & organisms.

Biological, chemical and physical properties that are always changing.

Soil Characteristics

A medium in which plants grow.

An “ideal” soil is fertile, deep, easily crumbled, well drained and fairly high in organic matter.

Soil fertility is vital to a productive soil. A fertile soil is not necessarily a productive soil. Poor drainage, insects, weeds, diseases, drought, hardpans, and other factors can limit production, even when fertility is adequate.

Soil Composition

Soil is made up of:

- Mineral matter- sand to clay; 45%
- Organic matter; 5%
- Water- in the pore spaces; 25%
- Air- in the pore spaces; 25%

These are the proportions in a loam-textured soil & they vary from time to time and place to place.

Soil Formation

The exposed surfaces of rocks, gravel, sand and silt particles are constantly being broken down by physical and chemical weathering.

As soils are formed during the weathering process, some minerals and organic matter are broken down to extremely small particles; colloids.

Soil Formation 2

Chemical weathering- involves six processes:

Solution- solids dissolved to separate ions

Hydrolysis- react w/water→Hydroxides

Carbonation-carbon dioxide→ Acid

Hydration- combined w/water, softer

Oxidation- loss of electrons

Reduction- gain of electrons

Important Physical Properties of Soil

Color- determined by O.M., drainage, and degree of oxidation/weathering

Texture- amounts of different size particles

Structure- arrangement of soil particles into aggregates

Drainage- water movement in/on the soil

Soil Depth- vertical distance into a soil to a layer that restricts root growth

Soil Color

Light- low O.M., coarse texture, leached

Dark- more O.M., parent material

Red/Brown (subsoil) relative free movement water/air

Yellow (subsoil) drainage impediment

Gray (mottling) too much water/ too little air

Soil Texture

Relative amounts of sand, silt and clay

Refer to a soil textural triangle

Sand is the coarser particles, feel rough when rubbed between the thumb and fingers

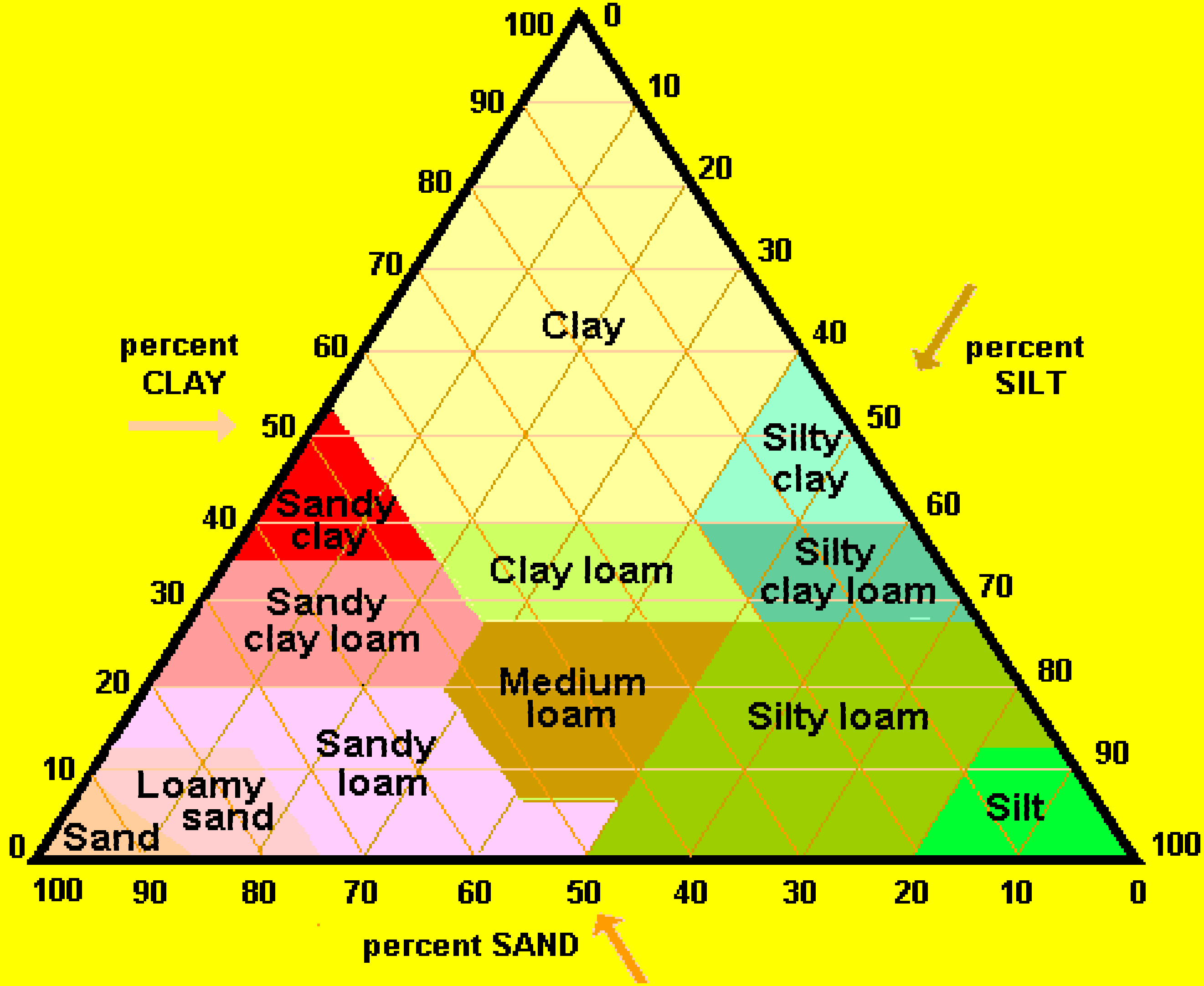
Silt feels smooth/floury; wet- smooth, not slick or sticky

Clay particles are fine textured. Smooth when dry; slick and sticky when wet

Eight or nine textures generally used; STPAL

is moving to soil textural classes.

Soil Textural Triangle



Soil Organic Matter

Organic matter was once a living, breathing organism, either plant or animal. Organic materials breakdown into humus under favorable temperature, oxygen and moisture conditions. What we measure in a soil sample as organic matter is the end product of decomposition. As earthworms, insects, bacteria, **fungi** and microbes feed on organic matter, nutrients are released that are available for use as food by growing plants.

Benefits of Soil Organic Matter

Improves soil physical condition, “soil tilth”
Increases water infiltration and water holding capacity
Improves soil structure and aeration
Storehouse of plant nutrients N, P, S, Zn etc.
Increases soil exchange capacity/CEC

Cation Exchange

One teaspoon of clay particles has a surface area that will cover an acre of land. For the same measure, sand particles will have a surface area about equal to a sheet of writing paper.

Clay and the organic fraction of the soil are referred to as colloids. These colloids have a negative (-) charge, attracting positively (+) charged particles.

This soil property is important, as it enables a soil to hold positively charged nutrients; negatively charged nutrients will leach through the soil; in the soil solution.

Cation Exchange Capacity

The net total negative charge of a soil (or it's capacity to exchange one cation for another) is referred to as Cation Exchange Capacity or CEC.

Factors affecting CEC:

percent clay, type of clay, amount O.M., soil pH

Basic Cations include: Calcium, Ca^{++}, Magnesium, Mg^{++}, Sodium, Na^{+}, Potassium, K^{+} and Ammonium, NH_4^{+}

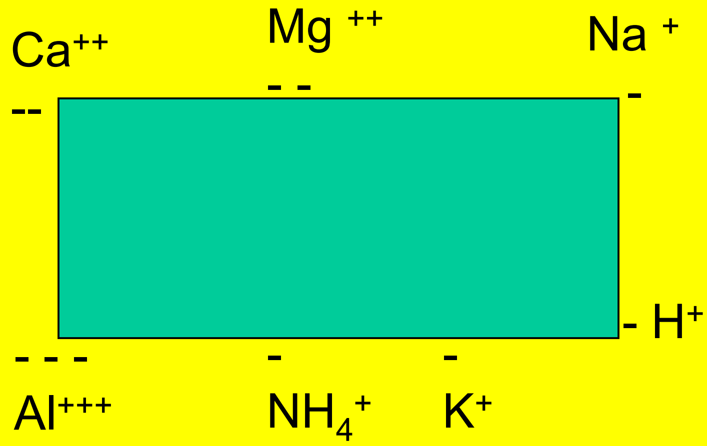
Acidic Cations: Aluminum, Al^{+++}, Hydrogen, H^{+}; may dominate exchange sites in highly weathered, acidic soils. (Fe, Mn)

Monovalent, Divalent, or Trivalent (cations/anions)

Estimated CEC

Soil component	**meq/100gm.**
Organic matter	200
Vermiculite clay	150
Montmoroillonite clay	100
Illite clay	30
Kaolinite clay	10

Soil/Organic matter



Soil solution

Cl^{-}

NO_3^{-}

PO_4^{---}

SO_4^{--}

Lime reaction:

Step 1. $Al^{+3} + CaCO_3 + OH^{-}$ ----> $Ca^{+2} + Al(OH)_2 + OH- + CO_2$

Step 2. $H^{+} + OH^{-}$ ----> HOH (pH goes up)

Soil Moisture Storage

Size and total volume of pore space are a function of soil texture and structure.

Both available and unavailable water increases as clay content increases. Thus, sands have a much lower water-holding capacity than clay soils.

Soil water holding capacity is important for irrigation amounts and frequency. There are listed numerical values of water storage capacities for common soil textures and soil series names.

Plant Nutrients

Plants need 17 elements for plant growth. These are called the essential elements.

Carbon, C; Hydrogen, H and Oxygen, O; come from the air and water, non-mineral elements.

There are 13 other elements (nutrients) that are grouped into three categories:

Major nutrients

Secondary nutrients

Micronutrients

The Major Nutrients

Nitrogen, N

Phosphorus, P

Potassium, K

Plants require these in larger quantities; most likely to be deficient.

These are the three elements on a fertilizer bag/label. ($\mathbf{N} - \mathbf{P}_2O_5 - \mathbf{K}_2O$)

Nitrogen

Dark green color of leaves; usually responsible for increasing plant growth than any other element. Amino acids and proteins.

Excess- succulent growth, weak spindly plants, few fruit

Deficiency- chlorosis in older leaves, reduced growth

Plants absorb most of their N in the form of ammonium or nitrates, with nitrates being the largest quantity. Mobile in the plant; nitrates may leach in sandy soil.

Phosphorus

No other nutrient can be substituted for it. Proteins and amino acids.

Excess- micronutrient deficiencies of Zn and Fe

Deficiency- reduced growth, purpling in foliage, veins or leaf margins

Fixed by Al, Fe and Mn in acid soils; fixed by Ca in alkaline soils. Important in root development of young plants. Mobile in plant; doesn’t leach except in organic mixes. Phosphate.

Potassium

Important in protein synthesis and enzyme activation. Over 80 plant enzymes require K for activation.

Excess- causes N deficiency and may affect uptake of other positively charged nutrient elements.

Deficiency- marginal burn or scorch affecting photosynthetic activity. Short internodes, weak stalks, lodging

Involved in photosynthesis, plant-water relations, disease resistance, drought and stress tolerance and quality in fruits and vegetables. Mobile/Leach

The Secondary Nutrients

Calcium, Ca

Magnesium, Mg

Sulfur, S

These are not any less essential than the major nutrients, only being used in a smaller quantity.

Lime, if needed to raise soil pH, will supply calcium and/or magnesium. Calcitic or Dolomitic lime

Gypsum contains Ca and S; neutral salt.

Calcium

Important in the structure of the plant- cell walls. Stimulates root and terminal bud development.

Excess- interferes with Mg absorption; replaces K, Na and NH_4 on soil complex; causes high soil pH-micro's

Deficiency- inhibition of bud and root tip growth, blossom-end rot on vegetables

Important in pH control by reducing acidity. Limited mobility in the plant, one-way ticket; moderately leachable.

Magnesium

Central element of the chlorophyll molecule, actively involved in photosynthesis and P metabolism

Excess: interferes with uptake of K, NH_4 and Ca

Deficiency: reduced growth, marginal chlorosis, interveinal chlorosis starting at leaf tips at lower to mid-plant. Leaves are stiff and brittle. Intercostal veins (branching) are twisted

Leaches from soils, is mobile in the plant. Foliage plants susceptible. Epsom salts and Dolomitic lime, if pH is low.

Sulfur

Plant proteins, a part of certain amino acids. Necessary for chlorophyll formation.

Excess: over-application of S to lower soil pH

Deficiency: symptoms are general yellowing of younger leaves or in severe cases the entire plant

High N rates may induce S deficiency. Is not mobile in the plant, but is leachable in the soil.

The Micronutrients

Boron, B; Copper, Cu; Manganese, Mn ; Zinc, Zn; Iron,Fe; Molybdenum, Mo and Nickel, Ni; Chlorine, Cl

Micro meaning small; at one time called trace elements or minor elements, but not of minor importance.

Soil availability depends on pH

Deficiencies likely above pH 6.8; exception is Mo

Many micronutrients are enzyme activators. Used in smaller quantities than major or secondary nutrients.

Iron

Deficiency: interveinal chlorosis on younger tissue that may change from yellowish to white.

Conditions for deficiency include soils high in Ca, poorly drained soil, high soil pH, high soil P, Cu or Zn.

Acid loving plants: azaleas, blueberries, camellias, roses, etc.

Can be corrected with chelated forms of iron and other type fertilizers containing iron , as well as amendments that lower soil acidity; Aluminum sulfate & sulfur. **Caution!**

Boron

Growth and formation of new cells. Sugar/carbohydrate transport.

Excess: over application may cause problems with
small grains

Deficiency: symptoms vary; stunted growth,
yellow to white color new leaves, terminals.
Symptoms on new growth, as it's
immobile in the plant. Overlimed acid soils.
Plant fruit, fleshy roots with necrosis or
abnormalities; breakdown of internal tissues.

Leaches in the soil, especially in acid and sandy soils with low O.M.

Zinc

Enzymes, Reproduction- flowering & seed production, Protein metabolism

Deficiency- acidic sandy soils with low O.M.
Calcareous soils, Subsoils. Associated with N uptake and metabolism.

Symptoms- purple leaf margins, like P, but moving toward center of leaves, purple blotching
Rice with brown/bronze spots.

Low solubility in soil; Low mobility in plants.

Molybdenum

Biological nitrogen fixation by Rhizobium

Deficiencies- soils with low pH and hi Fe, Al oxides
Soybeans pH 5.2-6.2.

Symptoms- general yellowing, stunting, interveinal mottling and cupping of older leaves followed by necrotic spots on tips and leaf margins.

Immobile in soil; Mobile in the plant

How Much Fertilizer To Raise Soil Test Levels

Soil test levels can be raised if the rate of P_2O_5 and K_2O application exceeds the rate of removal by the harvested crop (s).

General rule of thumb:
12 – 28 lb of phosphate above crop removal, to raise STP level by 1 ppm. Av. 20 lb added.

8 – 16 lb of potash above crop removal to raise STK level by 1 ppm. Av. 12 lb added.
Continued on next slide.

Raising Soil Test Levels- Continued

The *amounts required will depend on* the initial soil test level, the rate of crop removal, soil texture, clay minerals present, organic matter level, and the tillage system. What are the limitations?

Most agronomists would consider a 4 to 8 year approach in raising ST P and K levels to optimum levels. Faster (economics, risk of runoff of P)

Nutrient Removal in Harvested Crops

Crop	Unit	N	P_2O_5	K_2O
Corn	lb/bu	0.75	0.44	0.29
Soybeans	lb/bu	4.00	0.80	1.40
Cotton	lb/bale	32.00	14.00	20.00
Milo	lb/cwt	1.50	0.75	0.38
Wheat	lb/bu	1.15	0.55	0.34
Rice	lb/bu	0.55	0.29	0.18
Sugarcane	lb/ton	2.00	1.25	3.50
Bermuda	lb/ton	46.00	12.00	50.00

Examples of Plant Food Removed in Harvested Crop

Crop	Yield/Ac	N,lb	Phosphate,lb	Potash,lb
Corn	200 bu	150	88	58
Soybeans	40 bu	160	32	56
Cotton	2 bale	62	24	28
G. Sorghum	70 cwt	105	53	27
Wheat	70 bu	81	39	24
Rice	150 bu	83	44	27
Sugarcane	30 ton	60	38	105

PPI data

Soil pH

The term pH defines the relative acidity or alkalinity of a substance.

The pH scale ranges from " **0** " to " **14** ", a pH of " **7** " being neutral.

0-------------------------7-----------------------14

Acid Alkaline

pH is defined as the negative logarithm of the hydrogen (H^+) ion concentration.

Causes of Low Soil pH

*Leaching of calcium and magnesium

*Soil erosion on newly prepared areas

*Crop removal, ex. sugarcane, hay fields

*Use of acid-forming fertilizers:

1.8 lb lime neutralized per lb N; N Soln, AN, Urea

5.25 lb lime neutralized per lb N; Am. sulfate

pH - Hydrogen Ion Activity

Soil pH is expressed in logarithmic terms, not a linear scale!

Each pH unit change means a **tenfold change** in acidity or alkalinity.

Ex: pH 4 is 10 times as acidic as pH 5

Older literature spoke of a soil being sour (acid) or sweet (basic or alkaline)

pH is one of the most important chemical reactions in soils

Soil pH has a profound effect on <u>availability of nutrients and microbial activity.</u>

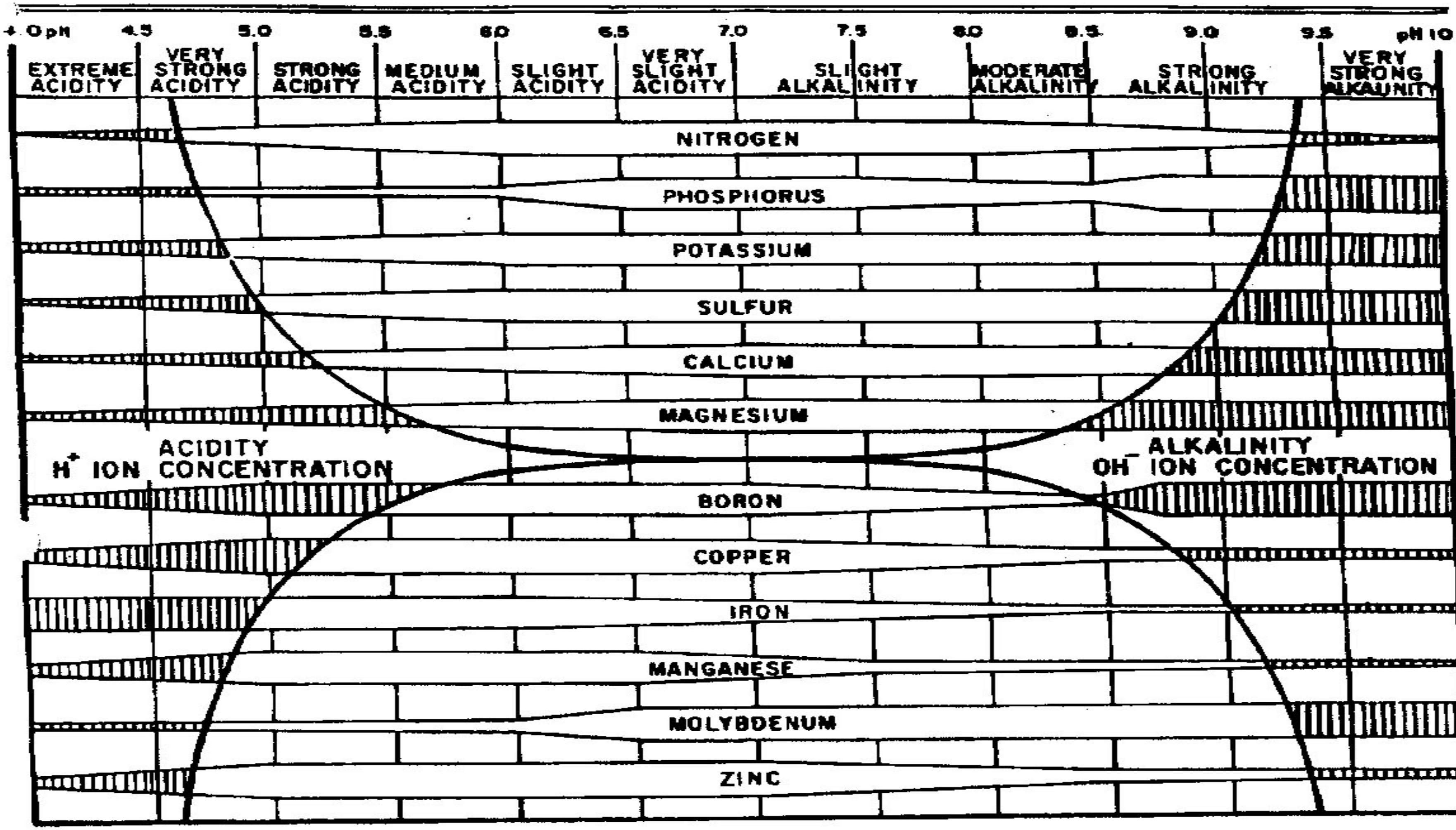


Figure 1.–Effect of soil pH and associated factors on the availability of plant nutrient elements. The width of the band for each element indicates the relative favorableness of this pH value and associated factors to the presence of the elements in readily available forms (the wider the band the more favourable the influence). It does not necessarily indicate the actual amount present since this is influenced by other factors. (Reproduced from *Changing Patterns in Fertilizer Use*, p. 152, 1968, by permission of the Soil Science Society of America.)

Limestone makes Fertilizer Work. Fertilizer Efficiency Goes Up as Soil Acids Go Down

SOIL ACIDITY	NITROGEN	PHOSPHATE	POTASH
Extremely Acid 4.5 pH	30%	23%	33%
Very Strong Acid 5.0 pH	53%	34%	52%
Strongly Acid 5.5 pH	77%	48%	77%
Medium Acid 6.0 pH	89%	52%	100%
Neutral 7.0 pH	100%	100%	100%

Adjusting Soil pH

Base it on a Soil Test!!!! Lime or Sulfur requirement.

Lime raises the soil pH; Sulfur reduces soil pH, more acid.

The old adage " if a little is good, more is better" will get you in a bind if you over-apply either of these materials.

Raise pH - AgLime, Dolomitic lime, Hydrated lime (caution)

Lower pH- Elemental sulfur, aluminum sulfate (caution)

Soil Testing

Purpose- supply clients with enough information to make a wise choice regarding applications of soil amendments and fertilizers.

Measures the plant-available portion of soil nutrients. Soil test results form the basis for nutrient recommendations.

A **Routine soil test** from the LSU AgCenter Soil Testing and Plant Analysis Laboratory costs $7/ sample which provides a soil texture, pH, Calcium, Magnesium, Phosphorus, Potassium, Sodium, Zinc, Copper, Sulfur and a lime or sulfur requirement to adjust soil pH, if required for the crop (s) to be planted.

Philosophy of Soil Test Fertilizer Recommendations

1. Base them on soil test results

2. Recommend that lower testing soils be built up to higher test levels by adding fertilizer

3. Apply maintenance amounts of plant nutrients to higher testing soils to keep them there and keep productivity high (Vegetables and high value crops)

4. Not apply specific nutrients to soils testing <u>very high</u> in these nutrients

Using Your Soil Test Results

Need to understand the information on the results sheet.

*Soil test results and ratings (interpretations)
*Suggested fertilizer and lime recommendations
*Fertilizer management practices or concerns
(Soil Test Information Sheet/RecSheet)

Soil Area

*Soils are classified into two areas, upland & alluvial. Upland soils are those in the Coastal Plains (hill soils) and the Loessial soils, like the Macon Ridge in northeast LA.

*The alluvial soils are those in the river bottoms.

Soil pH (Soil Reaction)

*Soil pH indicates the level of active acidity.

*Maintaining a soil pH between 5.8 to 6.5 will generally provide a favorable environment for growth and development.

*Lime recommendations are made to correct problems with soil acidity; Mn &Al

*Recommendations are based on the soil pH, soil texture and the crop to be grown.

*Two types of lime: Calcitic or Dolomitic

*Look at soil test Ca and/or Mg levels- Lime

Phosphorus- P

*In LA, the soil test for P is **Mehlich III**

*Test results given as ppm of Extractable P, a measure of the relative availability of P.

*Not a measure of total phosphorus.

*Recommendations as lbs. of Phosphate/Ac (P_2O_5)

Soil Test Ratings

Most laboratories use some form of rating scale within which soil-test values are placed.

An example of this :

Very low

Low

Medium

High

Very high

Now, what does this mean to you as you review a soil test report?

Very Low

*Less than 50 % of the crop yield potential is expected without addition of that nutrient.

*A large portion of the crop nutrient requirement must come from fertilization.

Low

*50 to 75 % of the crop yield potential is expected without addition of the nutrient .

*Yield increase due to the added nutrient is expected.

*A portion of the crop nutrient requirement must come from fertilization.

Medium

*75 to perhaps 95 % of the crop yield potential is expected without the addition of the nutrient.

*Yield increase to the added nutrient is expected.

*A small portion of the crop nutrient requirement must come from fertilization.

High

*Yield increase to the added nutrient is not expected.

*The soil can supply the entire crop nutrient requirement.

*No additional fertilizer is needed.

Very High

*Yield increase to the added nutrient is not expected.

*The soil can supply much more than the entire crop requirement.

*Additional fertilizer should not be added to avoid nutritional problems and/or adverse environmental consequences. P is a big issue.

Calcium, Magnesium,Potassium, Sodium, Zinc, Copper & Sulfur

* Cations are extracted by Mehlich III extraction solution and procedure

*Reported as Extractable nutrients, ppm.

*Calcium/ Magnesium levels – type of lime

*Recommendations for K as lbs. Potash/Ac (K_2O)

Organic Matter

*Expressed as a percentage

*No rating system

*Measures the resistant state of O.M. in soil

Consider this:

An acre of soil measured to a depth of six inches weighs about 2,000,000 pounds, meaning that 1% organic matter in the soil would weigh about 20,000 pounds. It takes about 10 pounds of organic material to decompose to 1 pound of organic matter, so it takes at least 200,000 pounds (100 tons) of organic material applied to the soil to add 1% stable organic matter under favorable conditions.

Additional Tests

Soil Organic Matter, $3/sample

DTPA Micronutrient Test- Zn, Fe, Mn and Cu. , $4/sample

Heavy Metal Test- As, Cd, Pb, and Zn., $4/sample

Optional Soil Tests- Al, B, S, Soluble salts and Extractable oil; $4 for each analysis; separate tests

Storm Test- Measures EC, Total Soluble Salts, SAR, etc.; $5/sample

Soil-less Routine (Potting mixes)- Ca, K, Mg, P, pH, conductivity, nitrates ; $7/sample

Plant Analysis Ag Routine metals, $6; Total N, $6; Ag Routine metals +N, $10;
Ag Routine metals + Heavy metals, $10;
All Plant metals + N, $14

Irrigation Water Tests Routine ($7), Quick ($4)

Fertilizer

Produces results that are considered desirable; applied to obtain some desired plant response; applied whenever you expect to get a desired plant response- **Ratings**.

Fertilizer needs should be based on soil test results ~ 3 years.

A properly taken soil sample, analyzed by a soil testing lab will give you recommendations on the fertilizer nutrient needs of the crop (s) you will be growing.

Fertilizer Selection

Recognize the plant response you are seeking

Contains the needed nutrient (s)

Releases the nutrients when needed- not always!

Cost effective

Safe and convenient to use

Environmentally friendly

Fertilizer Law

Louisiana Dept. of Agriculture and Forestry- State Law
Requiring fertilizer manufacturers to guarantee the claimed fertilizer analysis on a bag of fertilizer.

Nutrient analysis is based upon a percentage of weight. The analysis is sometimes called the "grade."

All fertilizers are labeled with three numbers that give the percentage by weight of **nitrogen**, **phosphate** and **potash**.

All fertilizers are based on **100 pounds**; ex: 8-8-8 contains 24 lb. of nutrients per 100 pounds of fertilizer.

Common Nitrogen Fertilizers

Fertilizer material	% Nitrogen
Ammonium nitrate	34
Ammonium sulfate	21
Urea	45
Nitrogen solutions-UAN	32, 30, 28

Common Phosphate Fertilizers

Fertilizer material	**% P_2O_5**
Triple superphosphate (TSP)	*46*
Diammonium phosphate (DAP)	46
Monoammonium phosphate (MAP)	48-52
Ammonium polyphosphates (10-34-0)	34

Common Potash Fertilizers

Fertilizer material	% K_2O
Muriate of potash	60
Sulfate of potash magnesia (K Mag)	21

Complete/Incomplete/Balanced

Complete- contains the three major nutrients; N, P and K

Ex: 12-6-6

Incomplete- lacks one of the major nutrients

Ex: 34-0-0 ; 0-0-60 ; 18-46-0 (DAP)

Balanced- contains the three major nutrients in the same proportions

Ex: 8-8-8 ; 13-13-13

Incomplete to Complete Fertilizer

Fertilizer	**Analysis**	**Amount**
Urea	45-0-0	100 lb
Triple superphosphate	0-46-0	100 lb
Muriate of potash	0-0-60	100 lb
Produces	45-46-60	300 lb
With a **grade** of	~ **15-15-20**	**for every 100 lb**

Conventional Fertilizer- Pros and Cons

Advantages

Fast acting

Some are acid-forming

Lower cost

Disadvantages

Greater burn potential (fertilizer salts)

Solidifies in the bag when wet

Nitrogen leaches readily

Manures/Sewage Sludge- Pros and Cons

Advantages

- Low burn potential
- Relatively slow release
- Contains micronutrients
- Conditions the soil

Disadvantages

- Salts may be a problem
- Bulky; hard to handle
- Odor
- Expensive per pound of actual nutrient
- Weed seeds may be a problem
- Heavy metals in sewage sludge

Organic Fertilizers

Refers to nutrients contained in fertilizer products derived solely from the remains (or a by-product) of a once living organism.

Cottonseed meal, pelletized chicken litter, corn gluten and all manures are examples of organic fertilizers. If sold as a fertilizer, should have a fertilizer analysis stated on it.

Many times sold as a soil conditioner, without a guaranteed fertilizer analysis. Some horticultural products have fertilizer added to them.

Depend on soil organisms to break them down. Slow….

Manure is a Complete Fertilizer

Low in the amount of nutrients it can supply.
Analysis for N, P, K and % Moisture if used in a Nutrient Management Plan.

Varies in nutrient content according to the animal source, what the animal has been eating and type of storage conditions.

Manures are best used as soil conditioners.

Fresh manure should not be used in contact with tender plant roots.

Soluble Salts- Fertilizer

Fertilizers don’t burn or damage plants if applied correctly.

Fertilizers are salts: nitrates, sulfates, phosphates, chlorides, etc.

Consider table salt (Sodium chloride); we have a fertilizer material, Muriate of potash (Potassium chloride.)

Fertilizer applied to the soil dissolves in the soil moisture and diffuses out into the soil. Tender roots near fertilizer have water drawn from them and the surrounding soil; roots begin to dehydrate and collapse if the salt concentration is high, roots “burn” and plants may die or suffer severe damage.

Salt/Sodium Problems

Salts/sodium -accumulate on top of the soil; white crust or sifting of white “powder”.

Fertilizer applied repeatedly without sufficient water to leach or wash accumulated salts through the soil. Clay-type soils, more problems; check irrigation H_2O quality!

Problems do occur in fields/gardens, with excess fertilization. Then came the 2005 Hurricanes!

Gypsum for Sodium Problems

Gypsum is calcium sulfate, a neutral **salt**.

Does not increase or decrease the soil pH.

High sodium areas should receive an application of gypsum, based on calculations, to release Na from the exchange sites.

Thorough watering/irrigation/rainfall, will move salts deeper into the soil profile (away from the active rooting zone).

Calcium is left on the soil exchange sites.

Sodium sulfate formed is water soluble & moves downward, **if the soil can percolate!!! Silty clays and Clays??**

Fertilizer Application Methods

Broadcasting

Banding

Starter solutions

Side-dressing

Foliar

Thanks for your attention!

Are there any questions/comments ?