

# **KNOW YOUR SOIL**

## **A HANDBOOK FOR ORGANIC GROWERS AND GARDENERS IN TEMPERATE AND SUB-TROPICAL REGIONS**

By: Amigo Cantisano, Organic Ag Advisors

Colfax, CA

*This handbook gives enhanced understanding of soil nutrients and their roles in promoting plant growth. It was prepared originally to assist in interpreting soil test results for organic growers and gardeners, but it also provides useful guidance in ensuring proper nutrient balance, and to avoid over fertilization and environmental contamination. In most cases, the diction of the author was retained to ensure proper interpretation.*

(Edited and adopted by Julian Dumanski, RDV, World Bank)

### **INTRODUCTION**

There are libraries full of information on growing, and this can be complex and confusing. This compendium provides sufficient information to make an informed decision without overwhelming detail. The article, written by Amigo Cantisano of Organic Ag Advisors, represents 20 years of knowledge accumulated from reading, interpreting and using thousands of soil tests.

### **ORGANIC MATTER (OM)**

Organic Matter is defined as all living and decaying residues, including weeds, crop residues, decaying roots, microorganisms and anything which is added to the soil in the form of composts, manures, cover crops, mulches, leaves, etc. These materials all contain many nutrients for future plant growth, including carbon which is the most basic food source for the soil's microlife and (indirectly) for the plants themselves. This carbon feeds the microbes and earthworms, stimulating their activity and increasing their populations.

As the microbes proliferate they in turn act as food for other microbes, which also "mine" the soil for the minerals the plants need. Acids are secreted by the microbes which "etch" rock surfaces and expose mineral particles for micro food as well as plant nutrients. The microbes also secrete gum-like substances which help form soil aggregates, thus improving soil structure and the penetration of air, water and roots.

This whole process of organic matter accumulation is critical to the formation of topsoil and the growth of crops. It is necessary to have a regular supply of organic material for the soil's microlife. This is particularly important in soils which are tilled or exposed, because desiccation by sun and wind causes the loss of carbon to the atmosphere as carbon dioxide (CO<sub>2</sub>).

Increasing the organic matter content will improve water penetration, water-holding capacity, soil structure, microbial biomass, nutrient availability, drought, and heat stress resistance, resistance to compaction and more. Increasing the soil's organic matter content is perhaps the most important improvement a farmer can make.

Soils which are below 2% organic matter (OM) in the upper horizon are low in organic matter. They do not have enough essential food (carbon) to feed the micro and macro organisms which provide all fertility to plants.

Raw organic matter decomposes, under proper conditions, into humus. Humus has been “digested” by soil microbes and earthworms, creating a soil-like material which has high levels of organic acids (e.g. humic, carbonic and fulvic acids), and a very high cation exchange capacity (or ability to mobilize calcium, potassium, and other cations as plant nutrients).

Humus is full of soil microbial life and acts in much the same way as a yogurt culture or sourdough starter, in stimulating soil life. Humus also, as a product of the soil digestion process, is a highly concentrated source of plant available nutrients.

One way to visualize humus is to think of the difference between raw organic materials going into a compost pile and the rich earth-like material which comes out of a finished pile.

It is good to add organic matter and humus at least once a year to most soil, more often to soils with very low (under 2%) OM contents. The two best ways to increase the OM are to add compost and to grow cover crops. OM can also be increased with manures and sheet-composting but the results are definitely inferior to those achieved through aerobic composting and cover cropping.

## COMPOST

### Good Compost

Compost provides available and slow-release forms of all necessary plant nutrients and vitamins. It is also an excellent source of humus, which benefits soil microbiology, soil buffering (the soil's resistance to radical change), and more. Compost contains significant amounts of plant available nitrogen phosphorus, potassium and trace minerals.

When making or shopping for compost, quality is more important than quantity. Look for material which is dark brown to black, smells like the forest floor after a rain, has no identifiable large materials in it, and is low in un-decomposed residues. Choose a material based on animal manures, that is low in wood or rice byproducts and is fully aerobically composted.

There are many “composts” on the market which in fact are nothing more than raw organic material. Beware of “compost” made from cedar or redwood as these materials contain substances which can negatively effect plant growth for a long time after their application.

Poor compost can actually set plant growth back as it decomposes in the soil because it robs essential nutrients such as nitrogen from the plant and soil until it decomposes fully and becomes like earth. In addition, poor compost may introduce weed seeds, pathogens and other problems that you would rather avoid.

Quality compost, on the other hand, provides nutrients that are immediately available to the plant, and has no negative effects on the soil or plants.

### COMPOSTING TIPS

Compost can be improved by the addition of some of the same minerals which may be deficient in your soil. Materials which are appropriate to add to a working compost pile include Soft Rock Phosphate (1.8-9.0kg/m<sup>3</sup> of composting material), Greensand (1.8-18.1kg/m<sup>3</sup>), Kelp Meal (0.2-0.4kg/m<sup>3</sup>), Rock Dusts (1.8-18.1kg/m<sup>3</sup>), Soil Min (0.2-0.9kg/m<sup>3</sup>), Azomite (0.2-0.9kg/m<sup>3</sup>), Wood Ash (0.2-0.4kg/m<sup>3</sup>). These materials should be thoroughly mixed into the pile at the beginning of the composting process. Do not add lime or gypsum to compost piles.

The composting process will benefit greatly from the addition of a compost inoculant such as Compostar or Biodynamic Compost Starter. Inoculants provide an active culture of beneficial microbes which speed the decay process of the compost and increase the humus and microbial content of the finished material. Inoculants are applied as liquid spray watered on as the compost pile is being made up or turned. Adding some mature compost from a previous aerobic compost pile will also help inoculate the new pile with beneficial microbes.

### APPLYING COMPOST

If the compost is of good quality, aerobically digested, and at or near a completely humified level, it can be safely applied at almost any period of plant growth.

The prime times for compost application are just prior to planting the desired crop or when incorporating (or turning in) the residues from the previous crop or cover crop. Compost should be worked into the soil where possible. As this is not possible in perennial plantings, it is best to apply the compost to the soil surface and then mulch with another organic material.

In all cases it is best to apply the compost when the soil is moist or to irrigate immediately after application. This is particularly important to the beneficial microbes in the compost, which are damaged by the desiccation of sun, wind and heat.

Compost can and should be applied along with any other fertilizer or soil amendment that is being used in the soil building process. The humus and biological activity of the compost greatly assists the decay process of other fertilizers, rapidly increases the level of nutrients available to the plant. Compost will also limit leaching of other fertilizers.

### RATES TO USE

Application rates for compost are the subject of much debate. Our feeling is that regular moderate applications of compost are the most sustainable soil-building method. Compost should be incorporated at least once a year and 2- 3 times per year is better. If it is applied this often, there is no need for a large amount at any one time.

When first developing a piece of ground into a garden or farm, use relatively large amounts to build the soil up quickly. If the soil is highly sandy, rocky, or a heavy clay, think of compost as a major soil amendment. Heavy doses will make a big difference quickly.

People often apply far more compost than the soil needs, particularly in small garden situations. You never need to put on more than a 2-3 cm layer of good compost and for most situations this is too much, unless you are in the first year of a soil-building program. A 2-3 cm layer is equivalent to over 900 metric tons (approximately 600 m<sup>3</sup>) of compost per ha. Keep in mind that many successful organic farmers grow excellent, high yielding vegetable crops with 4.5-9.0 metric ton of compost per ha! More is not necessarily better in the case of compost applications.

Quality compost will yield a good plant response when spread at 0.6 cm deep (equivalent to about 7.5 m<sup>3</sup> yards per 300 m) on vegetable crops. For orchards and vineyards, use 4.5-9.0 metric ton/ha or 10-30 kg per mature tree or vine, less on younger ones. For flower gardens, use the same rates as vegetable gardens for new lawns, apply 0.6-1.25 cm. For renovating existing lawns, apply 0.6 cm after coring or aerating turf.

If you have extra compost, save it for future crops or other areas. Keep in mind the need to apply the compost at least 2 times per year and you will never have an overload of material at one time. You are better to apply more frequently than to apply too much at once, since the soil biology needs time to digest the organic material.

## MANURES

All forms of animal manures can be used to build your soil. Manures can be a source of macro and micro nutrients, organic matter and beneficial soil microbes. Aerobically composted manure is far superior to raw or undigested manure for the following reasons:

- 1) Raw manure does not provide nutrients to plants until it is converted to humus by soil and compost microbes. This process ties up certain minerals, causing a temporary significant reduction in available nutrients, especially nitrogen. A nitrogen deficiency can highly impact rapidly growing plants. The deficiency is magnified if the manure has been mixed with something high in carbon, such as wood shavings, sawdust, straw, or rice hulls (all common manure contaminants). The problem gets worse when large amounts of raw manure are added to the soil.

- 2) Heavy applications of pure poultry (chicken or turkey) manure can cause other problems - an over supply of "hot" nitrogen which can burn plant roots and possibly contaminate water sources.

- 3) Raw manure can carry soil contaminants such as pesticide residues, unwanted salts, soil pathogens, seeds, antibiotic residues, etc., which can give problems.

4) When large amounts of raw manure (or other raw organic material) are worked into or laid on top of the soil, there is a definite risk of increasing some species of pest insects. Raw manure acts as an initial food source for sowbugs, slugs, snails and earwigs. After they consume much of this raw organic matter they will grow to a large population which will then search for other things to eat, especially your crops! Centipedes and symphyllids can also increase to crop-damaging levels. Both of these organisms feed on the roots of growing crops and stunt their growth.

All of the problems of manures can be eliminated or greatly reduced by composting. Manure makes an excellent addition to the compost pile in nearly any amount. Compost aerobically in order to receive full benefit from the manure.

There are no “proper” application rates for raw manure, but if you are forced for some reason to use it, never apply more than a 1.25 cm layer at a time.

## MULCHES

Mulches can be described as (usually) organic materials which are placed on the top of the soil to provide a blanket effect. A good mulch will increase the soil's water-holding capacity, reduce evaporation, keep the soil structure soft and open, increase the organic matter content, suppress weeds and provide slow-release nutrients. Mulches are generally applied during the warm and active growing season to help keep soil temperatures in balance and reduce stress to the crop.

Mulch is applied from 1.25cm to 15cm deep. The deeper the layer, the greater the effect of the mulch on soil-building. Raw manures are sometimes laid on top of the ground as mulch (1.25 to 5 cm). This technique can work well for perennial plantings, but keep in mind the above drawbacks of using raw manures.

Other materials which are used for mulching include compost, spoiled hay, leaves, grasses, weeds, wood products, etc. Keep in mind that raw organic matter can increase populations of pest insects; these critters love mulches. Quality aerobic compost is far and away the best mulching material.

## COVER CROPS (Green Manures)

Cover crops are our favorite method for building the soil's organic matter and humus content. All soils must have a cover crop in their rotation to effect a truly sustainable agriculture. There is a season for a cover crop on every garden or farm.

The principle reasons for planting a cover crop are:

- 1) To provide erosion protection.
- 2) To build the soil organic matter and humus content and improve the structure of topsoil and subsoil. To increase the microbial activity and biomass in the topsoil. To provide food for the soil microbes and earthworms which are so vital to plant health.

- 3) To provide competition for and suppression of winter, spring or summer weed growth.
- 4) To increase water infiltration from rainfall and irrigation. In standing water areas and in heavy soils, to increase oxygen content and improve drainage. In lighter soils to increase water holding capacity.
- 5) To recycle and conserve nutrients. Cover crops extract nutrients from the subsoil and deposit them on the topsoil, thereby increasing their availability. When legumes are added to a cover crop mixture, they not only cycle phosphorus and sulfur but also increase available nitrogen.
- 6) To provide habitat, prey, nectar and pollen for beneficial insects and mites. The blooming periods of covers are tremendous stimulants for beneficial insects particularly Lacewings, Big Eyed Bugs, Predatory Mites, Ladybugs, Syrphid Bugs, Minute Pirate Bugs, Anagrus and many other Wasps and Spiders, as well hundreds of other good guys.
- 7) To provide aesthetic value and color. A bright, lush green cover crop is definitely more attractive to the grower and visitors than dead bare ground areas.
- 8) To break up the subsoil, clay layers and plow soles for increased water and air penetration.

### CHOOSING A COVER CROP

Winter annuals are often used for cover cropping because they make maximum use of the winter and spring rains, and reach their peak before the garden or farm space is needed to grow spring and summer crops.

For example, legume/oat mixtures are used with excellent results in perennial orchards and vineyards because they are vigorous, compete well with weeds, fix nitrogen, grow quickly, can be mowed to increase regrowth and organic matter, and reach their peak in April through May, depending on the climate and rainfall. They are also excellent predator verified to dramatically reduce the incidence of many pests. Other good fall/winter cover crops include Bell Beans, Fava Beans, Austrian Winter Peas, and White Lupins.

### COVER CROPS FOR SUMMER

Summer covers can be grown in rotation with winter crops or as a quick catch crop, with the aim of building fertility and suppressing weeds. The best choices for vegetable gardens and farms include legumes such as Chinese Red Cowpeas, Sesbania, Crotonaria or Soybeans or nonlegumes such as Sudangrass and Buck-wheat. All of these covers require good moisture supply.

### INCORPORATING OR TURNING UNDER THE COVER CROP

When the cover crop reaches full bloom, it is at its highest soil building potential. If turned under at this point, it will be decomposed rapidly by the soil's microbes, and will contribute the maximum amounts of nitrogen and other nutrients to the soil for the next crop.

Covers can be incorporated into the soil by disking, rototilling, spading or forking. If the cover crop is shredded with a mower, weed-eater or scythe prior to incorporating, it will break down much faster.

The best way to speed-up humus building decomposition is to spray or sprinkle the cover crop with a microbial inoculant, just prior to working it into the soil. A microbial inoculant is a culture of plant-decomposing bacteria and fungi. Two of the best known microbials are Biodynamic Field Spray and Biotron.

If it is too difficult for you to turn the cover crop under, another option would be to cut the cover crop at ground level and put the tops into the compost pile to break down. As with any composting, a compost inoculant will enhance decomposition.

## **Macro Nutrients**

### NITRATE NITROGEN (NO<sub>3</sub>)

Nitrogen exists in the air spaces in the soil, but most plants and microbes cannot make use of this gaseous form until it is "fixed" into a more available, soluble form (either ammonium, NH<sub>4</sub> or nitrate, NO<sub>3</sub>) This process of converting gaseous nitrogen to a mineralized available form is called nitrogen fixation.

Nitrate is the form of nitrogen predominantly utilized by plants. Plants need large amounts of nitrate nitrogen (NO<sub>3</sub>) for all of their growth processes. Nitrogen is an essential constituent of plant proteins (chlorophyll, enzymes, growth hormones, etc.), and comprises a significant portion of the protoplasm or living substance of cells. Any imbalance of nitrogen will cause serious disruption to the plant's internal processes.

Without an adequate supply of nitrogen, appreciable plant growth cannot take place and plants will remain stunted and undeveloped. On the other hand, excessive nitrogen results in overly lush plants which are more susceptible to sucking insects such as aphids, whiteflies, leafhoppers, etc. as well as foliar and soilborn diseases such as powdery mildew, root rot, pythium, scab, blight and other pathogens. Excess nitrogen reduces the taste as well as the keeping quality of all produce. Flowers and vining crops such as tomatoes will fail to flower and set fruit when the nitrogen is too high.

The nitrate test reading should be 40-60 PPM for most vegetable crops. Orchard and vineyard crops require 30-40 PPM nitrate. Grains and pasture should be between 20-30 PPM. Lawns should be 30-40 PPM. If your soil tests below these levels it will be necessary to supplement the nitrogen supply.

### HOW TO INCREASE NO<sub>3</sub>

When discussing nitrogen supplementation a convenient way of quantifying available nitrogen is in pounds per acre. Most garden crops require 170-225kg of available nitrate nitrogen per ha per year. With a good composting and cover crop program you can supply virtually all the needs of plants.

One of the best ways to increase plant-available nitrogen is to grow a legume cover crop. Symbiotic bacteria which depend for their nutrients on legume plants (peas, vetches, clovers, beans, alfalfa, etc.), are able to extract nitrogen from the air and return it to the soil in plant available form. When you grow legumes in your rotation you can increase considerably the amount of available nitrogen for future crops.

Non-symbiotic bacteria and algae also fix nitrogen, but they live independently and without the support of higher plants. Their main food sources are carbon, phosphorus and calcium. These microbes can supply as much as 110kg of nitrogen per ha per year.

Plant-available nitrogen is also supplied to the soil by organic materials such as manures and composts. These materials are largely insoluble in water and are broken down by biological activity and oxidation/reduction until they are finally mineralized into nitrate nitrogen for plant use. So the addition of composts is also a very important way to increase the nitrogen supply for the plant.

### ORGANIC NITROGEN FERTILIZERS

It is often also useful to supplement the nitrogen levels with organic fertilizers, particularly during the soil-building phase or while growing "heavy feeders" (nitrogen-loving vegetables such as corn, broccoli, cabbage and leafy greens). The organic grower has a whole host of wonderful nitrogen sources, including blood meal, cottonseed meal, fish meal, fish emulsion, and Chilean Nitrate.

Fish meal and blood meal give long-term, slow-release nitrogen for sustained plant growth and are perhaps the best choice. Fish emulsion or Mermaid's Fish Powder are excellent materials for supplying an "instant" shot of nitrogen, as they are soluble and can be watered in for immediate plant needs. They don't last long, however, and need to be re-applied weekly in moderately to severely nitrogen deficient soils. They also work well as foliar feeds.

Chilean Nitrate is a fast-acting source of nitrogen as well. It also doesn't last long and needs to be re-applied frequently in all but heavy clay soils. Its major drawback is its high level of sodium which can be injurious if used excessively. Do not use Chilean Nitrate on soils with a sodium level above 100 PPM. Apply Chilean Nitrate with care on all soils; the fast acting, soluble N can burn root of plants if over-applied.

### ESTIMATED NITROGEN RELEASE (ENR)

Nitrogen is released from organic matter and humus by the actions of soil microbes. The higher the organic matter and humus, the more N is available in the soil. The ENR is an estimate of the amount of N which will be released by the microbes over a growing season. This amount can vary greatly based on soil temperature, biological activity (or lack thereof), soil moisture and the ability of the soil's organic material to release N through biological decay. Soils that have been amended with

high levels of carbonaceous materials (i.e. sawdust, wood chips, straw, hay, leaves) will release the N very slowly, if at all, until the carbon has been digested by the soil microbes.

When soils test at 3-5% organic matter, most crops will receive adequate N over the season, requiring only small supplementation with outside sources.

## PHOSPHORUS (P)

The soil phosphorus level is the most important factor after organic matter and humus levels. When the most fertile soils in the world are analyzed, the levels of humus and phosphorus are always superiors.

P controls and activates plant roots, fruit bud formation and flowering, as well as the processes of cell division and sugar formation in the sap. Sugar levels regulate the plant's resistance to insects, disease and cold, and determine the fruit's eating and keeping qualities. P also impacts the N fixation and growth of legumes, the formation of seeds in all crops, crop maturation, and more.

P is measured in two ways, the plant-available form, and the reserve form which is unavailable to the plant, but which becomes available (converts to the first form) by the action of soil microbes. The levels in the soil are constantly changing due to the action of the microbes.

Soil P is held for the plant's roots in the humus. The higher the humus, the greater the available P. P availability is also greatly affected by the soil pH, which should be maintained between 6.0 and 6.5 (see section on pH). If pH levels are outside this range, the soil will require supplementation with P, even though the soil test may show adequate levels.

Most soils for vegetables and flowers should have at least 40 PPM of available P. Some vegetable crops require more than 60 PPM. Grains can get by with 20-30 PPM, but the yield and quality will increase when above 40 PPM. Fruits and grapes should have at least 40 PPM. Pastures and lawns should have at least 30 PPM.

## HOW TO INCREASE P

The best way to increase the available P level is to increase the organic and humus. Compost and cover crops are the most efficient ways to do this. Composts made from bird manures such as chicken or turkey are highest in P; cow and horse manures are low. Adding P materials to the compost pile greatly increases P content and availability.

All legume plants help cycle P by pulling it up from the subsoil, concentrating it in their bodies, and leaving it near the surface in plant-available form when they die or go dormant. Buckwheat is not a legume but is also an excellent recycler of P. There must be adequate reserve P in the soil for these plants to cycle, however.

## ORGANIC PHOSPHORUS MATERIALS

P is very immobile in the soil, and generally not water soluble. If a soil is low in P, it is wise to put some P into the subsoil when planting all perennials. This will stimulate the root activity and subsequent plant growth. If working with deep beds, etc., incorporate the P thoroughly so that the roots will come into contact with it quickly.

The best material for raising soil P is Soft Rock Phosphate (aka "Colloidal Phosphate" or "Soft Phosphate"). This fine powder contains up to 20% P, as well as calcium and many trace elements which the plant and soil will utilize. About 280 kg/ha are recommended if the available P level is 30-50 PPM, but more can be applied for available P below 30 PPM.

Soft Rock Phosphate should be broadcast over the soil and worked in where possible. Soft P can also be banded under the plant row. It will not burn plant roots.

In "no-till" situations, broadcast Soft Rock Phosphate on the surface and plant legumes or Buckwheat to move the P down into the soil in plant-available form.

Generally one application of Soft P at the above rates will be adequate for 2-3 years, longer if compost and cover crops are added regularly.

Another option for P is Bone Meal, which is an excellent source but considerably more expensive than Soft P. Rates to use and application methods are the same. Bone Meal is slightly more available to the plant than the Soft P, especially in cold soils so some growers use equal amounts of each. Bone Meal outperforms Soft P in greenhouses, cold frames and small containers.

In some cases it is necessary to supply P immediately with liquid feeding or foliar feeding. Fish emulsion and Mermaid's Fish Powder contain some soluble P. Higher levels are found in Omega 2-7-7, or bat or seabird guano. These materials can be mixed with water and applied as a side dressing or foliar fed to the plants.

## POTASSIUM

Potassium (aka "Potash") is important for increasing crop resistance to disease, and for stimulating rooting activity, photosynthesis, starch formation, translocation of sugar, chlorophyll production and more.

Most soils contain high levels of potassium (K), but in forms that the plant cannot absorb. The primary challenge in an organic growing situation is to "liberate" the soil's fixed K and convert it into the plant-available form,  $K_2O$ . This process takes place very slowly in soils and is greatly influenced by soil texture, organic matter content, microbial activity, soil temperature and soil structure. Loose, non-compacted soils with liberal amounts of humus are rarely low in available K. Soils without these attributes require good management to improve the available K.

The available K should be at least 150 PPM for most plants, with 250 PPM for highest-yielding vegetables and root crops.

## HOW TO INCREASE K

Increasing the organic matter and humus will have a dramatic impact on the K status. Improved soil structure through reduced tillage, reduced tractor or human compaction, double-dug beds, additional organic matter, etc., is the cheapest and best fertilizer there is! Growing cover crops and applying compost will greatly increase available K. These remedies take time and may not correct a bad situation within one season, but are well worth the effort.

## ORGANIC POTASSIUM MATERIALS

Some situation warrant the addition of potassium fertilizers. Root crops, particularly potatoes and carrots, often respond to additional K as fertilizer. If the soil test indicates between 50-150 PPM and you are growing root crops, liberally apply composts made from animal manures (excellent sources of K).

The gardener can use wood ash, which contains up to 50% K plus other minerals. CAUTION! It is very easy to overdose the soil with wood ash. Too much ash will sterilize a soil! Recommended rates are 0.45kg/10m<sup>2</sup> annually (450-560kg/ha) if the soil tests at 100-150 PPM. Above 150 PM use half the above rate. The ashes should be broadcast and worked in. Do not put wood ash near germinating seeds.

A better source of K is Kelp Meal. Algit Kelp Meal or Soil Min Geologically Composted Kelp are excellent sources of K as well as a broad spectrum of other elements, growth hormones, vitamins and more. These kelps also greatly stimulate earthworms and microbes. If the soil is below 150 PPM, use 0.45-0.9kg/10m<sup>2</sup> (450-900kg/ha), broadcast and worked in. Above 150 PPM, use half that rate. Add to a working compost pile at 0.36-0.5kg/m<sup>3</sup>.

For farmers and market gardeners, a cost-effective K supplement is Mined Sulphate of Potash, which contains 50% K, as well as 18% sulfur. This material is quite active and should be used at low rates. If soil test is below 150 PPM add 225-336kg/ha (1kg per 45-60m<sup>2</sup>). Soil testing at 150-250 PPM need 110-170kg/ha (1kg per 35-45m<sup>2</sup>). Soil testing above 250 PPM need no additional potassium.

## EXCESS POTASSIUM

If your soil contains more than 350 PPM potassium, there is a potential for a toxic potassium condition. K in large amounts can be toxic to soil microbes and plants. Suggested remedies for this problem:

- 1) Do not add any more K! Eliminate the use of wood ash, potassium fertilizers or other known high K sources. Compost will still be beneficial, even if it contains substantial K. Avoid using raw manures!

- 2) Add gypsum to the soil surface. Gypsum, with water, will leach excess potassium out of the topsoil. Because gypsum is highly mobile in water, it may be useful to apply gypsum more than

once a year to improve the soil quickly. Use  $2.25 \text{ kg}/10\text{m}^2$  per application. You may apply up to 4 times per season. Broadcast the gypsum on soil surface and water thoroughly.

3) Grow crops which use a lot of K, such as corn, sudangrass or potatoes.

### SULFUR(S)

Sulfur is essential for the formation of amino acids and proteins, and it is utilized by some soil microbes for organic matter decay. Legumes require large amounts of available S. Sulfur deficiencies often resemble nitrogen deficiencies. Also, N and S often enter the plant together to form plant protein compounds. It has been said that S and N are "brothers", and that a shortage of either will impact the availability of the other, even if the other is in adequate supply.

The soil test level for sulfur for all crops except vegetables should be at least 20 PPM, with high yielding vegy crops requiring at least 30 PPM.

### HOW TO INCREASE S

The major source of sulfur in the soil is organic matter. Increasing the organic matter will increase the available sulfur. Compost and manures as well as legume cover crops are important sources of organic matter. (See first section).

To increase sulfur levels more quickly, add compost and gypsum. Gypsum contains about 18% S in the plant-available form. Gypsum is highly water-mobile and should be applied consistently in soils that are low to moderate in organic matter. This will supply adequate S in most cases. If the soil tests below 20 PPM, add gypsum at a minimum of  $0.5\text{kg}/10\text{m}^2$  (450kg/ha). Two applications per year may be useful in low CEC and sandy soils.

“Soil Sulfur” is a highly concentrated (98% S) supplement, toxic to most soil microbes and earthworms and should not be used unless there is a very high calcium reading and a pH above 8.0 on your soil test. In this case only, apply Soil Sulfur at 1120kg/ha ( $1.1\text{kg}/10\text{m}^2$ ) annually until pH drops to under 7 (usually 1-2 years).

### SOIL pH

Soil pH is a general indicator of the balance between soil acidity and the cation elements calcium, potassium, magnesium and sodium. Soil pH has a dramatic impact on plant growth and soil microbial activity.

The pH is changing constantly. Although the lab test only indicates the pH was at the time of sampling, it is a good indicator of the trend in the soil.

A pH of 7.0 is neutral. Below 7.0 the soil is considered acidic; above 7.0 the soil is alkaline. Most plants, and all beneficial soil microbes, do best when the pH is between 6.0-6.5, slightly acid.

Generally soils which are low in organic matter or in high rainfall areas tend to have a low pH. A soil with a pH below 6.0 usually requires the addition of one of the cation elements to raise the pH to the desired level. Calcium is the most commonly added cation. See Calcium for further information.

Increasing the organic matter/humus will raise soil pH over a period of time, or eventually acidify a high pH soil. OM beneficially adjusts pH imbalance.

Soils above 7.0 pH (alkaline) usually have an excess of one of the cations (salts). Reducing the toxic levels of that element will lower the soil pH and bring the microlife into balance. Usually we suggest the use of gypsum, soil sulfur and/or increased organic matter to lower the pH. See the specific cation headings.

## **Cations as Nutrients**

### CATION EXCHANGE CAPACITY (CEC)

Cations are positively-charged elements in the soil, such as potassium, calcium, magnesium and sodium. These cation minerals are held in the soil by interaction with negatively-charged particles of clay and humus in the soil. The cations can be mobilized and made available to a plant when one cation is exchanged for another on the exchange site. This process is called Cation Exchange, and the soils ability to provide "exchange sites" for cation minerals is called Cation Exchange Capacity (CEC). CEC is influenced by the quantity and quality of clay and humus in the soil. The higher the CEC, the more cation nutrients are available to the plants and the soil micro-organisms.

The CEC in good quality soils ranges from about 15 to 30 or 40 milliequivalent per 100 gm (me/100g). High quality compost ranges between 50-75 me/100g. Soils with CEC below 15 have little capacity to "hold" cations and prevent their leaching. In these soils it is necessary to "spoon feed" any cations that are low, i.e. add smaller amounts more frequently, since large amounts will merely leach out of the soil before the plants and microbes can make use of the nutrient.

CEC is strongly affected by the organic matter in the soil because organic matter decomposes into humus. Humus is high in organic matter, and this provides the soil with many cation exchange sites as well as many other benefits.

The best way to increase the CEC is to raise the humus content. The best materials for this purpose are high-quality compost and legume cover crops. See the preceding discussion on organic matter for further information.

### BASE SATURATION

The soil contains a pool of positively charged (base) minerals called cations or cation salts (described above), which are important plant nutrients. These include potassium (K), calcium (Ca),

magnesium (Mg), and sodium (Na). All of these positively charged cation minerals are competing for positions on the negatively charged clay and humus particles in the soil. There is an optimum balance of these cationic elements, and maximum biological activity and plant growth will occur when this balance is achieved. For the cations mentioned, the optimum balance for many soils is approximately 5-7% K, 10-15% Mg, 70-80% Ca, and <3% Na.

Very few soils are naturally in balance. Fertilization, cultivation and irrigation all change the balance, as does the cropping pattern. If your soil test shows significant deviation from the optimum levels note it will be very important to take corrective action. A soil which is low in calcium, for example, can be improved to the optimum balance over period of 2-3 years by simply adding an appropriate calcium source. On the otherhand, if the test shows a particular element to be too high, it can be modified by increasing the cations which are too low, and by leaching and microbial action on the excessive element.

None of these changes will take place overnight and you should expect to take a number of years to correct a soil which is out of balance.

### MAGNESIUM (Mg)

Each molecule of chlorophyll produced in the plant leaf is built around a single atom of magnesium. As chlorophyll is essential for photosynthesis, magnesium plays a very important role in crop production.

Most soils contain adequate to high levels of magnesium. A deficiency is rare but possible in high rainfall areas.

Magnesium is a cation (positively charged) element which binds closely with clay and humus. Soils which are high to excessive in magnesium are often described as clays, gumbos and adobes. Magnesium is the element that binds clay together. Clay that is used for pottery is extremely high in magnesium. Something which is good for pottery lacks porosity and is death to soil microbes and plants.

An over abundance of magnesium can cause phosphate, potassium and nitrogen deficiencies. High magnesium and low calcium levels permit organic matter residues to decay into alcohol, a sterilant to bacteria and other soil microlife. High magnesium may cement clay soils tightly together, creating a crust that excludes oxygen, preventing water retention and proper in soak or capillary return during dry spells.

As stated earlier, deficiencies of magnesium are rare. If your soil tests more than 150 PPM magnesium there is adequate magnesium available. Virtually all soils contain much more magnesium than indicated on the soil test. If the test indicates levels above 300 PPM to minimize the effects of too much magnesium are necessary.

### HOW TO DECREASE Mg

The best remedies are to add humus and compost, grow cover crops, and add gypsum at least twice a year. Gypsum (a source of calcium and sulfur) should be broadcast on the surface and irrigated in. If your soil can be describe as a clay and your soil test has high magnesium numbers, apply gypsum at 4.5 metric tons/ha (4.5kg/10m<sup>2</sup>) twice the first year, with annual applications thereafter of 2.25 metric tons/ha (2.25kg/10m<sup>2</sup>). For further information on gypsum see the section on calcium.

### HOW TO INCREASE Mg

In the unusual event that your soil tests low, the simplest remedy is the application of dolomite (a source of calcium and magnesium). Use light rates to avoid creating a toxic level of magnesium. Never apply more than 2.25 metric tons/ha (2.25kg/10m<sup>2</sup>). It would be better to use half this amount and to apply it twice. Do not apply dolomite more than one time without re-checking your soil via a test. It is easy to use too much dolomite. For more information on dolomite, see the calcium section.

### CALCIUM (Ca)

Calcium is the most important element for soil structure, microbial activity and cell building in the plant. It is associated with the development of protein, it assists root development, movement of carbohydrates, cell wall formation, seed production and other processes.

Soils which are low in available calcium are said to be “tight”, “sticky” or “hard to work”, and tend to have poor structure, water absorption and water-holding capacity.

A shortage of available calcium severely limits the soils microbial activity and ability to create humus and plant available nutrients. This can result in mite infestations, weather stress, low biological nitrogen fixation, increased susceptibility to foliar diseases (such as mildew and Botrytis), poor water infiltration and more.

Soils low in calcium and high in magnesium tend to be exceptionally tight and low in air and microbial activity, with consequent plant stress, particularly in the root zone. Calcium is the main element in each cell, and a shortage of Ca will cause poor plant growth, fruit density, small clusters, flower abortion, poor set, etc.

Calcium is a highly mobile element in slight acid soils, and it quickly leaches out of soils low in organic matter and microbial activity. High rainfall and irrigation with calcium-poor water can increase this problem.

Most fields will respond to low rates of calcium fertilization. Severely deficient soils require higher rates, applied annually or semi-annually until the levels are corrected.

### HOW TO INCREASE Ca

The practice of adding calcium is often called liming, because Ca deficiencies often (but not always) show up with low pH, and lime raises both pH and Ca levels. However, lime is not the only choice for correcting low Ca. To determine the appropriate calcium material to apply, first look at your soil pH.

If the pH is below 7.0 and the calcium is below optimum but the magnesium is adequate (above 150 PPM) the material of choice will be Oystershell Flour Lime or high Calcium Mined Limestone. Both these materials contain primarily calcium carbonate, a source of calcium and carbon.

If the pH is below 7.0 and both the calcium and the magnesium levels are rated as low or very low (a rare occurrence), use dolomite (a mined material rich in calcium & magnesium). Most soils should not require dolomite, although there is an occasional exception.

If the pH is 7.0 or higher the best calcium material will be gypsum (a mined mineral composed of calcium and sulfur). Gypsum is not a lime and will have minimal effect on pH, which, in this case, you don't want to raise anyway.

### APPLYING CALCIUM TO THE SOIL

It is better to apply small amounts of calcium annually than to use large amounts sporadically, as the calcium will leach down below the soil horizon with rainfall and irrigation.

Incorporating calcium into the soil when tilling or digging will cause the fastest reaction and soil improvement. Calcium can also be applied on the surface in "no till" or permanent plantings, although the reaction time will be slower.

No matter what the application method, try to spread the material as evenly as possible. An over-application of calcium can be more detrimental than no application at all. Never add calcium to the planting hole of a perennial. Always spread it on the surface. More is not better!!!

You can also mix calcium materials with your compost after the compost is finished. Mix in the calcium just prior to applying the compost to the soil.

### SODIUM (Na)

Sodium is an essential element for plant growth, but is never found deficient in the soil; excessive sodium is the more common problem. High levels of sodium cause plant and microbial problems, and very high levels cause soil sterilization and plant damage or death.

The test level should be below 100 PPM. Levels under 100 PPM generally have no problems with sodium. Soils above 100 PPM may have problems to some degree, depending on the organic matter content and the crop grown. Orchard crops and vineyards are the most sensitive to excess sodium.

The higher the organic matter, the lower the risk of sodium toxicity. Increase the organic matter if the sodium reads above 100 PPM. Soils above 150 PPM should follow the directions below to leach excess sodium from the soil.

### HOW TO LOWER Na

- 1) Do not add any salty materials. Many problems have been caused from the overuse of salty manures or other materials excessive in sodium, especially salty water.
- 2) Increase the organic matter. Most soils with high Na also have low OM, which compounds the problem, as OM acts as a buffer for excess Na. Cover crops are the best way to improve this problem.
- 3) Leach the excess Na with gypsum and clean water. Use 2.25kg/10m<sup>2</sup> (2.25mt/ha). Broadcast on the soil and leach with clean water. Apply at least twice within the next year. Four applications at the above rate would be better.
- 4) Increase the soil microbiological activity by inoculating the soil with sodium-eating microbes. These microbes occur in aerobically digested compost and may be increased by using a high quality microbial inoculant.

### MICRONUTRIENTS

By definition micronutrients are essential nutrients that occur in the soil and are used by the plant in very small amounts. These micros, despite their small amounts, are every bit as important as the macro elements N, P or K.

Good organic matter management is the best way to ensure adequate availability of micronutrients. The higher the humus content, the greater the level of available micronutrients.

The most important micros are zinc, iron, manganese, copper, boron and selenium, but there are many more which science hasn't yet positively identified to be necessary for plants.

### ZINC (Zn)

Zinc is essential for the transformation of carbohydrates and the regulation of sugar consumption in the plant. It forms part of the enzyme systems which regulate plant growth.

Optimum zinc levels should be between 3.5-.7.0 PPM. If your soil tests below 3.5 add Algit Kelp Meal or Soil Min at 450kg/ha or 0.5kg/10m<sup>2</sup> for all crops. These materials should be broadcast and worked into the soil where possible.

Foliar feeding with kelp extracts such as Maxicrop or ShurCrop in combination with Fish Emulsion or Mermaid's Fish Powder will greatly assist the plant's ability to absorb micronutrients from the soil.

In severe situations, when the soil tests below 1.5 PPM Zinc, it may be necessary to apply concentrated zinc materials such as zinc sulfate or zinc chelates.

### MANGANESE (Mn)

This element plays a role in many of the vital processes in a growing plant, including the enzymatic breakdown of carbohydrates, nitrogen metabolism and more.

Soil levels for manganese should be between 20-50 PPM. If your soil tests below 20 PPM add Algit Kelp Meal or Soil Min at 450kg/ha or 0.5kg/10m<sup>2</sup>. These materials should be broadcast and worked into the soil where possible.

Foliar feeding with kelp extracts such as Maxicrop or ShurCrop in combination with Fish Emulsion or Mermaid's Fish Powder will greatly assist the plant's ability to absorb micronutrients from the soil.

### IRON (Fe)

Iron is essential for the formation of chlorophyll and for photosynthesis. It is the activating element in several enzyme systems. It is also important in respiration and other oxidation systems of plants and is a vital part of the oxygen carrying system.

Soil iron levels should be from 29-50 PPM for most crops. Levels above 50 PPM indicate a leached, acid soil. See recommendations for calcium if your soil tests above 50 PPM and has a medium to low calcium level. If your soil tests below 20 PPM, add Algit Kelp Meal or Soil Min at 450kg/ha or 0.5kg/10m<sup>2</sup> for all crops. These materials should be broadcast and worked into the soil where possible.

Foliar feeding with kelp extracts such as Maxicrop or ShurCrop in combination with Fish Emulsion or Mermaid's Fish Powder will greatly assist the plant's ability to absorb micronutrients from the soil.

If the soil tests below 10 PPM, a one time application of iron sulfate at 112kg/ha (0.1kg/10m<sup>2</sup>) should bring the level up to a point where it can be maintained using the above methods. Use zinc chelates at the same rate if the soil is sandy and has organic matter below 2%.

### COPPER(Cu)

Copper plays an important role in plant growth as an enzyme activator and as a part of certain enzymes which function in plant restoration. It is very important in the plant's reproductive stage of growth and plays an indirect role in chlorophyll production.

Soil copper levels should be between 1.0-3.0 PPM. It is easy to get above the optimum level if the crop is sprayed with copper compounds for disease control. Growers of peaches, nectarines, walnuts

and almonds should watch their soil to avoid reaching high levels of copper. Levels above 5.0 PPM can be toxic to plant and soil fungi.

Use gypsum, compost and cover crops to lower a soil which has too much copper. If your soil test below 1.0 PPM copper, add Algit Kelp Meal or Soil Min at 450 kg/ha or 0.5kg/10m<sup>2</sup>. These materials should be broadcast and worked into the soil where possible.

Foliar feeding with kelp extracts such as Maxicrop or ShurCrop in combination with Fish Emulsion or Mermaid's Fish Powder will greatly assist the plant's ability to absorb micronutrients from the soil.

## BORON (B)

Boron is needed in protein synthesis. It is associated with the increased cellular activity that promotes maturity, with increased set of flowers and fruit, and with yield and quality. Boron also affects nitrogen and carbohydrate metabolism and water relations in the plant.

The optimum level for boron is 0.5 to 2.0 PPM. At high levels boron can become quite toxic to soil microflora as well as plants. Boron toxicity can even kill plants. If your soil tests above 2.0 PPM boron, it will be necessary to take corrective action. The best method is to apply gypsum and quality compost 2 to 4 times per year in combination with clean water. If your soil has a high boron soil test, it may be useful to check your farm water supply for boron contamination.

If your soil tests below 0.5 PPM boron, add Algit Kelp Meal or Soil Min at 450kg/ha or 0.5kg/10m<sup>2</sup>. These materials should broadcast and worked into the soil where possible.

Foliar feeding with kelp extracts such as Maxicrop or ShurCrop in combination with fish Emulsion or Mermaid's Fish Powder will greatly assist the plants ability to absorb micronutrients from the soil.

Solubor and Boron Fines are extremely concentrated and should be used only as a one-time application by commercial-scale growers in a crisis situation and only on the basis of a plant tissue test. These fertilizers are toxic to plants and soil microlife if over-applied. Never apply more than 22kg/ha. Never use in a garden.

## SOLUBLE SALTS

This reading indicates the level of potentially harmful soluble salts including sodium, chloride, boron, magnesium and others. When these levels are above 1.0 there is some risk of plant damage and/or reduced microbial activity. When levels get above 2.0 some plant damage nearly always occurs. Levels between 0.2 and 1.0 appear to create no problems for most plants.

When the tests show levels above 1.5, leach the soil with gypsum and clean water, and increase the organic matter. Changing the water source may have the biggest long-term impact. See previous instructions for more information on gypsum and organic matter.

## FOLIAR FEEDING

Foliar feeding is the technique of spraying nutrients onto the leaf surface of active growing plants. All plants absorb nutrients through the stomata on their leaves and openings on their stems. Foliar feeding has been shown to be up 20 times more efficient than soil-applied nutrients.

Foliars help the plant when it may not be getting enough nutrition from the soil (as in low fertility or cold soils, or soils in some type of stress). Most plants also respond when foliar feeding is timed to coincide with seedling emergence, stress caused by drought, heat, cold, mechanical or insect damage, or the onset of disease-susceptible periods. Foliars can also be timed to induce rapid growth phases or to encourage flowering, fruiting or seed formation. Many crops benefit from 6-8 foliar applications per season. Some growers apply weekly foliars at low concentrations to improve nutrient balance.

Foliar feeding should not be done in the heat of the day. It is important to use a spreader sticker with all foliar sprays. Also check the pH of the spray mixture and make sure it is between 5.5 and 6.5 for maximum effect. Apple cider vinegar is excellent for lowering a high pH.