FERTILIZER FACTS

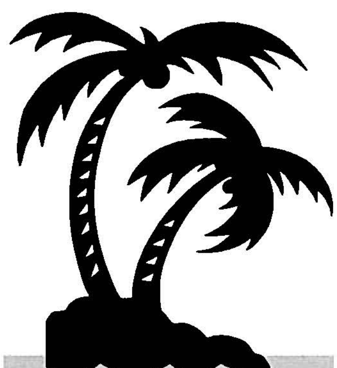
Number 1. Essential Plant Nutrients

Peter Motavalli and Thomas Marler - College of Agriculture and Life Sciences - University of Guam

Plants require 13 mineral elements for growth. These elements are necessary for plants to complete their life cycle and are called essential plant nutrients. Each of these nutrients has a critical function in plants and is required in varying amounts in plant tissue (Table 1). If any one of the essential nutrients is deficient, plant growth may be restricted.

Macronutrients (nitrogen, phosphorus, potassium, calcium, magnesium and sulfur) are plant nutrients required in the largest amounts. Micronutrients (iron, copper, manganese, zinc, boron, molybdenum and chlorine) are required in relatively smaller amounts. Additional mineral nutrient elements which are beneficial to plants, but not necessarily essential include sodium, cobalt, vanadium, nickel, selenium, aluminum and silicon. The nutrient elements differ in the form they are absorbed by the plant, by their functions in the plant, by their mobility in the plant, and by the plant deficiency or toxicity symptoms characteristic of the nutrient.

Nutrient deficiency or toxicity symptoms often differ among



"Essential plant nutrients are necessary for plants to complete their life cycle and include nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, iron, copper, manganese, zinc, boron, molybdenum, and chlorine"

Table 1. Essential plant nutrients: their relative amounts in plants, functions and classifications.

Name	Chemical symbol	Relative % in plant*	Function in plant	Nutrient category
Nitrogen	N	100	Proteins, nucleic acids	Primary macronutrients
Phosphorus	P	6	Nucleic acids, ATP	
Potassium	K	25	Catalyst, ion transport	
Calcium	Ca	12.5	Cell wall component	Secondary macronutrients
Magnesium	Mg	8	Part of chlorophyll	
Sulfur	S	3	Amino acids	
Iron	Fe	0.2	Chlorophyll synthesis	Micronutrients
Copper	Cu	0.01	Component of enzymes	
Manganese	Mn	0.1	Activates enzymes	
Zinc	Zn	0.03	Activates enzymes	
Boron	B	0.2	Cell wall component	
Molybdenum	Mo	0.001	Involved in N fixation	
Chlorine	Cl	0.3	Photosynthesis reactions	

*Relative amounts of mineral elements compared to nitrogen in dry shoot tissue may vary depending on plant species.

species and varieties of plants. A nutrient deficiency occurs when a nutrient is not in sufficient quantity to meet the needs of the growing plant. Nutrient toxicity occurs when a plant nutrient is in excess of plant needs and decreases plant growth or quality.

One way to understand the differences in nutrient deficiency symptoms among the plants is to learn the function and the relative mobility of the nutrient within the plant. Table 2 describes the general symptoms of nutrient deficiency and excess often observed for those nutrients. Some nutrients, such as nitrogen, phosphorus, potassium, magnesium, chlorine and zinc, can be easily moved within the plant from old plant parts to actively growing plant parts, such as young leaves. Other nutrients, such as sulfur, iron, copper, manganese, boron and calcium, are not easily moved within the plant. Therefore, the deficiency of the mobile elements usually initially occurs with older leaves while that of the immobile nutrients occurs with the young leaves or stem tips.

Five types of deficiency or toxicity symptoms are observed:

1. **Chlorosis** - yellowing of plant tissue due to limitations on chlorophyll synthesis which gives plants their normal green color. This yellowing can be generalized over the entire plant, localized over individual leaves or isolated between some leaf veins (i.e. interveinal chlorosis).

2. **Necrosis** - death of plant tissue, sometimes in spots.

3. **Accumulation of anthocynanin**, a plant pigment, resulting in a purple or reddish color.

4. **Lack of new growth.**

5. **Stunting or reduced growth** - new growth continues but it is stunted or reduced compared to normal plants.

Mild nutrient deficiencies may not produce obvious symptoms such as chlorosis. However, significant reductions in crop yields can occur with such deficiencies. This situation is termed "hidden hunger" and can only be detected by plant tissue analysis or by poor yields. Another problem with using visual symptoms for identifying nutrient deficiencies is that insect damage and plant disease may produce similar symptoms on plants.

Table 2. Generalized symptoms of plant nutrient deficiency or excess.

Plant Nutrient	Type	Visual symptoms
Nitrogen	Deficiency	Light green to yellow appearance of leaves, especially older leaves; stunted growth; poor fruit development
	Excess	Dark green foliage; plant may be susceptible to falling down and damage due to drought, diseases and insects. Fruit and seed crops may fail to yield.
Phosphorus	Deficiency	Leaves may develop purple coloration; stunted plant growth and delay in plant development.
	Excess	May cause micronutrient deficiencies, especially iron or zinc.
Potassium	Deficiency	Older leaves turn yellow initially around margins and die; irregular fruit development.
	Excess	May cause deficiencies in magnesium and calcium.
Calcium	Deficiency	Reduced growth or death of growing tips; blossom- end rot of tomato; poor fruit development and appearance.
	Excess	May cause deficiency in magnesium or potassium.
Magnesium	Deficiency	Initial yellowing of older leaves between leaf veins spreading to younger leaves; poor fruit development and production.
	Excess	High concentration tolerated in plant; however, imbalance with calcium and potassium may reduce growth.
Sulfur	Deficiency	Initial yellowing of young leaves spreading to whole plant; similar symptoms to nitrogen deficiency but occurs on new growth.
	Excess	May cause premature dropping of leaves.
Iron	Deficiency	Initial distinct yellow or white areas between veins of young leaves leading to spots of dead leaf tissue.
	Excess	Possible bronzing of leaves with tiny brown spots.
Manganese	Deficiency	Interveinal yellowing or mottling of young leaves.
	Excess	Older leaves have brown spots surrounded by a chlorotic circle or zone.
Zinc	Deficiency	Interveinal yellowing on young leaves; reduced leaf size; leaf margins may become wavy.
	Excess	May cause iron deficiency in some plants.
Boron	Deficiency	Death of growing points and deformation of leaves with areas of discoloration.
	Excess	Leaf tips become yellow followed by necrosis. Leaves get a scorched appearance and later fall off.

Adapted from: W.F. Bennett (ed.), 1993. Nutrient Deficiencies & Toxicities in Crop Plants, APS Press, St. Paul, Minnesota.

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FERTILIZER FACTS

Number 2. Fate of Nutrients in Soils

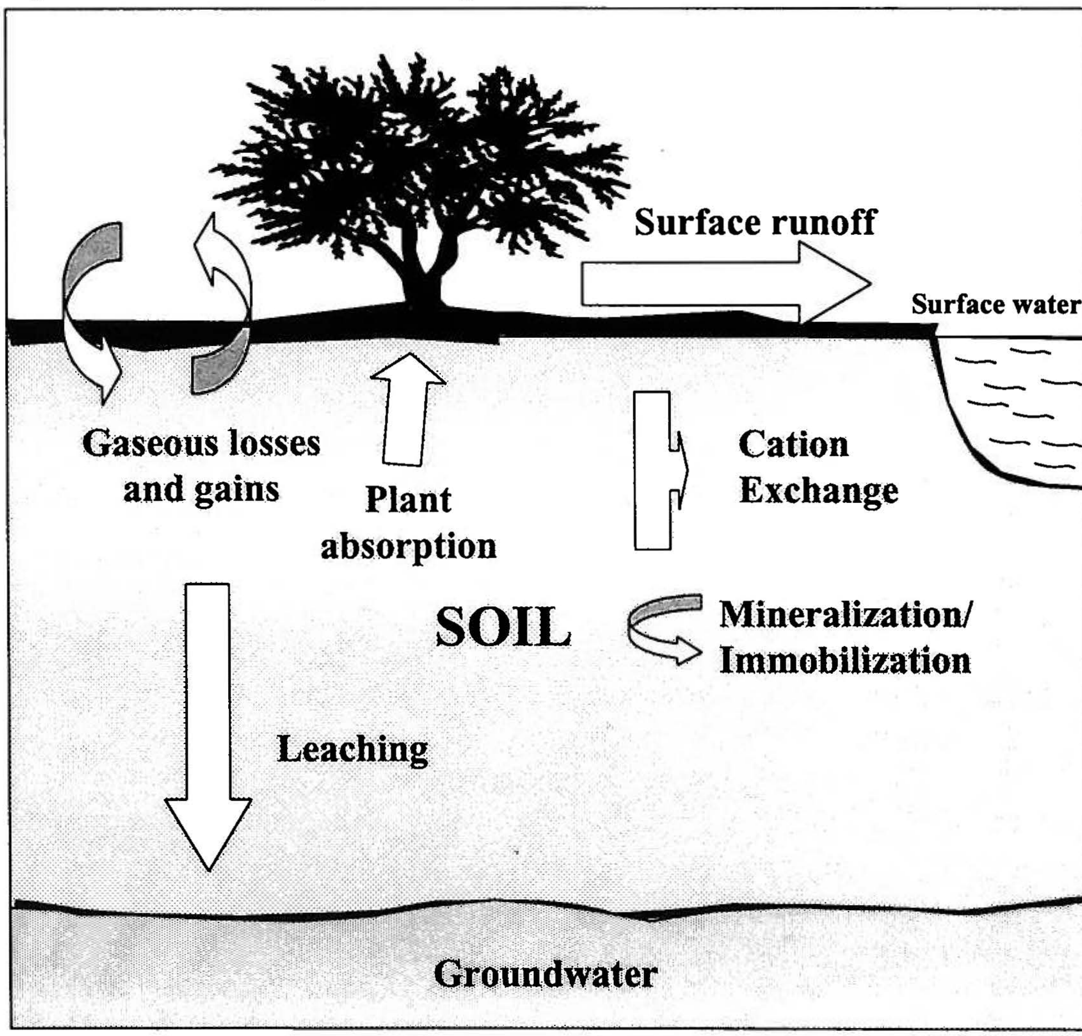
Peter Motavalli, Thomas Marler and Jacob Kuhn - College of Agriculture and Life Sciences - University of Guam

The nutrient elements essential for plant growth, such as nitrogen, phosphorus and potassium, undergo several natural transformations and interactions in soils and the environment. These processes are important because most plants are only able to take up certain chemical forms of each nutrient. Therefore, many of the soil processes can make the nutrient elements unavailable or slowly available for plant absorption. While nutrient elements may differ in the transformations they undergo, some important common processes are listed below. An understanding of these processes may aid in better management of fertilizer and other nutrient sources.

Mineralization - In most unfertilized soils, the largest proportion of nutrients cannot be used by plants because they are contained in organic compounds. Organic compounds are generally different from inorganic compounds because they contain carbon. Mineralization is the process by which organic nutrients are converted to inorganic forms which plants can take up through their roots and use for growth. For example, the nitrogen (N) contained in protein is mineralized to ammonium. This process is controlled by

"The nutrient elements essential for plant growth, such as nitrogen, phosphorus and potassium, undergo several natural transformations and interactions in soils and the environment "

Figure 1. Generalized diagram showing nutrient transformations in the environment.



the activity of microbes (bacteria and fungi), and, therefore is affected by environmental factors such as temperature and moisture.

Immobilization - Addition of organic materials (for example, wood chips) which contain a small proportion of N and other nutrients can cause the soil microbes to remove nutrients from the soil and reduce the amount of nutrients available for plant absorption. Frequently, the addition of woody materials without added N fertilizer can result in short-term N deficiency in plants. The general rule is that organic materials with an organic carbon to N ratio of greater than 30 will cause N immobilization. Addition of supplemental fertilizer N or an organic material with a high proportion of N can reduce the risk of N immobilization in the soil.

Cation exchange - The surfaces of small clay or organic particles often have an overall negative charge on them. These negative charges can attract and retain nutrients which have a positive charge on them. Many of the nutrients exist in the soil solution as charged molecules called ions. An ion with a positive charge is called a cation and an ion with a negative charge is called an anion. Common nutrients which exist as positively-charged cations are potassium (K^+), calcium (Ca^{+2}), magnesium (Mg^{+2}) and ammonium (NH_4^+). These cations are held on exchange sites and can be taken up by plants. The cation exchange capacity of a soil is a good measure of the ability of a soil to hold nutrients and is an indicator of a soil's fertility. In acidic soils, the exchange sites are dominated by hydrogen (H^+) and aluminum (Al^{+3}), which are elements that do not add to a soil's fertility.

Leaching - The movement of water through soil can result in the transport of nutrient elements down and out of the rooting zone of the plant. This process of nutrient loss is called nutrient leaching and is a serious environmental concern in areas where excessive nutrients enter groundwater. Leaching of nutrients also reduces the efficiency of fertilizer use since the nutrients will no longer be available for plant uptake. The forms of nutrient which usually leach are those which are not readily retained by soil through processes such as cation exchange. Leaching of N usually occurs when N is in the nitrate (NO_3^-) form. Phosphorus does not usually leach through soil, except for soils with a high sand content, because it readily reacts and is retained in soils with a higher proportion of clay.

Surface Runoff - Losses of nutrients from surface water runoff can be significant when soil erosion occurs in a field. Nutrients may be in a dissolved form, attached to eroded soil particles, or contained in organic matter that is flushed away in runoff water. Phosphorus pollution of water generally occurs as a result of erosion carrying soil particles and the attached phosphorus to nearby surface water, such as rivers or the ocean.

Gaseous Losses and Gains of Nutrients - Losses of nutrients through transformation to gaseous nutrient forms include the processes of volatilization, denitrification and oxidation/reduction. Ammonia volatilization occurs when ammonium-based fertilizer is added to the soil surface and the ammonium (NH_4^+) is converted to ammonia (NH_3) gas. This process usually occurs under hot, windy conditions in alkaline soils. Denitrification is the process by which nitrate (NO_3^-) is converted to gaseous N forms. This process is favored in wet soils with a large amount of organic matter. Under extremely wet conditions, nutrients can also be reduced to gaseous forms. The release of sulfur as hydrogen sulfide gas (H_2S) from low-lying wet areas is an example. The biological conversion of gaseous N to inorganic N in the soil is called N fixation and results in a gain of N in the soil. Legume plants, such as long beans, form a symbiotic relationship with a bacteria located in the plant roots in which the bacteria fix the N from air and the plant supplies carbohydrate to the bacteria. The relationship can be inhibited if N fertilizer is applied to legume plants.

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FERTILIZER FACTS

Number 3. Soil Reaction

Peter Motavalli and Thomas Marler - College of Agriculture and Life Sciences - University of Guam

Soil reaction, or whether a soil is acidic, neutral or basic, is an important soil chemical characteristic, primarily because it affects the availability of plant nutrients and plant growth. Soil reaction also affects soil microbial activity, soil exchange capacity, and the physical structure of the soil. An understanding of the concept of soil reaction can assist you in your fertilization decisions and help you in determining whether to correct acidic or basic conditions in soil.

Acidity is caused by the presence of hydrogen (H^+) ions in water. The higher the concentration of H^+, the higher the acidity. The pH scale which ranges from 0 to 14 is a measure of the amount of H^+ in a solution. A difference in one pH unit represents a ten-fold difference in H^+ concentration. If a solution has a pH lower than 7 it is said to be acidic. If the pH of the solution is equal to 7 it is neutral, and if the pH is greater than 7 the solution is basic. Examples of common household items which are acidic are vinegar and lemon juice. Examples of bases are bleach and baking soda.

"An understanding of the concept of soil reaction can assist you in your fertilization decisions and help you in determining whether to correct acidic or basic conditions in soil"

Figure 1. The pH scale and its significance.

pH	Range	Common chemicals	pH range of most soils
14	Basic		
13		Lye	
12		Bleach	
11		Milk of magnesia	
10		Borax	
9			
8		Sea water	
7	Neutral	Distilled water	
6	Acidic	Milk	
5		Boric acid	
4		Orange juice	
3		Vinegar	
2			
1		Battery acid	
0			

The pH of most soils ranges from 3.5 to 10.0. At low soil pH, the availability of plant nutrients such as phosphorus and molybdenum is reduced. At high soil pH, the availability of plant nutrients such as phosphorus, iron, manganese, zinc, copper and boron is reduced. Soils have different capacities to resist changes in soil pH or, more specifically, the amount of acid or base it takes to lower or raise the soil pH by one unit. This soil property is called the soil pH buffering capacity and is affected by factors such as the amount and type of clay or organic matter in the soil.

Many soils in the humid tropics are acidic and the high exchangeable aluminum in these soils can have toxic effects on plant root growth. This problem occurs in soils with pH less than 5.5. Soils with pH above 7 can be described as being calcareous (contains calcium carbonate, $CaCO_3$), dolomitic (contains dolomite, $CaCO_3$ & $MgCO_3$) or sodic (contains sodium carbonate, Na_2CO_3). Although calcium carbonate has low solubility, it acts to increase soil pH. In calcareous soils, such as many of the soils on Guam underlain by limestone, calcium carbonate buffers against decreases in pH. Therefore, lowering the pH of highly calcareous soils using acidifying amendments such as elemental sulfur or ammonium-based fertilizers is often not economically feasible.

Several common agricultural practices can lead to increased soil acidity. These practices include repeated use of ammonium-based nitrogen fertilizers and harvest and removal of plant material without fertilization. Long-term applications of some organic materials or composts can also acidify soil.

The most common soil amendments for increasing soil pH are called agricultural liming materials. Several liming materials are available including burned lime, hydrated lime, marl, and industrial byproducts such as slag and flyash. Coralline limestone found on Guam and on many Pacific islands is also a potential liming material. However, the most common liming materials used are calcitic (contains calcium carbonate) or dolomitic (contains both calcium and magnesium carbonates) limestone. The effectiveness of liming material is determined by its chemical composition and the fineness of the particles. The chemical effectiveness of a liming material in neutralizing acidity is often expressed in relation to the effectiveness of calcium carbonate. In addition, the finer the particle size of a liming material, the faster it will reduce soil acidity. The neutralizing index is a measure often used for evaluating the effectiveness of a specific liming material. This index is the product of the calcium carbonate equivalence and the particle size distribution of the liming material.

To determine the liming requirements of your soil, submit soil samples to your regional Soil and Plant Testing Laboratory. The Laboratory will be able to recommend the appropriate rate of liming depending on your soil characteristics and the type of plant you wish to grow.

Table 1. Optimum pH ranges for local crops.

Plant	Optimum pH range	Plant	Optimum pH range
Banana	5.5 – 6.5	**Onion**	5.8 – 7.0
Bell pepper	5.5 – 6.8	**Orange**	6.7 – 7.5
Cabbage	6.0 – 7.5	**Papaya**	6.0 – 7.0
Cabbage, Chinese	6.0 – 7.5	**Sweet Pepper**	5.5 – 7.0
Cantaloupe	6.0 – 7.5	**Pineapple**	5.0 – 6.0
Corn, Sweet	5.5 – 7.5	**Potato, Sweet**	5.2 - 6.0
Cucumber	5.5 – 7.0	**Pumpkin**	5.5 – 7.5
Eggplant	5.5 – 6.5	**Sugar Cane**	6.0 – 8.0
Lemon	6.0 – 7.5	**Taro**	5.5 – 6.5
Mango	5.5 – 7.5	**Tomato**	5.5 – 7.5
Okra	6.0 – 7.5	**Watermelon**	5.0 – 6.8

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FERTILIZER FACTS

Number 4. Factors to Consider in Selecting a Fertilizer

Peter Motavalli and Thomas Marler - College of Agriculture and Life Sciences - University of Guam

There are several factors to consider when choosing your fertilizer material or other soil amendments, such as lime and manure.

Availability - One of the most important factors affecting fertilizer selection on Guam and other Pacific islands may be availability. Suppliers on Guam stock certain types of fertilizers depending on demand and other business reasons. The selection of fertilizers is also limited due to Guam's long distance from fertilizer manufacturers. On many Pacific islands, fertilizers are very difficult to obtain and organic nutrient sources, such as animal manures or plant residues, are more widely available.

If you are located on an island where fertilizer is available and you have a special fertilizer need, you may wish to talk to any one of the fertilizer dealers, garden centers, nurseries, hardware, or discount stores on island to see if they are willing to make a special order for you.

> **"One of the most important factors affecting fertilizer selection on Guam and other Pacific islands may be availability"**

Organic amendments, such as animal manure, shredded paper, wood chips and sewage sludge, are among the wide assortment of organic materials that are periodically available on islands. On Guam, the U.S. Military, the U.S. Natural Resources Conservation Service, and the Government of Guam through several of its agencies, such as the Guam Department of Agriculture, the Guam Environmental Protection Agency and the local mayors' offices, often facilitate distribution of these materials.

Nutrient content - There is a wide array of fertilizers with various nutrient contents (Table 1). The nutrient content of a fertilizer material is called the fertilizer "analysis". All fertilizer packages have the fertilizer analysis written on them and by convention are expressed as % nitrogen (N), % P_2O_5 (phosphorus pentoxide) and % K_2O (potassium oxide). To convert % P_2O_5 to % phosphorus (P) multiply % P_2O_5 by 0.44. To convert % K_2O to % potassium (K) multiply % K_2O by 0.83.

Many fertilizers are manufactured to contain a high concentration of a single nutrient. For example, urea contains approximately 45-46% N and triple superphosphate contains 44-48% P_2O_5. However, other fertilizers contain more than one nutrient such as diammonium phosphate (16-21% N and 46-53% P_2O_5) and ammonium sulfate (21% N and 23% sulfur (S)). Fertilizer blends are mixtures of several fertilizer nutrient sources which produce a desired analysis. For example, banana growers require fertilizers with a high proportion of potassium in them and, therefore, one fertilizer blend produced for these growers has an analysis of 10-5-22. Higher analysis fertilizers contain a higher concentration of nutrients and, therefore, are often more economical because of the high costs of shipping to Guam. Organic amendments are generally low analysis nutrient sources, but often contain a wide variety of macro- and micronutrients.

Nutrient availability and chemical reactivity - Fertilizer and soil amendment characteristics which affect the rate at which plant nutrients become available to the plant and the rate that the soil amendment will react in the soil are:

Solubility of the product - Chemically complex materials like organic amendments are less soluble than simple compounds, such as fertilizer salts, and are decomposed by biological activity. Common agricultural and coralline limestones are also not very soluble and may take a number of months to react with the soil. Advances in the fertilizer industry have provided a category of fertilizers that are called controlled or slow-release fertilizers. These fertilizers release their nutrients over time because the fertilizer is usually coated with a material which slowly breaks down in the soil. Fertilizer solubility is also important when fertilizers are used in combination with irrigation or pesticide application systems. Fertilizer injection into irrigation systems requires highly soluble fertilizers. Many of the phosphorus fertilizer sources are not very soluble and often require other application methods besides through irrigation.

Particle size and form - Smaller particles are usually more rapidly soluble and, therefore, more available for plant absorption. However, granular forms may be easier to apply than powdered forms because of the effects of wind and the method of application. The different particle sizes of several fertilizer sources in fertilizer blends can result in a problem of particle segregation in the fertilizer bag and reduce the uniformity of a fertilizer application. Some fertilizers avoid this problem by having all the fertilizer nutrient sources together in each granule of the fertilizer blend.

Acid, neutral or base forming - The application of ammonium-based fertilizers, such as ammonium sulfate, can increase soil acidity. Other fertilizers, such as potassium sulfate, tend to have no effect on soil pH. Yet others, such as potassium nitrate, can result in a decrease in soil acidity. The differences in the effects of these fertilizers on soil pH are due to the different chemical reactions these fertilizers undergo when applied to soil. Several soil amendments are used primarily to adjust soil pH including those that increase pH (agricultural limestone, slaked lime, marl, and calcium oxide) and those that decrease soil pH (elemental sulfur, aluminum sulfate, iron sulfate, and sulfuric acid).

Salt index - Fertilizer materials vary in the effects they have on increasing the salt concentration of the soil solution. High salt concentrations can damage plants, especially when plants are in the seedling stage. Placement of fertilizer materials directly next to seeds or seedlings can result in reduced germination or early growth. This salt injury can be avoided by placing the fertilizer a small distance from the seed or seedling. In general, higher analysis fertilizers cause less salt damage than low analysis fertilizers since less fertilizer material is needed to apply the same amount of plant nutrients. In addition, nitrogen and potassium fertilizer salts generally have much higher salt indexes compared to phosphorus fertilizers.

Cost and convenience - A major limiting factor for use of fertilizers in the Pacific Islands is often cost. The expense of transporting fertilizers to the region drives up fertilizer prices. However, many consumers are more concerned with convenience when applying fertilizers. In general, specialty fertilizers, such as slow release and highly soluble forms, cost more than bulk fertilizers.

Table 1. Some common fertilizer sources and their nutrient analysis.

Nutrient Source	Nitrogen % N	Phosphorus* % P_2O_5	Potassium* % K_2O
Sources of One Primary Macronutrient:			
Urea	45–46	0	0
Ammonium nitrate	33-34	0	0
Ammonium sulfate	21	0	0
Single superphosphate	0	16-22	0
Triple superphosphate	0	44-48	0
Potassium chloride (muriate of potash)	0	0	60-62
Potassium sulfate (sulfate of potash)	0	0	50
Sources of Two or More Primary Macronutrients:			
Diammonium phosphate	16-21	46-53	0
Monoammonium phosphate	11	48-55	0
Triple 16	16	15-16	15-16
10-20-20	10	20	20

*% P = % P_2O_5 x 0.44; % K = % K_2O x 0.83.

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FERTILIZER FACTS

Number 5. Forms of Fertilizer and Other Soil Amendments

Peter Motavalli and Thomas Marler - College of Agriculture and Life Sciences - University of Guam

Fertilizers and other soil amendments are available in several forms. The effectiveness of each form depends on management practices and environmental conditions. The relative cost and availability of each fertilizer material may also affect the form of fertilizer selected. Among the types of fertilizers to consider are:

Solid, liquid and suspensions - Liquid fertilizers are easier to handle since they can be applied with irrigation or spray equipment. If liquid fertilizer is combined with pesticide application, consideration must be given to the compatibility of the mixed chemicals. The choice of liquid fertilizers is limited compared to solid fertilizers because only certain fertilizers are sufficiently soluble to remain in solution.

"Fertilizers and other soil amendments are available in several forms. The effectiveness of each form depends on management practices and environmental conditions"

Storage of many solid fertilizers can be a problem because they pick up moisture (hygroscopic) and the particles cake together. Fertilizer suspensions are concentrated liquid fertilizer in which fertilizer crystals are precipitated and kept from settling by a suspension agent. With this form of fertilizer, extra care must be exercised to keep the suspension agitated during application to insure uniformity.

Slow release fertilizers - Slow release fertilizers are designed to allow the fertilizer nutrients to slowly dissolve in the soil solution. Many forms of slow release fertilizers exist including those that are coated with sulfur (sulfur-coated urea or SCU) or resin (Osmocote, Nutricote) and those that are combined with another chemical (isobutylidene diurea or IBDU; Ureaform or Polyform).

Natural organic nutrient amendments, such as animal manures, are also a type of slow release nutrient source since a proportion of the organic nutrients in the organic source is slowly mineralized to a plant-available form.

The advantages of slow release fertilizers are that nutrients are available longer over the growing season, fertilizer can be applied less frequently, the risk of fertilizer salt injury is decreased, and the potential loss of fertilizer nutrients due to leaching is decreased. These factors increase fertilizer efficiency and decrease potential for groundwater pollution after slow release fertilizer is applied.

The principal disadvantage of slow release fertilizers is their high cost compared to regular fertilizers. In addition, under certain conditions, plants may require immediately high levels of available nutrients, which would not be satisfied by slow release fertilizers. Initial research also indicates that slow release fertilizers may breakdown faster under the tropical environmental conditions of Pacific islands, lessening the effective time that slow release fertilizers may release nutrients.

Organic chelates versus salts to provide micronutrients- Changes in the chemical forms of added micronutrient fertilizers in soil can reduce the amount of micronutrients available for plant absorption. For example, if the inorganic iron salt, ferric sulfate, is added to the calcareous soils of Northern Guam, much of the iron changes into an unavailable form.

One method to avoid soil transformation of micronutrient fertilizers is by directly spraying plant leaves. Another method is to use micronutrient fertilizers which contain chelating agents. The chelating agent is an organic compound to which the micronutrient binds making it more soluble. Chelated micronutrients are more effective than inorganic salts when applied to soil. However, chelating agents are usually more expensive than inorganic salts. They also vary in their stability in soil.

Among the major chelating agents that are used in agriculture are ethylenendiaminetetraacetic acid (EDTA), diethylenetriaminepentaacetic acid (DTPA), cyclohexanediaminetetraacetic acid (CDTA) and ethylenediaminedi (o-hydroxyphenylacetic acid) (EDDHA). For iron chelates, the order of stability in soil from greatest stability to least stability is:

EDDHA > CDTA or DTPA > EDTA

Organic versus inorganic - Fertilizers and other nutrient amendments can contain plant nutrients in either an inorganic or organic form. Most plants only absorb inorganic forms of plant nutrients, and, therefore, organic nutrients must be converted to inorganic forms to become available to the growing plant. The process by which organic nutrients are converted to inorganic nutrients is called mineralization.

The soil contains many microorganisms which decompose and mineralize organic nutrients. The rate at which this process occurs will be affected by such factors as climate, soil texture and the amount and composition of the organic material added. In general, a wet and hot climate and sandy soils will have higher decomposition rates than other climates and soil types.

Woody materials high in lignin will decompose slower than green materials high in organic nitrogen. Inorganic salts, such as ammonium nitrate, release inorganic nitrogen which is immediately available to the growing plant. Organic sources of nitrogen, such as manure, are often converted to inorganic nitrogen slowly over the growing season. A notable exception to this rule is urea which is a manufactured organic form of nitrogen. Urea is rapidly converted to ammonium when added to soil. Inorganic nitrogen in the form of nitrate can be leached down and out of the plant's root zone and be lost for plant uptake and possibly contaminate groundwater. Both organic and inorganic nutrients can contaminate surface waters, such as streams, when the process of soil erosion deposits nutrient-rich soil into the water.

Table 1. Some common organic nutrient sources and their approximate nutrient analysis (dry weight basis)*.

Nutrient Source	Nitrogen %N	Phosphorus** $\%P_2O_5$	Potassium** $\%K_2O$
Manures:			
Cattle	2.2	1.6	2.5
Swine	2.1	2.2	1.4
Poultry	4.4	4.8	3.1
Horses	1.7	0.7	1.8
Other:			
Sewage sludge	5.6	5.1	0.4
Seaweed	0.6	0.1	1.3
Fish meal	4.0	23.2	0
Wood ash	0	1.8	5.5
Bone meal	3.9	22.0	0
Grass clippings	4.0	1.1	2.4
Sawdust	0.2	0	0.2
Tangantangan (Leucaena):			
Leaves	3.9	0.3	1.8
Stems	1.7	0.2	1.9

*Actual nutrient analysis may vary.
**$\%P = \%P_2O_5 \times 0.44$; $\%K = \%K_2O \times 0.83$.

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FERTILIZER FACTS

Number 6. Methods of Fertilizer Application

Peter Motavalli and Thomas Marler - College of Agriculture and Life Sciences - University of Guam

There are many existing methods for applying fertilizers. Among these methods are:

Broadcast - Fertilizer is uniformly spread or sprayed over the entire soil surface, often followed by incorporation using a tillage implement.

Localized placement - this method consists of placing the fertilizer in a band or localized point close to the plant. Localized placement includes starter, deep, surface, top-dressing and side-dressing fertilizer placements. This method is used for several reasons including providing fertilizer nutrients to seedlings with immature root systems, overcoming soil processes which reduce nutrient availability such as precipitation of phosphorus, convenience due to the difficulty of applying fertilizer to rows of fully-grown plants, and cost-saving since less fertilizer may be required when a limited soil volume is involved.

"There are many existing methods for applying fertilizers including broadcast, localized placement, foliar sprays, fertigation, injection, and precision application"

Foliar sprays - fertilizer is sprayed directly on the leaves of the plant. This method is usually used to overcome micronutrient deficiencies caused by soil conditions. Uptake of the nutrient is by absorption through openings on leaves called stomates.

Fertigation - fertilizer is applied through the irrigation system. If trickle irrigation is used then fertilizer is released from emitters at a point source and results in an effect similar to localized placement.

Injection - Fertilizer or manure is placed into the soil using a tanker and an implement which cuts through the soil and injects the fertilizer behind the cutting edge of the implement. The most common fertilizer applied in this manner is anhydrous ammonia, which is not currently available on Guam or other Pacific islands. Manure can also be applied using this method.

Precision application - the most modern method of fertilizer application uses advances in mapping technology to apply fertilizer in varying amounts to a field based on previous soil sampling. This method requires sophisticated computer software to allow the fertilizer spreader to recognize its geographic position in relation to the soil test results and then adjust the amount of fertilizer applied. Use of this method requires a significant investment in equipment and is currently not used in the region.

For further information, contact Guam Cooperative Extension, College of Agriculture and Life Sciences, University of Guam, Room 105, Mangilao, Guam 96923. Telephone no. (671) 735-2080.

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