

MINERAL NUTRITION OF PLANTS *

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1. Introduction

The inquiry into processes and factors which control plant life can be traced back to ancient times. These were indeed the simple trials on agricultural practices such as ploughing and tilling which brought about measurable increases of crop yields.

Van Helmot who lived from 1577 to 1644 A.D. is considered to be the first to conduct scientific experiments on plant life to investigate the factors which affect growth.

The rapid developments in the field of chemistry in the nineteenth century opened a new chapter in the study of soils and plants. By the beginning of the century Theodore de Saussures had shown that carbon and elements of water combine together in the plant, and that nitrogen which was so essential for growth was obtained from the soil.

Further progress on plant nutrition awaited the development of new techniques of growing plants under controlled conditions in sand and water cultures. With these developments during the first quarter of the twentieth century, the essentiality of the 10 major elements, C, H, O, N, P, K, Ca, Mg, S and Fe became firmly established.

The introduction of nutrient culture procedures for the study of mineral nutrition provided a convenient method to determine the extent to which an element is essential to normal plant growth.

1.1 General classification and nomenclature

However, with the discovery that elements such as manganese, copper, zinc, boron and molybdenum

were also equally important and essential for normal growth, but required in smaller quantities, a broad classification of essential elements was introduced. In this classification, C, H, O, N, P, K, Ca, Mg, S and Fe were generally referred to as "major" elements while Mn, Cu, Zn, B and Mo were called "rare" "trace" or "minor" elements.

1.2 Fundamental features of plant nutrition

The essential feature in the nutrition of plants is the ability of living plant organisms to take up from soil, water and air, the necessary primary ingredients and transform these into complex compounds. The chain of events which take place during this process involves complex physico-chemical reactions, some of which are only partly understood. The fact that no less than fifteen elements (viz. C, H, O, N, P, K, Ca, Mg, S, Fe, Mn, Cu, Zn, B and Mo) participate in these processes indicates the magnitude and complexity of the mechanisms involved. Among the essential elements, carbon, hydrogen and oxygen are obtained almost entirely from water and air, and are hence not regarded as mineral nutrients. Mineral nutrition of plants would therefore involve only those chemical elements which are normally taken up by plants from the soil.

2. Chemical Composition of Soils

2.1 Chemical composition of the earth's crust

Some 14 chemical elements make up 99.5 per cent of the earth's crust. Of these, oxygen and silicon make up about 74 per cent in the average composition. If considered by volume, oxygen makes up 90

per cent of the earth's crust, and most of it is combined with silicon and aluminium in minerals.

2.2 Availability of mineral nutrients

The soil is a heterogeneous medium made up of solid, liquid and gaseous components in different proportions. In most common soils the solid component which is made up of the minerals and organic matter, makes up about one half of the soil volume. The other half is made up of the soil solution and air (See Figure 1).

A small but an important fraction of the various elements in the soil minerals occur in a form in which they can be replaced by other elements. This fraction in the soil, usually referred to as "exchangeable ions", play a very important role in plant nutrition. The supply of this easily exchangeable fraction of ions is maintained by the gradual weathering of rock minerals; but the rate at which this occurs, and the chemical "activity" of the ions which go into solution depends on the nature of minerals present. Hence it can be said that the mineral composition of the soil can have a very important bearing on the fertility of a soil.

However, the "activity" or the concentration of a cation in solution does not provide any information on the supplying power of these nutrients. Since at the same "activity" of a given cation, the clay-mineral association of a soil can supply the plant much more of that cation than from a true solution. This is chiefly because apart from the nature and concentration of ions present in the medium, their availability to plants is governed by several other factors, of which the following may be considered the more important:-

- (a) Nature of the soil colloid
- (b) Cation and anion exchange phenomena
- (c) Soil pH
- (d) Fixation
- (e) Effect of complementary ions

3. Functions of Mineral Nutrients

The proof that an element is essential for the normal growth of a plant implies that such an element has a

definite and an indispensable function to be performed in the plant.

On the basis of the functions performed by mineral nutrients, these elements could be broadly classified into three main groups. The first of these have as their main function the formation of structural units in cell building. Members of this group are nitrogen and sulphur. The second group has both a structural as well as a catalytic function in metabolism. Elements in this group are phosphorus, calcium and magnesium. The third group comprises of elements which have almost exclusive catalytic functions in plants. All the micronutrients except probably boron falls into this category.

3.1 Catalytic functions of nutrient elements

The nutrient elements which have a catalytic function are associated with enzymes, and these enzymes again are broadly classified into two groups: (i) the metal-activated enzymes, and (ii) the metallo-enzymes.

Among essential elements manganese and magnesium function in many enzyme reactions as activators. On the other hand zinc, iron, copper and molybdenum are often found to be bound firmly to enzymes and functions as metallo enzymes. With regard to the catalytic functions of enzymes, it is interesting to note that in most instances the metal ion associated with an enzyme can perform a catalytic function in its inorganic state in the absence of the protein component. It is thus said that these elements in their inorganic state possess in a rudimentary or primitive form the functions that they perform so efficiently when combined or associated with an organic radicle. An example is the oxidation of ascorbic acid by salts of copper. When copper forms part of the enzyme called ascorbic acid oxidase, its catalytic function increases a 1000 fold.

3.2 Functions of macronutrients

3.2.1 Nitrogen

Nitrogen is taken up by plants mostly as nitrates, ammonia, urea, or some derivative of these compounds. However, plants with symbiotic bacterial

nodules or other microbial associations can take up nitrogen in the elemental form. Whatever the source of nitrogen, during transformations within the plant, ammonia is produced as one of the inorganic intermediate products of metabolism. The ammonia thus formed is received by organic carboxylic acids, forming ultimately amino acids. These are so to say, the building blocks of proteins.

Apart from proteins and amino acids, nitrogen enters into a large number of biologically important compounds, among which are these known as purines and pyrimidines. The proteins also lead to the formation of enzymes and co-enzymes. By entering such a vast range of biologically important compounds in the plants, nitrogen plays a major role in cell building and growth.

3.2.2 Phosphorus

Phosphorus enters the plant as the ortho-phosphate radicle and remains so in both the inorganic and organic compounds of plants. It enters into a large number of compounds and plays a key function in the transfer of energy during the various metabolic processes. In glycolysis the sugars carrying phosphate radicles play a very important role and enters several intermediary breakdown products. It is also associated with several genetically important compounds called nucleic acids.

3.2.3 Potassium

Although potassium is a macro-element and hence required in large quantities, it has not been observed to form any metabolically important compound. In the plant it exists largely as soluble inorganic salts, and to a smaller extent as soluble organic salts. Its absence or deficiency causes many visible symptoms to occur.

3.2.4 Sulphur

Sulphur is taken up by plants mostly from the soil in the form of sulphate. However, if the sulphur dioxide content in the air increases appreciably it may be taken up in the gaseous state through leaves.

Sulphur is a constituent of the amino acids, cystine, cysteine and methionine, and hence enter into the composition of proteins.

3.2.5 Calcium

Although calcium is taken up by plants in relatively large quantities its role is not clearly understood. Being a very immobile element, its deficiency shows a marked effect on the growth and development of young shoots. Curling of young leaves and appearance of chlorotic patches on leaves are typical symptoms of calcium deficiency. Calcium starved plants show retarded root development which consequently weaken the anchorage of plants.

Calcium ions have also been shown to function as an activator of a number of enzymes, and in fact in the case of the enzyme amylase, calcium has been found to stabilize its molecular structure.

3.2.6 Magnesium

Ten per cent of the magnesium present in the leaf is contained in chlorophyll. It is the only metal constituent in the chlorophyll molecule. Deficiency of magnesium results in a loss of the yellow pigments xanthophyll and carotene in addition to chlorophyll. The fact that chlorosis due to a deficiency of magnesium begins with mature leaves indicates that it is a very mobile element.

Magnesium is known to play a very important role in enzyme activities, although a few other elements like manganese can substitute magnesium at least partly in these activities. Magnesium has been implicated to assist the movement of phosphorus from the root to shoot.

3.3 Functions of micronutrients

3.3.1 Iron

Iron has several important functions to perform in the plant. Iron functions through the formation of a complex ring compound called iron porphyrin (or heme) which by association with specific proteins forms a series of very important enzymes and activators.

Iron is also known to occur in forms other than as the heme, for example in the enzyme xanthin oxidase. In general, in many of its reactions involving electron transfer iron is believed to function through the reversible oxidation, reduction change.

3.3.2 Manganese

Manganese seems to be very closely associated with the manufacture of the chloroplasts and chlorophyll. In this role it behaves somewhat similar to iron. Manganese is also associated with molybdenum in the synthesis of amino acids from nitrates.

3.3.3 Zinc

Zinc is known to be a constituent of a number of enzymes of which alcohol dehydrogenase and carbonic anhydrase are the most common. The latter enzyme catalyse the reaction, $\text{H}_2\text{O} + \text{CO}_2 \rightleftharpoons \text{H}_2\text{CO}_3$

3.3.4 Copper

Copper is a constituent of several enzymes, some of which catalyse the oxidation of substances directly by oxygen. This property of copper containing enzymes is already present in simple copper salts in a very mild form. When metallic copper enters a specific protein to form an enzyme, this catalytic property of the ionic salt is increased several times. A common example is the copper bound enzyme ascorbic acid oxidase which catalyse the oxidation of ascorbic acid to a substance called dehydroascorbic acid and water. It is thought that copper in these enzymes function through the cyclic conversion of cupric to cuprous and back. Other copper enzymes

found in plants are, polyphenol oxidase, laccase and probably cytochrome oxidase.

3.3.5 Boron

Boron is thought to be associated with the translocation of sugars.

3.3.6 Molybdenum

Molybdenum is required for nitrate assimilation in plants, and this occurs through the enzyme nitrate reductase, which has molybdenum as one of its specific components. It is interesting to note that molybdenum not only enters the composition of the enzyme nitrate reductase, but also directly assists in its formation.

Molybdenum is also a component of the enzyme system which helps to break down nitrates to nitrites with the release of energy. In this case molybdenum appears to be associated with an enzyme, which has iron in addition to Mo in its composition.

4. Nutrient Requirement of Plants

Methods for the study of nutrient requirements

Simultaneously with the search for factors which control plant growth, efforts were directed to a search for a simple and convenient method to determine the nutrient requirements of plants. Extensive studies during the past 150 years or so have resulted in the near perfection of several interesting techniques to evaluate nutrient requirements in plants. Some of the more important procedures are; (a) fertilizer experimentation, (b) bioassay experiments, (c) sand and water culture experiments, (d) soil analysis, (e) plant analysis and (f) leaf analysis.

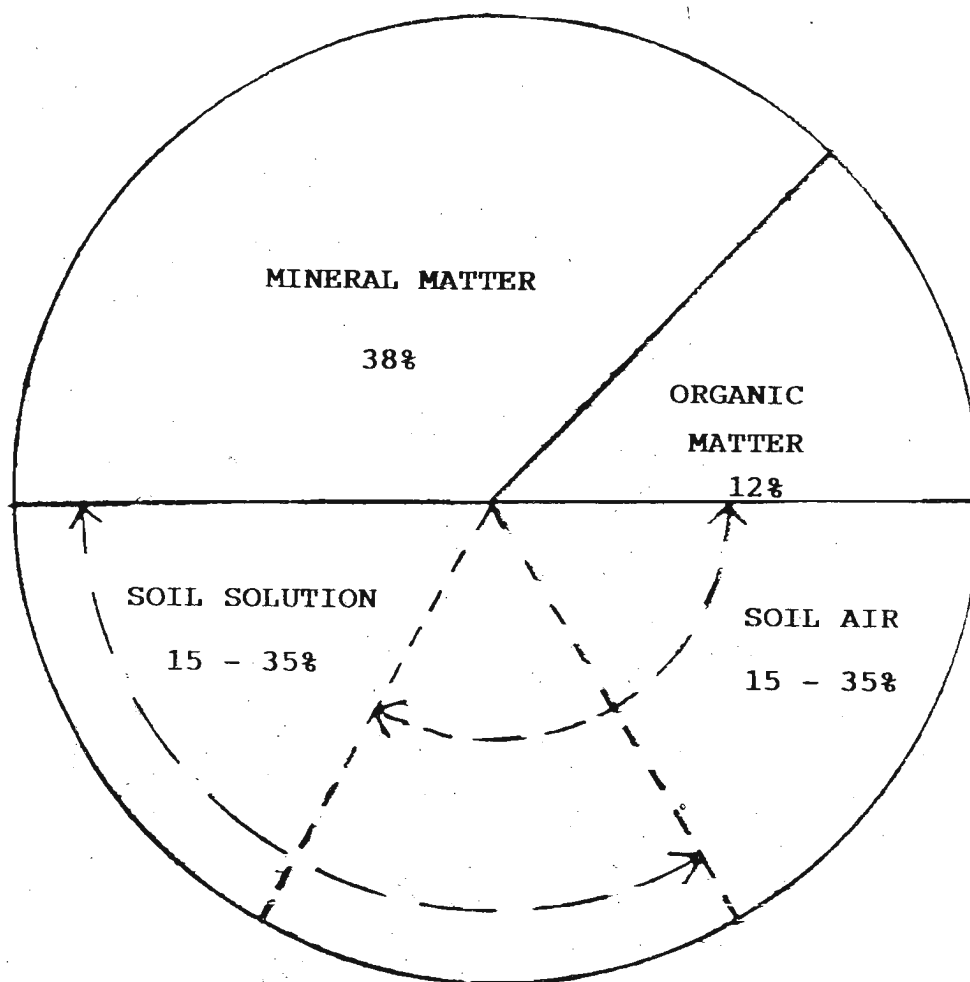


Figure 1 - Diagram showing broadly the distribution of materials in the Earths Crust

PLANT NUTRITION AND FERTILIZER USE IN RICE AND UPLAND ANNUAL CROPPING

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1. Plant Nutrition

Plants require chemical elements for their growth and development. Carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium and iron are necessary for all plants and hence are called essential elements. In addition some elements like molybdenum, boron and chlorine are important for some plants. Plant nutrition deals with the provision of these elements to plants to enable their growth and development.

2. Plant nutrition in the natural habitat

In the natural habitat, plant nutrition is a natural process. Plants take in carbon and oxygen as carbon dioxide from the atmosphere for photosynthesis, oxygen as gas from the atmosphere and soil air for respiration, hydrogen and oxygen as water from the soil and other elements also from the soil. In the natural habitat there is an equilibrium between the rate of plant intake of nutrients from the habitat and the rate of release of the nutrients into the habitat by way of soil formation and decomposition of plant debris.

Early people gathered their food from the forest without upsetting this equilibrium too much or for too long a period.

3. Plant nutrition in traditional farming

The farming practices adopted by the traditional farmers were very close to the natural ecology. The policy followed was sustainable use of the resource base without drastically interfering with its nature and composition.

3.1 Lowland paddy

Until about 1950, the paddy farmers in Sri Lanka farmed wet lowlands to paddy obtaining 30-40 bushels per acre or 1.5-2 tons per hectare. Lowlands generally get enriched with accumulations of nutrients that come down from the adjacent upper slopes. From such a land, removal of 1.5-2 t/ha does not badly deplete the soil. Where depletions were observed, as in the wet zone where the soil is poor in calcium and magnesium, the traditional paddy farmers added bone meal to the soil.

3.2 Shifting cultivation

Uplands on the other hand do not get enriched with supplies from elsewhere. What the traditional farmer did there was to fell the nutrient rich forest, liberate the nutrients locked therein by burning, and to crop the field as long as the liberated nutrient reserve was adequate to support crop. After that the land was fallowed to forest. This system is called shifting cultivation.

3.3 Home gardening

The traditional farmers also developed the art of home gardening. Trees and crops were grown around the house for many reasons; easy protection, improvement of microclimate and enhanced soil fertility by domestic waste and farmyard manure. Here too the efficiency of farming depended on the low volume of food removed from it in comparison to the total biomass found in it.

4. Manures

With settled farming and continuous removal of crop produce from the field the farmers gradually learned the need to replenish the nutrient reserve in the soil

in order to avoid nutrient depletion and crop failure. Early farmers applied farmyard manure, household waste, human excreta, plant parts, crushed bone etc. to the soil to keep the land productive. They come from organic sources and are called manures. Manures are bulky and contribute to soil fertility not only by supplying nutrients but also improving soil structure, aeration, water holding capacity and cation exchange capacity.

5. Fertilizers

With advances in science and technology, the population increased the world over and the demand for food increased. In Sri Lanka the population was only 1 million in 1800 and it rose to 8 million in 1950 from where it has now doubled. Also, petroleum and mineral industries produced compounds with high concentrations of plant nutrients. They are called fertilizers. Plant breeders too increased the genetic potential of the crop varieties to respond to added fertilizer and to produce high yields. Combination of these factors led to commercial farming which involved cropping of larger extents of land, more frequently and for longer periods with high yielding varieties and resorting to fertilizer application.

Out of the essential elements nitrogen, phosphorus and potassium are needed in large quantities and hence called major nutrients. It is these nutrients that are generally applied in the form of fertilizer. Over the past three decades, fertilizer became the biggest single input that contributed the most to increase in crop production. Consequently application of manure became less popular.

6. Rice

Rice is the most important crop in Sri Lanka. It covers the largest extent of land for any single crop.

In the wet lowlands, rice produces a yield of about 2 t/ha without much fertilizer because of the eutrophic nature of the lowlands and the better conditions available for dinitrogen fixation. More fertilizer is necessary in the uplands. Fertilizers generally used in paddy are urea which has 45% nitrogen, concentrated super phosphate with 45% phosphorus expressed as P_2O_5 and muriate of potash with a K_2O concentration of 60%. Nutrient levels recommended for moderate paddy yields are 80kg N, 55kg P_2O_5 and 45kg K_2O per hectare. Timing of fertilizer application is determined on the ease of nutrient availability, the vulnerability of fertilizer to loss, and the demand times of the crop for nutrients. Accordingly, all phosphorus and half potassium are applied at or before planting (basal dressing) and half potassium and all nitrogen when the crop is growing (top dressing). In addition, returning of paddy straw to the field and application of tree and bush loppings are recommended.

7. Upland annual crops

Upland annual crops differ from paddy by requiring well drained soil conditions. There are many such crops grown in Sri Lanka and the general levels of fertilizer recommended for them in kg/ha/season are as follows;

	N	P_2O_5	K_2O
Cowpea, green gram	30	60	45
Maize, finger millet	70	55	50
Manioc, sweet potato	100	50	90
Cabbage	200	130	90
Carrot, beet	215	125	150
Chilli, tomato, brinjal	150	125	100

Liberal dressings of farmyard manure and green manure are also recommended.

ORGANIC MANURE FOR CROP PRODUCTION *

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The use of chemical fertilizers in the developing countries has increased considerably during recent years. In many tropical countries it has brought substantial increases in crop yields and has also been a principal input in the cultivation of high yielding crop varieties. High yielding varieties also require higher nutrient input than ordinary varieties.

The nutritional depletion of soils by these high demanding crops coupled with the destruction of the vegetation through farming, felling of trees for timber, bush fires and over grazing impoverish the soils if soil management practices are neglected.

Organic matter improves the soil for plant growth. Sources of organic materials are available to every farmer i.e. residues from harvests, crop straw, stalks and any vegetable matter, urban or kitchen wastes, brush woods, animal manure etc. Therefore attempts should always be made to use organic manures because it improves the soil physical condition, soil nutrient status and soil biological properties.

A new method developed in Europe is to make compost out of brush wood and use it as fertilizer. This method can be used with advantage in countries like Sri Lanka, where the raw material is available in plenty for the farmer.

Preparation of Brush Wood Compost

There are two methods for preparation of brush wood compost.

Manual Method

1. Raw materials

- (a) The raw materials should be plant debris
- (b) Several varieties of plants are mixed

- (c) The plant materials are chopped to small particles using a machine or manually by a knife
- (d) Diameter of the largest particle should be below 8 mm
- (e) Any mineral fertilizer or chemical (excepting Calcium hydroxide which is sometimes added to control the pH of the mixture) is never added

2. Humidification

These materials are soaked in water for at least 24 hrs. (Normally this process is done on rainy days).

3. Formation of Compost Pile

- (a) Materials must remain undisturbed for a minimum of two weeks (for starting the fermentation process)
- (b) Heaps are carded by fork and form a triangular pile of width 2.2m height 1.6m with a minimum volume of about $4m^3$
- (c) The pile is covered with soil or old compost layer of 2 cm thickness
- (d) Temperature is allowed to rise up to $60^{\circ}C$ (if it is too high water should be added to control the temperature $60^{\circ}C$).
- (e) After 90 days, compost is formed and can be used for crops as manure
- (f) When the compost is formed the largest pieces of material can be crushed between the thumb and the forefinger

Industrial Method

- (a) Living plant material from forests and urban areas are collected and transported by tractors
- (b) Materials are chopped using a machine (diameter of largest particle should be below 8 mm)
- (c) Water is applied using "sprinklers" for minimum period of 24 hours
- (d) Materials must remain undisturbed for minimum of two weeks
- (e) Heaps are carded using a machine and a triangular pile is formed
- (f) Dimensions are double figures of the manual method
- (g) Temperature is allowed to rise up to 70°C
- (h) Materials are kept for 6 months for fermentation and then used for crops.

Chemical composition of the Brush Wood Compost

	After 1 month	After 3 months
pH	5.7	7.1
Total N (%)	0.43	0.97
P ₂ O ₅ (%)	0.12	0.17
KO (%)	0.30	0.48

Application of Brush Wood Compost

- (a) For agricultural crops
- 50-80 tonnes/ha

- (b) For market gardening
- 100 tonnes/ha

- (c) Creation of an agricultural soil industry region
- 500 tonnes/ha

- (d) For the tree culture
- Sufficient experience is not available but
planting time 60 kg/tree

- (e) In dry region to cover the soil
- 10 cm thickness as a mulch

A coconut grower can prepare a compost pile in his own land to meet the requirement of manure for coconut using the plant debris obtained from hedges, livefences, shrubs, weeds available in his own land. In addition green matter from road side bushes and jungles also can be used for compost.

In addition to the supply of essential plant nutrients for coconut, compost improves soil structure in such a way that it facilitates root penetration of coconut palm which in turn gives rise to a wide spread root system. Soil aeration is also increased due to improved soil structure. The moisture retention capacity of soil can also be enhanced by addition of compost.

The multiplication of the population of soil micro-organisms and earthworms as a result of compost application would enhance the supply of plant nutrients to the palm and improve the soil structure. The nutrient retention ability of soils can be improved by compost addition. All these factors ultimately lead to formation of good fertile soil which may give a better coconut yield.

LEAF AND SOIL ANALYSIS - A USEFUL TOOL IN THE DETERMINATION OF NUTRIENT REQUIREMENTS OF COCONUT*

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Coconut production in Sri Lanka is often affected by deficiencies of minerals such as nitrogen, phosphorus, potassium and magnesium. Application of the correct fertilizer mixture at the proper time is important for optimum production. The nutrient requirements of the palm are determined by a number of factors such as the nutrient status in the soil and in the plant, level of production etc.

The soil and leaf can be chemically analysed to determine the content of nitrogen, phosphorous, potassium, magnesium and other nutrients. Depending on the levels of these nutrients, appropriate amounts of fertilizer can be applied. These analytical methods can therefore be used to avoid excessive application of fertilizer, thereby reducing costs. Also, when the production is above average, the appropriate amount of fertilizer can be determined using data from soil and leaf analysis. Thus, this technique is an important and an efficient tool in determining the nutrient requirements of coconut in a given location. However, in order to use this method effectively, it is necessary to adopt correct techniques to obtain soil and leaf samples. Improperly collected samples will not reflect the correct nutrient status of the palm, thereby misleading the researcher in his recommendations.

Data from soil and leaf analysis could be used to rectify mineral deficiencies. Since these analyses are expensive, it is necessary to first determine the need for it. For example, if palms show clear visual symptoms of mineral deficiency, then soil and leaf analysis may not be required to determine corrective action. In most instances, the general fertilizer recommendations of the Coconut Research Institute are adequate to achieve a high production. It is pertinent to mention here that by adopting the CRI general fertilizer recommendations with a modest level of management, yields in the region of 5000 to 9000 nuts/ac/year have been obtained. Thus, in

many instances, it may not be necessary to carry out an expensive soil and leaf analysis programme to achieve a high yield.

Nevertheless, there are instances where data from soil and leaf analysis can be used to increase profitability by economising on fertilizer usage. The leaf number 14 (i.e. first fully opened leaf being number one) has been found to be the best for determination of nitrogen, phosphorous and potassium levels, whereas samples from both 6th and 14th leaf are necessary to determine magnesium levels. About five leaflets each from either side of the selected frond are collected. The 10 leaflets thus collected are bundled together and labelled giving details such as the date of collection, identification, locality, frond number etc. Leaf samples should reach the laboratory quickly, at least within two days after sampling, where they will be cleaned and a smaller sample taken for drying in the oven. The dried sample is then mechanically ground to a powder for use in analysis. The sample size depends on a number of factors such as the extent of the holding, age of palms, soil type, management practices, deficiency symptoms etc. It is very important to select representative palms in a plantation and it may be necessary to sample about 2-3 palms per each one acre block to eliminate variability.

Soil samples are normally collected from the manure circle area or from the centre of the coconut square. Samples from manure circle area would give information on the status of nutrients and their availability to the palms whereas samples from the centre of the square will give a general idea on the nutrient status and availability of that particular soil. Generally, soil is sampled at two depths, 0-25 cm ("surface soil") and 25-50 cm ("sub soil"). Because of the high variability of nutrient content observed in soil samples, it is necessary to collect about 0.5 kg of soil from each of the 3-5 sites per 10 - acre block of uniform soil type.

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Then these samples are mixed to make a composite sample and about 1 kg of soil is taken into a clean plastic bag and labelled with details such as the date of collection, identification, locality, site and depth of sampling etc. During soil sampling, it is necessary to avoid roads, drains, pits, termite mounds etc. Soil samples should reach the laboratory quickly, but in any case within two days after sampling, for drying and grinding.

Sampling is normally carried out at the end of the dry season, as otherwise interpretation of results could be difficult. However, with certain safeguards, sampling could be done at other times also.

During sampling, it is necessary to avoid contamination of samples with extraneous matter. Also, it is necessary to clearly know the objective of sampling,

i.e. for fertilizer requirement, check possible nutrient deficiency, to check the nutrient status of palms and/or soil etc. before attempting sampling.

From the foregoing, it would be obvious that sampling of leaf and soil has to be carried out very carefully with due consideration to all aspects and requires expertise and experience. We have observed that estate staff often collect samples, mostly soil, on their own. It is unlikely that these samples are collected on the basis indicated above, and the usefulness of such samples to evaluate the nutrient status of the holding is doubtful. It is therefore best to obtain the services of the staff of the Coconut Research Institute in this endeavour.



Soil and leaf analytical laboratory

EFFICIENT USE OF DOLOMITE IN COCONUT CULTIVATION*

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Magnesium deficiency is fairly widespread in coconut, particularly in the wet zone of Sri Lanka. In many instances it is the yield limiting nutrient, second to potassium. Once magnesium deficiency symptoms appear in adult coconut, it is necessary to apply relatively expensive imported kieserite fertilizer at the rate of 1 kg per palm at six monthly intervals until the palms recover. Hence regular application of dolomite is essential as a long-term preventive measure. Dolomite is a locally available cheap source of magnesium and its regular application, at about 1 kg/palm/year would generally provide the magnesium requirements of coconut. Questions are often asked about the use of dolomite and urea in fertilization of coconut and the restrictions in mixing dolomite and coconut fertilizers.

Dolomite is a naturally occurring mineral containing carbonates of magnesium and calcium. It is excavated from large deposits in Matale region and ground and sold in Sri Lanka as a magnesium (Mg) fertilizer. Generally, dolomite contains 18% MgO with particle sizes to allow 100% to pass through 30 mesh (0.6 mm) and 50% to pass through 100 mesh (0.15 mm) sieve.

The water solubility of dolomite is about 1% and hence the availability of Mg to plants is slow, compared to that of kieserite ($\text{MgSO}_4 \cdot \text{H}_2\text{O}$; 24% MgO) and epsom salt ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$; 16% MgO) which have water solubilities of about 40% and 100%, respectively. However, dolomite is produced locally and is much cheaper, whereas both kieserite and epsom salt are imported and expensive. The current prices of a metric ton of magnesium fertilizer are - Rs.750 for dolomite, Rs.6,600 for kieserite, and Rs.9,600 for epsom salt.

Dolomite is a basic material having a pH around 9.0 in 1:1 water. Hence if dolomite is mixed or stored with nitrogenous fertilizers such as urea or ammonium sulphate under moist conditions, there can

be a loss of nitrogen in the form of ammonia gas to the atmosphere. Studies show that when NPK fertilizer is mixed and stored with dolomite for seven days under moist conditions, about 22% of nitrogen is lost. However when dolomite was applied to a damp mixture of a clay soil and NPK fertilizer, in a proportion similar to field application, there was hardly any loss of nitrogen even after six weeks. Under similar conditions, about 6% of applied nitrogen was lost in sandy loam soil and 10% of applied nitrogen was lost in sandy soil.

Hence, dolomite should not be mixed and stored with fertilizers containing nitrogen, such as the Young Palm Mixture (YPM, 13-12-17), Adult Palm Mixture (APM, 12-6-32), urea, ammonium sulphate etc.

In order to reduce the loss of nitrogen from nitrogenous fertilizers, dolomite is best applied with a time lag before or after the application of YPM (13-12-17), APM (12-6-32), urea etc. However, this would involve two separate applications incurring extra labour and cost.

Considering the available research data on efficiency and economics, dolomite could be broadcast immediately after YPM or APM is broadcast within the recommended manure circle area. Fertilizers, specially YPM (13-12-17) or APM (12-6-32) or urea, should be applied during the rainy season when the soil is moist, after the heavy showers. The soil needs to be turned over to cover the fertilizers and the area should be mulched with weed trash, fronds, husks etc.

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FUNDAMENTALS OF PLANT MINERAL NUTRITION

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Introduction

Soil is the medium in which almost all crops are grown. The first thing that a germinating seed does is to send down a root to explore the soil. The main function of the root at this stage is to provide the plant with water. When a germinated seed is planted in a vessel containing a known weight of forest soil, and regularly watered for several months, it grows well. If the dry weight, of the plant and the soil are recorded, it can be seen that while the plant has gained several kilogrammes, the weight loss of the soil is only a few grammes. The plant is made mainly out of C, O & H. The amount of minerals found in a plant body is very small. The weight gain in the plant is due to the deposition of carbohydrates and other C, H & O containing compounds. Plant leaves have the ability to absorb the CO_2 in the air and to react it with root absorbed water to produce sugar. The energy needed for breaking and making of bonds is derived from sunlight. Hence the process is known as photosynthesis.

A detailed chemical analysis of plant tissues indicate that they contain large number of mineral elements in small quantities. While the concentrations of some mineral elements can be expressed as percentages of plant dry weight, the concentrations of others can only be expressed as parts per million on $\mu\text{g/g}$, dry weight. These two types are known as macro or major nutrients (eg. N, P, K, Mg, Ca, S) and micro-nutrients (eg. Mn, Zn, Fe, Mo, B) respectively. Several mineral ions (cations like NH_4^+ , K^+ , Mg^{2+} , Ca^{2+} and anions like SO_4^{2-} , NO_3^- , CO_3^{2-}) are dissolved in the water found in the soil and hence it is referred to as soil solution.

As a plant grows its dependency on soil increases, water as well as mineral nutrients needed for growth, development and differentiation are obtained from

the soil. These minerals are essential for plant growth.

Chemistry of Mineral Nutrition

In plants there are two major translocating streams or pipe lines. They are the xylem and the phloem. The nutrients and water in the soil solution are absorbed by the roots and are translocated to actively transpiring leaves via the xylem. Some of the nutrients together with photosynthetically fixed carbon in leaves are re-distributed to other plant parts such as young shoots, fruits, root and bark through the phloem. While the movement in the xylem is uni-directional (ie. from roots to leaves) the movements in phloem are multi-directional. Thus chemical analysis of plant tissues and the saps in these pipe lines would be useful in studying the events and processes related to the mineral nutrition of plants. While it is relatively easy to collect the xylem sap, the collection of the phloem sap is rather difficult or at times impossible. The main reason for this is the quick sealing ability of the phloem vessels which is an efficient, effective defence mechanism evolved by mother nature. Imagine what would happen if the phloem vessels do not possess this property; every time when a plant is attacked by an insect or an animal or a branch of tree is broken due to wind it would bleed to death.

The xylem sap is a very dilute solution of mineral ions, some amino compounds with no dissolved sugars where as the phloem sap is a sugar rich solution. This fact is quite easily seen if the refractive indices and osmotic pressures of the two saps are compared. Xylem sap can be sampled by either cutting the top of a plant in the night and collecting the fluid that oozes out of the cut end of the stem that is intact with the soil (root bleed sap) or applying a mild vacuum to a piece of freshly cut stem (tracheal

sap). The well known example for phloem sap is the fluid collected during the tapping of the inflorescence of the coconut or kithul (*caryota*) tree.

The mobilities of most mineral ions in the xylem are more or less equal. But the mobility of ions in the phloem is rather complicated. While some are very mobile (eg. K, Mg, N), others are immobile in the phloem (eg. Ca, S).

Water and nutrient needed for crop production are obtained from the soil. When the supply of any one of them is poor the productivity is decreased and plant begins to show hunger signs or deficiency symptoms. While the deficiency of phloem mobile elements are seen in old leaves the hunger signs of phloem immobile elements are observed in young leaves. When the supply of an element is in excess, it can become toxic to the plant. The deficiency or toxicity of a single element can easily be identified by a trained eye. When there are deficiencies in the supply of more than one element their identification becomes difficult and such situations are rectified by resorting to chemical analysis of the plant tissues.

Soils and Fertilizers

The productivity of a land depends on the condition of its soil, particularly on the availability of nutrients and water and its ability to provide correct environmental conditions needed. In this regard emphasis is laid on physical, chemical and biological properties of the soil. It is often found that when forests are cleared for agricultural ventures the productivity and fertility of the lands deteriorate with time. In most of the tropical countries the availability of productive agricultural land is gradually declining. The one and only way out is the rapid rehabilitation of the degraded lands. The approach will have to be scientific. The first step should be the identification of causes for the degradation and then to evolve cultural practices that would improve the conditions. This could best be done by comparing a degraded

land with a natural system. There are several primary differences between a natural ecosystem and an agricultural land. The natural system is self sustaining. All the nutrients in it, except N, have come from the soil. Whereas almost all the N in the natural ecosystem has originated from biological N_2 -fixation, and major part of it is from symbiotic fixation. The symbiotic association between plant roots and N_2 fixing bacteria has been known for a long time. There is a very efficient nutrient cycling system operating in a natural system. The main features of this are that a very high proportion of the nutrients in the system are held in organic form and inputs and outputs of the system are low.

During the clearing of the forest most of the organic matter in the system is destroyed, and physical erosion of the soil mass and leaching of nutrients take place at high proportions. The net result is an infertile degraded soil. Several physical, chemical and biological properties are measured to assess the condition of a soil. A discussion of this is beyond the scope of this article. Restoration of the fertility to some extent can be achieved by addition of chemical fertilizers. Urea (46% N), Sulphate of Ammonia (21% N), rock phosphate (12% P), single super phosphate (7.9-8.7% P) triple super phosphate (18.3-21.8%P), muriate of potash (49.8% K) Kieserite (14.5% Mg) and dolomite (12% Mg) are the commonly used ingredients for fertilizer mixtures. However their use efficiency is around 30%. In other words for every three bags of fertilizer added to the soil only one bag is taken up by the crops and the rest is lost due to volatilization, leaching and fixation. The fertilizer use efficiency can be increased by incorporating crop residues into the soil and by growing more than one crop at a time.

The composition of the fertilizer mixture is determined by the crop requirement and the availability in the soil. Hence field experiments are regularly being conducted in all parts of the world to assess the quantity of each ingredient needed.

Alternanthera sessilis (Linn.) - AMARANTHACEAE

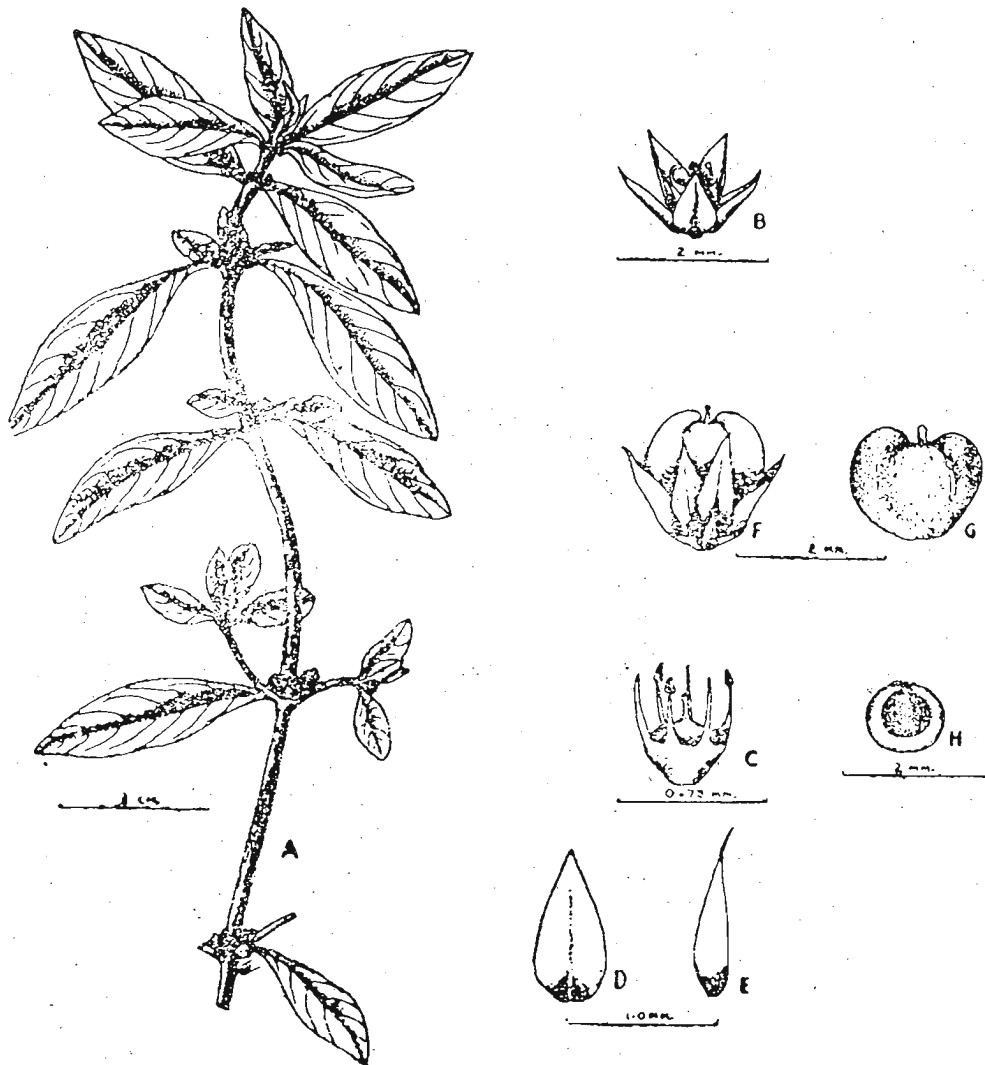


FIGURE. *Alternanthera sessilis*. A, branch with leaves and flower heads. B, lateral view of a flower. C, flower with perianth removed showing 3 fertile stamens alternating with antherless staminodes, all united to form a cup round the ovary. D, bract. E, bractlet. F, fruit with persistent perianth. G, fruit with persistent style. H, seed.

Sinh. Mucunuwenna ; *Tam.* Ponnankani, Pounanganni ; *Hindi* Majriya ;
Sans. Shalingcha, Meenakshi, Paththera.

A prostrate herb with numerous, subquadrangular, glabrous stems, 15—60 cm long, often rooting at nodes ; internodes 1.5—7 cm long, younger ones with 2 opposite lines of hairs, often purplish red ; leaves simple, opposite, 1.5—5 cm long, 0.7—1.7 cm broad, varying in shape from linear to oblong-oval, nearly sessile, tapering to base, subacute, very faintly serrate, glabrous, veins 6—9 lateral pairs, prominent below ; flowers white, regular, bisexual in densely crowded, small, axillary heads, sometimes slightly spicate, bracts membranous, 0.7 mm long, 0.4 mm broad, ovate, acute, bractlets as long but narrower and cuspidate ; perianth segments 5, 1.6—1.8 mm long, 0.6—0.8 mm broad, oblong-ovate, scarious, acute ; stamens 3 ; filaments 0.5 mm long, with 3, alternating, antherless staminodes, all united at base to form a short cup round the ovary ; anthers 1-celled ; ovary superior, 0.5 mm long and as broad, glabrous, 1-locular with a single pendulous ovule from a basal funicle, style 0.2 mm long ; fruit flat, kidney-shaped, 2 mm long and as broad enclosed in the persistent perianth segments ; style persistent in the depression, 1-seeded ; seed round, 1.2 mm diameter, glabrous and shining, depressed at the hilum.

Flowers all the year round.

ILLUSTRATIONS. Rheede, Hort. Mal. 10 : pl. 11 ; Wight, Ic. Pl. Ind. Orient. pl. 727. 1840—1843 ; Kirtikar and Basu, Indian Med. Pl. pl. 794, 1933 ; Herb. Peradeniya., drawing.

DISTRIBUTION. Occurs in humid places throughout the warmer parts of India, Ceylon and other tropical countries. In Ceylon, this plant is very common growing in wet places in the low-country especially around tanks and ponds.

India. Wallich 6921 c ; Punjab, etc., T. Thomson ; Upper Gangetic Plain T. Thomson and J. D. Hooker ; Assam. Simons ; Dehra Dun, King ; Maisor and Carnatic, G. Thomson ; Concan, etc., Stocks. Ceylon. Central Prov., Thwaites C. P. 2908 ; Peradeniya, Bot. Gard., Jayaweera 2872, Oct. 1966 ; Southern Prov., Tissa Tank, Dec. 1882 without collector's name. Andaman Islands. South Andamans, Ranguchang, King, May 1891 near sea coast. Indo-China. Hue and vicinity, Squires 39, Jan.-May 1927. Philippine Islands. Luzon ; La Union Prov., Lete 1, 1927. Alabat Island : Ramos and Edano 48331, Sept.-Oct. 1926. French Guiana. Herb. Sagot 480, 1857.

COMPOSITION. The vegetative and reproductive parts of this plant are said to contain traces of hydrocyanic acid.

USES. This plant is a popular pot herb, frequently eaten in Ceylon. It is a cholagogue laxative, and is useful in chronic congestion of the liver, biliousness and dyspepsia associated with sluggish liver. Owing to its diuretic and diluent properties it may be employed with advantage in acute and chronic pyelitis, cystitis, gonorrhoea, and strangury. It is also said to increase the flow of milk in nursing mothers. The expressed juice of the plant is given with cow ghee for the treatment of snake-bite. In West Tropical Africa it is used as a poultice for boils, abortifacient and remedy for indigestion, while in Madagascar it is often used as a galactagogue.

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