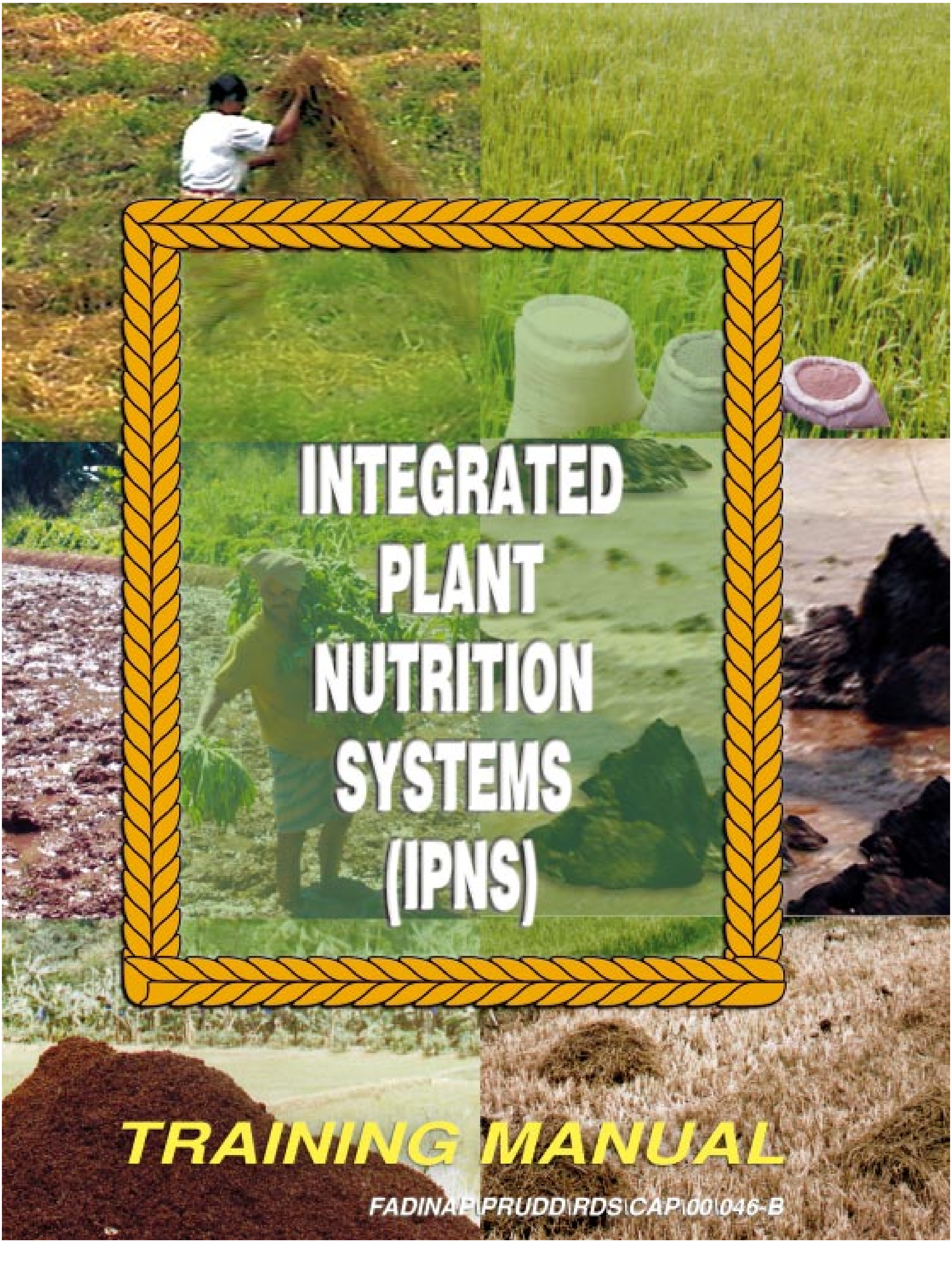

INTEGRATED PLANT NUTRITION SYSTEMS (IPNS)

TRAINING MANUAL

FADINAP\PRUDD\RDS\CAP\00\046-B

Contents

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List of abbreviations

AP & H	Animal Production and Health
DOA	Department of Agriculture
FAO	Food and Agriculture Organization
IL	Low country intermediate zone
IM	Mid country intermediate zone
IPNS	Integrated plant nutrition systems
IU	Up country intermediate zone
LCDZ	Low country dry zone
LCIZ	Low country intermediate zone
NRMC	Natural Resources Management Center
OFC	Other field crops
TDM	Top dressing mixture
WHO	World Health Organization
WL	Low country wet zone
WM	Mid country wet zone
WU	Up country wet zone

CHAPTER I

Soils, Soil Formation and Plant Nutrients

This chapter deals with soil characteristics, weathering of rocks and soil formation, profile characteristics, soils of Sri Lanka, plant nutrients, their role in plant nutrition, different types of chemical fertilizers and organic manures.

This chapter has the following broad objectives

i. To provide knowledge on soils, weathering of rocks, soil formation, profile characteristics of soils and soil-plant nutrition relationship.

ii. To provide information on soils of Sri Lanka and their fertility characteristics.

iii. To provide knowledge on plant nutrients, their characteristics, their role in crop growth, plant deficiency symptoms, different ways of nutrient losses, sources of plant nutrients, chemical and organic fertilizers, and fertilizer use efficiency.

Section 1

SOILS

What is soil?

- The uppermost crust of the Earth's surface which supports plant life.
- It is a product of rock weathering and biological processes.
- It is composed of solid particles and pore spaces filled with air and soil water between the particles.
- The constituents are mineral matter, water, air and organic matter both living and dead (Fig.1). The quantity of these constituents varies with the locality.
- Climate, vegetation and man have influenced the soil variations that are found.
- It gives anchorage to plants and is a store-house for plant nutrients and water.

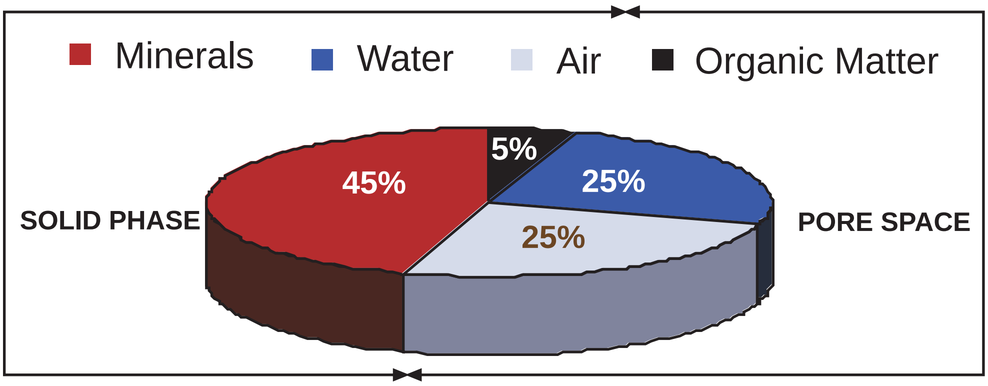


Fig. 1. Major components of a typical soil

Solid phase consists of

- Mineral constituents including weathered rock fragments.
- Organic matter, both dead and living micro and macro organisms.

The mineral constituents are

Sand	Large particles which are coarse, and individual particles are easily visible (0.02 – 2 mm in diameter) most common mineral component is silica (SiO_2)
Silt	Medium-sized particles which are 0.002-0.02 mm in diameter
Clay	Small particles which less than 0.002 mm in diameter is referred to as colloids.

By definition, particles larger than sand are not soil.

Liquid phase

- Soil water which occupies the pore spaces (between mineral particles) carries the plant nutrients to the roots.

Soil air

- It occupies pore spaces similar to soil water. It fills these voids when soil water is absent.
- It carries respiratory products of roots and soil-organisms.
- It has a higher concentration of carbon dioxide than atmospheric air.

Soil texture

- Refers to the relative proportion of sand, silt and clay present in a soil.
- Based on these proportions soils are classified into various textural classes.
- Clayey soils have a larger percent of clay. They are considered more fertile than sandy soils but are difficult to work.
- Sandy soils are easy to work but are less fertile. They have low water retention capacity.
- Loamy soils are in between sandy and clayey soils. They are best for arable cropping.

Soil structure

- Refers to the arrangement of the different particles into soil aggregates.
- Roots move between these aggregates.
- A compact soil will resist root movement.
- The organic matter content helps the soil aggregation process.

Soil type

- Soils are heterogeneous in nature.
- Heterogeneity depends on the nature of parent material and the external factors of climate, vegetation, aspect and time.
- Soils that are similar in physical and chemical characteristics are referred to as of the same soil type.

Soil fertility

- Is the capacity of a soil to supply plant nutrients in adequate amounts to facilitate optimum growth and obtaining the yield potential of a crop.
- Many soil properties determine the availability of plant nutrients to plants.

SOME SOIL PROPERTIES THAT DETERMINE SOIL FERTILITY

Soil colour

- Reddish to brownish colour shows well-drained conditions. Degree of yellowness and mottling shows poor drainage. Gray to dark colour indicates the presence of organic material.

Soil depth

- Refers to the depth to which plant roots can penetrate the soil and is the distance between the lowest and the upper most horizons of the soil.

Bulk density

- A compact soil has a higher value while an organic soil has a lower value.

Water holding capacity

- Sandy soils have a low capacity than clayey soils. This property is important for irrigation.

Field capacity

- Refers to the moisture content of a soil after the loss of gravitational water.
- At this point, water is held in soil micropores, which is available to plant roots, until the water content down to a lower value.
- This lower value is referred to as the permanent wilting point.
- The amount of water available between field capacity and permanent wilting point is referred to as available water.
- This value is important in determining irrigation intervals.

Soil pH

- Is a measure of the soil acidity or alkalinity of a soil.
- Measures the negative logarithm of the hydrogen ion activity of the soil solution.

Soil acidity

Is caused by many factors such as

- Excessive rain which leaches basic cations (Ca, Mg, K)
- Use of nitrogenous fertilizer like urea, ammonium sulphate etc.
- Oxidation of iron pyrite containing minerals.

Correction of soil acidity

- Soil acidity is corrected by liming; soils which have a pH value of less than 5.5 could be limed.

Salinity and alkalinity

- Occurs in arid and semi arid regions, where precipitation is insufficient to meet evapotransporation needs of plants, when salts move up to the surface.
- Salt affected soils occur within irrigated lands.
- Salts are added through irrigation water; through over-irrigation and salts accumulate in poorly drained areas.
- Salt content in soils is measured in terms of electrical conductivity (EC).
- A saline soil has a pH of less than 8.5, but soils are well flocculated. The EC is more than 4 deci Seimens per meter (4dS m^{-1}.)
- Soils which are saline cause problems to crops during dry weather. Loss of crop yield from poor growth is common.
- Alkaline soils have high pH and a high concentration of sodium in them.
- Alkaline soils are deflocculated, drainage is poor and growing plants is difficult due to high pH and higher content of sodium in the soil.
- Draining, flushing after ploughing and addition of organic matter and gypsum could correct these problems.

Cation exchange capacity (CEC)

- The power to retain cations at the surface of soil colloids is referred to as the cation exchange capacity.
- Soil colloids of clay and organic matter have this property due to the presence of negative charges at the surface.
- CEC is defined as the sum of cations held by a kilogram of soil. It is expressed in Cmol/Kg soil.
- Clays like kaolinite have low CEC and the CEC is pH dependent. Organic matter has a large CEC but it too is pH dependent.
- Montmorillinitic clay has high CEC due to the negative charges developed through loss of cations during formation of these clays.
- Practices like fertilization, liming, irrigation and addition of organic manures can increase the exchangeable cations.

Soil organic matter (SOM)

- Consists of living organisms, dead plant and animal residues.
- Is the most chemically active portion of the soil.
- Is a reservoir for various essential elements.
- Contributes to CEC.
- Promotes good soil structure.
- Buffers soil pH.
- Promotes good air and water relations in plants.

Humus :

Is the portion of the organic material that has been transformed into a relatively stable form by soil microorganisms. (organic colloids).

Functions of organic matter in soil

- Supplies N, P and S to plant growth.
- Increases CEC in a soil.
- Have large surface area and has high CEC.
- Holds up to twenty times their weight of water.
- Holds cations and anions and releases them slowly.
- The ratio of C:N:P:S is 10: 1: 0.5 : 0.1
- Effects the breakdown of pesticides and weedicides.
- Chelates micronutrients such as Zn, Mn and Cu making them more available to plant roots.
- Buffers extreme acidity, salinity and alkalinity.

Fate of organic material added to soils

- Undergoes decomposition (only bio-degradable materials) through soil macro and micro fauna and flora.
- Final degradation is made by soil microorganisms.
- The final product is a humus type material which has a C: N ratio around 9:1- 12:1.
- All complex carbon products are converted into simple compounds.

The nitrogen cycle

This is one of the most important naturally occurring events. It is discussed under

- Nitrogen fixation.
- Conversion of N in soil.
- Plant and microbial uptake of soluble N compounds.
- Agronomic circulation and removal of N.

Nitrogen fixation

- Nitrogen is a very inert gas which constitutes 78% of the atmospheric air; it has low chemical reactivity.
- For use by plants it has to be converted to ammonium (NH_4^+) or nitrate (NO_3^-)
- Only a few microorganisms can utilize N gas which is referred to as N fixation.
- Fixation is effected by microbial action, industrial synthesis and high thermal combustion and lightning.

Conversion of N in soil

Forms of N occuring in soils

- Soluble mineral forms, ammonium, nitrate, nitrous oxide (gas)
- Soluble organic compounds, urea, aminoacids.
- Living organisms, plant roots, fungi, bacteria, soil animals.
- Insoluble forms, organic nitrogen, ammonia bonded to clay.

Transformation between the different forms is mediated by soil microorganisms.

Mineralization

- l Conversion of N in organic residues and soil organic N into soluble forms through mineralization.
- Carbon sources are degraded sources of energy.
- N in excess of microbial need is liberated.
- The following sequence of reactions takes place.

i. **Ammonification:** Complex protein compounds are broken down to ammonium compounds by microorganisms.

ii. **Nitrification:** Ammonium compounds are oxidized to nitrite and to nitrate by two specific types of soil bacteria, *Nitrosomonas and Nitrobactor.*

iii. **Denitrification:** The nitrates are reduced to nitrogen gas under poorly aerated conditions through specific microorganisms.

Other cycles found in nature

- Carbon cycle
- Sulphur cycle
- Phosphorus cycle

Assignment

1. Look for physical characteristics of a soil in your area.
   (Note: e.g. Texture by feel, colour visually, drainage by soil colour)

Section II

SOIL FORMATION

WEATHERING OF ROCKS AND SOIL FORMATION

Introduction

Rock weathering and soil formation takes place at the same time. Rocks disintegrate and decompose under natural conditions to give rise to parent material on which soils develop. The soil which form out of the parent material has no resemblance to the latter.

Weathering refers to the chemical and physical disintegration and decomposition of rocks that take place due to the minerals contained in them being not in equilibrium under the temperature, pressure and moisture conditions of the atmosphere - lithosphere interphase.

Rocks contain a single or a number of different minerals. Minerals are chemical substances that are either simple elements like graphite or contain a number of elements forming complex compounds.

ROCK WEATHERING

Physical Weathering

Disintegration and decomposition of rocks result in the formation of new chemical compounds. Disintegration takes place due to physical changes brought out by external elements of:

- Temperature changes
- Moving water
- Frost
- Moving ice
- Wave action
- Wind
- Plant roots

Temperature changes

The expansion and contraction due to temperature changes of hot and coldness results in cracking of rocks.

Moving water

Can carry large boulders, that crack and break in their path.

Frost

Freezing of water results in increase in volume. Water entering cracks and crevices of rocks expands resulting in cracking of rocks.

Moving ice

Can disintegrate rocks.

Wave action

Carry sand which abraises and cuts the surface of rocks.

Hot wind

Blowing over deserts carries sand, which abraises rocks and breaks them.

Plant roots

Enter crevices in rocks and with growth exert pressure to widen cracks.

Physical weathering does not alter the chemical composition of the rocks.

Geochemical Weathering

Takes place in the C horizon; the weathering reactions that take place are oxidation, reduction, combinations of both in alternate cycles, hydration, solution and hydrolysis.

Oxidation

Occurs in well-aerated rocks. The most important specific reaction is that of ferrous to ferric ion.

$$Fe^{2+} \longrightarrow Fe^{3+} + e^{*}$$

* e = electron transfer

Reduction

Takes place in environments where the material is water saturated, oxygen supply is low and biological demand for oxygen is high; e.g. Ferric ion is converted to ferrous form. If the ferrous ion persists in the system it reacts to form sulphides and related compounds which impart a green and blue green colour to the soil.

Oxidation – Reduction

Fluctuations from oxidizing to reducing conditions in response to variations in weather throughout the year. Under these conditions, ferrous and manganese ions remain stable even in the oxidized state.

Hydration

Refers to the association of water molecules or hydroxyl groups with minerals, often without actual decomposition or modification of the mineral itself. For example, Anhydrite is converted to gypsum.

$$CaSO_4 + 2H_2O \longrightarrow CaSO_4 . 2H_2O$$

Hydrolysis

Is the attack of highly charged hydrogen ion on the crystal structure of minerals. For example, Feldspar is converted to silicic acid and potassium is released. Hydrolysis results in complete disintegration or drastic modification of weatherable primary minerals.

Factors involved in soil formation

- Parent material
- Relief / Topography
- Climate
- Organisms
- Time

Parent material

Is defined as the state of the soil system at time zero of soil formation. In general, younger the soil the greater the influence of, and relationship of, soil properties to the soil parent material.

Relief / Topography

Within specific geographic regions the following soil properties are found to be relief related.

- Depth of soil profile
- Thickness and organic matter content of a horizon
- Relative wetness of profile
- Colour of profile
- Degree of horizon differentiation
- Soil reaction (pH)
- Soluble salt content
- Kind and degree of pan development
- Temperature

Climate

Exhibits its influence on soil formation by control of the chemical and physical reactions taking place in the soil and by its control over organic matter content and through erosion and deposition of soil materials. Rain water dissolves soluble materials, promotes vegetation and contributes to organic material and is involved in transport of materials.

Following changes are brought by rain.

- Soil pH decreases.
- N content increases with increased rainfall.
- Clay content increases with increased rainfall.
- Carbonate content decreases with increased rainfall.

Temperature

With increase in temperature soil colour becomes more reddish, N content and soil organic matter content decreases, and clay content increases.

Organisms

Organic material found in the A horizon are acquired through the passage of material passing through the alimentary tracts of insect larvae, worms and associated soil fauna. Voids are caused by borrowing insects and worms. Channels are made by roots and rhizomes of plants.

Time

Young, immature and mature soils are described to relate their properties to time. Young soils have more weatherable minerals and senile soils have more sesquioxides of heavy minerals.

The Soil Profile

Fig. 2. Landscape and soil profile of Red Yellow Podzolic Soils (Galigamuwa)
Photo : Soil Science Society of Sri Lanka

A complete soil profile is a vertical exposure of a surfacial portion of the earth's crust that includes all the layers that have been pedogenically altered during the period of soil formation and also the deep layers that influenced pedogenesis. A soil profile may be observed in a freshly dug pit, along a road bank, etc. (Fig. 2)

Fig. 3. Soil profile of Reddish Brown Earths in the Anuradhapura district Diagramatic representation

Source: C.R.Panabokke

Soil Horizon

Is a layer of soil approximately parallel to the soil surface, with characteristics produced by soil forming processes. (Fig. 3) In the field morphological characters of colour, texture, consistency, structure, cutans, nodules or concretions, voids, and boundary characters are used in distinguishing horizon differences.

Master horizon designations

i. Organic horizons on mineral soil surfaces

Designation O – Organic horizons formed or forming above the mineral part, dominated by fresh or partially decomposed organic materials.

ii. Mineral Horizons

A : This horizon has organic matter accumulation adjacent to the surface, horizons that have lost clay, iron and aluminium with resultant concentration of quartz or other resistant minerals of sand or silt size.

Sub division of A

Al : Mineral horizons formed at the surface where humified organic matter is associated in the mineral fraction. Dark or dark gray in colour.

A2 : Mineral horizon where clay, iron and aluminium are lost and quartz occur.

A3 : A transitional horizon between A and B, with characters of overlying A1 or A2, but also have some characters of B.

AB : A transitional horizon between A and B having an upper part dominated by properties of A and a lower part by B but the two parts cannot be easily separated.

AC : A transitional horizon between A and C having subordinate properties of both A and C but not dominated by either characters of A or C.

B Horizon: The dominant features are :

i. Accumulation of illuvial clay, iron and aluminium sesquioxides and humus.

ii. Coating of the sequioxides by darker or stronger colours

Sub division B

B1 : A transitional horizon between B and A1 or between B and A2 in which the horizon is dominated by properties of overlying A1 or A2.

B2 : A transitional horizon without clearly expressed subordinate characteristics.

C Horizon : Is a mineral horizon excluding bed rock, that is either like or unlike material on which the soil formed.

R Horizon : It is presumed to be like the parent rock from which the adjacent overlying layer or horizon has formed.

Table 1: Comparison of soil horizon nomenclatures of 1962 and 1981

	Old (1962)	New (1981)
A Horizon	O	O
	-	Ap (Cultivated soils)
	A1	A / Ap
	A2	E
	A3	AB / EB
	AC	AC
B Horizon	B	B
	B1	Btl /Bw
	B2	BC / CB Bt3
C Horizon	C	C
R Horizon	R	R

Assignment

1. Observe a soil profile in your area and try to demarcate various horizons (Note : Freshly cut pit or road bank could be used)

Section III

SOILS OF SRI LANKA

SOILS OF SRI LANKA AND THEIR FERTILITY CHARACTERISTICS

i. Sri Lanka has a wide diversity of soil types. This diversity is chiefly due to climate and topographic factors.

ii. The mean annual rainfall varies from 1250 – 5000 mm in the south western quarter of the island to less than 1250 mm in the northwest and southeastern parts of the country.

iii. Based on the rainfall patterns, three geographic zones, dry, wet and intermediate zones have been identified.

iv. The topographical boundaries are low country 0 – 300m, mid country, 300-900m and the upcountry > 900m.

v. The parent material of most soils has been dislocated and is considered to be colluvial and colluvial residuum.

Soil classification

Classification of soils based on morphological and other characters began with the work of Dokuchaev *etal* in the 19th century. The most accepted types of classification are those developed by of the United States Department of Agriculture (USDA) (Soil Taxonomy) and the FAO-UNESCO. The former is used due to its simplicity.

In the USDA system there are 11 orders and a large number of sub-orders, great groups, sub-groups, series and families. In this discussion classification is confined to orders, suborders and great groups, only.

Soils of the Dry and Semi- Dry Intermediate Zones.

Older name of great group	New name (USDA) of great group
Reddish Brown Earths	Rhodustalfs
Low Humic Gley soils	Tropaqualfs
Non-calcic Brown soils	Haplustalfs
Red Yellow Latosols	Haplustox
Alluvial soils	Tropaquents and Tropofluvents
Solodized Solenetz	Natraqualfs
Sandy Regosols	Quartzipsamments
Grumusols	Pellusterts
Immature Brown Loams	Ustropepts

Fertility characteristics of dry zone soils

(See Soil Map of Sri Lanka Fig. 4)

a. Reddish Brown Earths (RBE)

These soils are confined to the dry zone and occur in a catenary sequence, occupy the crest, the well-drained upper and mid slopes of the undulating landscapes. The colour of the surface is reddish brown when dry, turns to dark reddish brown when moist. A subsoil horizon with a high propotion of quartz gravel is present, the depth to the gravel layer is variable. Soils are extremely hard when dry, friable to firm when moist. Soil reaction is slightly acid to neutral. Base saturation is 60-80% . Soils are low in P but are reasonably high in K. They have a low water holding capacity with a rapid release of soil moisture at low tensions. The organic carbon content of the soils is low, 1-2% .

b. Non-Calcic Brown soils (NCB)

Occur in most parts of North Kurunegala, Anuradhapura, East Polonnaruwa and East Moneragala and Batticaloa Districts. Colour of the surface soil is dark brown to dark greyish to red yellowish brown. These soils are shallow. The surface layers are sandy loams and the water holding capacity is low with rapid infiltration. During rain upwelling of water is frequent. Soil reaction is medium acid. These soils are poor in organic carbon and P content. Base saturation is 50-70% with high % of Ca^{2+} in the bases. They are easily workable than the Reddish Brown Earths.

c. Low Humic Gley soils (LHG)

They are developed from colluvial deposits on the foot slopes of undulating landscapes. They are characterized by wetness or gleying throughout the profile. Soils are extremely hard when dry and sticky when wet, drainage is poor and base saturation of subsoil is 90-100%, soil reaction is moderately alkaline . They have a high CEC and are more suitable for rice but other crops can be grown with proper drainage.

d. Red-Yellow Latosols (RYL)

Occur in the North Western parts of the Puttalam and Jaffna peninsula and in few locations in the northern and south eastern parts of the country. These soils are deep with no clear horizon boundaries. The physical properties of these soils are good. Base saturation is 20-60% and soil reaction is medium acid. They have rapid infiltration and low water holding capacities. They are very low in plant nutrients as very little weatherable materials are found.

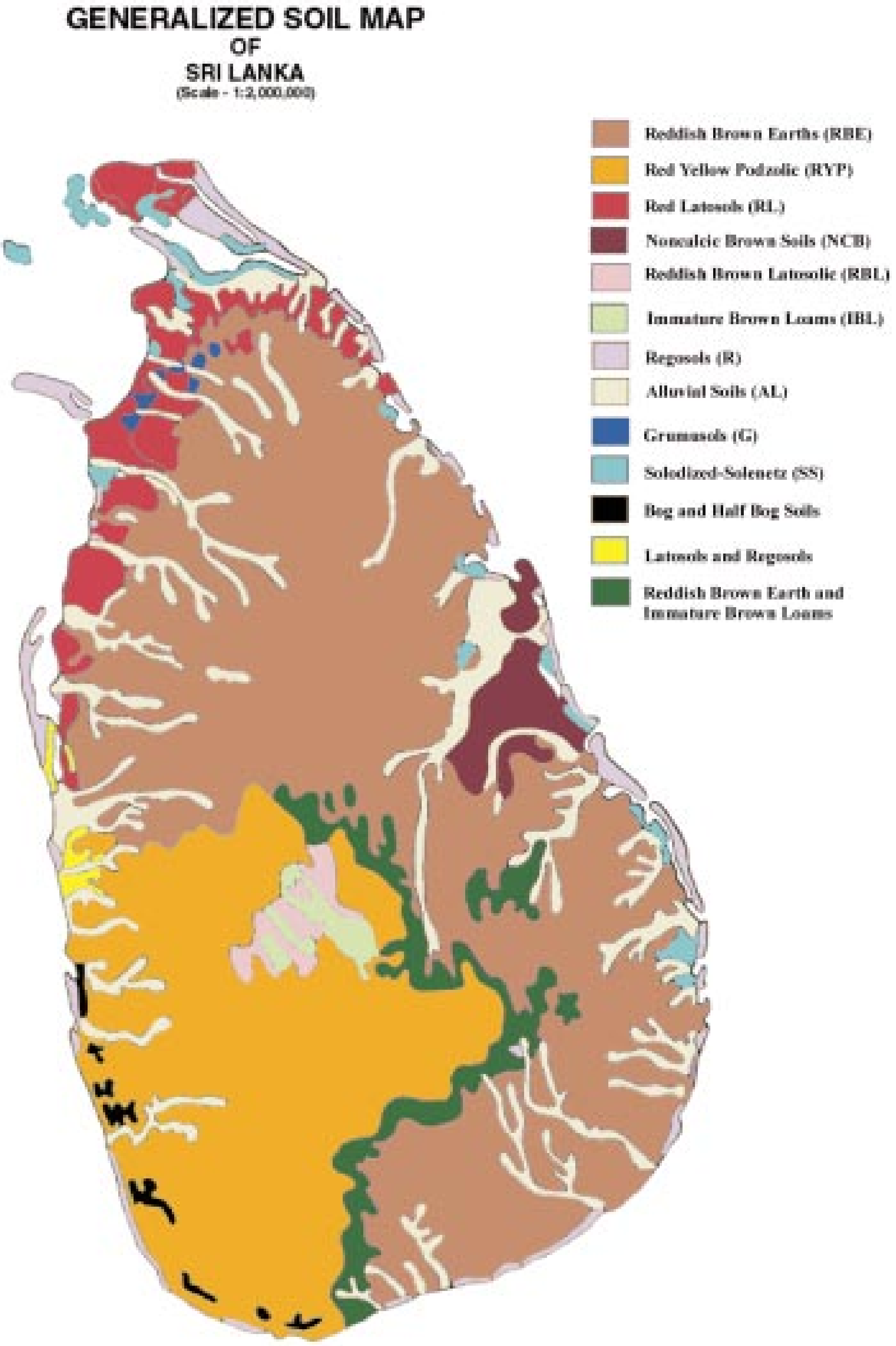


Fig. 4: Soil Map of Sri Lanka

Source: NRMC, Department of Agriculture

e. **Alluvial soils (AL)**

Are found on flat flood plains. The poorly drained alluvium shows a greyish colour; better-drained soils are brownish to yellowish brown. Soil reaction is slightly acidic to slightly alkaline. Base saturation is 60-90%. They have more organic carbon, P and K than RBE soils. Poorly drained soils are suitable for rice but in well-drained soils many arable crops can be grown.

f. **Solodized -Solenetz (SS)**

Their occurrence is related to the presence of sodium salts in the parent material. These soils have a columnar structured B horizon. They occur on estuaries and in inland valleys of the Mahaweli system B in the Kandakadu – Tirikonamadu area. These soils are poorly drained and are generally not suitable for profitable cropping, except with amendments.

g. **Regosols (R)**

They are sandy and are found along or near the coast line. Regosols found in areas of Kalpitiya, Nilavelly and South of Batticaloa district, have weakly humiferous horizons overlying yellowish or brown sand. Texture is fine sand to coarse sand. Infiltration is rapid ; underneath the sandy layer a film of fresh water often floats over saline water due to difference in densities. This enables growth of deep-rooted plants and irrigation of shallow-rooted crops. Soils are very low in soil organic matter content and plant nutrients. Generally, crops can be grown with high management.

h. **Grumusols (G)**

These soils are formed from transported material mainly of alluvial nature. They are found in pockets of Murunkan, Hettipola (Matale District) and Ambewila (Ratnapura District). Soils are black to very dark gray brown with a higher percentage of clay. The clay is of the expanding type and cracks during dry seasons. A low amount, of gilgai is formed due to shrink and shrivel characters. These soils have a high CEC and are very productive. Drainage is poor and soil reaction is neutral.

i. **Immature Brown Loams (IBL)**

Found along the western borders of the Ampara and north eastern borders of the Badulla District. Soils are relatively infertile, shallow and need good management for crop production. The soil reaction is slightly acid to neutral. They are relatively young soils.

Soils of the Wet Zone and Semi-Wet Intermediate Zone of Sri Lanka

Older name	New name (USDA)
Red-Yellow Podzolic soils	Rhodudults/ Tropudults
The Modal group	
Sub group with strongly mottled subsoil	Tropudults
Sub group with soft or hard laterite	Plinthudults
Sub group with prominent A1 horizon	Tropohumults
Sub group with semi-prominent A1 horizon	Tropudults
Sub group with dark B horizon	Humudults
Reddish Brown Latosolic soils	Rhodudults/Tropudults
Immature Brown Loams	Eutropepts/Dystropepts
Bog soils/ Half Bog Soils	Tropohemists/Troposaprists
Latosols and Regosols. (on old red and yellow sands)	Quartzipsamments

Fertility characteristis of the wet zone and semi-wet intermediate zone soils

a. Red – Yellow Podzolic soils (RYP)

Are found both in the lowlands and central highlands. They occur in diverse land forms that are found mostly in the hilly parts of the country. Certain geomorphic variations have given rise to the modal groups.

a (i). Sub group with a strongly mottled subsoil

This group of soils is found in the semi-wet intermediate lowlands of the Kurunegala district. The colour of the surface soil is dark brown to reddish brown. Surface soils have loamy to sandy loam texture and subsoils are sandy clay loam to sandy clay. These soils are acidic in reaction; have low base saturation and low CEC. During dry weather the subsoil becomes very hard and limits root movement. Requires addition of organic materials for good management.

a (ii). Subgroup with soft or hard laterite

These soils have hard laterite formed at depths of 125 – 250 cm. The 'Cabook' which is soft laterite becomes irreversibly hard upon drying. They are found in the uplands of the Colombo, Gampaha and Kalutara district on the foot slopes. The base saturation is 15-30% and CEC is very low. Requires good management to grow crops.

a (iii). Sub-group with prominent A - horizon

These soils are found under wet grasslands (pasture) of the Nuwara Eliya district at elevations around 2000 m. These soils have low base saturation (5-10%). Soils have high organic matter (5-15%). Soils are strongly acidic and need liming before growing crops.

b. Reddish Brown Latosolic soils (RBL)

These soils are found in the Kandy, Galagedara, Mawanella and Middeniya areas. They have excellent physical properties. They are deep soils resistant to erosion. Base saturation is 25-35%. Soils are medium acid and have high water holding capacity. These are some of the most fertile soils found in the area.

c. Immature Brown Loams (IBL)

These are found in the Kandy, Matale and Mawanella regions. They have low base saturation and low CEC. The soil reaction is acidic.

d. Bog and half-bog soils (BHB)

They are found in the low-lying areas of the Colombo, Kalutara, Galle, Matara and Ratnapura districts. They are ill-drained. Bog soils have over 30% organic matter while half bog-soils have lesser amounts of organic matter. These soils are strongly acidic. The CEC is high but base saturation is low. Because of their poor structure and low bulk density, the management of these soils is difficult.

e. Latosols and Regosols on old red and yellow sands

These are found in the Madampe – Negombo areas. They have low clay content, low base saturaion and high amount of free sand. They have poor water holding capacity and needs good management for growing crops. The soil reaction is acidic and organic matter content is very low.

Assignments

1. Find out the major soil groups in your district by referring to the soil map. By observing the soil profile and soil, make comparisons given in literature and your own observations.
2. List major crops grown in your area, both annuals and perennials.

Section IV

PLANT NUTRIENTS

Introduction

The success of farming depends largely on the growth of crops. Crop growth is influenced by a number of factors of which plant nutrients are an important group. There are 16 nutrient elements considered essential for plant growth.

An essential plant nutrient element has the following characteristics

i. The completion of the life cycle of the plant cannot be achieved in the absence of such an element.

ii. Plays a specific role in the plant.

iii. Causes set back to growth of the plant showing visual symptoms when the plant is deficient in it.

Essential elements are inorganic in nature and they are grouped into

i. Primary nutrients – Required in larger quantities

ii. Secondary nutrients – Needed in lesser amounts than primary nutrients

iii. Micronutrients – Required in small quantities

These sixteen elements are listed in Table 2. Carbon, hydrogen and oxygen are obtained from air & water. The other thirteen elements are referred to as fertilizer elements and have to be obtained from the soil. Their addition in quantities necessary for plant growth will increase the growth rate, dry matter content and yield of the crop.

- Plant nutrients are usually absorbed through roots. Roots have the ability to absorb nutrients selectively.
- Root absorption takes place both as active and passive absorption.

  Active absorption takes place as an exchange phenomenon and requires energy. Most plant nutrients are absorbed in this manner.

  Passive absorption is part of the transpiration cycle (mass flow). Water and some dissolved solutes are absorbed by this process.
- Gas exchange takes place through the stomata found in leaves. Carbon dioxide required for photosynthesis and oxygen required for plant respiration are exchanged through the leaves.

The supply of an adequate quantity of a particular nutrient for crop growth depends on both the behaviour of that nutrient in the soil and the ability of the crop root system to utilize it.

When these elements are not available to the plant in quantities optimum for growth, the quantity and quality of yield is affected.

Table 2. NUTRIENTS ESSENTIAL FOR PLANT GROWTH AND FORMS IN WHICH NUTRIENTS ARE TAKEN UP BY PLANTS

Nutrient	Chemical symbol	Form taken up by plant
Primary Nutrients		
1. Carbon	C	CO_2, HCO_3^-
2. Hydrogen	H	H_2O
3. Oxygen	O	H_2O, O_2
4. Nitrogen	N	NH_4^+, NO_3^-
5. Phosphorus	P	$H_2PO_4^-$, HPO_4^{-2}
6. Potassium	K	K^+
Secondary Nutrients		
7. Calcium	Ca	Ca^{2+}
8. Magnesium	Mg	Mg^{2+}
9. Sulphur	S	SO_4^{2-}
Micro Nutrients		
10. Iron	Fe	Fe^{2+}, Fe^{3+}, chelate
11. Zinc	Zn	Zn^{2+}, $Zn(OH)_2^0$, chelate
12. Manganese	Mn	Mn^{2+}, chelate
13. Copper	Cu	Cu^{2+},chelate
14. Boron	B	$B(OH)_3^0$
15. Molybdenum	Mo	MoO_4^-
16. Chlorine	Cl	Cl^-

Deficiency of an element

When an essential element is at a low concentration in the plant tissues it will result in the decrease in normal growth of the plant, affect the crop yield and produce more or less distinct deficiency symptoms.

- Typical deficiency symptoms are not often clearly defined. Masking effects due to other nutrients, secondary causes like disease, herbicide toxicity or insect infestation can confuse field diagnosis.
- Waterlogged conditions or dry soils and mechanical damage can often create symptoms that mimic deficiencies.
- Deficiency symptoms always indicate severe starvation.

Insufficient levels

When the level of an essential plant nutrient is below the required amount for optimum yields or when there is an imbalance with other nutrients it is considered insufficient.

The symptoms of this condition are seldom clearly visible, resulting in poor yield.

Toxicity

Certain essential plant nutrients, if taken up in excess will often cause nutrient imbalances and will result in poor plant growth, delayed maturity, stunted and spindly growth and also show visible symptoms of chlorosis or necrosis.

Hidden hunger

There are no visual symptoms of deficiency but the plant is not producing at its capacity. When the plant reaches the level where symptoms appear the yield may already have been greatly reduced.

Identification of nutrient hunger signs is basic to profitable crop production. Deficiency symptoms can be categorized into five types.

1. Chlorosis, which is yellowing, either uniform or interveinal of plant leaf tissue due to reduction in the chlorophyll formation.
2. Necrosis, or death of plant tissue.
3. Lack of new growth or terminal growth resulting in rosetting.
4. An accumulation of anthocyanin and / or appearance of a reddish colour.
5. Stunting or reduced growth with either normal or dark green colour or yellowing.

The following simple key (Table 3) gives a place to start diagnosing nutrient deficiencies.

Table 3. KEYS TO NUTRIENT DEFICIENCY SYMPTOMS IN CROPS

NUTRIENT	COLOUR CHANGE IN LOWER LEAVES
N	Plant light green, older leaves yellow
P	Plants dark green with purple cast, leaves and plants small
K	Yellowing and scorching along the margin of older leaves
Mg	Older leaves have yellow discolouration between veins-finally reddish purple from edge inward
Zn	Pronounced interveinal chlorosis and bronzing of leaves
NUTRIENT	**COLOUR CHANGE IN UPPER LEAVES (Terminal bud dies)**
Ca	Delay in emergence of primary leaves, terminal buds deteriorate
B	Leaves near growing point turn yellow, growth buds appear as white or light brown, with dead tissue.
NUTRIENT	**COLOUR CHANGE IN UPPER LEAVES (Terminal bud remains alive)**
S	Leaves including veins turn pale green to yellow, first appearance in young leaves.
Fe	Leaves yellow to almost white, interveinal chlorosis at leaf tip
Mn	Leaves yellowish-gray or reddish, gray with green veins
Cu	Young leaves uniformly pale yellow. May wilt or wither without chlorosis
Mo	Wilting of upper leaves, then chlorosis
Cl	Young leaves wilt and die along margin

Assignments

1. Observe any deficiency symptoms shown in crops grown in your area. Symptoms given above could be a guideline for your study.
2. Look out for iron toxicity in paddy especially in wet zone areas.

Fig. 5. Nitrogen deficiency in rice

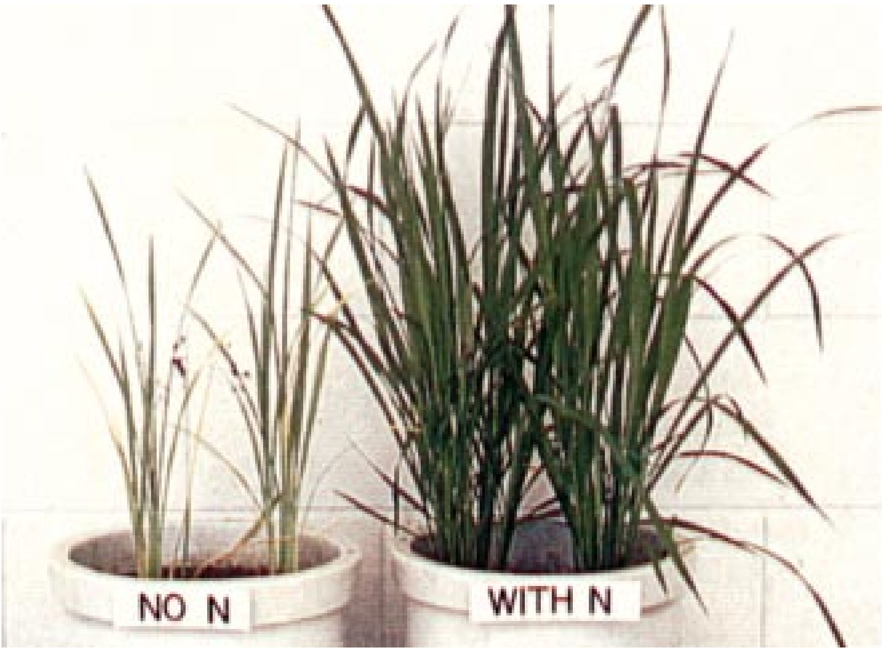


Fig. 6. Rice plants with and without nitrogen

Note: See Appendix 1 &1a for nutrient deficiencies and toxicities of other elements.

Source: IRRI

FATE OF NUTRIENT ELEMENTS IN SOIL

- Nutrients are lost through

  Crop removal

  Erosion

  Leaching

  Volatilization

  Denitrification

  Fixation

Crop removal

- Plant species have specific requirements of plant nutrients.
- Nutrient removal depends on

  Growth condition

  Crop sanitation

  Cultivation

  Yield obtained
- Grain crops require more nitrogen than other nutrients. Pulses require more phosphorous while crops such as tomato, banana and pineapple require more potassium compared to other nutrients.

Erosion

- Entire top soil is lost through erosion by water; this results in loss of soil phosphorus.

Leaching

- Water percolating through a soil profile carry dissolved nutrient elements. Nutrients are easily lost in humid regions and sandy soils.
- Bare soil loses more nutrients than cultivated soils.

Volatilization

- Nitrogen is easily lost through volatilization as ammonia, particularly in paddy soils and upland soils with poorly drained areas. This is referred to as ammonia volatilization. This loss is enhanced by high temperature and wind.

Denitrification

- Nitrate form of N is lost through denitrification where nitrogen gas or nitrous oxide is released. This loss occurs mainly in paddy soils and in upland soils which are saturated with water periodically or part of the time.

Fixation

- Takes place by conversion of a nutrient to an unavailable form.
- Phosphorus is converted to unavailable forms both in acidic and alkaline soils.
- Potassium and ammonium N can be fixed by certain clay minerals.

CHEMICAL FERTILIZERS

- Fertilizers are substances intended for improving the nutrition of plants.
- Promote growth by increasing plant mass and yield.
- Increase the harvested mass such as leaves, fruits and grain.
- Improve quality, market quality, value and nutritional quality.

Note: See Appendix 2 for Fertilizer Standards

NITROGEN NUTRITION AND FERTILIZERS

Function in plants

- Makes up 1-4% of the dry weight of plants.
- Taken up from the soil in the form of nitrate (NO_3^-) and ammonium (NH_4^+).
- Combines with carbohydrate metabolism to form aminoacids and proteins.
- Essential constituent of protein, chlorophyll etc.
- Assimilation in plant depends on type of plant, stage of maturity and supply in the soil.

Sources of N to plants

- Free living microorganisms fix 16-50 kg N/ha/year
- Organic matter in soil by decomposition produce 1-2% of N per year and contribute to 20-45 kg N/ha.
- About 6 kg N/ha/year are brought by rainwater.

Nitrogen fertilizers

Urea

- Ammonia is made by compressing hydrogen and air at high temperature using a catalyst.
- Is manufactured by combining ammonia and carbon dioxide gas under high pressure.
- Is a white crystalline organic compound containing 40-48% N.
- The pelletted form containing 46% N is used as a fertilizer.
- Is soluble in water.
- Used both as a soil and foliar applicant.
- Contains an impurity of biuret, which is formed during the prilling process.
- Biuret in excess quantities is harmful to plants.
- Use of urea having less than 1% biuret is allowed by Sri Lanka standard.
- Urea is hygroscopic. When mixed with triple super phosphate, it tends to lose its granular form due to hydration.
- Urea on addition to soil is converted to ammonium carbonate and to nitrate by enzymatic reaction and microbial action.
- Addition of urea to uplands results in acidification of soils.

Ammonium sulphate

- Contains 21% N and 24% S
- Is light grey or white in colour
- Is soluble in water
- In upland soils it is converted to nitrate

PHOSPHORUS NUTRITION AND FERTILIZERS

Functions in plants

- Makes up 0.1-0.4% of the dry matter in plants.
- Involves in carbohydrate breakdown for energy release, cell division and transfer of inherited characters.
- Stimulates early root growth and development.
- Hastens maturity of plant

- Improves fruit and seed production
- Involves in energy transformation.

Plant uptake is governed by

- Type of plant.
- Stage of plant maturity.
- Competition between plant roots and soil chemicals for phosphorus in soil and fertilizer.
- Absorbed in the $H_2PO_4^-$ and HPO_4^{2-} forms.

Phosphorus fertilizers

- P in fertilizers is expressed as $P_2 0_5$.
- The calculation is P_2O_5 content = P content x 2.29 or P_2O_5 content x 0.44 = P content.

Rock phosphate (RP)

Both imported rock phosphate containing high citric acid soluble P (28% total P_2O_5) and local Eppawala rock phosphate of low citric acid soluble P (30% total P_2O_5) are marketed in Sri Lanka. Rock Phosphate is specially recommended for perennial crops grown in the acid soils of the wet zone. This material gets slowly solubilized in soils with lower pH values. Eppawala rock phosphate (ERP) is not recommended for annual crops but is recommended for tree crops grown in acidic soils.

Triple superphosphate (TSP)

Contains 45-50% P_2O_5. According to Sri Lanka standards it should contain 46% P_2O_5, 12 – 16% Ca and 1-2 % S. Most of the P is in water soluble forms; it is recommended for all food crops.

Diammonium phosphate (DAP)

- Contains both N (18%) and P (46% P_2O_5) and is water soluble.

POTASSIUM NUTRITION AND FERTILIZERS

Function in plants

- Regulates cell water balance.
- Stimulates enzyme activity.
- Used in storage and release of energy.
- Influences processes of cell division, formation of carbohydrate, translocation of sugars and synthesis of proteins.

Forms of K in soils

Based on the degree of availability.

- Difficultly available 90-98%.
- Slowly available 2-10%.
- Readily available 1%, easily absorbed by plants.
- Equilibrium exists between the three.

Potassium requirement of plants

- Seeds contain 0.1 – 1.0%.
- Makes up 1-4% of the dry matter of plants.
- Absorbed as K^+.

Potassium fertilizers

- K is expressed as K_2O in the fertilizer trade.
- K x 1.23 =K_2O and K_2O x 0.83 = K.

Muriate of potash (Potassium chloride)

- Contains 48-62.5% K_2O.
- Sri Lanka standard stipulates 60% K_2O.
- Is pinkish red or white in colour.
- Water soluble.
- Not suitable for crops like tobacco as presence of chloride leads to poor burning quality.

Sulphate of potash (Potassium sulphate)

- Contains 50% K_2O, 16% S and not more than 2% Cl.
- Water soluble.

Magnesium Nutrition and Fertilizers

Function in plants

- Metallic element of chlorophyll. Plays an important role in photosynthesis.

Deficiency symptoms

- Frequent on acid coarse-textured soils, under high annual rainfall.
- Occurs in soils with high Ca or K.

Magnesium fertilizers

Dolomite limestone (12%Mg); Insoluble in water.

Magnesium sulphate

- Kieserite $MgSO_4.7H_2O$ (18%Mg); Partly soluble in water.
- Epsom salt $MgSO_4.7H_2O$ (10%Mg); water soluble.

Synthetic chelate – Mg EDTA

- Rates of Mg recommendation vary with crop, degree of deficiency and source.

Calcium Nutrition and Fertilizers

Function in plants

- Cell walls are built up of calcium containing substances.

Deficiency symptoms

- Yellowing of young leaves.
- Failure of new leaves to emerge.
- Empty groundnut shells.
- Blossom end rot in tomato and other fruits of chilli, brinjal etc.
- Deficiency occurs in acid sandy soils.

Calcium fertilizers

- Calcium is found in limestone, dolomite, TSP and gypsum.
- Gypsum contain 23% Ca. and is a source of sulphur too.

Sulphur Nutrition and Fertilizers

Function in plants

- Sulphur is an essential element of proteins, found in sulphur containing amino acids such as cysteine and methionine.
- Involves in the metabolic activities of vitamin B.
- Facilitates the stabilization of protein structure.
- Total S content in plant tissues is 0.2 to 0.5%

Deficiency symptoms

- Youngest leaves turn uniformly yellowish green or chlorotic due to inhibition of protein synthesis.
- Restricted shoot growth, uneven flower production.
- Short stunted plant, thin and woody.

Sulphur containing fertilizers

- Ammonium sulphate - 24% S
- Gypsum (ordinary) - 16% S
- Single (ordinary) superphosphate (SSP or OSP) - 12%S

Micronutrients, their role in plant nutrition and micronutrient fertilizers

Availability to plants

- Availability depends on soil pH. Boron, copper, iron, manganese and zinc availability decreases with increase in pH from 5-7.
- Availability of molybdenum increases with increase of pH.
- Mineral soils with substantial organic matter can have adequate micronutrients.
- High organic matter containing soils require addition of copper and manganese.
- Plant analysis should be done to confirm micronutrient deficiencies.

Specific elements and their nutrition

Boron (B)

- Boron deficiency occurs in coarse-textured soils in the wet zone.
- Boron deficiency occurs with decrease in soil moisture.
- Boron is involved in cell division, fruit formation, carbohydrate and water metabolism, protein synthesis, and seed development in plants.
- Translocation within plants do not occur. A constant supply is necessary throughout the growing season.
- Application rates vary from 0.1 to 3 kg/ha.
- Range between boron deficiency and toxicity is very narrow. Over application can result in crop failure.

Boron fertilizer

- Borax 11% B.
- Sodium tetraborate 14% B.

Copper (Cu)

- Sandy soils contain low amounts of copper. Copper content increases with clay content of soil.
- Available copper content increases with organic matter in mineral soils.
- Deficiency occurs in high organic soils, acid sandy soils and in calcareous soils.
- Copper has a role in enzyme systems.
- Deficiency symptoms are die-back of twigs and yellow leaves in citrus, die back of leaves in vegetables and tip-burn in cereals.
- Copper has a residual crop response. Over application results in toxicity.

Copper fertilizers

- Copper sulphate
  Cu SO_4. $5H_20$ 25% Cu.
- Copper chloride
  $CuCl_2$ 17% Cu.
- Synthetic chelates
  Cu EDTA 9% Cu.

Iron (Fe)

- Iron is involved in respiratory reactions and enzymatic reactions.
- Availability of iron decreases with the increase of soil pH. Soils which are poorly drained and with free carbonates are deficient in Fe.
- Too much liming results in iron deficiency (lime-induced chlorosis)
- Iron deficiency appears as yellowing of the interveinal regions of leaves.
- Severe deficiency results in chlorosis and the leaves turn white and eventual leaf loss.
- Iron toxicity occurs in low pH soils
- Iron deficiency is corrected by foliar application.
- Iron fertilizers applied to soil are ineffective as they are converted to unavailable forms.

Iron fertilizers

- Ferrous sulphate 20%. Fe.
- Iron chelates Fe EDTA 7% Fe.

Manganese (Mn)

- Availability of Mn is related to soil pH, organic matter content and degree of aeration.
- Deficiency occurs in alkaline soils, sandy soils and organic soils.
- Toxicity results in acid soils.
- Manganese is involved in enzyme systems related to chlorophyll production, metabolism of carbohydrates and N.
- Deficiency symptoms appear as interveinal chlorosis (could be confused with Fe or Zn deficiency). In severe cases there is chlorosis, leaves turn brown and leaves die.
- Basal application of fertilizer Mn is suitable to correct deficiency. Like Fe, foliar application is the best.

Manganese fertilizers

- Manganese sulphate 23 -28 % Mn.
- Synthetic chelates Mn EDTA 5-12%Mn.

Molybdenum

- Molybdenum availability is low in acid soils. Liming can correct deficiency.
- Molybdenum involved in N fixation in legumes. These crops require higher rates.
- Molybdenum deficiency is common in cauliflower causing leaf marginal scorching.

Molybdenum fertilizers

- Ammonium molybdate 54% Mo.
- Sodium molybdate 39% Mo.

Zinc

- Availability to plants decreases with increasing soil pH. Coarse-textured soils and low organic matter containing wet soils are marginal in zinc.

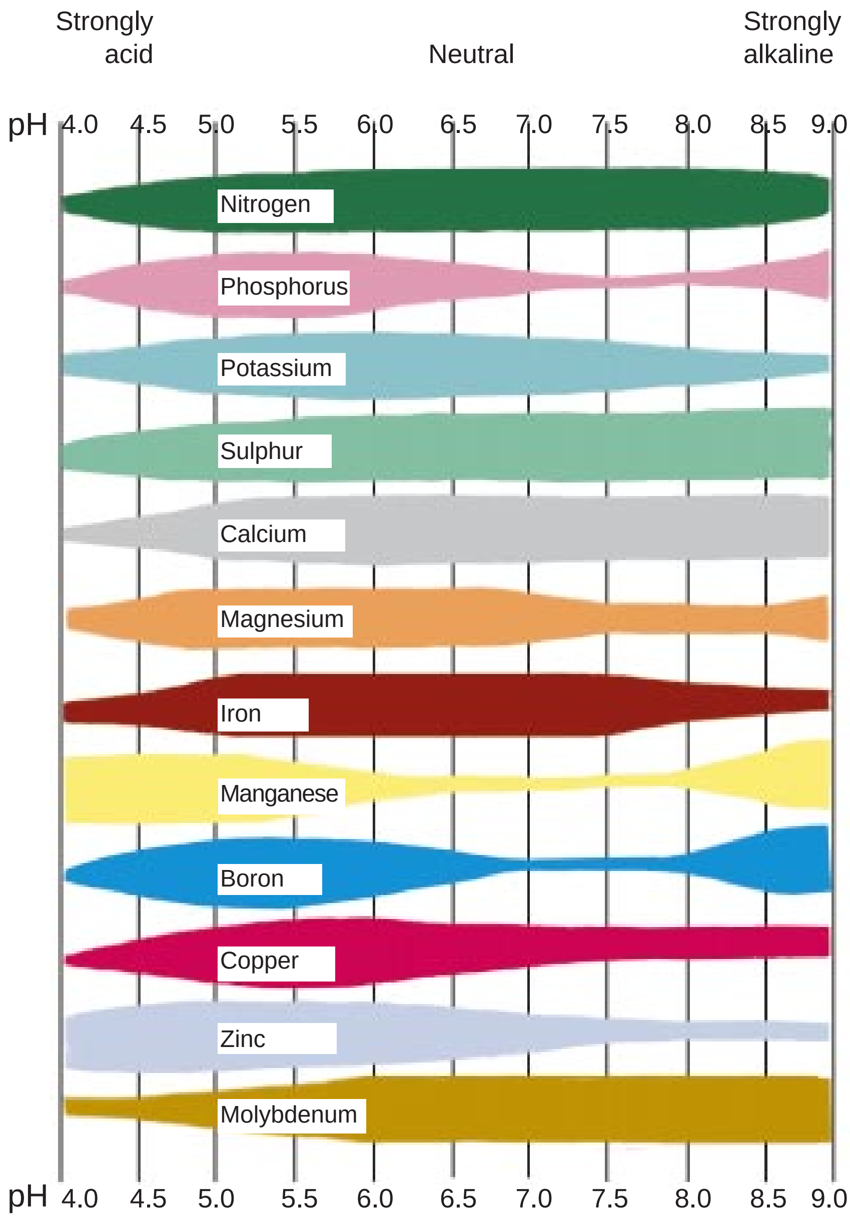


Fig.7 Influence of pH on the availability of plant nutrients in organic soils. Shaded areas indicate maximum availability.

Source: Lucas & Davis 1951

- In plants, Zn is involved in enzyme systems, essential to protein synthesis and seed production.
- Zinc deficiency vary with crops. In legumes spots appear on older leaves giving a mottled appearance.
- In fruit trees, rosetting appear at terminal points; narrow leaves with yellowing between veins.
- In cereals, yellow stripes appear in leaves; seed production is reduced.
- Fertilizer zinc has a long term residual benefit.

Zinc fertilizers

- Zinc sulphate 36% Zn.
- Zinc EDTA 6 – 14% Zn.

Nutrient Interactions

- It is important to maintain a limited range of nutrient concentration for plant growth, through proper soil management and fertilizer practices.
- High levels of one nutrient in the soil may depress the uptake of another to make the latter a limiting factor for growth of the plant.

Examples of nutrient interactions

- Excess copper adversely affects iron interaction.
- Antagonism by iron and manganese; zinc and iron.
- High levels of P, induce zinc deficiency.
- Potassium and calcium induce magnesium deficiency.

Synergistic nutrient interactions

- N - Helps the uptake and utilization of all micronutrients.
- Mg - Increases P uptake.
- P - Favour Mo uptake.

Assignments

1. Collect samples of common chemical fertilizers and look for characteristics which will help to identify them visually.
2. List the places where chemical fertilizers are available in your area.

ORGANIC MANURES

General features

- Bulky - Low bulk density.
- Low content of plant nutrients.
- Contains all essential plant nutrients.
- High application rates are necessary.

Types of organic manures

- Plant origin
- Animal origin
- City wastes
- Industrial wastes
- Composted materials

Fig. 8. Sunhemp

Note: See appendix 3 for list of green manure plants.

Plant origin

Green manures

- Two types

a). Grown in the field for *insitu* application. Plants are ploughed at flowering due to high concentration of N.

e.g. *Crotalaria juncea* (Sunhemp)

Sesbania rostrata

b). Leaves and tender stems lopped from trees are applied to soils after ploughing.

e.g. Gliricidia,Tithonia diversifolia (wild sunflower) etc.

- Most green materials could be used.
- Legume and composite plants have high N.
- Materials with high C:N are not suitable.
- Should be applied and buried in the soil.

Fig. 9. Gliricidia

Fig. 10. Wild Sunflower

Crop residues

Crop residues such as rice straw, corn stover, grain stover and other crop stover could be used. Grain husks, corn stalk and other materials could also be used.

Fig. 11: Rice straw application

- Crop residues such as straw have high C:N ratio. Therefore application to the soil before seeding has to be done. C:N could be narrowed by addition of N fertilizers.
- Requires adequate moisture for decomposition.
- Residues of graminaceous crops supply K and silica to plants.

Animal origin

- Includes dung, urine, grasses and feed stuff, and bedding of animals.
- They have materials at various stages of decomposition.
- Contains small amounts of plant materials.
- The amount of plant nutrients depends on
  - Species
  - Age of animal
  - Feed given
  - Nature of collection

Note: See Appendix 4 for livestock population in Sri Lanka

Fig.12 : Cow shed with facility for collecting dung

Animal dung

- Pure dung is seldom collected separately except from poultry in battery cages.
- Animal dung has more plant nutrients than farmyard manure (FYM).

Poultry litter

- Are of two types - Layer litter
  - Broiler litter
- Layer litter cotains poultry excreta, feed material and feathers in a substratum collected for over one year. This material is richer in plant-nutrients than broiler litter.
- Broiler litter is changed every 40-45 days.

City wastes

- Collection of garbage from households, factories, garages, markets, streets, slaughter houses etc. is referred to as city wastes.
- This material is allowed to decompose.
- The decomposed material is collected, dried and sieved before marketing.

Industrial wastes from agriculture

- Fruit and vegetable canning factories have waste materials.

Compost

- Is an inefficient method of converting organic material to a humus like material; about 40-60% of the N in the material used for composting are lost.
- Composting regulates the bio-degradation process, enables value addition to waste materials and allows the recycling of plant nutrients.
- Composting could be carried out at the domestic or industrial scale.
- Domestic composting allows the systematic disposal of garbage and also recycles this material on crops or floriculture.
- The composting at industrial scale focuses on waste management.
- City compost may contain heavy metals and pathogens if the composting procedure is not perfect.

Composting methods

Two types

- Aerobic
- Anaerobic

Aerobic method

- Air is allowed freely for full oxidation of the biodegradable material.
- No smell is found in the finished product.
- The finished product has no resemblance to the original material.

Under the aerobic methods many forms are operated

- Raised beds - Heap method
- Dug in beds - Pit method with a protective roof
- Barrel method
- Wormy compost

Fig. 13. Heap method of compost making (aerobic method)

Note: See Appendix 8 for compost making methods

Anaerobic method

- Air is not used for the decomposition process.
- Finished product has an offensive odour.
- Often the original material could be identified.
- Has high moisture content over 85%.

Note: See Appendix 5 for organic manures and their nutrient composition

Fertilizer use efficiency (FUE)

Fertilizer use efficiency (FUE) can be defined in two ways. Soil scientists equate FUE with the percentage of the applied nutrients (through fertilizer) utilized by a crop.

Thus,

$$\text{FUE} = \text{Percentage of applied nutrient utilized by the crop}$$

$$= \frac{\text{Amount of fertilizer nutrient removed by the crop}}{\text{Amount of fertilizer nutrient applied}} \times 100$$

A FUE of 100% means the entire amount of fertilizer added to a soil is removed by the crop. This is very unlikely because fertilizer nutrients added to a soil undergo four types of disposal; they are

- Removed by the crop;
- Remain in the soil solution but is not removed by the crop;
- Fixed to the soil and not available; and
- Lost through leaching and other forms.

The FUE for nutrients like nitrogen (N) will be limited to one season whereas phosphorus (P), potassium (K) and other nutrients will last for longer periods due to residual effects. The FUE for N is generally less than 50% while for P and K the values are often less than 15-20% for a growing season of a crop. The residual effects of P and K will last for a longer period and FUE for P and K at later stages may be as low as 2-3%.

From an agronomic point of view, FUE is defined as the amount of produce per unit of applied nutrient. i.e.

$$FUE = \frac{Y_F - Y_O}{N}$$

where Y_F = yield of the fertilized treatment; Y_O = yield of the unfertilized control; and N = amount of applied nutrient.

The actual yield level and the response to fertilizer will be influenced by many aspects of crop management.

Assignments

1. Look for the availability of different manures of animal origin in your area and list them.
2. Search for manures of plant origin available in your area and list them.
3. Prepare compost using materials available in the area.

CHAPTER 2

Balanced Fertilizer Use, Soil Testing, Economics of Fertilizer Use

This chapter deals with, balanced fertilizer use, its importance, law of the minimum, basis of fertilizer recommendation, adverse effects of imbalanced and overuse of fertilizer and manure, soil testing and economics of fertilizer use.

It is intented to achieve the following broad objectives

1. To know the meaning of balanced fertilizer use, its importance, effects of unbalanced and overuse of fertilizer.
2. To get knowledge on soil testing and collection of soil samples.
3. To get information on economics of fertilizer use.

Section I

IMPORTANCE OF BALANCED FERTILIZER USE

Introduction

The presence of adequate quantities of nutrients in forms accessible to plant roots in soil solution is essential to attain optimum crop growth. Environmental factors and soil plant nutrient content and its availability determine the capacity of a plant to absorb such nutrients. Soil fertility determines the capacity of a soil to supply nutrients. The capacity of a soil to supply nutrients depends on many factors of which moisture content plays a big role.

Balanced fertilizer use

- Maintaining the balance between the crop nutrient requirement and the capacity of the soil to supply these nutrient is the basis of balanced fertilizer use. Supplementing the soil's capacity to supply the crop requirement has to be done by means of adding chemical fertilizer or organic manure to the soil.
- An understanding of the nutrient requirement is the most important aspect of balanced fertilizer use.
- Plants have specific nutrient requirements based on crop species and cultivars. Some species have a higher requirement of certain nutrients. Cereals requires more N while legumes require more available phosphorus. Sugar cane, banana and tomato require more potassium.
- In practice soils have the capacity to supply calcium, magnesium and most micronutrients. But enhanced crop production limits the availability of these nutrients.
- Practical experience shows that addition of sulphur, calcium, magnesium, zinc and boron are helpful to certain crops. eg. tea and cocoa.
- Application of calcium at pod initiation for groundnut is beneficial.
- Application of molybdenum for heading of cauliflower is important.

- Addition of zinc, magnesium and sulphur is necessary to sustain rice yields over 200 bu/ac.
- Balanced fertilization requires the use of both chemical fertilizer and organic manure to supply the requirement of major, minor and micronutrients.

Effects of unbalanced fertilization on crop yield and sustainability

- When the elements essential for efficient plant nutrition and economic production are low in availability or unbalanced, then chemical fertilizers and soil amendments are required, to enhance crop yields.
- Incorrect fertilizer recommendation or unbalanced/inadequate availability of nutrients can lead to depletion of soil nutrient reserves and loss of plant nutrients supplied in excess.
- Lack of balance nutrients also encourages excessive uptake of these nutrients supplied in excess, but with no benefit.
- Unbalanced fertilization is an uneconomic waste of scarce resources.

Importance of balanced fertilizer use

To maintain sustainable agricultural systems while achieving optimum yields, a supply of adequate and balanced amounts of plant nutrients must be provided at the correct time.

Balanced fertilizer application,

- Increases fertilizer use efficiency.
- Increases crop yield and quality.
- Improves nutrient value of the crop residues, which can be used as manure.
- Minimizes build up of high levels of residual nutrients, antagonisms and negative interactions.
- Can reduce pesticide requirements and produce healthier food.
- Reduces adverse effects of wasteful fertilizer application; i.e. eutrophication, groundwater pollution or air pollution.

Adverse effects of imbalanced / overuse of chemical fertilizer on the environment

The role of fertilizer as a causal agent for pollution is widely acknowledged.

- Nitrate leaching and subsequent accumulation in groundwater.

  Effects of excessive use of chemical fertilizers in the Regosols along the western coastal belt in the Kalpitiya peninsula are well known. These soils are used for the cultivation of high-value cash crops such as potato, onion and vegetables under lift irrigation. These soils contain over 98% sand and as a result have very little water or nutrient retention ability. High accumulations of salts were recorded from water drawn from wells used for irrigation, (10mg N/l, 300-400 mg Cl^-/l). The comparable value for nitrate N in non-cultivated or lightly fertilized coconut lands was less than 2 mg N/l. The average annual increase in groundwater chloride and nitrate-N concentrations within the intensively cultivated area was estimated at 5 and 2 mg/l respectively. This is equivalent in the case of nitrate to a leaching loss rate of 60-120 kg N/ha/year. The deterioration of groundwater quality and nutrient loss from such practices were unacceptably high.

In the Jaffna and Kilinochchi districts in the northern Sri Lanka, a variety of cash crops are grown under supplementary irrigation. The major soils in the Jaffna peninsula are the calcic red-yellow latosols, which are shallow, fine-textured and well-drained. In the Kilinochchi district, red-yellow latosols are interspersed with alluvial soils of variable drainage and texture. Analysis of water samples from 65 wells from the two areas used for agricultural and domestic purposes showed varying degrees of contamination. The nitrate-N concentration in 79% of the farm wells in Jaffna was higher than the WHO recommended safe value of 11.3 mg/1. Wells used for domestic water supplies had low nitrate levels. The wells in the Kilinochchi district had very low nitrate – N content.

- Build-up of nutrients

  Fertilizer application rates in the upcountry in relation to potato and vegetable cultivation are 3-4 times higher than the DOA recommendation while application rates of animal waste are as high as 10-65 t/ha. A soil build-up of P and K levels many times higher than in the average soils was observed in such areas. Olsen extractable P values ranging from 25 ppm to well over 600 ppm and K values from 0.1-1.5 meq K/100 g soil were recorded. Due to the hilly terrain of lands used for vegetable cultivation nutrient leaching and accumulation in water bodies takes place easily.

Liebig’s law of the minimum

An excess of a particular nutrient over another nutrient which is in short supply could follow the phenomenon of the law of minimum.

German scientist Justus Von Liebig (1803-1873) propounded the law of the minimum which states;

- If a particular element is deficient, plant growth will be poor even when all other nutrient elements are abundant.
- If the deficient element is supplied growth will increase.
- Increasing the particular element may not be helpful beyond this point as another element will be in short supply and limit growth.

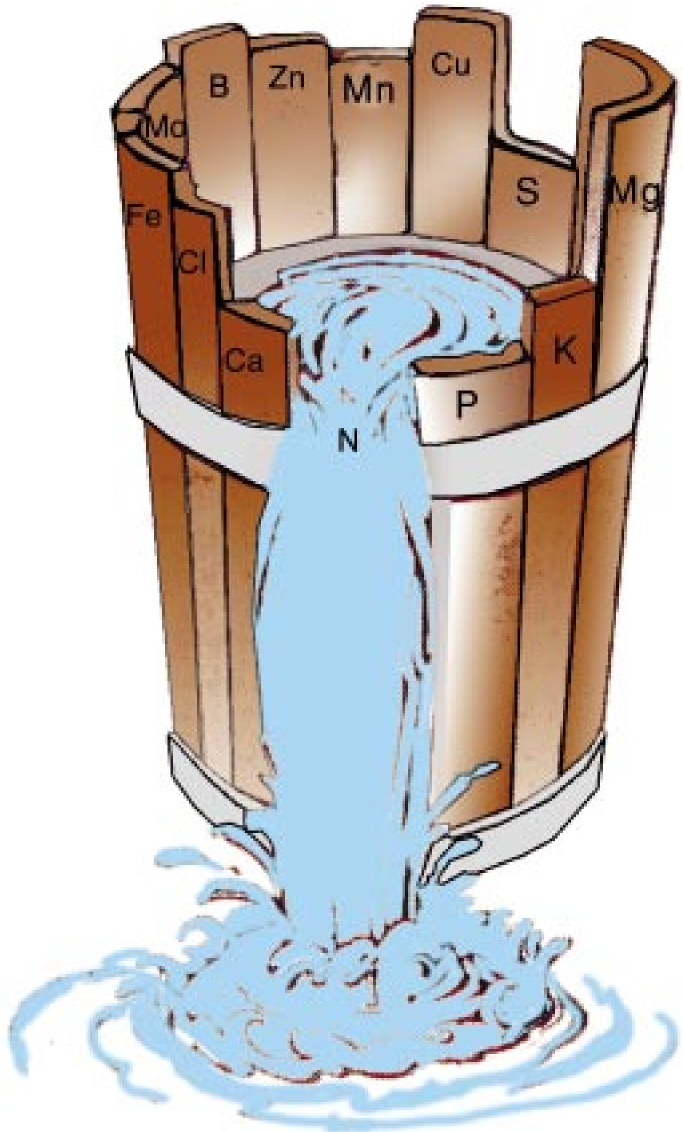


Fig: 14 The law of the minimum as shown by a splintered barrel

Liebig illustrated the law as a wooden barrel with staves of unequal length. The capacity of the barrel is limited by the shortest stave(in this case, nitrogen) and can only be increased by lengthening that stave. When that stave is lengthened, another one becomes the limiting factor.

Section II

SOIL TESTING

- Routine soil testing is done in farmers fields to determine nutritional status of soils and fertilizer needs. Tests are available to evaluate nearly all elements essential for plant growth.
- Soil tests produce best management when used in conjunction with other good farming practices.
- Samples must be taken deep enough to give a good measure of the soluble nutrients through out the crop rooting depth.
- Soil tests give an index of nutrient availability rather than a precise measure of the total amount in the soil.

Soil Sampling

- Soil samples sent to laboratory must represent that part of the field that is required to be tested.
- Follow the basic rules

i. Keep accurate records of past fertilizer applications, crop yields, soil problems etc.

ii. Use a proper tool like an auger, mammoty, spade, tube etc. to obtain soil from the correct depth.

iii. Each sample must represent a uniform soil area.

a) Narrow slope range, similar soil colour, texture and depth.

b) Crop height and yield.

c) Wet or salty spots, eroded knobs etc.

iv. Avoid field variability due to :

a) Poor judgement in sampling.

b) Failure to clean tools between sampling.

c) Contamination with non soil material.

d) Inadequate mixing of sub samples.

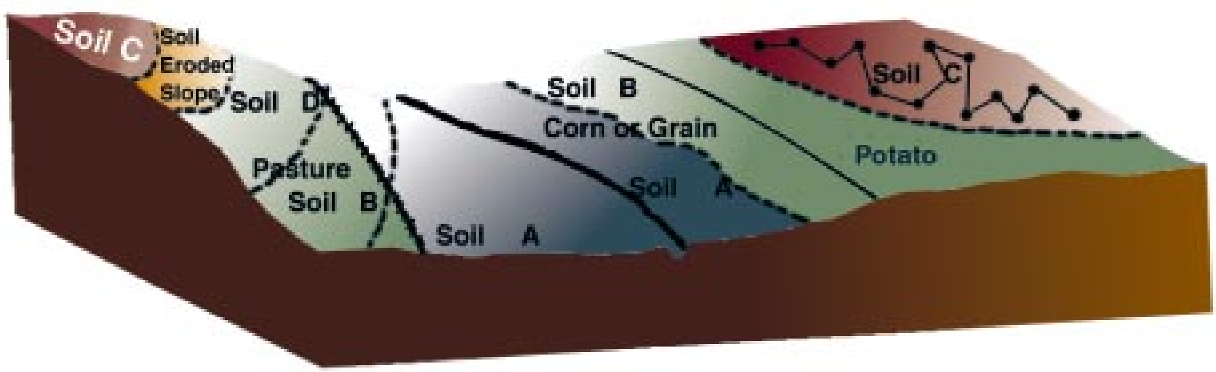


Fig: 15 Sample soils on soil type and crops that were grown

Note : See sampling points in soil C

- Sampling of fields once every two years is sufficient.
- Avoid sampling after application of fertilizers, liming material or organic manure.

Laboratory analysis

- Laboratories will analyze for the following in routine analysis;

i. Soil texture

ii. Soil pH (measures acidity / alkalinity)

iii. Electrical conductivity (measures salinity / alkalinity)

iv. Available P content (mmols 1^{-1})

v. Exchangeable K content (C mols / kg soil)

vi. Soil organic matter content (%)

- If further analysis is required on secondary micronutrients, analysis will be made on;

i. Calcium, magnesium and sulphate-sulphur

ii. Micronutrients except molybdenum and chloride. (Not included in general analysis).

Plant analysis

- Helps to determine sufficiency or deficiency of plant nutrients through the analysis of various plant parts like leaves, stems or leaf petioles
- Time of sampling, age of plants, type of plant part to sample are decisive in sampling.
- Plant analysis helps to determine toxic levels of certain elements.
- Plant analysis verifies visual symptoms.
- Plant analysis will not have any relationship as to what will happen from plant growth to maturity. Plant analysis of annual crops will not permit to carry out corrective measures.

Fertilizer application

- Generally all fertilizers are applied to the soil before establishment of crops.
- Exception is nitrogen and under rare instances potassium is recommended as a top dressing.
- Fertilizers should be added to help the growing seedling / plant to capture the material by roots.
- Banding, deep placement, side dressing, top dressing are some methods of fertilizer application. Always cover the fertilizer material with soil under upland conditions. In paddy-rice, cover the basal fertilizer with a mud film. Top dressing should be done with a small film of water and retain the water for 2-3 days.
- Some fertilizers like urea and other soluble salts could be applied as a foliar dressing in extremely diluted concentrations.

Fertilizer recommendations

Appropriate fertilizer recommendations provide plant nutrients needed to sustain maximum production and profitability while minimizing environmental impact of fertilizer use. The knowledge of nutrient removal, nutrient uptake patterns by crops and capacity and availability of nutrients in the soil reservoir helps to formulate correct fertilizer recommendations.

Fertilizer recommendations are based on many assumptions, real experiments, data analysis, statistical analysis and field testing.

- Assumptions are based on plant nutrient removal based on upper ground part analysis of most cereal crops, tubers and fruits along with stems and leaves in other annual crops. Plant tissues are dried, ground and representative samples are analyzed in laboratories. Table 6 gives information on rice crop removal of plant nutrients.
- Based on this information the nutrient requirement of a crop at a particular yield level could be evaluated.
- Fertilizer experiments are carried out to determine the response of a crop to one or more nutrients. Different combinations of plant nutrients at various rates are combined in these experiments. The best combination and rate is assumed to give best results.
- Soil and plant analysis: Give an indication of what plant nutrients the soil has in store,and the status of nutrient concentration in the plant .
- Values arrived by all these combinations are tested both at research stations and farmers fields before fertilizer recommendations are given.
- Any chemical fertilizer recommenda-tion, should take into account the nutrient value of added organic manure to avoid over supply.

Section III

ECONOMICS OF FERTILIZER USE

- Research has found that higher yields are closely related to profitable crop production.
- Higher crop yields help to reduce per unit cost of production and to obtain maximum profit.
- Proper use of fertilizers provides the greatest opportunity for obtaining higher yields.
- Fertilizer application complements the effects of other management practices and gives higher crop yields.
- Profit depends on the relationship between cost of production, inputs such as fertilizers and the increased value of crop yield. An understanding of incremental cost and return is necessary to determine this.

Economics of fertilizer use is the profit per unit area that is obtained by the addition of fertilizer to a crop.

Increased use of fertilizer for a crop tends to increase yield at an increasing rate, then at a decreasing rate and finally more addition will infact completely decrease the yield. This is demonstrated by the law of diminishing returns.

Effect of fertilizer on yield of Rice

Table 4: Total production and marginal production of rice (Hypothetical example)

Amount of fertilizer (kg) applied per ha.	Total product (t/ha)	Marginal product (t/ha)
0	2.4	-
50	3.2	0.8
100	4.3	1.1
150	5.6	1.3
200	6.2	0.6
250	5.1	-1.1
300	3.8	-1.3

Above table shows the effect of increasing fertilizer levels on the yield of rice. Marginal product increases with increase of fertilizer and then falls to zero and takes negative values.

Maximum yield and maximum economic yield

Maximum yield in the above example is 6.2 tons/ha when 200kg of fertilizer is used and the corresponding marginal product is 0.6. When marginal product is zero yield is at its maximum.

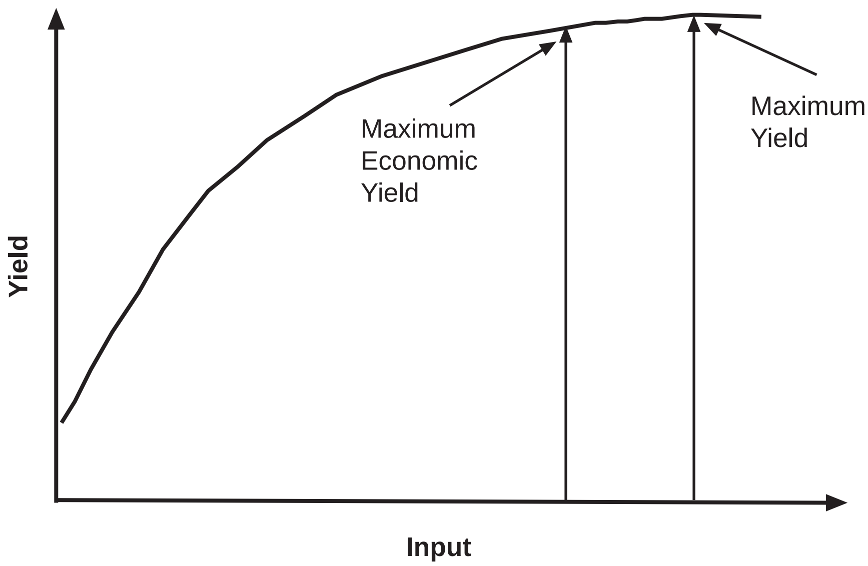


Fig.16, Relation between maximum yield and maximum economic (profit) yield

When represented graphically (Fig.16), at maximum yield, the increase in output in response to the last unit applied is zero. However at the maximum economic yield, the value of additional output for the last unit of fertilizer applied is equal to the cost of that unit of fertilizer. In economic terms, the value of marginal product is equal to the marginal cost. This is the point of production at which the maximum profit is obtained. Up to this point adding one or more units of fertilizer results in a net increase in the total profit.

Beyond this point, the value of additional output resulting from the addition of one or more units of fertilizer is less than the cost of fertilizer.

This shows that the point of maximum yield is not always the point of maximum profit. Also, the point of maximum economic yield depends on the level of management of the other inputs need for production.

Fertilizer application, cost of production and net profit

The cost of production of crops continues to rise due to increases in input prices. Crop prices often do not increase enough to keep pace with production costs. Therefore, to remain profitable it is necessary to lower the unit cost of production. The most realistic means to increase yields is the application of fertilizer. Application of fertilizer makes the cost of cultivation per unit area (per acre) also to go up. However, the resulting increase in yield more than compensates for increase in cultivation cost and as a result, the unit (per kg or ton) cost of production is lowered. This leads to an increase in net profits from crop production. The decrease in unit cost of production insures the grower against price declines. In other words, at higher yields, the price at which the crop can break even, is reduced greatly.

Table: 5 Optimal Application of Fertilizer and Revenue (Hypothetical example)

Amount of Fertilizer (kg)	Total Cost of Fertilizer added (Rs)	Marginal Cost (MC) (Rs)	Total Production (Kg)	Total Revenue (Rs)	Marginal Return (MR) (Rs)	Net Return (Rs)
0	0	0	2400	24000	–	24000
50	400	400	3200	32000	8000	31600
100	800	400	4300	43000	11000	42200
150	1200	400	5600	56000	13000	54800
200	1600	400	6200	62000	6000	60400
250	2000	400	5100	51000	-11000	49000
300	2400	400	3800	38000	-13000	35600

When marginal return is zero maximum crop yield or maximum total return (revenue) is obtained, this is between 200 kg to 250 kg of fertilizer. But the economic yield is when MC = MR which may be above 200kg level but of course below 250kg. At this point net return is at maximum and the optimum profit is obtained, indicating that excessive use of fertilizers is not giving an economic return.

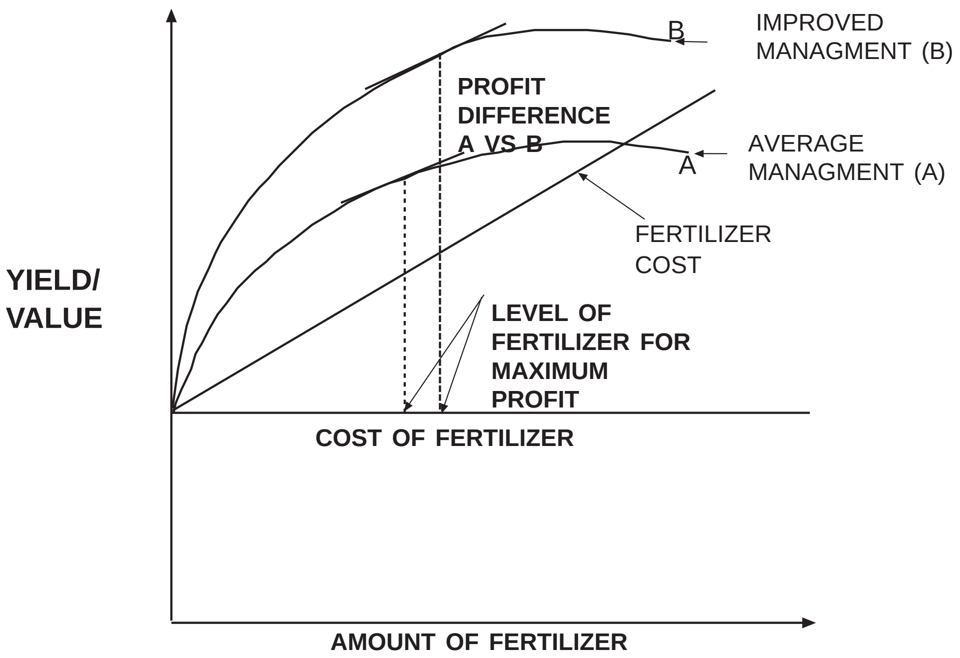


Fig. 17 Relation between economic (profit) yield and level of management

As shown in the Fig. 17 the maximum profit under average management is at point A and under improved management at point B.

Also, because the maximum economic yield is dependent on the value of production, any changes in the relative prices can affect the point of maximum profit.

When the price of output increases with the fertilizer price remaining constant, the fertilizer rate for maximum profit increases.

Alternatively, if the fertilizer cost increases at constant crop price, the fertilizer rate at maximum profit declines.

Economics of nutrient use

Also, in the application of fertilizer it is necessary to consider the most economical source of nutrients than the per unit (kg) cost of product.

Often urea is the most economical source of providing a unit of N than alternatives such as ammonium sulphate or ammonium nitrate.

Likewise, per unit cost of nutrients in fertilizer mixtures is usually higher than that in straight materials. However, the cost of mixing, transporting and applying must also be considered in comparing the two sources.

Use of organic manure

The use of organic manure, when cheaply available is a good alternative to chemical fertilizer use. However, due to limited availability and handling costs, organic manure has limited potential under most situations.

Due to other benefits such as supply of micronutrients and organic components that increase soil moisture retention and reduce leaching of nutrients, organic manure gives greater benefits than chemical fertilizers.

Therefore, when conditions permit, it is beneficial to use organic manure in crop production.

Note: See Appendix 9 for Economics of IPNS

Assignments:

1. Collect a sample of soil from a farmer's field in your area on the basis of principles given.
2. Study the DOA soil testing programme for farmers in your area.

CHAPTER 3

Integrated Use of Organic Manures and Chemical Fertilizers and Principles

INTEGRATED USE OF ORGANIC MANURES AND CHEMICAL FERTILIZERS AND PRINCIPLES

This chapter is on Integrated Plant Nutrition Systems (IPNS) and concerns with its definition and its objectives. Practices of IPNS by farmers and pros and cons of using chemical fertilizer and organic manure, IPNS versus organic farming are also dealt. Socio-economics of IPNS, its impact on the environment, limitations of organic manure use, its practice in different cropping systems and the constraints of its practices in Sri Lanka are also discussed.

It is expected to achieve the following broad objectives

1. To know the meaning of Integrated Plant Nutrition and objectives of IPNS.
2. To know what went wrong with chemical fertilizer use.
3. To compare the use of chemical fertilizers with the use organic manure.
4. To familiarise with organic manure application and to know limitations.
5. To provide knowledge on organic farming against IPNS, managing nutrient balance in IPNS, socio-economics of IPNS and its impact on the environment.
6. To know IPNS practices for different cropping systems and drawbacks of IPNS in Sri Lanka.

INTEGRATED PLANT NUTRITION SYSTEMS (IPNS)

Definition of IPNS

- Integrated Plant Nutrition System is a holistic approach to plant nutrition by obtaining the nutrients from both inorganic and organic sources to maintain and sustain soil fertility and enhance crop productivity in a framework of an ecologically compatible, socially acceptable and economically viable situation.

Need for integrated use

- Organic manures sustain soil fertility at a low level of production.
- Chemical fertilizers have concentrated forms of nutrients. Application results in leaching, fixation and build-up of certain nutrients at the expense of others, resulting in nutrient imbalances.
- Fertilizer use efficiency (FUE) is low in all chemical fertilizers and organic manure when used singularly.
- Combined use of organic manures and chemical fertilizers increases FUE

Objectives of IPNS

- Increasing the fertilizer use efficiency.
- Increasing the return to investment on fertilizers.
- To use a balanced system of crop nutrition management.
- To account for the different amounts of plant nutrients, in a budget sheet giving the following:

1. Available in the soil.
2. Available from organic sources.
3. Available in crop residues.
4. Derived from biological fixation.
5. Derived from fertilizers and their residual effects.

When preparing a budget, a whole cropping system is looked into than a singular crop, over a long term.

What has gone wrong in fertilizer use?

- Before chemical fertilizers were introduced, organic forms were used.
- Green manures, crop residues and FYM were used in large quantities.
- A season of farming was followed by a fallow period for replenishment of soil fertility.
- Chemical fertilizers supplied sufficient plant nutrients for obtaining high yields. These fertilizers did not provide the crop requirement of all nutrients.
- The continuous use of chemical fertilizers destroyed the soil structure, turned the soil acidic and brought about nutrient imbalances resulting in nutrient interactions.
- The organic matter in the soil did not improve with application of chemical fertilizers resulting in erosion and loss of top soil.
- The yield increases obtained during the early years of chemical fertilizer use evened out and addition of extra fertilizers did not bring the desired benefits.

Farmer practices of IPNS

- Vegetables, potato and green leafy vegetables are cultivated using both organic and chemical fertilizers.
- Here farmers obtain higher yields than farmers using either chemical fertilizers or organic manures.
- Extension of this practice to other crops has resulted in increases of yield and sustainability of production at a higher level.

Chemical fertilizers or organic manures

- To sustain crop yields, the rate of removal has to be balanced by added amounts. Use of chemical fertilizers is necessary for supplying the nutrient requirement but without recycling of crop residues, yields will suffer.
- If only organic manure is used land will benefit but yield will be lower.
- Availability of nutrients from organic manure is slow but long lasting.
- Use of organic manure improves the physical, chemical and biological conditions of the soil.
- Singular use of chemical fertilizers has an adverse effect on the soil structure. If the organic matter is low the bulk density increases.
- Use of chemical fertilizers along with organic manure gives a soil rich in nutrients with good physical and microbiological properties. This will increase the availability of nutrients.

- Application of organic manure results in formation of water stable aggregates which could resist erosion.
- Combined use of chemical and organic fertilizers increases cation retention and improves nutrient availability.
- Addition of manure widens the C:N ratio in soil. Singular use of chemical fertilizers narrows this ratio.
- Addition of mineral N fertilizers results in instant increases of N but organic manures increases the available N.
- Fixation of fertilizer P could be reduced and effectiveness of fertilizer K can be increased when chemical fertilizer is combined with organic manures.
- High analysis fertilizers have low contents of micronutrients, but combined use with organic manure makes these nutrients available to plants.
- Combined use of manure and chemical fertilizers results in higher return to investment and better cost-benefit ratios.
- Thus it is beneficial to use both manure and chemical fertilizers for crop production.

Organic farming or IPNS?

- Organic farming systems do not use any synthetic form of plant nutrient.It also avoids the use of pesticides and weedicides. Organic manure of animal origin should not have artificial ingredients fed to animals and animals should not be treated with antibiotics or steroids as growth promoters.
- Obtaining green manure continuously from trees results in removal of plant nutrients from soils, which are not easily replenished. This results in poor growth of the green manure trees itself, which could result in a short fall of supply of the material. Thus a limitation to resource management occurs.
- Organic farming maintains the productivity at a low level. Where demand for food is becoming more increasing organic farming *per se* cannot meet the required demand.
- Plants obtain nutrient sources in the ionic form. Whether they come from organic or inorganic forms, the type of ions is the same.
- It is best to combine the use of both manure and mineral fertilizers rather than manage the singular use of manure.

Managing a nutrient balance in IPNS

- IPNS attempts to keep a balance between crop removal and nutrient addition to the soil. In this respect a book keeping exercise has to begin with the first step of how much the soil already has.
- Soil analysis for evaluating the nutrient availability and its limitations that could reduce the productivity, has to be done at the begining.
- The yield goal of the cropping system of single or multiple crops that would be grown over time (say one year) has to be evaluated to arrive at the nutrient removal.

- The quantity of mineral fertilizers to be applied has to be decided on soil test values for P and K.
- The addition of organic manures to supplement the requirement of the minor and micronutrients has to be evaluated.
- Nitrogenous fertilizers to be used on crop demand rather than on blanket recommendations has to be practised.
- Limitations to FUE by drought, surface erosion, poor drainage are to be avoided.
- Correct application practices in basal and top dressing applications of both organic and chemical fertilizer have to be adopted.
- Crop residues have to be recycled to supplement the nutrient pool of the cropping system.
- If legumes are included in the cropping system, credit has to be given for possible biological nitrogen fixation (BNF).

Socio economic side of IPNS - Scope and limitations

- Any IPNS practice has to be economically sound and socially acceptable. Organic manure should be available easily in acceptable forms and types.
- Crop residues are often burnt instead of recycling. Scarcity of labour, and the time gap between two crops may limit the use.
- Organic manure for many farmers is not available in their own holdings. The holding size often limits animal husbandry. Transported material is too expensive and transport to the farm is laborious.
- Chemical fertilizers are easily available and literature on their use is more comprehensive. Organic manure and crop residue management has not been given the same importance.
- Use of FYM, poultry litter and other animal wastes is popular among farmers. But sewage, sludge and urban compost are not popular among them.
- Financial credit is available only for mineral fertilizers. There is no organized credit system to help the farmers to use organic manure and crop residues.
- Chemical fertilizer market is controlled with a standard product but organic manure is sold without any standards.
- Storage and retail marketing of organic manure is limited. It is not easily accessible to most farmers.
- Farmers who have domesticated animals do not have facilities to collect,store and market the animal waste.
- The scope for IPNS is limited to a few high value crops in the present circumstances. Farmers growing these crops may be encouraged to follow IPNS.However, a large number who have access to organic manure do not use them.

IPNS and the environment

- Chemical fertilizers are considered to be environmental pollutants. Nitrogen fertilizers when used in excess can be leached or washed through erosion into waterways and reservoirs. Eutrophication of reservoirs have been reported from time to time.
- Nitrogeneous compounds in organic manures too are converted to nitrates. Any excessive use and leaching could bring the same environmental hazard as using excessive amounts of urea or ammonium sulphate.
- Nitrogen fertilizers can acidify soils, but when used with organic manure can buffer acid formation to a certain degree.
- Liming can change the pH and improve CEC. Liming can be a corrective measure to improve the crop environment.
- Excessive build-up of P and K in soils results in nutrient interactions. In high P built-up soils, both zinc and copper availability can be a problem. At high levels of K in the soil, magnesium becomes limiting. By following IPNS these excesses can be cushioned.
- Excessive use of organic manures can limit the availability of copper as the latter is lost through leaching. Following IPNS will benefit the situation.
- Combined IPNS, benefits the development of soil structure and reduces erosion hazards.
- IPNS practices produce more healthy plants which minimizes the necessity to use pesticides and fungicides, which are harmful to the environment.
- Excessive nitrate leaching into groundwater and drinking water is harmful. IPNS can increase the anion retention when mineral and organic fertilizer is used together.
- Ploughing and land preparation is easy on lands following IPNS. Ploughing deep to expose the sub-surface soil does not arise in these lands.

IPNS and fertilizer use efficiency

Chemical fertilizer in the form of salts, when added to soils gets converted into ionic forms after dissolving in the soil solution. Substances like urea under go extra cellular enzymatic decomposition to form ammonium compounds, which are either absorbed by the plant roots or converted to nitrates, which are absorbed or lost in leaching or converted to gases in the N cycle.

Organic manure produces organic acids (humic acid) which have the capability of holding cations and anions. Soils rich in organic matter can hold more cations than otherwise. Ammonium ion like other cations can be adsorbed to organic acid molecules after replacing H. This adsorption helps to release the cations slowly to the plants. If not for the organic molecules certain chemicals reactions can make most nutrients unavailable to the plants.

Most plant nutrients are available at certain pH ranges. Addition of organic manures can buffer pH, making more materials available to plants. Soil organic matter has a high CEC values and CEC is pH dependent. If liming is done to increase pH then the CEC will also increase. The CEC from organic manure is temporary.

Organic manure application and limitations

- Organic manures are of plant and animal origin.
- Plant materials have easily and slowly biodegradable materials. The variety, age and plant part determine the composition and the quickness of decomposition.
- Younger leaves and tender stems have more water, more N and less other minerals and decompos faster. Matured leaves and stems have more cellulose containing material, which takes a longer time to decompose.
- Crop residues such as straw have mature tissues with high C:N ratio. They take a longer time to decompose. Direct application will cause the temporary immobilization of soil N.
- Animal wastes have more N than plant parts. They decompose faster than plant materials. Application of N rich materials like blood meal will result in losses of N through volatilization.
- Composted material is suitable for direct application. But exposure of such materials to the elements results in nutrient losses through leaching.
- Care should be taken in using urban compost made out of sewage materials and industrial wastes. Such materials could contain both pathogenic microbes and heavy metals.
- Heavy metals such as cadmium, arsenic, lead and mercury are toxic to environment. These heavy metals are known to accumulate in the body.
- Organic manure decomposes faster in the soil. A crop residue takes one to two weeks to decompose depending on the moisture content of the soil and the type of material. Manure of animal origin decomposes within a few days.
- Application of organic manure should be timed in such a way to get the maximum benefits both in terms of plant nutrient supply and the addition of the carbon source.
- Incorporation to the soil is better than leaving at the surface. Some farmers give top dressings of well-decomposed manure, to crops.
- Poultry litter should not be applied immediately before seeding or transplanting as the ammonia gas released may increase the pH and kill the plants.
- Well-dried organic manure can be kept for a few months in polyvinyl bags.
- Liming should be done before adding organic manure in order to conserve N.

- Organic manure application to ill-drained soils could result in the formation of toxic compounds; particularly if the material is rich in sulphur.
- Recent findings indicate that rice straw can be added to bog soils. The silica content of the straw benefits the soils.

INTRODUCTION TO IPNS PRACTICES FOR CROPS AND CROPPING SYSTEMS

Suitable organic materials for IPNS

Many materials that are organic in nature are suitable for IPNS. Materials that can be used are classified into:

i.	Plant residues	-	Crop residues Green manure
ii.	Animal wastes	-	Animal manure Slaughter house wastes.
iii.	Compost	-	Consists of both plant andanimal materials whichare wastes which also includes city garbage.

Crop residues

Rice straw, corn stover and vegetable residues can be applied directly or after composting. Direct application is cumbersome and due to high C:N ratio of the materials, it takes a longer time to decompose in the soil.

Green manure

Are of two types

- Which are grown *in situ* and ploughed into the soil.
- Lopped leaves and tender stems which are applied to the soil.

Grown insitu

Plants like *Crotalaria juncea and Sesbania rostrata* can be grown before establishing crops and ploughed in at flowering during land preparation. Soils with low content soil organic matter will lose more carbon if N high green manure is used.

Animal wastse

- Animal dung and urine of large animals found mixed with bedding and feed stuff are used as farm yard manure (FYM). Poultry litter can be used both as a basal and top dressing. The material content of the FYM and litter varies considerably depending on many factors.
- Slaughter house wastes and fish meal are not available in Sri Lanka in large amounts due to poor collecting facilities. If collected and treated properly it could become and important source of organic manure.

City wastes

City garbage can be composted and used. It is high in extraneous materials like silica but is a useful material if properly composted. It can be used for floriculture and fruit culture in places close to cities.

Above materials are available for IPNS. The quantities that may be ideal for application would be comparatively larger than the rates of chemical fertilizer. But it is important to add any available amount of organic material available at appropriate times.

Some IPNS practices followed in Sri lanka

Rice-Rice Cropping Systems

- Straw recycling is followed. The straw left behind after the previous crop is added to the next crop at recommended rates. Over 12-15% increases in yield are obtained.
- Supplementing straw recycling with cowdung at 2 t per ha. has increased the yields to 7.0-8.5 t per ha. This yield could be sustained through continuous application.
- Farmers of Matara district add 1-1.5 t of poultry litter per acre and 20%-40% yield increases have been reported.
- Farmers who use mineral fertilizers along with cowdung at 2t per/ac., green manure and burnt husk have given 10-10.5 t per/ha . These yields can be sustained through continuous application.

Rice – Other Field Crops (OFC) Cropping Systems

- Rice straw is added as mulch for chilli, onion, and vegetable crops. Addition of organic manure in the form of cowdung, goat dung or poultry litter is practised.
- Higher yields and less crop damage due to pests are reported.

Other Field Crops (OFC) - Food Crops Cropping Systems

- Chilli and onion farmers extensively practice the combined use of mineral fertilizers and organic manure.
- The farmers who have used larger quantities get better yields and quality crops.
- Farmers who have practised the addition of cowdung to irrigated and fertilized kurakkan have obtained yields of 1800-2000 kg. per acre in the Moneragala district.

Vegetable – Vegetable Cropping Systems

- Up country farmers often over use both mineral fertilizers and organic manures. Amounts of 30-40 t/ha of Farmyard manure (FYM) are used with three to four times the recommended rates of mineral fertilizers.
- Farmers who cultivate *‘Keera’* vegetables - use FYM, poultry litter and even pig dung to supplement the mineral fertilizers.
- Most farmers who venture into commercial vegetable production, use organic-inorganic fertilizer combinations. By this they get high yields than farmers who use only one of them.
- Farmers who cultivate *‘Innala’* use organic – inorganic fertilizer combinations.

Other crops

- *'Kiriala'*, pineapple and banana crops are generally cultivated using mineral fertilizers. Farmers who have used organic sources in addition to mineral fertilizers have obtained better yields and quality products.
- Farmers growing ginger at commercial level follow IPNS to obtain higher yields.

Some shortcomings of IPNS practices in Sri Lanka

- Farmers following straw recycling in rice-rice cropping systems skip a few seasons-due to socio economic reasons. By this, the necessary fertility build-up is retarded.
- Some farmers expect a overnight yield increases through straw recycling after the first season of application. Not finding this, some give up.
- Straw is generally not applied to rice-fallow systems.
- No importance is given to the recycling of crop stover of maize, chilli, onion etc. This depletes the organic carbon in the soil.
- Certain vegetable farmers build up man made soil profiles by bringing new earth to fill the top soil.
- Farmers who go for high intensive vegetable production often apply micronutrient solutions as foliar applications. The imbalance of plant nutrition may have necessitated them to do so.
- Fertilizer practices carried out on sandy regosols of Kalpitiya have shown groundwater pollution. The overuse of N fertilizers has contributed to this. Addition of organic manure may not be the best way to reduce pollution. A more nutrient efficient FUE approach has to be followed.

Assignments

1. Study the present adoption of IPNS in your area in different crops and cropping systems.
2. List main sources of plant nutrients applied by farmers in your area.

CHAPTER 4

IPNS for Rice, Vegetables, Chilli, Onion, Maize, Fruits, Root and Tuber Crops

Section I

IPNS FOR RICE

This chapter concerns with the major cereal crop of Sri Lanka which is rice. The chapter consists of general information on rice cultivation, nutrient removal by the rice crop, rice growing soils, and associated problems, rice based cropping systems, fertilizer recommendation for rice and IPNS practices.

It is expected to achieve the following broad objectives.

1. To provide information on general aspects of rice cultivation in Sri Lanka.
2. To know nutrient removal by the rice crop, and proven IPNS practices and assoiated problems in rice growing soils.
3. To provide information on rice based cropping systems practiced in different agro-ecological zones.
4. To know present fertilizer recommendation, and suggested IPNS practices.

Introduction

- Rice is the main cereal crop grown in Sri Lanka; it is grown under diverse environmental conditions; from drought prone areas of the dry zone to water logged and flood prone plains of the wet zone.
- Rice is grown in flat valleys almost at sea level to highly dissected terrains up to 1000 m above sea level. The temperature range varies from 17^0c to 40^0c.
- Due to the diversity of the environment and the soil conditions a number of growing systems and cropping patterns have been identified, like the *'Kekulan'* cultivation, and the *'meda'* cultivation etc. Cultivars used, crop duration and yields obtained vary according to these patterns and systems.
- Reported national average yield is 3.78 t/ha. But farmers who have practiced IPNS have obtained yields over 10 t/ha and sustain that level of production over the years.
- Under good management an average yield of 6-7 t/ha is easily achievable.
- IPNS practices that are in use are the application of rice straw, green manure, dried cow dung/poultry manure, 'charred' rice husk and chemical fertilizers.
- Improvement of chemical, physical and biological status of the rice growing soils, have been achieved using IPNS.
- More than 90% of the cultivars grown in Sri Lanka are 'New Improved Varieties' (NIV) with yield potentials over 10 t/ha. These yields are possible under favourable growing conditions.
- Rice cultivars are classified based on time taken from seedling to maturity.

Fig. 18: Demonstration to obtain 200 bushels of rice per acre using IPNS

Long aged (5 – 6 months) photo periodic sensitive 'Ma-Wee'
Medium aged (4 – 4 1/2 months)
Short aged (3 – 3 1/2 months)

- Current fertilizer recommendations for rice are based on Agro Ecological Zones (AEZ), soil texture, crop management and age of cultivar.
- Urea is the chief source of N, and the incorporation of urea is found to improve N efficiency.

Nutrient Removal in Rice Cultivation

Rice is an annual crop and it removes a considerable amount of nutrients proportional to the yield obtained. Higher quantities of potassium and silica are found in the straw and rice husk.

Table 6. Typical N, P, K, and Si content in rice straw and amounts removed by grain and straw in a 5t/ha crop (dry matter basis)

Nutrient	Content (%)		Removal (kg) by a crop yielding 5t/ha grain		Total removal (kg/ha)
	Straw	Grain	Straw	Grain	
N	0.74	1.26	37	63	100
P	0.10	0.26	5	13	18
K	1.81	0.32	90	16	106
Si	5.00	1.70	250	85	335

PRESENT SITUATION OF FERTILIZER USE IN RICE CULTIVATION

A major portion of fertilizer used in Sri Lanka is for rice. The fertilizer consumption pattern for the recent past shows that the Sri Lankan rice farmers use the recommended level or more than that of N for rice. But P use is about half the recommendation and the K use is three fourth of the recommendation. This shows an imbalance fertilizer use in rice cultivation.

Secondary or micronutrients are not generally recommended for rice cultivation in Sri Lanka and present studies show that there is a yield response to S, Zn and Cu application.

N application

Rice is very highly responsive to N application. Responses to N application vary with soil type, landscape, and crop duration and management conditions. As a thumb rule to produce 20 kg of rice, addition of 1 kg of N is needed. The N use efficiency in Sri Lanka is less than 30% due to high leaching and volatilization losses. Therefore, split application and soil incorporation are essential to increase the efficiency. Basically 3-4 split applications are recommended depending on the age of the variety. Generally urea should be mixed with soil after application to increase the N use efficiency. It is recommended that basal application of urea should be thoroughly mixed with the soil at the final land preparation.

Supplementary application is recommended if the crop management conditions are high with assured water supply. N should be applied to keep the leaf N content above 2.5%. This is particularly important at the heading stage and soil should be at field capacity. Weed free fields should be ensured and the soil should be maintained at field capacity before N application.

P application

Generally rice soils in Sri Lanka are low in available P. The responses to P application vary with soil type, pH and agro-ecological zones. The optimum response to P application in the dry zone is about 25-30 kg P_2O_5/ha and in the wet zone it ranges from 30-80 kg P_2O_5/ha depending on the soil type and soil pH. P application is generally recommended as a basal dressing and should be applied at the final land preparation and should be thoroughly mixed with the soil.

K application

Rice is one of the crops which predominantly absorb K. Response to added K in Sri Lanka vary with agro-ecological zone, soil, water supply, crop yield and season. Generally K is applied as a basal dressing for all rice crops. But additional K is recommended for iron toxic soils. Recently, additional K has been recommended if the targeted yields are high (more than 5t/ha.) to maintain soil fertility. Sufficient K (above 1.5% in leaf dry matter) after flowering is necessary to facilitate carbohydrate translocation, which enhances the grain filling to give an increased 1000 grain weight.

PROVEN IPNS PRACTICES IN RICE PRODUCTION FOR THE LOW COUNTRY DRY (DL) AND INTERMEDIATE ZONES (IL)

- Falling soil fertility of rice growing soils due to many reasons necessitates the use of IPNS to increase production.
- Application of chemical fertilizers alone cannot increase yields beyond the 6 t/ha limit.
- Addition of rice straw has improved the situation. Yields of 6.0 – 7.0 t/ha are possible with combined rice straw applications and recommended NPK applications.
- Addition of organic materials per acre.

i. Two tons of dried cow dung.

ii. Total weight of rice straw of the previous crop.

iii. Two hundred and fifty kg of charred rice husk

iv. One ton of green manure *(Glyricidia, Ipil-Ipil, Tithonia etc.)* had been recommended per acre to supplement the chemical fertilizers added.(N composition in leaves on dry basis in such materials should be greater than 3%).

- Basal application of 50 kg TSP and 50 kg. MOP along with 20kg of urea per acre.
- Supplementing the NPK with $ZnSo_4$ one kg/acre to meet the requirement of zinc.
- Rate of urea increased to total of 130-140 kg/ac. to meet the N demand.
- The utilization of this package with the following ensures a yield of 180-200 bu/ac.

i. Quality seed paddy of proven cultivars of;

(a) BG 357, BG 358, BG 360, BG 379/2, BG 352

(b) AT 354

ii. Closer spacing at 10 cm x 10 cm planting or 3 bu/ac for seed sowing.

iii. Proper irrigation, weed control etc.

- Direct application of rice straw without any addition of Nitrogeneous materials to narrow the C : N is possible.
- Rice straw in small heaps should be evenly placed on levies, before land preparation.
- Impounding of water results in imbibing and loss of tensile strength.
- After land preparation the heaps are distributed evenly on the levies and incorporated to the soil with the second ploughing.
- Other organic materials should be added after the second ploughing.

RICE GROWING ENVIRONMENTS

Diverse rice growing environments occur in Sri Lanka. Generally most of the soils are low in available P and exchangeable K. In addition soils in the dry and intermediate zones are low in organic matter content.

Associated problems in rice growing soils

Agro-Ecological Zone	Soil Type	Associated Problems
1. Low Country Dry Zone (DL)	Reddish brown earths	Presence of a shallow gravel layer, very hard when dry, sticky when wet, salinity due to poor drainage conditions in certain areas. Rice is grown in moderately to imperfectly drained soils.
	Low humic gley soils.	Deep soil, ground water table close to the surface, hard when dry, sticky when wet, salinity due to poor drainage conditions.
	Non calcic brown soils.	Poor in water retention and nutrients, salinity due to poor drainage specially in Mahaweli System B.
	Red yellow latosols.	Low water holding capacity and high leaching losses, salinity problems in coastal areas.
	Alluvial soils.	Deep soil, coarse soils are low in nutrients and water holding capacity.
2. Low Country . Intermediate Zone (IL)	Red yellow podzolic soils.	Low CEC, poor nutrient status and high leaching losses. Iron toxicity may occur in certain areas.
	Low humic gley soil.	Iron toxicity in certain land classes.
3. Mid Country Intermediate Zone (IM)	Immature brown loams/ Reddish brown latosolic soils.	Iron toxicity occur in valleys(first or second order Reddish brown latosolic soils.) P deficiency common in third order valleys.
4. Mid Country Wet Zone (WM)	Immature brown loams/ Reddish brown latosolic soils.	Iron toxicity and P deficiency very common.
5. Up Country Intermediate Zone (IU)	Red yellow podzols.	No major constraint other than water availability. Steepness of land is a problem.
6. Low Country Wet Zone (WL)	Mineral soils/Red yellow podzolic on laterite/Alluvials	Iron toxicity, P, Mg Ca and exchange-able K very low. Salinity in coastal rice lands.
	Bog soils.	High organic matter with poor drainage. Flooding in coastal areas. Salinity, iron toxicity in certain areas.

Note: See appendix 6 for agro ecological zones (map)

1. LOW COUNTRY DRY ZONE (DL)

Cropping Systems

i. Rice / Rice cropping system

Major crop is rice, This system is mainly found in major and minor irrigation schemes with assured water supply. Rice is grown both in maha and yala seasons.

ii. Rice / Other Field Crops (OFC) cropping system

Major crops are rice during maha and chilli, onion during yala. This system can be found in some major irrigation and minor irrigation schemes as well as in rainfed conditions. Shortage of water in yala season limits rice cultivation.But, shortage of water occurs in certain rainfed areas; thereby the farmers adopt Kekulan cultivation (dry ploughing) during maha season to conserve water.

iii Rice / Fallow cropping system

Major crop is rice which is mainly rainfed. Maha rain is sufficient for a short aged rice crop, but yala rain is not sufficient for rice or any other OFC.

Organic manure sources

Available organic materials are rice straw and green manure. Recommended straw application rate is about 4-5 t/ha. and green manure is recommended 2-3 t/ha. Application of cowdung is 5 t/ha. Poultry manure can also be applied at the rate of 3 t/ha. Charred rice husk can be applied at the rate of 625 kg/ha.

Fig. 19 Stray cattle do not contribute much to IPNS

Recommended fertilizer practices

(Refer DOA fertilizer recommendation for rice)

Farmer practices of IPNS

- Recycling of rice straw with chemical fertilizer
- Use of cow dung and poultry manure

Suggestions for improving the present systems of IPNS and fertilizer use efficiency (FUE)

- Planting of *Gliricidia*, or *Ipil Ipil* on the major bunds and hedge rows to supply green manure.
- Use of charred rice husk.
- Cultivation of sandwich crops.

Fig. 20: Straw recycling

Assignments

1. List organic materials available in the area for use in IPNS programme in rice.
2. Give your opinion of not using available organic materials for IPNS in rice.

2. LOW COUNTRY INTERMEDIATE ZONE (IL)

Cropping Systems

i. Rice / Rice

Major crop is rice and mainly found in major and minor irrigation schemes and under rainfed conditions.

ii. Rice / Other Field Crops

Major crops are rice, green gram, cowpea and black gram. There may be a water shortage during yala season; these farmers practice Kekulan cultivation for early establishment of the crop.

iii. Rice / Fallow

Similar to rice/fallow system found in the dry zone.

Organic manure sources

Green manure is prevalent as *Gliricidia. Mee, Keppetiya, Ipil Ipil and Sooriya*. Application rate is about 4-5t/ha of green materials. Apply crop residues at 2.5 to 5 t/ha. Cowdung 5t/ha and poultry manure 3t/ha and paddy husk charcoal 625 kg/ha can be applied.

Recommended fertilizer practices

(See DOA fertilizer recommendation for rice)

Farmer practices of IPNS

- Recycling of rice straw
- Use of cowdung and poultry manure

Suggestions for improving the present systems of IPNS, and FUE

- Use of green manure and cultivation of *Gliricidia and Ipil Ipil* around the fields as green manure.
- Growing of sandwich crops.
- Use of charred rice husks.

Fig 21: Preparation of charred rice husk

Assignments

1. List different organic materials available for IPNS in rice in the area.
2. Suggest ways of increasing the available materials for IPNS in rice.

3. MID COUNTRY INTERMEDIATE ZONE (IM)

Fig. 22: Why burn rice straw ?

Cropping Systems

I. RICE /RICE

Major crop is rice and short aged rice cultivars are cultivated during yala season due to water scarcity.

II. RICE / VEGETABLE

Major crops are rice and vegetables. Yala rains are not sufficient for a rice crop. Well drained soils are used for vegetable cultivation.

Organic manure sources

Available organic materials are rice straw, rice husk and green manure *(Gliricidia, Wild sunflower, Ipil Ipil, 'Kekuna'),* and animal waste.

Recommended fertilizer practices

(See DOA fertilizer recommendation for rice)

Farmer practices of IPNS

Farmers use rice straw as the main source of organic manure, and rarely use cowdung or poultry manure for their rice crops, but use these materials often for vegetable cultivation. Farmers also use green manure crops as organic manure, in small quantities.

Suggestions to improve present system of IPNS and FUE

- Use of both rice straw and chemical fertilizer.
- Use of available green manure plants.
- Use of cow dung and poultry manure to supplement chemical fertilizer.
- Cultivation of legumes and incorporation of crop residues.
- Use of charred rice husk.

Assignments

1. Study various organic materials use for rice in the area.
2. What are the IPNS practices done by the farmers of your area.

4. MID COUNTRY WET ZONE (WM)

Cropping Systems

Rice /Rice

Major crops is rice which is grown in both yala and maha seasons.

Organic manure sources

Available organic materials are rice straw, green manure *(Gliricidia; Wild sunflower, Ipil Ipil, Kekukna, Kaduru)* and animal wastes such as poultry manure.

Recommended fertilizer practices

(See DOA fertilizer recommendation for rice)

Farmer practices of IPNS

Farmers use rice straw as the main source of organic manure and rarely use cowdung or poultry manure for their rice crops, but they use these materials in large amounts for vegetable cultivation.

Some farmers use green manure crops as organic manure sources but not in big quantities.

Suggestions to improve present system of IPNS and FUE

- Use of rice straw along with recommended levels of chemical fertilizer.
- Use of green manure available in the surroundings.

Fig 23: Green manure application

- Use of cow dung, poultry manure to supplement chemical fertilizer.
- Use of rice husk charcoal.

Assignments

1. Study materials available for IPNS in the area.
2. What are the strengths and weaknesses of IPNS presently done in the area.

5. UPCOUNTRY INTERMEDIATE ZONE (IU)

Cropping systems

Rice/potato/vegetable

Rice /vegetable /vegetable

Rice /vegetable

Rice /rice

Major crops are rice, potato, vegetable.

Available organic manure sources

Available organic materials are rice straw, paddy husks and green manure *(Gliricidia; Wild sunflower, Ipil Ipil)* and animal waste such as poultry manure.

Recommended fertilizer practices

(See DOA fertilizer recommendation for rice)

Farmer practices of IPNS

Farmers add high amounts of poultry manure and cattle manure for vegetable and potato crops. But they rarely use organic or green manure for their rice crop. Since they use high amounts of TSP and MOP for vegetables or potato, such soils are rich in available P and exchangeble K.

Suggestions to improve IPNS practices

- Use of decomposed rice straw as a supplement to chemical fertilizer for potato and vegetables.
- Use of organic manure as poultry manure and cowdung for potato and vegetables.

Assignments

1. List the organic materials available for IPNS for rice in the area.
2. Suggest ways of increasing the available materials for IPNS in rice in the area.

6. LOW COUNTRY WET ZONE (WL)

Cropping systems

There are several cropping systems

- Mawee lands - Rice / fallow
- Devaraddri - Rice / fallow
- Rice / Rice

Available organic manure sources

Available organic materials are rice straw, green manure *(Gliricidia; Kekuna, Kaduru),* rice husk, rice husk charcoal and animal waste such as poultry manure,

Recommended Fertilizer Practices

(See DOA fertilizer recommendation for rice)

Farmer practices of IPNS

- Use of NPK fertilizer
- Use of rice straw.

Suggestions to improve the present system of IPNS and Fertilizer Use Efficiency (FUE)

- Straw recycling in addition to recommended levels of NPK.
- Poultry manure 3t/ha with recommended levels of NPK.
- Additional levels of K to overcome Fe toxicity
- Cultivation of reduced iron tolerant varieties such as BW 267-3 and LD-356 to escape Fe toxicity.
- Application of about 625 kg/ha of charred rice husk.
- More balanced nutrient management.

Fig. 24: Iron toxity in Rice in the low country wet zone

Assignments

1. Study various organic materials used in the area for rice cultivation.
2. List the problems you observe for potential use of organic materials for IPNS in the area.

Package of IPNS practices to obtain 200 bu/ac of rice in the dry & intermediate low country regions.

A) Fertilizer inputs to be used per ac (4000 m^2)

1. Organic manure

a)	Rice straw	-	Entire quantity of the previous season rice crop but not less than 3 tons
b)	Cow dung	-	Dried cow dung 2 tons
	or		
	Poultry manure	-	Well rotted poultry manure 1 ton
c)	Green manure	-	Tender loppings with leaves of *(Gliricidia/Ipil Ipil/ Karanda/Wal Sooriya/Sooriya* etc.) 1 ton.
d)	Rice husk charcoal	-	250 kg of rice husk charcoal.

2. Chemical Fertilizers

a)	Urea	120	-	140 Kg
b)	TSP	45	-	50 Kg
c)	MOP	45	-	50 Kg
d)	Zinc sulphate	1	-	2 Kg

B) Time of application

1. Organic manure

Rice straw	-	After first ploughing
Green manure		
Cow dung	-	After second ploughing
Rice husk charcoal		

2. Chemical fertilizers

Basal application	20 kg urea, 45-50kg TSP, 30 Kg MOP,1-2 Kg Zinc Sulphate. Apply before levelling and incorporate into the soil.
Top dressing.	Apply urea, based on DOA recommendation or based on colour of youngest leaf. (use leaf colour chart). Apply 20 Kg of MOP one before the last top dressings along with urea. Apply only urea at the last top dressing.

Section II

IPNS FOR VEGETABLES

This section deals with the general importance of cultivating vegetables in Sri Lanka, vegetable growing eco-systems and cropping systems involving vegetable crops, IPNS practices by farmers and DOA fertilizer recommendation, and the suggestions and improvements to future IPNS programmes.

Following broad objectives are to be achieved by the user.

1. To get knowledge on important aspects of vegetables grown in Sri Lanka.
2. To know vegetable growing eco-systems and different cropping systems.
3. To know the DOA fertilizer recommendations, practices of IPNS by the farmers and suggestions to improve present IPNS practices.

Introduction

- Vegetables are an important component of the Sri Lankan diet.

They provide

a.	Minerals	b.	Vitamins
c.	Fibre	d.	Energy

- Most vegetables grown in the country are consumed locally, a small percentage is exported to countries like Maldives and the Middle East.
- The demand for vegetables is high, per capita consumption is far below the required standards of WHO.
- Vegetables have a horizontal demand throughout the year but the supplies are seasonal due to crop and location differences.
- This results in price fluctuations and less demand for certain high priced vegetables during off seasons.
- Our production trends are very low improper fertilization and nutrient management are reasons for yield and income losses.
- Current demand for vegetable quality

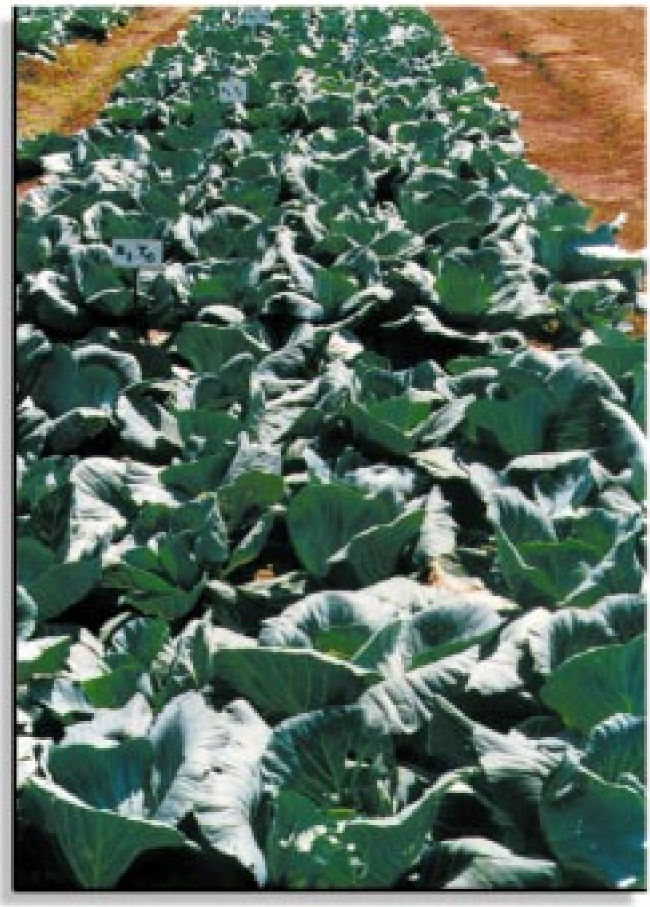


Fig 25 Cabbage grown as a monocrop in UCWZ

such as appearance, right size, colour, flavour and keeping quality is increasing.

- Vegetables free from residues of heavy metals and pesticides are preferred and such vegetables fetch high prices.
- Over use of Nitrogeneous fertilizers with high accumulation of NO_3-N in tissues are also not advocated for health reasons.
- In Sri Lanka vegetables are broadly classified into local and exotic.
- Local vegetables are those endemic species or introduced from time immemorial, whereas exotic vegetables have been introduced recently.
- A large number of local vegetables like 'tibbatu', 'thalana batu' and 'thumba karawila' have a high consumer demand.
- Vegetables are grown under different systems of mono cropping and mixed cropping. The latter is practiced when land is limited.
- Mixed cropping systems carry two to three crops or even 6 to 7 crops. Often a relay system is found in many places.

Vegetable growing eco-systems

- Exotic vegetables are extensively grown in the up country regions of both wet and intermediate zones.
- Exotic vegetables are grown under good management practices and with supplementary irrigation.
- Local vegetables are limited to the mid country and low country regions. Their management levels are lower compared to the level of the exotic vegetables. Supplementary irrigation is practiced in some areas but rainfed cultivation is very common.
- Intensive cultivation of local vegetables under selected crops is done in different geographical areas.
- Gotukola is a special crop in the Chilaw-Arachchikattuwa areas. Brinjal and *'Beeralu'* radish is produced extensively in the Matara and Wariyapola areas. Tomato and Okra are grown in the Matale district in the intermediate zone.
- Yams for using as vegetables are common in the Gampaha and Kalutara districts.

Nutrient management in vegetable production (Farmer practices).

- Vegetable growers add more than the recommended rates of fertilizer and organic manure applications. This habit is universal.
- Farmers apply high doses of fertilizers and sometimes foliar nutrient solutions though the latter has not proved to be essential.
- Phosphorus fertilizers which are recommended to be applied as a basal application are applied with top dressings which results in wastage and high build up of P in the soil.

- Top dressed fertilizers are not covered up by soil and losses occur.
- Some farmers apply organic manure as top dressings.

1. VEGETABLE BASED CROPPING SYSTEMS OF THE UP COUNTRY WET ZONE (WU)

Recommended practices

- Vegetables are cultivated throughout the year either in rotation with potato or otherwise.
- Addition of organic manure as well rotted cow dung, poultry litter and chemical fertilizers are recommended.
- Liming at 2t/ha every 1-2 years is recommended. Lime should be added 2-3 weeks before the addition of chemical fertilizers.
- Nutrients from organic manures used should be accounted for; this requires the adjustment of PK in the chemical fertilizers used.
- Soil testing in every two years will enable the evaluation of the nutrient status of the soils.
- A starter dose of P and K fertilizers is necessary in spite of a heavy build up of these nutrients in the soils.
- No P fertilizers should be added as top dressings.
- All N fertilizers should be covered with a layer of soil to prevent volatilization losses. Use only straight fertilizers.

General farmer practices

- Farmers do not allow the soil to rest and only a short period is allowed from one crop to another.
- A few farmers transport soil from elsewhere to be applied as top soil. The reason for this is not well known, but nematode build up, nutrient build up and acidification of soils, may be

Fig 26: Intensive application of cowdung

some of the reasons.
- Farmers add large quantities of organic manure to soil after liming. The rates vary from 20-60 t/ha. which is too high.
- Liming is done with quick lime and dolomite. The former is used in lesser quantities but the latter sometimes exceeds recommended practices. Fields are not allowed more than a few days (3-4 day) after liming which is not desirable
- Ammonia based fertilizer mixtures when added to limed soils liberate ammonia gas, polluting the atmosphere.

- Many farmers continue to use fertilizer mixtures. This results in the use of phosphorus containing mixtures as top dressings.
- Most farmers apply liquid fertilizers 2-5 times depending on the types of crops.
- Farmers seldom recycle crop residue due to the fear of proliferation of disease organisms.
- Cropping systems follow a set pattern, which includes a crop of potato in the annual cycle. Radish is grown during the wet windy season with minimum addition of plant nutrients.

2. VEGETABLE BASED CROPPING SYSTEMS OF THE UP COUNTRY INTERMEDIATE ZONE (IU)

Recommended practices

- Vegetable growing areas are of two types.

a. Vegetable-potato growing uplands.

b. Rice-potato-vegetable growing rice lands.

- Practices listed for the WU are applicable.
- Poultry manure is recommended. Liming should be done according to the type of crop grown. Potato scab is controlled at low pH while clubroot of cabbage is controlled at high pH.
- Poultry litter has the capacity to correct acidity.
- Combined use of chemical fertilizers with poultry manure gives promising results (Table 8)

Table 7. Fertilizer recommendations for some vegetable crops

Crop	Recommendation (kg/ha)		
	N	P_2O_5	K_2O
Leek	200	125	90
Capsicum	90	100	80
Potato	150	125	150
Tomato*	90	150	80
Bean	100	125	90

*Except Badulla district

Table 8: Effect of organic manure and chemical fertilizers on cabbage yield.

Treatment	Yield (t/ha)
Control	10.4
Chemical fertilizer	55.0
Cattle manure	32.4
Compost	33.8
Poultry manure	58.0
Cattle manure+Chemical fertilizer	55.3
Compost+Chemical fertilizer	57.9
Poultry manure+Chemical fertilizer	88.1

Manure application rate - 10 t/ha, chemical ferilizer application rate - DOA recommended level.

General farmer practices

- Farmers pay attention to the vegetable / potato crop in rice based cropping systems than the rice crop.
- Organic manures are not used at the same rate as the WU farmers. Poultry litter is often used by the tomato growers.
- Other practices are similar to that of the WU, except in crops like brinjal.
- Brinjal farmers seldom apply organic manure, but farmers who have applied organic manure obtained higher yields.

3. VEGETABLE GROWING SYSTEMS OF THE MID COUNTRY WET AND INTERMEDIATE ZONES (WM & IM)

- Bulk of the traditional local vegetables are grown in this area. Many crops are grown rainfed both in uplands and lowlands.
- On the uplands vegetable-vegetable or vegetable-fallow systems occur depending on the availability of rainfall.
- In rice based cropping systems a maha crop of rice is followed by a yala crop of vegetables.
- Both mono and mixed cropping is carried out in rice based cropping systems.

Recommended practices

- Use organic manure as cow dung, poultry litter and other available sources.
- Lime the soil, if pH is low.
- Apply straight fertilizers based on soil test recommendations.
- Recycle crop residues, if free from diseases.

General farmer practices

- Farmers who grow quality vegetables apply organic manures as cow dung, poultry litter or green manure. Some farmers mulch their crops with straw of the previous rice crop.

- Mixed cropping is practiced in both twining and erect types of crops. These types of crops are fertilized at different times. As a result heavy application per unit area takes place.
- Most farmers rely only on chemical fertilizers, some have got used to foliar applications.
- Recycling of vegetable crop residues is seldom carried out.

4. VEGETABLE GROWING SYSTEMS OF THE LOW COUNTRY DRY AND INTERMEDIATE ZONES.

- Vegetable cultivators in the area adopt both primitive and intensive methods.
- Vegetable cultivation during the maha rainfed systems make use of available plant nutrients of the soil, often a dose of urea is applied to boost growth.
- Vegetables are grown round the year in the well-drained coastal regions of Kalpitiya and Nilavelly areas or as semi-perennial leafy vegetables in the Arachchikattuwa areas.
- An intensive form of vegetable cultivation has evolved around the lift-irrigated waters of the dug well programmes. These are distributed in the dry and intermediate regions of the Kurunegala, Puttalam, Matale and Anuradhapura district.
- A rice based cropping system is followed in the dug-well programme with rice being cultivated during the maha season.
- An unique feature of the intensive system of cultivation is the repetition of the same crop two to three times within the same season.
- Perennial crops of *tibbatu, thumba* and mormodica varieties are grown on uplands with heavy applications of chemical fertilizers.
- Cooking bananas are grown with or without irrigation using chemical fertilizers.

Recommended practices

- Use of organic manure as cow dung, goat dung, poultry litter, crop residues and green manure.
- Soil and water testing for quality of irrigation water of dug wells.
- Soil test based fertilizer recommendations using straight fertilizers will keep balance of plant nutrients.
- Erosion control of soils to retain top soil and mulching of soils to prevent salt movement upward.
- Recycling of crop residues and crop rotation should be practiced.
- Farmers practice monocrop often followed by another crop of the same species.
- Organic manure is not added as a general practice but a handful of farmers obtain higher yields, using organic manure.
- Farmers attempt to rely on chemical fertilizers and foliar applications.

5. VEGETABLE GROWING SYSTEMS OF THE LOW COUNTRY WET ZONE (WL)

- Vegetables are grown in association with rice based cropping systems; either during the maha season on well drained lands or on "ovita" of the rice lands.
- Vegetables are also grown on well-drained marshy lands and on uplands adjoining streams.
- Erect and twining type local vegetables and leafy vegetables are the main crops.

Recommended practices

- Draining of vegetable beds, erosion and flood control.
- Application of organic manure and chemical fertilizers after obtaining soil test values.
- Use of green manure and crop residues as mulches and a source of organic manure.
- Liming of soils to adjust pH when necessary.

Farmer practices

- Farmers have specialized in the production of certain species in identified locations. Brinjal and *'beeralu'* radish is grown in the Matara district.
- Here heavy application of organic manure is done; sometimes as basal and top dressings.
- The leafy vegetables are heavily fertilized both with organic manure and chemical fertilizers.

Fig 27: *Gotukola* cultivation at Arachchikattuwa

Assignments:

1. Find out ways of obtaining organic materials by farmers in the area.
2. List organic materials available in the area for IPNS in vegetables.

Section III

IPNS for Chilli, Onion and Maize

This chapter on chilli, onion and maize gives a general introduction to nutrient removal, farmer practices, cropping systems, current fertilizer recommendations and suggested IPNS practices using available materials.

It is excepted to achieve following objectives.

1. To know general characteristics of chilli, onion & maize.
2. To get information on cropping systems adopted in different agro climatical zones for these crops.
3. To impart knowledge on current fertilizer recommendations and farmer practices for these crops.
4. Suggestions for the adoption of IPNS in chilli, onion & maize.

1. Chilli

Introduction:

- Chilli is a cash crop grown in Sri Lanka and is used as a condiment in the daily diet.
- Chilli is grown from sea level to 1600 m above mean sea level. It is more adaptable to the dry and intermediate zones of the low country dry zone.
- Chilli was traditionally grown as a chena crop in the past. Several varieties are now systematically cultivated as an irrigated mono crop both in the well drained low lands and the irrigated uplands.
- It is grown as a rainfed upland crop during the maha season.
- Chilli is an annual crop (120-150 days) with a yield potential of 5t/ha (dry chilli) resulting in a heavy removal of plant nutrients.
- It is grown in soils generally low in plant nutrients and organic matter.
- Chilli is grown for both green chilli (vegetable) and dry chilli.

Nutrient Removal

Table 9: Nutrient removal by Chilli crop yielding 2 t/ha

Element	N	P	K	Ca	Mg	S	Total
Removal (kg/ha)	64	6	84	10	9	8	181

Source: Amarasiri and Perera

CHILLI GROWING ENVIROMENTS AND CROPPING SYSTEMS

The following chilli based cropping systems have been identified.

1. Chilli-fallow system: Rainfed uplands.

- Low input system
- Soil moisture is the major production constraint.
- Low chemical fertilizer and other input use.
- Uncertain rainfall.
- Establishing crop with first rains.
- No basal fertilizer application.
- Top dressing of fertilizer may be practiced depending on rain.
- Low application of organic materials.

2. Vegetable–Chilli system : Uplands with supplementary Irrigation

- Under agro-wells farmers establish the chilli crop in late August or early September to catch high prices for green chilli.
- High input system.
- Chemical fertilizers and pesticides used heavily.
- No organic materials applied.

3. Fallow - Chilli system : Uplands and Lowlands with irrigation.

- Establish chilli in December after heavy rain to avoid high incidence of pests & diseases due to excessive rains.
- Organic manure applications are rarely practiced.

4. Rice- Chilli system : Paddy fields under irrigation

- Major chilli growing system.
- Establish chilli crop after maha season's paddy harvest.
- Well drained and moderately drained soils are used.
- High input system using heavy doses of fertilizers and pesticides.
- Organic manures are rarely applied.

5. Chilli–Red onion System : Kalpitiya regosols

Fig 28: Chilli in Kalpitiya regosols

- Fairly intensive chilli production system.
- Soils are sandy regosols poor in nutrients and water holding capacity.
- High rate of application of fertilizer & irrigation is common.
- Application of organic manure, cover crops and use of crop residues is practiced by some farmers.

6. Green chilli – vegetable relay cropping system: Kalpitiya regosols

- Conditions are the same as in chilli and red onion systems followed in Kalpitiya.
- Chilli is grown for green pods mainly.

7. Chilli-Gingelly cropping system : Rainfed uplands in Jaffna coastal belts and areas of Anuradhapura & Polonnaruwa.

- Chilli is planted to catch the maha rains.
- Not an intensive system and depends on rains.
- Crop residues of gingelly are used.

8. Chilli-Onion system in uplands in Vavuniya.

- Chilli crop grown in well drained reddish brown earths.
- Organic manure application not commonly practiced.
- Chemical fertilizers and liquid fertilizers are mainly used.

Farmer practices

- Practices of nutrient management differ greatly from place to place. Farmers of the eastern coast keep cattle for a few nights on the land to enrich the soil with dung and urine.
- Farmers of Jafna, Kalpitiya and some in the Anuradhapura district add cattle manure before planting their crops.
- Some farmers use poultry litter.
- Chemical fertilizers in the form of mixtures are added as basal and top dressings.
- Farmers who use straight fertilizers often add urea as a top dressing but seldom cover it with soil.
- Foliar fertilizers are sprayed by most farmers.

Recommend fertilizer practices (DOA)

Fertilizer recommendations are given under two methods of chilli cultivation.

a. Irrigated cultivation
b. Rainfed cultivation

Table 10 : Chilli (Irrigated & Rainfed)

Time of Application	Irrigated			Rainfed		
	Amount of Fertilizer (kg/ha)			Amount of Fertilizer (kg/ha)		
	Urea	TSP	MOP	Urea	TSP	MOP
1. Basal dressing at planting.	-	100	50	-	100	50
2. Two weeks after transplanting (TD)	65	-	50	65	-	50
3. Four weeks after transplanting (TD)	85	-	-	65	-	-
4. 8 weeks after transplanting (TD)	85	-	-	65	-	-
5. 12 weeks after transplanting (TD)	85	-	-	65	-	-
Total	**320**	**100**	**100**	**260**	**100**	**100**

TD - top dressing

Recommended usage of organic materials

Depending on the availability of different organic materials, farmer can choose different forms for chilli cultivation. Both under irrigated or rainfed conditions organic matter application is beneficial.

1. Animal manure

These should be used 2-3 weeks before planting by incorporating to the soil.

Materials used :

a. Cowdung 10-15 t/ha

b. Poultry manure 3-4 t/ha

c. Goat dung 5-6 t/ha

Depending on the conditions and availability, application either individually or in combination can be done.

2. Mulching

- Depending on the availability of materials such as rice straw, Gliricidia leaves, crop residues or other suitable materials mulches can be placed in between rows in standing crops.

Fig 29: Mulching chilli with straw

- Rate : Generally 5-8 t/ha on dry matter basis up to a thickness of 2-4 cms above ground.

3. *Crop Residues*

- These could be ploughed in to the soil. Even weeds can be incorporated.
- Ploughing immediately after harvest of the crop.
- Recycling the residue gives better results.
- Avoid planting the same crop after incorporating crop residues from identical crops.
- Do not apply crop residues infected with pests & diseases.

4. *Green Manure*

Green manure crops can be grown during the fallow season if enough soil moisture is available. It can also be used as a rotational crop. This can be ploughed in when 50% flowering has taken placed. eg. Sun hemp.

- About 30-40 kg/ha of seeds of a green manure crop is required for establishment.
- Green manure crops should be incorporated to the soil at least 3-4 weeks before the establishment of the chilli crop.
- Green manure crops grown outside such as gliricidia can be brought in and ploughed in at least 3-4 weeks before establishment of the chilli crop.

5. *Compost*

Compost can be prepared in the field and applied before planting of the chilli crop.

Application is similar to that of cattle manure.

- Compost at the rate of 5-10 t/ha is sufficient.
- Crop residues can be composted and used subsequently.

Assignments

1. Study chilli based cropping systems in your area.
2. Identify and list different organic materials which can be used for IPNS in chilli cultivation.
3. Note different IPNS practices for chilli done by farmers and suggest improvements.

2. Red Onion

Introduction

- Red Onion is a condiment crop which is an important part in the Sri Lankan diet.
- Red Onion is grown in different parts of the country for two purposes.
  - i. For bulb production.
  - ii. For spring onions.
- Bulb crops are important cash crops for the producers.
- Per capita requirement of red onion is 4-7 kg/yr and the present production is enough only to provide 2 kg/y per head.
- Red onion is grown as a monocrop which fits into the following identified cropping systems.

RED ONION BASED CROPPING SYSTEMS

1. Red onion cultivation in hilly areas : Ratnapura district. (Ambewila, Sooriyakanda, Kolonna area)

- Grown in maha under rainfed conditions to fetch higher prices.
- Some soil conservation practices are adapted. Lands are prone to soil erosion.
- Chemical fertilizers are used. Organic manure usage is limited.
- Production is affected by fungal diseases.

2. Red Onion – Red onion system: Trincomalee district.

- Practiced in sandy soils in the Nilaveli area.
- Continuous cultivation is practiced due to better soil and climatic conditions.
- Fertilizer application is very frequent due to sandy nature of soil.
- Mainly chemical fertilizers are applied with little or no organic manure.

3. Potato/Tobacco – Red Onion system : Jaffna.

- Very high income generating system, practiced under irrigation.
- High organic material application. Cowdung, green manure & crop residues.
- Fertilizers are applied sufficiently.
- Crop establish in the yala season.

4. Rice–Red onion system : Ratnapura district.

- Red onions are grown under irrigation in paddy fields after maha rice.
- Chemical fertilizers are used.
- No organic manure is applied.

5. Rice – Red onion : Jaffna.

- Similar to rice-big onion cropping system in the dry zone areas.
- Application of organic manure is high.

- Planting done after maha rice crop.

6. Systems in sandy regosols: Kalpitiya

a Red Onion – Red onion system

b. Red Onion – Green chilli system

c. Red Onion – Vegetable – Red Onion system

d. Red Onion – Sweet potato – Red Onion system.

- Red onion grows well in sandy regosols.
- Apply high fertilizer and frequent irrigation to compensate for quick leaching.
- Organic manure is used.
- Can be grown throughout the year except in very wet months of November and December.
- Liquid fertilizer is used.
- Red onion/Red onion system exposes crops to disease problems.

7. Red onion – Vegetable/ OFC system: Telulla, Moneragala.

- Red onion crop is establish in yala.
- Maha crops are vegetables / OFC.
- Chemical fertilizer is used sufficiently.
- Organic manure usage is low.

Proven IPNS practices used by farmers.

- Soils are prepared to seed the bulbs by keeping cattle on the land or applying large quantities of organic manures like cowdung/poultry litter, specially by the Nilavelly farmers. Few farmers apply green manure.

Fig 30: Red onion grown in regosols

- Seed bulbs are planted at a close spacing on the sand.
- Often two irrigations are given daily. 6-8 applications of chemical fertilizer mixtures are carried out.
- Cultivation of onions on raised beds is carried out in most of the other growing areas.
- Irrigation is done :

  By filling the furrow

  Sprinkling water

  Use of sprinklers

  Drip irrigation systems
- Two to three fertilizer applications are carried out.
- Few farmers practice the use of adding organic manure before planting seed bulbs. Farmers who do it get better yields.

- Farmers seldom mix applied fertilizers with the soil, they presume that fertilizers will dissolve in the irrigated water and will be used by the crop.
- Farmers cultivate hilly slopes even up to 45% in the Sooriyakanda area resulting in severe soil erosion.

Recommended practices

- Application of organic manures before planting into the holes.

  Animal wastes – Farm yard manure, dried cowdung, poultry litter, goat dung etc.

  Green manure of sunhemp, gliricidia, thespesia etc.

  Crop residues of green gram, black gram, cowpea.
- Mulching of beds with rice straw, rice husk and other crop residues after planting.
- Application of chemical fertilizers and incorporating into the soil.
- Application of ammonium sulphate as basal fertilizer for sandy coastal soils. Top dressing with NK fertilizers.
- Limit over irrigation.

3. Big Onion

Introduction

- It is a condiment crop which is an essential ingredient of the daily diet of Sri Lankans.
- Total annual requirement is 90,000 tons of which 50% is imported despite the possibility of producing it locally.
- Area under cultivation is 3000 ha producing about 22500 tons.
- Potential yield is about 30 t/h however average yield is 10 -12t/h.
- Big onions are mostly grown in the central parts of the island on well drained RBE/LHG soils. It is grown as a yala crop in paddy soils as well as in uplands using irrigation water supplied through reservoirs or that is lift irrigated from dug wells or drainage channels.
- Farmers growing big onions raised from seedlings on beds with little or no addition of plant nutrients.
- Seedlings are planted on raised beds.
- Some farmers use organic manures before planting the seedlings. Many rely on chemical fertilizers only.
- A close spacing followed by over applications of NK fertilizers as a top dressing is practiced.
- Often farmers try to correct the imbalanced application of nutrients brought about by overuse of fertilizer by spraying foliar nutrients.

BIG ONION - BASED CROPPING SYSTEMS

1. Rice – Big onion system : Lowland paddy fields low country dry zone

- Comparatively high input system.
- Big onion is grown during the yala season after the maha season rice at the end of April rains.
- Low application of organic manure.
- Chemical fertilizer and liquid fertilizer are applied frequently.

- Heavy use of fungicides & insecticides.
- Rice straw is available as a crop residue.

2. Vegetable / OFC – Big Onion System : Uplands of low country dry zone (DL)

- Mostly practiced under agro-wells.
- Big onions are planted after the previous season vegetables such as long bean, okra, brinjal and OFC like maize, chilli, cowpea, soybean, black gram & finger millets.
- Establishment of onions a few weeks earlier than the first cropping system to catch higher prices.
- Use of organic manure is very low.
- Use comparatively high doses of fertilizer & pesticides.

RECOMMENDED PRACTICES

- Are similar to that of the red onion crop.
- Poor quality irrigation water containing dissolved salts can reduce yields.
- Fertilizers should be applied to meet the yield targets.
- Over application of N fertilizers results in bulbs with very poor keeping quality.
- Conservation methods to prevent the loss of top soils in uplands are necessary.
- Recycling of crop wastes should be practiced.
- Crop rotation to control pathogen build up is necessary.

Fig 31: Sunhemp grown for green manuring of onion

Assignments:

1. Study onion based cropping systems in your area
2. Identify and list different organic materials that can be used in IPNS for onion cultivation.
3. List diffrent IPNS practices done by farmers and suggest improvments for onion.

4. Maize

Introduction

- Up to recent times maize was grown as a chena crop mixed with other cereals, legumes and other crops.
- At present it is grown as a monocrop with varying densities to give 50000 –60000 plants / ha.
- Maize is grown both as a rainfed maha crop and as an irrigated yala crop in the well drained paddy lands and uplands with supplementary irrigation.
- Farmers do not pay enough attention to balanced fertilization in growing maize. Under heavy densities of planting N fertilizers are used heavily on soils already depleted in organic carbon, P and K.
- Crop residues are seldom recycled and are often burnt, resulting in further depletion of soil carbon and loss of plant nutrients.
- Close planting with two to three seeds per hole results in only one plant growing fully and the others weakening to give small sized cobs.

Recommended practices

- Maize is a heavy remover of plant nutrients and the roots go deep up to 2m in loose soils. Thus adequate plant nutrients are necessary to obtain a crop yield of 6-8 t/ha.
- Basal application of fertilizers and mixing them with the soil are necessary.
- Application of organic manure, is beneficial.
- Crop residues as stover and cob stalks can be composted and applied to the next crop.

Fig 32: Maize

- Over use of N should be avoided.
- N deficiency results in a loosely filled cob, while potassium deficiency results in empty cob ends. Phosphorus deficiency results in shrunken grains. (See appendix 1a)
- A balanced fertilizer management should be followed. Heavy yielding varieties should be compensated by adding more plant nutrients.

- Maize could be grown mixed with legumes such as ground nut, green gram or cowpea. This increases the land utility index.
- Farmers cultivating maize under rainfed cultivation must plant seeds along with the first rains. This will benefit the roots to capture the nitrates formed with bacterial action. Delay in planting results in the loss of these nitrates through leaching and denitrification.
- Maize roots are susceptible to poor drainage, which results in stunted and yellowing of leaves. Also water stagnation results in loss of N through denitrification of the soil N and any added N fertilizers. Adequate drainage should be provided. Top dressing of fertilizer should be done after the soils have been drained.

Assignments

1. Describe how maize crop residues can be used in your area.
2. Indicate different maize based cropping systems in your area.

Section IV

IPNS PRACTICES FOR FRUIT CROPS

This section deals with banana, papaw, pineapple, passionfruit, citrus, rambutan and mango which are important fruit crops grown in Sri Lanka.

The following are the broad objectives

1. To provide knowledge on physiological and nutritional characteristics of fruit crops.
2. To give information on current nutrient management practices of farmers and DOA recommendations.
3. To suggest IPNS that can be adopted for fruit crops.

Introduction to Fruit Crops Nature and Characteristics

The physiology and nutrition of fruit crops are different from annual crops in many respects. Some of the aspects which need consideration are

- Long vegetative phase (most of them are perenials)
- Large tree size
- Long life span
- Very high bio-mass
- Very low proportion of economical yield to total bio-mass at fruiting

e.g.

Banana	5 - 10%
Papaya	4 - 6%
Pineapple	50 - 60%
Passion fruit	5 - 10%
Lime	5 - 7%

- Very high non-productive biomass. eg. branches, wood, trunk etc. that had to be maintained.
- Very high food deposits in non-edible portions of the tree. eg., bark, wood etc.
- Large canopy with its yearly new flush.
- Very high maintenance of respiration of the tree.
- Yield is sensitive to weather, climate and nutrition.
- Balanced nutrition, time of application and soil conditions are critical factors that affect the final yield.
- Flowering, fruit yield (number of fruits and fruit size) and fruit quality (sugar and acid content, firmness, shape etc.) are governed by amount, type and availability of primary and micro nutrients.
- Amount, type, availability and solubility of nutrients in the soil also affect alternate bearing and fruit/ flower abscission.
- Plant nutrient removal alone is not a reliable measure to determine the nutrient requirement for most fruit crops.

Therefore, selection of proper fertilizer materials, appropriate time of application, suitable method of application and correct amounts are extremely important to obtain a good yield.

1. BANANA

- Extent cultivated: about 49,000 ha. which contributes to 46%of the total fruit crop extent in the island. (1997)
- Varieties and distribution:

Agroclimatic Zone	Varieties recommended
Dry Zone	Kolikuttu, Ambul, Seeni, Ash, Mondan varieties, Atamuru
Intermediate Zone	Kolikuttu, Ambul, Seeni, Anamalu, Ambon, Ash, Mondan varieties, Atamuru, Kitala
Wet Zone	Ambul, Ambon, Puwalu, Seeni, Anamalu, Rathambala, Suwandel, Bin kesel, Mondan varieties, Atamuru, Kitala

Current nutrient management practices

1. Farmer practices

Basal dressing

- Compost, about 5kg/planting hole. (kitchen waste, cattle manure or farmyard manure are also used).
- Poultry manure is not used for banana, as farmers believe that it promotes banana diseases.

Fig. 33: Pineapple intercrop with banana

- For banana under coconut, farmers use a layer of coconut husks in the bottom of the planting hole and a coir dust layer as a mulch to maintain moisture levels.
- However, organic manure application is not a common practice among farmers in Sri Lanka.

Top dressing

- No organic manure is applied in either commercial or homegarden cultivations.
- Most of homegardeners do not use any chemical fertilizer for their banana crops.
- Large-scale growers apply banana fertilizer mixtures available in the open market at about 1 kg/clump/ year with 2-spilt applications /year. However, gradually they are moving towards DOA recommendations. They very rarely use organic manure.

- Some farmers use other fertilizer mixtures such as coconut mixtures, paddy mixtures etc. about 1 kg/ clump/year with 2 equal splits.
- Time of fertilizer application and frequency depend on rain and economic condition of the farmer. However, commercial growers apply fertilizer three times a year with irrigation.

Mulching of banana clumps

- After the first top dressing application, some farmers use various mulching materials for banana (straw, coir-dust, saw dust, paddy husk, banana residues etc.) in order to reduce water evaporation from the soil surface and thereby maintain optimum soil moisture level. However, banana residues are not found to be a good material as a mulch due to pest infestation.

2. DOA recommendation

Basal dressing

Organic manure

- Compost or cattle manure at the rate 2-4 baskets/ planting hole before planting and also as top dressing once a year. (Spread over the surface around the clump and incorporate into the soil together with recommended chemical fertilizer).
- Wood ash whenever available.

Chemical fertilizer at planting

- No chemical fertilizer is recommended at planting as a basal dressing.
- Kieserite/ Magnesium Sulphate (Epsom salt) at the rate of 450g/ or Dolomite 600g/ planting hole for wet zone soils once in 2-3 years.

Fig. 34: Banana -mulching with banana clumps & leaves

Table 11: Top dressing fertilizer mixture

Fertilizer types	Wet zone amt.(g)	Dry & intermediate zone amt. (g)
Urea	110	120
Rock phosphate	150	-
Triple superphosphate	-	80
Muriate of potash	190	250
Total per clump	450	450

Time of fertilizer application

- First application : 2 months after planting
- Second application : 4 months after first application
- Fertilizer application should be done at 4 month intervals. This method is suitable for irrigated banana where soil moisture level can be easily maintained.
- For rainfed cultivation, 675g/ clump of the relevant fertilizer mixture is recommended at the onset of yala and maha rains. However, it is advisable to split the fertilizer amount in to 3 parts and apply 3 times a year whenever possible.

Disadvantages of current farmer practices

- Current farmer practices do not suit sustainable production of banana. They rarely use both organic and chemical fertilizers. However, plant removes nutrients from the soil for yield and other biological masses. Since these are not recycled within the system, the soil becomes unproductive with time. Further, intercropping banana with other crops lead to erosion of the soil. The result will be a degraded soil, which does not lead to sustainable banana production.
- Therefore, an Integrated Plant Nutrition System (IPNS) is more useful for fruit crops like banana.

Suggested IPNS programme for banana

Basal application

- Any kind of green manure, animal waste (solid/liquid), kitchen waste, crop residues or even high C/N ratio materials such as coir dust/saw dust / rice husks can be used as a basal organic material/ amendment for banana. If materials used have a high C/N ratio, it is advisable to mix them with low C/N ratio materials such as poultry, cattle manure etc. to achieve quick decomposition *insitu.* Banana trunks after harvesting should be composted before applying as an organic amendment.

- If poultry manure is used, mix with soil in the planting hole and allow to remain for a week to moisten before planting is done.

Top dressing

- Banana is a shallow rooted crop (45-60cm). Therefore, application of any kind of easily decomposable organic manure as a top dressing at 3 months interval is highly beneficial.
- For this purpose, cattle manure, FYM (solid/liquid), compost, green manure, poultry manure, goat manure and other animal waste could be used.

Amount of manure (dry basis) kg/clump

Poultry manure	3-5
Cattle and other animal manure	5-10
Green manure	7-10

Method and time of application

- Spread the organic material about 30cm away from the clump base but within one meter around the clump and lightly mix with the soil.
- Application at 4 month intervals along with recommended chemical fertilizer is suitable and economical.
- If the plantation is free of pests and diseases, chopped trunks/leaves of harvested banana plants can be used as a basal organic material for new planting holes after treatment with a suitable pesticide and allowing it to decompose in-situ. This will help to recycle the nutrients. This crop residue can be easily decomposed by mixing with cattle or poultry manure.
- Banana crop residue can also be used as a mulching material around and between clumps after chopping them, if banana pests and diseases are not present. This practice will conserve moisture.
- Since animal manure promotes banana pests especially banana weevils it is important to take precautions against them. Apply 10g of carbofuran into each planting hole before planting.

Assignments:

1. Study IPNS adopted in your area for banana.
2. List materials that are available in your area which can be used for IPNS.

2. PAPAYA

Extent cultivated : 2700 ha. (1995)

Varieties and distribution

Very few varieties have been identified for cultivation in Sri Lanka, as most varieties are susceptible to viral diseases in the wet zone.

Agroclimatic Zone	Recommended variety
Wet zone	Local selections
Dry zone	Ratne, Local selections, Solo Hawaii, Solo sunrise

- Papaya is a heavy feeder of plant nutrients and it is a fast grower and a heavy bearer. It bears fruits throughout the year with a peak fruiting season in May-July.

Current nutrient management practices

Farmer practices:

- Most farmers use cattle manure or compost before planting, at the rate of about 1-2 baskets/planting hole.
- A coconut husk layer is used when intercropping with coconut.
- No top dressing application of organic manure is practiced.
- Farmers do not follow the DOA recommendation of chemical fertilizers. Commercial growers use straight fertilizers as recommended by the DOA, but they add fertilizer more frequently than the recommendation. They also apply cattle manure as top dressing more frequently. This leads to over use of fertilizer and manure, resulting in more succulent and virus susceptible trees. Also, application of manure close to base of the plant may cause collar rot disease.
- Some commercial growers use fertilizers with drip irrigation systems (fertigation). However, amount, type and time of application are yet to be worked out.

Table 12: DOA recommendation (g/plant)

Agroclimatic Zone	Time of application	Urea	TSP	Rock Phosphate	Muriate of potash
Wet Zone	At planting	55	--	80	95
	2 months after planting	55	--	80	95
	After every 3 month interval	55	--	80	95
Dry & Intermediate Zones	At planting	60	40	--	130
	2 months after planting	60	40	--	130
	6 months after planting	60	40	--	130
	After every 3 month interval	60	40	--	130

TSP = triple super phosphate

- Despite papaya being a heavy feeder, foliar nutrient application is not yet recommended. Cattle manure at the rate of 5 – 10 kg/plant as basal dressing is recommended.
- Micronutrients so far have not been recommended though there are some reports on suspected deficiencies. However, in some areas bumpy fruit disorder occurs which is suspected to be due to boron deficiency. For such areas, spraying of 2% solution of sodium borate (borax) to foliage and fruits once in 2 weeks or soil application at 10g/ plant at the time of fertilizer application is found to be beneficial.
- Since papaya is a heavy feeder, proper nutrient management is needed for sustainable production. Since nutrient removal as yield and botanical mass is high and recycling of nutrients is low in papaya orchards, a frequent application of organic manure to the soil is very beneficial.

Suggested IPNS programme for papaya

Basal

- Follow fertilizer programme recommended by the DOA.
- Add 5-10 kg of cattle manure or 4 -5 kg of poultry manure/planting hole as a basal dressing 2 weeks prior to planting.
- Add chemical fertilizers as a basal dressing one week before planting as recommended by DOA.

Fig.35: Control weeds and use it for mulching

- Dolomite application before planting at the rate of 5kg/ plant leads to change of soil pH which enhances availability of plant nutrients.
- Add compost (5-10kg) / cattle manure (5-10kg)/ poultry manure (4-5kg) every 3-4 months as a top dressing around the plant and incorporate into the soil. This manuring can be done along with chemical fertilizers and irrigation should follow.

- Spray a 2% foliar nutrient solution which contains boron, at least once a month when the crop is 4 months old.
- Mulching the plants with straw, crop residues, any type of animal manure or even live mulch of short age crops like bush bean provides benefits to growing papaya trees.
- In general, application of ample amounts of compost and cattle manure or poultry manure to the soil as basal adressing and as top dressings would be highly beneficial.

Assignments:

1. Study actual situation of papaya growing in your area.
2. List various ways of using IPNS for papaya in your area.

3. PINEAPPLE

Extent cultivated: 6000 ha. (1995).

Varieties and recommended areas :

Varieties: Kew

Mauritius

- Practically both varieties can be grown in areas that are suitable for pineapple cultivation. Generally Kew is widely grown in Badulla and Moneragala districts and Mauritius in Gampaha, Kurunegala, Kegalle, Puttalam and Kalutara districts.

Current nutrient management practices

- Pineapple does not demand a rich soil. However, it responds well to added fertilizer under mildly acidic soil conditions.

Farmer practices

- Pineapple growers do not grow pineapple twice in the same field as they believe that after growing pineapple the soil is very much depleted of nutrients.
- Farmers generally do not use manure or chemical fertilizers as basal dressings.
- However, most farmers follow the DOA recommendation from 2 months after planting.
- They use coir dust as mulch along planting rows 6 months after planting to avoid moisture stress during flower initiating stage. However, coir dust is becoming a scarce material and therefore an alternative substitute has to be found.

Fig. 36: Coir dust mulch application in pineapple

- Some farmers use cadjan leaves as mulch along planting rows. However, pineapple growers do not apply organic manure.
- Recommended chemical fertilizers are applied 2 months after planting along the planting rows and incorporated into the soil. After second top dressing, the coir dust is applied as mulch. After coir dust mulching, it is difficult to continue fertilizing and therefore farmers broadcast fertilizers around the plant base which damages leaves.
- Soon after harvesting the main crop, the ratoon crop is fertilized in the same way as the main crop.

DOA recommendation

This recommendation is applicable only for wet zone.

Basal application

- No basal application is recommended.

Top dressing

- 1 month after planting (g/plant):

Urea	10
Rock phosphate	10
Muriate of potash	15

- At 3-4 monthly intervals repeat application of this mixture.

IPNS programme for pineapple

- Pineapple soils are heavily depleted of plant nutrients as the removal is very high (About 60% of the total biomass as economical yield).
- Amount of biomass that can be recycled during a 4-year crop is low.
- Soil erosion is comparatively high in pineapple growing soils.
- Since pineapple has a shallow root system, most of the applied nutrients are leached out.
- As organic matter application is not practiced for pineapple, retention of plant nutrients is low in the soil. As a result, soil becomes infertile.
- Therefore, in order to maintain good soil physical, chemical and biological properties, an IPNS programme should be adopted.

Suggested IPNS programme for pineapple

- A suitable and freely available organic amendment must be applied as a basal dressing into the planting furrows. Eg. Plant residues or animal waste.
- If coir dust is not available, use an alternative material for mulching to reduce evaporation especially, during flowering stage. Well-rotten saw dust, rice husk, cadjan leaves, banana trunk chops straw or any other composted material can be used.
- Mealy bug control should be effectively carried out before applying any mulch.
- Crop residues from the previous pineapple crop could be composted and utilized for the next crop.
- Heap soil at the plant base after every application of fertilizer so that it behaves as a soil mulch.

- Apply about 2-5 t/ha of dolomite lime as it provides Ca and Mg, as a basal dressing to avoid browning and internal breakdown of the fruit flesh.
- Foliar application of liquid fertilizer during dry periods is much beneficial, as soil application of nutrients is inefficient. Also, foliar application is easier than soil application especially during latter part of the growing season when ground cover is high.

Assignments :

1. If you are working in a pineapple growing area study the various practices of IPNS adapted in the area.
2. List organic materials available in the area that can be used in IPNS.

4. PASSION FRUIT

- Extent cultivated : 40 ha. (1997).
- Varieties and distribution:

Yellow variety : For dry zone

Purple hybrid : For wet and intermediate zone

Mani : For wet zone

Current nutrient management practices

Farmer practices

- Generally, compost or cattle manure is applied (about 10kg/ planting hole) before planting.
- Recommended straight chemical fertilizers are also applied as a basal dressing.
- Organic manure application as top dressing and mulching are not common practices.

Table 13: DOA recommendation (g/plant)

Agric.zone	Time	Urea	Rock phosphate	TSP	MOP	Kieserite
Wet	Basal	60	115	-	55	60
Zone	2 WAP	60	115	-	55	--
	6 WAP	60	115	-	55	--
	Thereafter at 6 monthly intervals (second year)	115	230	-	105	--
	3rd year	180	340	-	160	--
	4th year	235	455	-	210	--
Dry & Intermediate	Basal	70	--	105	50	--
Zones	2 MAP	70	--	105	50	--
	6 MAP	70	--	105	50	--
	Thereafter at 6 monthly intervals (second year)	140	--	205	105	--
	3rd year	205	-	310	160	--
	4th year	275	--	415	210	--

WAP- weeks after planting, MAP- Months after planting

- Viral diseases are the most limiting factor for production of passion fruit. Use of organic manure or compost can ameliorate the yield losses due to this problem.
- Also, growth retardation due to viral diseases can be suppressed by frequent application of ample amounts of organic manure or compost.
- Soil moisture conservation is a must for passion fruit cultivation in order to maintain the quality and quantity of fruit juice.
- Since recycling of residues of this crop is insufficient, organic manure should be supplied in addition to meet the demand.
- Passion fruit crop residues can be used as an organic manure and as a mulch.
- The soils are subjected to erosion leading to nutrient depletion.

Suggested IPNS programme for passion fruit

- Application of cattle (5-10kg/pit) or poultry manure (3-4 kg/pit) as basal, together with recommended chemical fertilizers.
- Top dressing with cattle or poultry manure (same rates as basal) together with recommended chemical fertilizers and incorporation with soil.
- Mulching with coir dust, straw or suitable composted material.
- Foliar feeding of suitable micronutrient solutions with high percentage of potassium at flowering stage has a major advantage on the final fruit yield.

Assignments :

1. Study IPNS practices adapted for passion fruit in the area.

5. CITRUS (Lime and Sweet Orange)

- Extent of cultivation : About 6000 ha. (1995).
- Varieties and distribution:

Lime

Local lime selections are mainly grown in the dry and intermediate zones whereas in the wet zone it is a common crop in home gardens.

Sweet orange - Bibile Sweet, Bibile Sweet seedless

Nutrient management practices

Farmer practices

- Cattle manure, kitchen waste, wood ash, coconut husks and compost are used as basal applications.
- DOA fertilizer recommendation is rarely used.
- Fertilizer application depends on socio-economic factors and water availability in the growing area.
- Inconsistent price for the product is the major drawback for citrus cultivation in Sri Lanka and hence growers do not attempt to invest too much in it. As a result, fertilizer is used at a reduced level.
- Moisture stress during the fruiting period must be minimized in order to obtain a good yield. Therefore, application of organic amendments as basal and topdressings and also as a mulch, promotes soil moisture conservation and high yields.

DOA recommendation

Table 14: DOA recommendation for Lime and Sweet Orange (g/plant)

Agroclimatic Zone	Time	Urea	TSP	RP	MOP
Wet zone	Basal	75	--	120	25
	Until bearing with increments of	75	--	120	25
	Up to maximum 2 splits/year	445	--	730	160
	Bearing plants 2 splits/year	355	--	680	320
Dry & Intermediate zones	Basal	80	100	--	45
	Until bearing, top dress with	80	100	--	45
	Up to (with 2 splits/year)	475	590	--	270
	Bearing trees (2 splits/year)	270	620	--	455

TSP - Triple super phosphate, RP - Rock phosphate, MOP - Muriate of potash

- Since organic manure and fertilizer application as well as moisture conservation measures are neglected by farmers, sustainable citrus yields are not achieved.
- Most of citrus growing soils do not have sufficient moisture levels throughout the year and therefore, moisture conservation measures are extremely important.
- Since citrus crops are very susceptible to micronutrient deficiencies, such as zinc and iron, major emphasis should be given to application of these nutrients as foliar feed at the correct time. At the time of moisture stress, foliar feeding of soluble major and micronutrient is essential.
- Since citrus crops give only marginal returns, farmers tend to intercrop them with other cash crops which lead to further decline of soil nutrient status.
- Nutrient deficiency symptoms are very common in lime trees that are grown in depleted soils. This leads to production of low fruit yield of poor quality. Therefore, it is very important to give major emphasis on nutrient management. This is easily approached through a proper IPNS.

Suggested IPNS programme for Citrus

- Apply compost (10-15kg) or cattle manure (5-6kg) or poultry manure (3-4 kg)/ planting hole as a basal dressing.
- Any other organic amendment like animal waste can also be used.
- Follow the basal chemical fertilizer recommended by DOA one week prior to planting.
- Locally available organic manure can also be used as top dressings once in 6 months which should be incorporated into the soil.

Fig. 37: Mulching of Citrus plants

- Follow the chemical fertilizer recommendation for top dressing when there is sufficient moisture in the soil.
- Maintain a mulch around the base of the plant, with materials such as rice straw, crop residues or any other suitable material.
- Spray foliar fertilizer especially during drought periods and also when nutrient defiency symptoms appear.
- Apply dolomite or kieserite as recommended by DOA.
- Practice irrigation whenever possible.

Assignments :

1. Study present practices of IPNS adopted in the area.
2. Give constraints and possibilities of using suggested IPNS programmes in your area.

6. RAMBUTAN

Extent cultivated : 825 ha. (1995)

Varieties and distribution

Few varieties have been recommended, but many varieties and strains exist.

Malwana special

Malayan Red

Malayan Yellow

Rambutan is extensively grown in Gampaha, Kalutara, Colombo, Ratnapura, Galle, Kegalle and Kandy districts. Rambutan needs lot of nutrients since it is a heavy bearer and an evergreen crop.

Organic matter is extensively used in Rambutan orchards.

Nutrient management practices

Farmer practices

Organic manure

- Most of farmers add compost, Compost – 2-3 kg. for a pit of 1 x 1 x 1m about 02 weeks before planting.
- Young plants are mulched with straw, plant trash or any organic material.
- Bearing trees are provided with 10-15 kg of compost twice a year.

Chemical fertilizer

- Basal dressing is applied 2-3 days before planting.

Table 15: DOA fertilizer recommendations (application per plant)

Time of applicaion	Urea (g)	Rock Phospate (g)	MOP (g)	Total(g)
1. Basal	120	115	110	345
2. 6 months after planting	60	115	55	220
3. 1 year	60	115	55	225
4. 2 years	180	345	165	690
5. 3 years	300	575	275	1150
6. Every 6 months thereafter	360	690	330	1380

- Top dressing frequency is as stated above. Apply fertilizer over the area where canopy spread is projected.
- Incorporate into the soil.
- Apply top dressing soon after harvesting or end of the fruit season. Split the first dose into two an apply one part each season.
- Do not apply chemical fertilizer during dry spells. Also, do not apply during rainy spells.
- Apply 2250 g of dolomite per tree per year, two weeks before chemical fertilizer is added. Incorporate into the soil.
- Apply organic manure to the trees liberally in addition to chemical fertilizers.

Suggested IPNS programme for Rambutan

- Add 10-15 kg of cattle manure or 4-5 kg of poultry manure into planting pit at least two weeks before planting.
- Dolomite (5kg / pit) as basal dressing
- Follow the fertilizer programme recommended by the DOA.
- Basal fertilizer + top dressing.
- Add compost 10-20 kg, or cattle manure 15-20 kg or poultry manure 5-10 kg per tree every 3-4 months as top dressing around the trees, and incorporate into the soil. This manuring could be done along with chemical fertilizers. Irrigation should be done when possible.
- Mulching is a must to maintain soil moisture.

Seedling /Root stock plant production

Temporary Iron deficiency is a general problem in young Rambutan seedlings. Yellowing of interveinal area of leaves that leads to chlorosis of entire leaf is suspected to be due to iron deficiency or unavailability of iron in the rooting medium or inability of the seedling to absorb the nutrient. In this regard, spraying of Ferrous sulphate (2%) will ease the problem.

Usual potting mixture is cattle manure, top soil and sand mixed in equal amounts. (well rotted cattle manure is very suitable). Potting mixture may be enriched with Keiserite or dolomite powder. Application rates should be decided accordingly. However, suggested rate is 3-4 kg of dolomite or 2-3 kg Keiserite per 100 cubic feet of potting mixture. 8-10 g of dolomite or 6-7 g of Keiserite per pot may be added. Potting medium should be kept under field capacity, always.

Assignments :

1. Study present practices of IPNS adopted in the area for Rambutan.
2. Give constraints and possibilities of using suggested IPNS programmes in your area.

7. MANGO

Extent cultivated: 12160 ha. (995).

Varieties and distribution

Large number of varieties are cultivated all over the island.

Dry Zone	Intermediate Zone	Wet Zone
Karatha Colomban	Karatha Colomban	Vellai Colomban
Vellai Colomban	Vellai Colomban	Peter passand
Willard	Peter passand	Gira amba
Kohu amba	Willard	Dil passand
Ambalavi	Betti amba	
	Kohu amba	
	Malwana	

Mango is commonly found in almost all districts except in the Nuwara Eliya district. Mango population in the island has been propagated through seedlings. Owing to that, the trees are heterogenous in size, yield quality and other characteristics. They are huge trees producing a large quantity of fruits. However, they are generally irregular or alternate bearers. Heavy yields are obtained usually once in few years.

Mango trees need a large quantity of nutrients to maintain the tree itself. In addition to that, they need more nutrients because nutrient removal through fruits is very high.

Nutrient management practices

Farmer practices

Basal drssing

1. *Organic manure*

- Most farmers add ample amounts of compost into the planting pit one to two weeks before planting.
- One third of the potting mixture for mango plants, consists of cattle manure or compost.

2. Chemical fertilizer

- No chemical fertilizer is added as basal dressing for mango plants at planting. However, chemical fertilizers are added to the planting pit by commercial growers. They follow the departmental recommendation.

Top dressing

i. Organic manure

Generally no top dressing of organic manure is used for mango by growers. However, mulching the trees with organic matter such as straw, plant residues etc. is a common practice in the dry zone.

ii. Chemical fertilizer

Farmers do not apply any fertilizer to mango trees except in few home gardens in the wet zone.

Commercial growers apply chemical fertilizers to mango trees as recommended by the Department of Agriculture. They do not use foliar nutrient sprays on mango.

Suggested IPNS programme for mango

1. Add 10-15 kg. of cattle manure / compost in every season at the onset of seasonal rains or two weeks before application of chemical fertilizers.

- Follow the fertilizer programme recommended by the DOA
- Mulching is a must to maintain soil moisture during fruit set and fruit growth. Mango flowers in dry spells. Fruit grows properly under good levels of soil moisture. Otherwise fruit abscission can occur. Therefore, mulching after flowering is more important. Apply mulch during the dry period.

Assignments :

1. Explore ways of maintaining organic matter in the soils under mango.
2. Give constraints and possibilities of using suggested IPNS programmes in mango.

SECTION V

Root and Tuber Crops

This section of chapter 4, deals with important root and tuber crops, sweet potato, Cassava, Xanthosoma, ginger and Amorphophallus.

Following are the broad objectives of this section on root & tuber crops

1. To provide knowledge on soil requirements, different ways of cultivating root and tuber crops and nutrient removal by selected tuber crops.
2. To provide information on cropping systems adopted for different root and tuber crops and nutrient management practices; both DOA recommendations and farmer practices.
3. To suggest on IPNS package for the different root and tuber crops.

Introduction

- Root and tuber crops form an important part of the Sri Lankan dietary habits. They are consumed boiled, baked, fried or made into sweet meats and preserves.
- Root and tuber crops are both indigenous and introduced. Potato is one of the most important introduced tuber crops.
- Botanically tuber crops are classified into shoot tubers like potato or root tubers like sweet potato or diascorea yams.
- Root crops are suited for medium and coarse textured soils. Loamy sands and loamy soils are best suited for their cultivation.
- These crops are grown under diverse conditions of uplands, modified paddy lands and under coconuts. Good drainage, soil fertility, soil depth and absence of gravel facilitate its cultivation. Adequate amounts of organic manure is necessary for the improvement of soil physical and chemical characteristics.
- Root and tuber crops are classified broadly under the following categories.

Local name	Botanical name
Potato	*Solanam tuberosum*
Innala	*Coleus rotandus*
Cassava	*Manihot utilisima*
Sweet potato	*Ipomea batata*
Kiriala	*Xanthosoma spp*
Gahala	*Alocasia spp*
Ginger	*Zingiber zeylanica*
Diascorea yams	*Diascorea alata*

- All root and tuber crops are heavy removers of plant nutrients. (Table 16). Thus a balanced fertilizer programme should be followed to sustain production.

Table 16: N, P and K removed by some common root and tubercrops.

Crop	Yield (t/ha)	Nutrient removal (kg/ha)		
		N	P_2O_5	K_2O
Cassava	30	180	22	160
Sweet potato	20	123	15	175
Amorphophallus	36	121	23	176
D. alata	25	163	30	126
Coleus	26	106	13	107

- Intercropping of coconut palms can be done when the palms are less than 5 years old and when palms are over 40 years of age. Moisture content of the coconut lands are important to manage both conditions for optimum results.

  See DOA fertilizer recommendation for Root & Tuber crops

1. POTATO (IRISH POTATO)

- Could be grown successfully in the Agro ecological zones of the up country wet zone (WU), up country intermediate zone (IU) and also on coastal beach sands and well drained Red yellow latasols of Jaffna. It could be grown on other soils but the limitations are the prevailence of bacterial wilt and early and late blight.
- Requires a well drained loamy to sandy loam soils. Often heavy textured soils are added with large amounts of organic manure to artificially change the texture.
- Potato fits into various cropping systems

  i. Potato – Vegetable system
  ii. Rice - potato system
  iii. Red onion - Vegetable - potato system
- It is grown both on uplands and well drained paddy lands with supplementary irrigation.
- Farmers add heavy doses of organic manure as wet cowdung grass mixtures or poultry litter. The rates of addition vary from 20-60 t/ha for cowdung mixtures and 05-20 t/ha for poultry litter.
- Over addition of chemical fertilizers and sometimes Mg and foliar applicants are carried out.
- Liming of soils are not done for potato but usually it follows a cabbage crop which has been limed the previous season. This practice is common in the Nuwara Eliya district.

Recommended practices

- Follow soil test based fertilizer recommendations.
- Use straight fertilizers to avoid build up of nutrients.
- Overuse of chemical and foliar nutrient applications results in the pollution of soil and the water ways.

- Control of erosion of soils is important to retain soil fertility as well as to prevent sedimentation of waterways and possible eutrophicafion of water reservoirs.
- Crop rotation to prevent cyst nematode build up should be practiced.
- Use cattle manure or poultry manure as organic sources.

2. SWEET POTATO

- Sweet potato is extensively grown in rice based cropping systems in the Godakawela – Ambewila area of the Ratnapura district and in Rajangane in the Anuradhapura district and also in some parts of the Puttalam and Kegalle districts.

Fig 38: Sweet Potato covers soil well

- It is also cultivated on uplands and in 'Ovita' soils of the well drained paddy lands.
- Sweet potato is extensively cultivated in the coastal beach sands of Kalpitiya in Puttalam and in Kinniya in the Trincomalee district.
- Addition of organic manure is carried out by farmers of Kalpitiya and Kinniya but most other farmers rely on added chemical fertilizers of which the NPK mixtures recommended for rice and potato are often used.

Recommended practices

- Addition of adequate amounts of organic manure and compost.
- Balanced fertilizers with NPK fertilizers.
- Soil test based fertilizer usage.
- Crop rotation to avoid pest and diseases and excessive build up of nutrients.

3. INNALA

- Innala is extensively grown in rice based cropping systems.
- During the yala season in the Godakawela area.
- During the maha season in the Elpitiya Bentara area.
- They are grown on raised beds with water allowed to seep into the beds.
- Farmers add NPK mixtures as a basal dressing and urea or NK mixtures as top dressings.

- Use of organic manure as cowdung, green manure or poultry litter as a basal application has given high yields.

Recommended practices

- Mixing of organic manure to soil before applying basal fertilizers.
- Use of straight fertilizers.

4. MANIOC (CASSAVA)

- It is grown in many parts of the country. Can be grown in all soil types except heavy textured soils.
- Crop requires a deep soil with sufficient drainage.
- Is mono cropped both as a rainfed crop in the uplands of the dry and intermediate zones and wet zone; also as an alternate crop in rice based cropping systems of the well drained wet zone.
- Manioc is intercropped with rubber in the early years of the rubber plants in new plantations and intercropped with short annual crops and vegetables.
- It is cropped between coconut trees.
- Farmers of the wet zone districts add organic manure and fertilizers. But farmers of the dry zone rely mostly on the nutrient available in the soils.
- NPK nutrients are added at the time of planting or at earthing up.

Recommended practices

- Use of organic manure as cowdung, poultry litter or green manure before planting.
- Addition of crop residues and rice straw as a mulch.
- Application of recommended rates of NPK fertilizers.
- Soil conservation after uprooting to prevent erosion and loss of top soil.
- Crop rotation to replenish soils.

5. KIRIALA - XANTHOMONAS / GAHALA - ALOCASIA

- Is grown as a home garden crop with minimum attention given to crop nutrition.
- Commercial cultivation is carried out between coconut plants and as a yala crop in rice based cropping systems with supplementing irrigation.

Fig 39: Intercropping Banana with Kiriala

Fig 40: Intercropping Coconut with Kiriala

- Farmers use coconut husks, coir dust mixed with cow dung or poultry litter to fill holes before planting.
- Rice straw and husk are used to cover beds by the Rajangane farmers.
- NPK fertilizer mixtures meant for rice are added as a basal application.
- Paddy rice NK mixtures are added as top applications.

Recommended practices

- Conservation of moisture by mulching with leaf litter, coconut husks or rice straw.
- Application of NPK fertilizers into holes and mixing thoroughly before planting.
- Application of a balanced mixture of fertilizers.

6. DIASCOREA YAM

- Growing of diascorea yams as a mono crop is carried out in small scale in the Kalutara and Gampaha district.
- It is intercropped with onion in the Jaffna, Batticalo and Trincomalee districts.
- Often grown as a hedge crop in the mid country wet zone and under tree cover in the low country and mid country regions.
- Many species of diascorea yams are grown.
- Farmers add composted materials or well rotted cowdung to planting holes.
- Some farmers add NPK mixtures as the basal application.
- Green leaves are added to mulch the soils.

Recommended practices

- Conservation of moisture by using coconut husk, rice straw, green leaves or leaf litter.
- Application of organic manures of 10-15 kg/hole.

- Application of recommended rate of NPK fertilizer as the basal and addition of NK fertilizer as top dressing.
- Avoid over use of chemical fertilizers.

7. GINGER

- Is grown both as a home garden and as a commercial crop.
- The local and Chinese types of ginger are grown for commercial markets.
- Grown on raised beds under coconuts and other tall canopied trees; or on paddy rice threshing floors.
- Requires well drained soils as crop is susceptible to water logging.
- Commercial farmers add cowdung and poultry litter on beds to plant the rhizomes.
- Mulching with coir dust, rice straw and leaf litter is carried out.
- Farmers add young coconut palm residues as the basal application and NK rice mixtures as top dressing.
- Often over addition of urea based fertilizer nutrients is carried out.

Recommended practices

- Application of organic manures including carbonized rice husk.
- Mulching of the crop with suitable mulching materials

  Rice straw

  Rice husk

  green leaves

  coconut fronds
- Composting of crop residues.

8. ELEPHANT YAM (Kidaran) Amorphophallus

- If is a crop grown in most parts of Jaffna and on coastal areas of Trincomalee, Batticaloa etc. Also grown in some parts of Hambantota and the Monaragala districts.
- Farmers who grow a commercial crop add high doses of organic manure as cowdung, goat dung or compost to each hole.
- Some farmers use NPK nutrients.

Recommended practices

- Mulching to conserve soil moisture, material suggested under diascorea yams could be used.
- Application of recommended NPK fertilizer.

Assingments

1. List Root and Tuber crops grown in your area and give different cropping systems adopted for these crops.
2. Study IPNS practices done in intercrops of your area and find strengths and weaknesses of the practices.

Appendix 1.

Deficiency and toxicity symptoms caused by different nutrients in rice plant

Phosphorus deficiency

Potassium deficiency

Sulphur deficiency

Iron toxicity

Source: IRRI

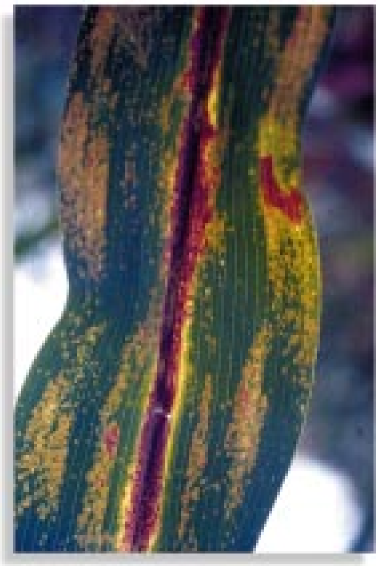
Appendix 1a.

Deficiency symptoms caused by different nutrients in Maize

N deficiency

K deficiency

N deficiency



P deficiency

Source: DOA

Appendix 2.

Fertilizer standards based on Sri Lanka Standards Institute (SLSI)

a). **Urea** SLS 618: 1983

General Requirements

- Material shall be in the form of prills or crystals and shall be free from visible impurities and dust.
- Prilled urea shall pass through a sieve of 2.36 mm square.
- Other requirements

	Characteristic	Requirement
i.	Maximum moisture % by mass	1.0
ii.	Total minimum N% by mass	46.0
iii.	Biuret % by mass, maximum	1.0

- Packaging : Polypropylene or jute bags with inner lining
- Marking :
  a. Urea, fertilizer grade in capital letters
  b. Manufacturer's name and address
  c. Registered trade mark if any
  d. Net mass in kg.
  e. Batch or code No.
  f. Date, month and year of manufacture
  g. % by mass of total N content.

b. **Ammonium Sulphate** SLS 620:1983

General Requirements

Material shall be in the form of crystals, usually colourless, and free from visible impurities.

Other requirements

Characteristics	Requirement
Moisture % by mass maximum	1.0
Total N % by mass minimum	20.6
Free acidity (as H_2SO_4)% by mass, maximum	0.025
Arsenic (as AS_2O_3)% by mass maximum	0.01

Packaging and making as for Urea.

c) **Triple Superphosphate** SLS 812 :1988

General requirements:

Material granular and free flowing, free from lumps and visible foreign matters.

Particle size

100% of the material by mass should pass through a sieve of 4.75 mm square.

Other requirements

Characteristics	Requirement
Moisture % by mass max	4
Total phosphate (as P_2O_5)% by mass minimum	46.0
Water soluble phosphates (as P_2O_5) minimum (% of total)	80.0
Free phosphoric acid maximum (as P_2O_5)	3.0

Packaging is as per urea.

d. **Potassium Chloride** SLS 644: 1984

General requirements

Material shall be crystalline and white, light gray or pinkish in colour. Free of impurities of clay or grit.

Other requirements

Characteristics	Requirement
Moisture % by mass, maximum	0.5
Potash content (as K_2O) % by mass minimum	60.0
Sodium (as NaCl) % by mass maximum (on dry basis)	3.5

Packaging and marking as per urea.

Source: Sri Lanka Standards Institute

Appendix 3.

Available plant species as green manure in the LCDZ and LCIZ

Plant species	Plant family	Local name
Aleurites moluccana	*Euphorbiaceac*	Kekuna
Alstonia macrophylla	*Apocynaceae*	Hawarinuga
Barringtonia recemosa	*Lecythidaceae*	Midella
Cebera manghas	*Apocynaceae*	Mudu-Kaduru, GodaKaduru
Croton lacciferus	*Euphrobiaceae (Leguminosae*)	Keppetiya
Curcuma zedoaria	*Zingiberaceae*	Harankaha
Datura metel	*Solanaceae*	Anththana
Erythrina sp	*Fabaceae (Leguminosae*)	Erabadu
Gliricidia sepium	*Febaceae (Leguminosae*)	Wetahira, Sewana
Jatropha curcas	*Euphobiaceae*	Wetaedaru
Manihot glaziovii	*Euphobiaceae*	India Rubber
Manihot sp.	*Euphobiaceae*	Alimannokka
Melia dubia	*Meliaceae*	Lunumidella
Michelia champaca	*Mangokiaceae*	Sapu, Gini sapu
Micolossa ceylanica	*Asteraceae (Composiae*)	Pupala
Mikania cordata	*Asteraceae (composistae)*	Watu-palu, Gahala-wel
Oroxylum indicum	*Bigoniaceae*	Totilla
Pagiantha dichotoma	*Apocynaceae*	Dee-Kaduru
Pavatta indica	*Rubiaceae*	Pavatta
Pongamia pinnata	*Fabaceae (Leguminosae)*	Karanda, Mangulkaranda
Premna tomentosa	*Verbenaceae*	Seru
Samanea saman	*Mimmosaceae (Leguminosae*)	Mara
Tephrosia purpurea	*Favaceae (Leguminosae*)	Pila
Thespesia populnea	*Malvaceae*	Gansooriya, Sooriya
Tithonia diversifolia	*Asteraceae (Compositae*)	Naththasooriya, Tiththa
Wickstroemia canescens	*Thymelaeceae*	Nahadunu, Maha patta

Appendix 4.

Different types of livestock populations in the country by districts

District	Buffalo	Cattle	Poultry	Goat	Sheep	Pigs
Colombo	13100	23300	862100	6100	0	6500
Gampaha	22200	51700	1227300	16900	100	19700
Kalutara	29900	40800	705100	14600	0	3700
Kandy	20400	58100	679400	29800	0	600
Matale	25700	50000	198300	13900	0	1700
Nuwara Eliya	6000	51600	178800	14500	200	400
Galle	12800	27100	279900	7300	0	400
Matara	10700	32700	146400	3900	0	100
Hambantota	59900	78800	112100	15500	0	1200
Jaffna	0	58300	274700	38700	3900	0
Kilinochchi	1400	17300	63400	14100	3200	200
Mannar	4700	50300	64600	9800	0	100
Vavuniya	1000	26700	55400	5300	0	0
Mullativu	6300	39400	79000	11300	300	200
Batticaloa	52700	121800	244700	31800	0	100
Ampara	33800	100900	273300	12400	0	100
Trincomalee	47900	75900	157600	21400	100	100
Kurunegala	142700	197500	1886100	58500	2000	9300
Puttalam	16000	92500	796100	52600	1400	18400
Anuradhapura	84500	147100	288700	42700	500	5500
Polonnaruwa	41300	48000	17400	14200	0	1900
Badulla	8300	80800	202100	20300	100	300
Moneragala	25000	67500	99500	4900	0	100
Ratnapura	19800	35400	198500	31700	0	2700
Kegalle	16600	24100	237800	22300	0	2000
Mahaweli ‘H’	6500	15400	59800	4300	0	1000

Source : Department of Census and Statistics, 1999

Appendix 5.

Organic materials and their nutrient composition

(a) Green Manure

Botanical Name	Common Name	% oven dry basis			
		N	**P**	**K**	**C:N**
1. Trees whose leaves are used					
Aleurites triloba	Telkekuna	2.34	0.17	2.65	19
Azadirachta indica	Margosa	2.38	0.20	1.30	20
Borassus flabellifera L	Palmyra	1.62	0.10	1.07	32
Cerebera adollam	Kaduru	2.31	0.10	1.80	22
Erythrina lithosperma	Dadap	4.00	0.29	3.95	14
Gliricidia maculata	Madera	4.15	0.27	3.00	12
Tamarindus indica	Tamarind	1.59	0.19	1.19	27
2. Plants whose leaves and stems are used					
Calotropis gigantea (L) Ait.f	Wara	3.86	0.30	3.45	11
Cassia occidentalis	Penithora	4.91	0.20	1.87	12
Croton lacciferus	Keppetiya	3.50	0.30	2.15	15
Tephrosia purpurea	Pita	3.73	0.28	1.78	11
Thespesia populnea	Suriya	3.43	0.25	3.30	14
Tithonia diversifolia	Wild sunflower	3.84	0.29	5.90	14

Source: Nagarajah, S. and Amarasiri, S.L. (1977)

(b) Crop Residues

Materials	Nutrient content (% oven dry basis)		
	N	**P**	**K**
Bean straw	1.57	0.32	1.34
Cowpea stems	1.07	0.14	2.54
Maize stover	0.70	0.06	1.19
Rice straw	1.10	0.16	1.40
Sugarcane trash	0.35	0.04	0.50

Source: FAO

(c) Wood wastes

Materials	**Nutrient content (% oven dry basis)**		
	N	**P**	**K**
Saw dust	0.12	0.02	0.06

Source: FAO

Appendix 5. (contd.)

Organic materials and their nutrient composition

Materials	Nutrient content (% oven dry basis)		
	N	P	K
Buffalo dung	0.75	0.2	2.0
Cattle dung	1.83	0.49	1.62
Cattle urine	2.5	0.05	2.12
Goat dung	1.33	0.30	1.39
Pig dung	2.82	1.17	1.49
Poultry manure	3.33	1.36	1.80
Farmyard manure (FYM)	0.80	0.18	0.61
Rural compost	1.12	0.42	1.22
Urban compost	0.57	0.62	1.16

Source: FAO

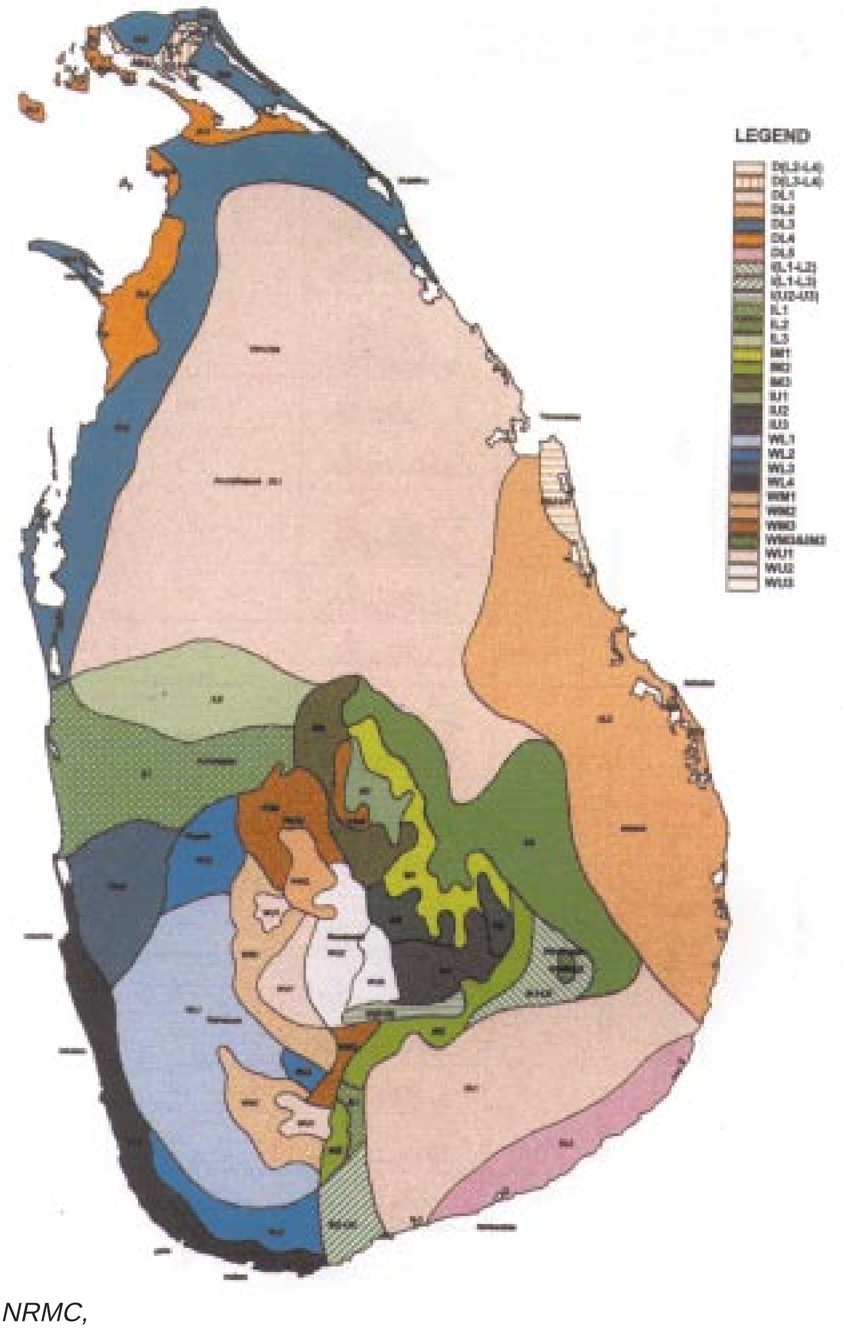
Excreta output of Livestock

Species	Average Body weight (kg)	Daily Excreata output (per individual)	
		Wet weight (kg)	Volume (m^3)
Buffalo	372.2	12.2	0.024
Chicken	2.05	0.1	0.0001
Cow	306.7	11.6	0.021
Sheep	32.5	0.76	0.0012
Swine	71.2	2.9	0.0043

Source: Department of AP & H

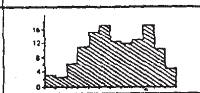
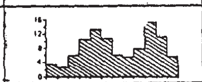
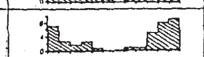
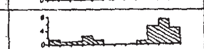
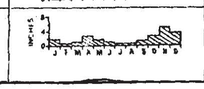
Appendix 6.

Agro - Ecological Regions of Sri Lanka



Source: *NRMC,*
Department of Agriculture

Appendix 6. (Contd.)

ZONE	AGRO-ECOLOGICAL REGION & SYMBOL		MONTHLY HISTOGRAMS OF 75% RAINFALL PROBABILITY FOR RESPECTIVE REGIONS	75% EXPECTANCY VALUE OF ANNUAL RAINFALL (INCHES)
WET ZONE	UP COUNTRY	WU_1		> 125
		WU_2		> 75
		WU_3		> 55
	MID COUNTRY	WM_1		> 125
		WM_2		> 55
		WM_3		> 50
	LOW COUNTRY	WL_1		> 100
		WL_2		> 75
		$WL_{3\&4}$		> 60
INTERMEDIATE ZONE	UP COUNTRY	IU_1		> 85
		IU_2		> 55
		IU_3		> 45
	MID COUNTRY	IM_1		> 55
		IM_2		> 45
		IM_3		> 35
	LOW COUNTRY	IL_1		> 40
		IL_2		> 45
		IL_3		> 35
DRY ZONE	LOW COUNTRY	DL_1		> 30
		DL_2		> 35
		$DL_{3\&4}$		> 23
		DL_5		> 20

Source: *NRMC,*
Department of Agriculture

appendix 7.

Nutrient removal by vegetables total and edible portion at harvest

Crop	Yield (t/ha)	Primary Nutrients (kg/ha)			Secondary Nutrients (kg/ha)		Micro-nutrients (g/ha)			
		N	P	K	Ca	Mg	Cu	Zn	Fe	Mn
Beet	52	139	20	171	29	9	90	172	2397	442
Leek	44	132	18	242	31	24	71	511	2614	906
Spinach	16	58	9	88	41	17	89	62	3371	371
Lettuce	10	16	2	23	5	2	9	35	430	46
Sweet Potato (T)	23	48	13	83	10	5	26	14	416	70
Sweet Potato (Total)		108	20	207	23	15	58	38	2147	255
Radish	35	73	11	118	42	11	25	112	1295	241
Cabbage	60	128	18	175	60	14	44	188	1365	382
Bittergourd (P)	30	80	12	88	6	10	83	13	447	113
Bittergourd (Total)		130	19	148	30	21	127	150	1563	281
Luffa (P)	30	41	9	54	5	5	32	53	626	58
Luffa (Total)		151	24	169	97	33	118	218	3198	342
Snakegourd (P)	30	40	6	52	17	7	55	55	492	103
Snakegourd (Total)		73	10	89	38	14	93	96	1256	285
Bean (P)	12	39	6	39	5	4	23	60	544	131
Bean (Total)		166	19	143	86	19	106	388	3831	1606
Okra (P)	18	59	9	76	15	10	50	87	455	158
Okra (Total)		95	14	131	62	24	86	172	1357	553
Capsicum (P)	10	25	2	14	9	5	18	20	147	44
Capsicum (Total)		67	5	63	23	9	56	70	1074	208
Brinjal (P)	25	57	9	74	1	6	47	162	153	37
Brinjal (Total)		130	18	241	58	21	141	251	571	210
Potato (T)	20	38	7	81	3	4	32	153	652	89
Potato (Total)		222	27	479	71	24	105	541	10546	2506
Tomato (F)	25	127	14	165	10	9	176	129	4103	126
Tomato (Total)		163	18	206	42	20	346	222	7709	344
Carrot (T)	31	70	14	104	23	10	53	158	1491	267
Carrot (Total)		159	24	237	52	20	114	430	3693	699

F = fruit; P = pods; T = tuber

Source: Amarasiri and Wijesundara

Appendix 8.

METHODS OF COMPOST MAKING.

There are several methods of compost making that are easily carried out by the farmers. The type of method to be selected depends on the following.

- Climatic conditions.
- Amount of waste material available.
- Type of waste materials.
- Demand for compost
- Labour, land, availability.
- Scales of operation
- Targeted use
- Generally climatic conditions, of extreme dry, wet and cooler climates reduces the chances of obtaining good composted material within a desired time.
- The amount of waste material availability from homesteads, gardens and cities decides on the type of composting method to be followed.
- Type of waste materials like city garbage, crop residues and FYM are important in deciding the methods of composting.
- The demand for compost, for own use or commercial purposes has to be decided in selecting the method.
- The land and labour availability decides on the type of system to be utilized. For urban home gardens barrel method is preferable.
- Commercial compost making requires rapid methods of composting.
- The targeted area, for food crops. ornamental plants decides on the type of compost to be used.

Material available for Compost making.

- Any biodegradable organic material found in nature or a byproduct of agro-based industries could be composted.
- Materials found common in homes like kitchen waste, garden refuse, leaf litter, animal dung could be used for composting.
- City garbage, slaughter house waste, wastes from timber mills, rice mills etc. could be composted.
- Crop residues, FYM, green leaves and stems are available in farms for composting.

Materials required for Composting.

- Composting requires materials of both high C:N and low C:N material to effect the bio degradation and to reduce loss of N.
- Requires 35-45% water by weight of the waste material.
- Requires a control environment to effect the bio degradation by microbial action.

Precautions necessary in composting.

- Care should be taken to avoid metallic substances to get into the compost piles.
- If human faecal materials are found in the waste thermal methods of composting should be carried out to prevent the spread of diseases.
- City garbage should always be composted using aerobic methods

TYPE OF COMPOSTING METHODS.

There are two major types.

- Aerobic
- Anaerobic

AEROBIC METHODS

Aerobic methods allow the microbial forms using oxygen to carry out the biodegradation.

There are many methods followed under aerobic methods. For small home gardens. Barrel or Bamboo - cage method could be used conveniently.

Barrel Method

A barrel as shown in the diagram (1) is cut opened at the bottom . House waste material are added from the top and compressed by a stick. The top is covered by a lid to prevent flies. As the barrel gets filled due to the pressure from the top composted material will flow out the vents due to pressure brought by the stick.

- There is a possibility of introducing earth worms to the barrel, compost made is of high quality.

Diagram 1 - Barrel Method

Bamboo Cage Method

This is similar to Barrel method. Operations are done as in Barrel method. Composted material could be removed from the space between bamboo sticks. see digram (2)

Diagram 2 - Bamboo Cage Method

Heap Method

This method could be used for preparation of compost in fairly large quantites. see digram (3)

The size of the heap should be decided on

- Amount of waste material available
- Labour availability
- Rainfall patterns.

In using Heap method the following should be considered.

- Removal of bottles, metalic items, plastic and polythene material.
- Cutting of material into smaller pieces and spreading
- Laying of high C:N material like grass/straw alternate with low C:N material like tender shoots/cowdung
- Addition of innoculum obtain fro a composted material or cowdung slury.
- Addition of water to saturate each layer
- Compacting each layer
- Covering up of the heap by black polythene or a mud film.

Where city garbage is used more aeration should be allowed, (eg. Chinese method)

- Earth worms could be introduced to the heap after cooling.
- The turning of the heap be carried out at 2 weeks, 4 weeks and 6 weeks interval.
- The composted material is available in 12-14 weeks.
- The composted material should be air dried, pounded and sieved before marketing.
- Heap method is more suited in areas with heavy rain.

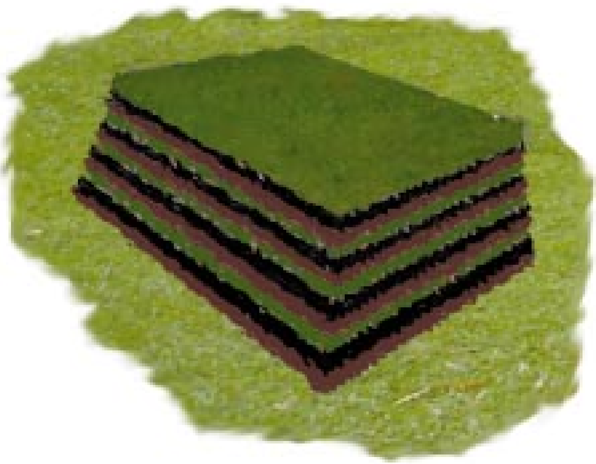
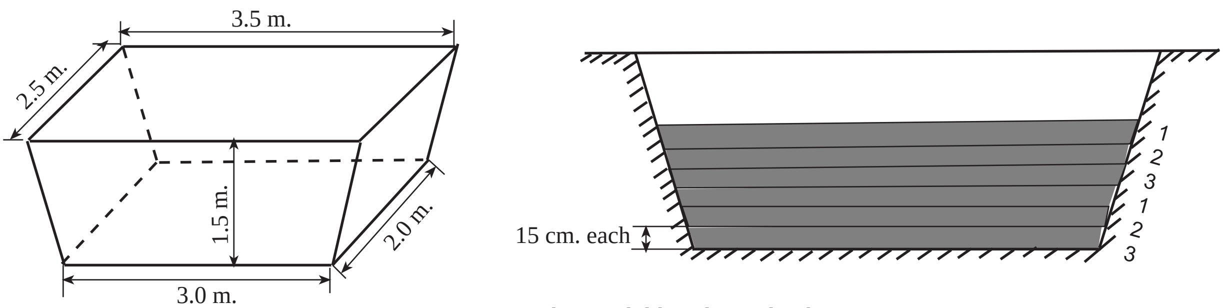


Diagram 3- Heap Method

Pit method

- Is an inverted heap method, more suitable to dry areas. A bund should be put round the pit to avoid seepage of water into the pit. A roof is required to keep off the rain. See digram (4). Procedure followed in Heap Method is practiced to fill the pit.

Digram (4a) - Pit method



Digram (4b) - Pit method

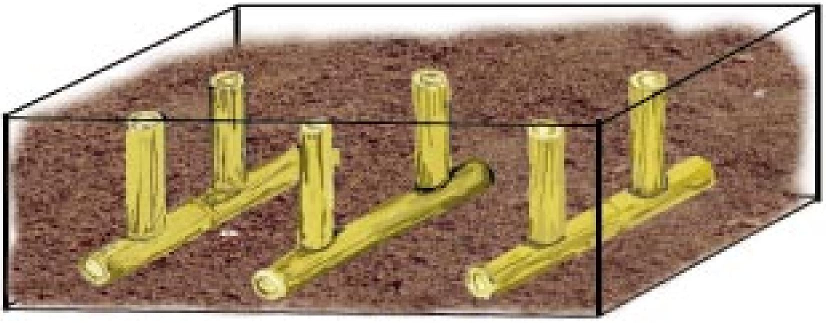
1. Silt straw mixture 2. Green manure (e.g. Gliricidia) 3. Stable manure (Cowdung)

Rapid method of Composting

For rapid decomposition a mixture of organic residues in the proportion of two parts of carbon rich material like straw, saw dust are mixed with one part of N rich material like legume leaves or animal dung. The leaves are shredded into smaller size and mixed thoroughly with the dung. This materials are heaped for two weeks. The turning should be done on the fourth, seventh and tenth day. Sufficient water has to be added initially and at each time of turning. The compost is ready after two weeks from the time of initial heaping.

High temperature compost. (Chinese method)

This method is suitable for composting material which could contain harmful parasites and pathogens which can affect human and animal health. It is ideal for composting urban wastes and animal wastes. Materials which are coarse and high in C/N ratio are laid in layers similar to that in the heap method and followed on top by more succulent material or animal dung, market refuse, slaughter house refuse etc. This piling system is carried out until a maximum height of 1-1.5 m is reached.



Digram (5) - High temperature compost.

At the time of making the heap a series of bamboo poles (septa broken) or PVC tubes 5 cm diameter are inserted for aeration purposes. See digram (5) After the heap formation is completed it is covered with black polythene or by a mud paste. Weights are kept on the top of the heap. Water in sufficient quantities are added at the time of piling up. The bamboo poles PVC tubes are withdrawn in 2-3 days, leaving the holes to remain. After four to five days the temperature rises to 60-70 C^{o} and the holes are sealed off. The first turning is done after two weeks and water is added in sufficient quantities to moisten the material. This is again heaped up and sealed with mud or covered with black polythene. Two more turnings are done at 4 weeks and 6 weeks. The compost is ready in 8 weeks.

ANAEROBIC METHODS

No air is allowed into the system and microbes uses other sources of material to break down complex organic forms. eg. Bio gas production. As air circulation is cut off, partial decomposting take place. The pit method of composting if covered by a layer of animal urine will result in the anaerobic decomposition of material which will be ready as compost in 6-8 months.

Bio-gas preparation results in anaerobic decomposition. Methane, carbon dioxide and hydrogen sulphide gases are produced. The bio-gas slurry forms a suitable material for addition in crop husbandry.

Continuous Supply of Compost for Crop Production.

A series of heaps or pits has to be organized if a continuous supply is necessary. This could be worked out for disposal of urban refuse.

Nature and Properties of finished composts.

The finished compost should have the following features:

(i) Dark brown to black in colour.

(ii) Practically insoluble in water.

(iii) Has a C/N Ratio ranging from 10 to 20.

(iv) Has a beneficial effect both on the soil and the growing crops.

Precautions necessary in using compost.

Compost made out of city garbage may carry,

- Heavy metals of Arsenic, Lead, Cadmium and mercury are extremely harmful to both humans and domestic animals.
- **Harmful to humans and animals.** Pathogens of diseases of Enteritis, Tuberculosis etc, **Pathogens** could be found in city wastes. Since their thermal death points are specific, care should be taken to allow the heating up of heaps.

Note: For additional reference see DOA publication on Organic manure usage.

Appendix 9.

ECONOMICS OF IPNS

Crop: Rice

Production area: 4000 m^2(1ac)

Treatment	Cost of Ferti. Rs. Cts.	Cost of Manure Rs. Cts.	Operational Cost Rs. Cts.	Total Cost Rs. Cts	Yield mt.	Gross Return Rs. Cts.	Net Return Rs. Cts.	Cost $Rs.Kg^{-1}$	VCR
No Fertilizer	-	-	10,000.00	10,000.00	1.0	11,000.00	1000.00	10.00	-
NPK Fertilizer	1432.00	-	10,000.00	11432.00	1.4	15,400,00	3968.00	8.13	3.07
NPK+Rice straw (RS)	1432.00	300.00	10,000.00	11732.00	1.8	19,800.00	8068.00	6.52	5.08
NPK+RS+ Cowdung (CD)	1432.00	1800.00	10,000.00	13,232.00	2.6	28,600.00	15368.00	4.97	5.44
NPK+RD+CD+Green manure +Rice husk charcoal	2740.00	2500.00	10,000.00	15,240.00	4.0	44,000.00	28760.00	3.81	6.29

The table shows Value Cost Ratio (VCR) increase with the use of different organic materials applied together with NPK alone has not given high VCR.

RS - Rice straw,; CD - Cowdung, RH - Rice husk, VCR - Value cost ratio

Source: DOA.