



Module No.

2

TEA RESEARCH Institute of Tanzania



On station fertilizer trials at NTRS



A well established tea field at Mufindi



Weed infested fields will

NUTRITION OF THE TEA PLANT.

FERTILIZERS AND MANURES.

Training module
February 2002

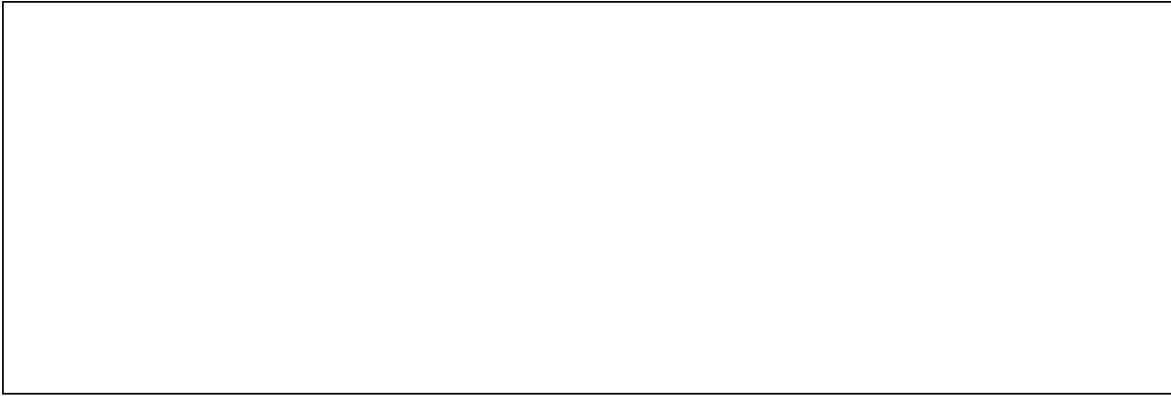
FOREWORD

This is the second of a series of training modules prepared by the Tea Research institute of Tanzania (TRIT). The first was on Rehabilitation of abandoned tea fields.

The application of fertilizer and manure is an important component of the normal intensive production of tea. Nutrients in the soil become depleted due to plant nutrient uptake and leaching leading to mineral deficiencies in the plants. Optimum fertilizer levels differ with locations and fertilizer may be based on analyses of soil and or foliage and symptoms of mineral deficiencies or toxicities. This training module is intended for Tea Growers, Managers, Researchers, Extension workers and Students.

TRIT acknowledges with thanks the generous financial assistance provided by the European Union through Stabex funds in the preparation of this training module

Prof Bruno. J. Ndunguru
Research Director, TRIT



SMILE!

HOW TO GET THE MOST OUT OF THE TRAINING COURSE

1. This Training Course belongs to YOU and rests largely with you.
2. Enter into the discussion ENTHUSIASTICALLY
3. GIVE FREELY of your experience
4. CONFINE your discussion to the problem
5. Say what you THINK
6. Only ONE PERSON should talk at a time. Avoid private conversation while someone else is speaking.
7. LISTEN ALERTLY to the discussion
8. BE PATIENT with other members
9. APPRECIATE the other fellow's point of view
10. BE PROMPT and REGULAR in attendance

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TECHNICAL TRAINING MODULE
A DETAILED SUMMARY

TITLE:

FERTILIZERS AND MANURES

NUTRITION OF THE TEA PLANT

- INTRODUCTION
 - Basic tea physiology
 - Soils and climatic conditions
- OBJECTS OF MANURING
- TERMINOLOGY
 - i. Fertilizers (inorganic)
 - ii. Manures (organic)
- ELEMENTS ESSENTIAL FOR PLANT GROWTH (with chemical symbols in brackets)
- COMPOUND FERTILIZERS
- STRAIGHT FERTILIZERS } choice based largely on cost considerations
- NITROGEN CARRIERS (commonly in use)
- PHOSPHATE CARRIERS (commonly in use)
- POTASH CARRIERS (commonly in use)
- MAJOR NUTRIENTS (MACRO-NUTRIENTS) FUNCTIONS AND DEFICIENCY SYMPTOMS
 - i. Importance of **n**itrogen
 - Deficiency symptoms
 - ii. Importance of **p**hosphorus
 - Deficiency symptoms
 - iii. Importance of **p**otassium
 - Deficiency symptoms
- TRACE OR MINOR NUTRIENTS (MICRO-NUTRIENTS) FUNCTIONS AND DEFICIENCY SYMPTOMS
- SOIL AMENDMENTS
- TREATMENT OF HUTSITES AND SOILS WITH pH HIGHER THAN OPTIMUM
- FERTILIZER STORAGE
- NUTRIENT REMOVAL BY THE TEA CROP AT DIFFERENT LEVELS OF PRODUCTION
- APPLICATION RATES
 - i. Mature Tea
 - ii. Immature (young) tea
 - iii. **P**lanting holes
 - iv. Infills
 - v. Mother bushes
 - vi. Nursery soils
 - vii. Nursery plants
- METHODS OF APPLICATION
- CURRENT FERTILIZER PRACTICES ON DIFFERENT ESTATES AND SMALLHOLDER TEA FARMS AND HOW THEY MAY BE IMPROVED UPON
- BULKING (MIXING) OF FERTILIZERS
- TIME AND FREQUENCY OF APPLICATION
- SOIL AND LEAF SAMPLING TECHNIQUES
- MANURE (organic)
 - Farmyard manure
 - Compost
 - Mulch - Leguminous
- ECONOMICAL FERTILIZER APPROACH (**c**ase study)
- SOCIAL ECONOMIC FACTORS GOVERNING FERTILIZER USE AND APPLICATION
- USEFUL HINTS ON FERTILIZERS AND MANURES
- CALCULATING FERTILIZERS
- PROFICIENCY EVALUATION

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NUTRITION OF THE TEA PLANT

FERTILIZERS AND MANURES

INTENDED FOR: EXTENSION, TECHNICAL STAFF AND FARMERS.
NUMBER: MAXIMUM 20 PARTICIPANTS PER SESSION
OBJECTIVES: AS A RESULT OF THIS THREE-DAY MODULE THE EXTENSION AND TECHNICAL STAFF WILL BE ABLE TO:-

1. FULLY UNDERSTAND THE PRINCIPLES AND TECHNIQUES OF FERTILIZER AND MANURE APPLICATION TO THE TEA PLANT.
2. IMPROVE YIELDS **AND PROFITABILITY** OF BOTH CLONAL AND SEEDLING TEA **BY OPTIMUM ECONOMIC FERTILIZER USAGE**.
3. DETECT NUTRIENT DEFICIENCY SYMPTOMS AND APPLY CORRECTIVE FERTILIZER MEASURES.
4. CALCULATE MIXTURES WITH N:P₂O₅: K₂O RATIO OF 25:5:5 FROM STRAIGHT FERTILIZERS.

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- CONTENTS:**
1. PRINCIPLES AND TECHNIQUES OF FERTILIZER AND MANURE APPLICATION TO THE TEA PLANT.
 2. MAJOR AND MINOR NUTRIENTS FUNCTIONS, DEFICIENCIES AND REMEDIES.
 3. COMPOUND AND STRAIGHT FERTILIZERS.
 4. RATES, TIME, FREQUENCY AND METHODS OF FERTILIZER APPLICATIONS.
 5. SOIL AND LEAF SAMPLING TECHNIQUES
 6. MANURE APPLICATION TO TEA

METHOD OF DELIVERY: THE COURSE IS PARTICIPATIVE AND DESIGNED TO PROVIDE A COMPREHENSIVE BALANCE BETWEEN THEORY AND PRACTICE. VISITS TO NEARBY TEA FIELDS WILL BE AN IMPORTANT ASPECT OF THE COURSE. PARTICIPANTS WILL BE ABLE TO ATTEMPT SOME PRACTICAL EXERCISES, WHICH WILL INCLUDE FERTILIZER APPLICATION.

DURATION: THREE DAYS

VENUE: CLOSE TO THE LOCATION OF THE PARTICIPANTS AND TEA FIELDS FOR PRACTICALS.

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- EQUIPMENT:**
- (i) PROTECTIVE CLOTHES - PLUCKING CAPE, APRON, GUM BOOTS AND GLOVES
 - (ii) RECEPTACLES: EMPTY (4 LITRE) TINS AND MEASURES (200 GRAMMES)

PRACTICALS: YOUNG TEA } FOR PRACTICAL DEMONSTRATION WITH
MATURE TEA } PARTICIPANTS ACTUALLY APPLYING FERTILIZER.

LOGISTICS: TRANSPORT, ACCOMMODATION, MEALS AND TEA FACILITIES TO BE ARRANGED BY THE MANAGER.

EQUIPMENT AND ARRANGEMENT

EQUIPMENT: PROTECTIVE CLOTHES - PLUCKING CAPE, APRON, GUMBOOTS AND GLOVES

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RECEPTACLE: CONTAINER EMPTY PAINT TIN (FOUR LITRES), MEASURE (200 GRAMMES)

PRACTICALS

- A. SPECIMEN:
- ONE BAG 50KGS OF NPKS 25:5:5:5
 - ONE BAG 50KGS OF MURIATE OR SULPHATE OF POTASH
 - ONE BAG 50KGS OF SULPHATE OF AMMONIA
 - ONE BAG 50KGS OF TRIPLE SUPERPHOSPHATE
 - ONE KG OF SINGLE SUPERPHOSPHATE
 - ONE KG OF NPK 20:10:10
 - ONE KG OF DIAMMONIUM PHOSPHATE
 - ONE KG OF UREA
 - HALF KG OF COPPER SULPHATE
 - HALF KG OF ZINC SULPHATE
 - HALF KG OF MAGNESIUM SULPHATE
- B. SPECIMEN:
- PRACTICAL IDENTIFICATION IN THE FIELD
 - POTASSIUM DEFICIENCY-WHITE BARK, THIN MAINTENANCE LAYER, MAT OF FALLEN LEAVES UNDER THE BUSH
 - NITROGEN DEFICIENCY - LARGE YELLOW LEAVES
 - PLASMOLYSIS - YOUNG TEA DEFOLIATION
 - MAGNESIUM DEFICIENCY - DARK INVERTED 'V' ALONG MIDRIB OF MATURE LEAF
 - ZINC DEFICIENCY OF TEA - REDUCTION IN LEAF SIZE, ROSETTING
 - PHOSPHATE DEFICIENCY - MATURE LEAVES DULL AND BRITTLE.

ACTIVITIES: OBSERVE, DISCUSS, COMMENT AND PRACTICALS
FILL IN PLANNED VISIT SHEET

GENERAL REQUIREMENTS:

HANDOUTS

FLIP CHARTS, FLIP CHART STAND

OHP

PEN, PENCIL, RUBBER, RULER,

FILE FOR EACH PARTICIPANT

MARKER PENS

MASKING TAPES

WRITING PADS

NOTE BOOKS

PLANNED VISIT SHEETS

IDEA SHEETS

ACTION ARISING FROM THE DAY

ASSESSMENT SHEETS

OBJECTIVES

PROGRAMMES

PROFICIENCY TEST

KEY ACTION PLANS

PROGRAMME

DAY ONE

TIME	DETAILS	ACTION BY
7.45	ALL PARTICIPANTS ARRIVE	ALL
8.00	INTRODUCING GUEST OF HONOUR TO OPEN COURSE	COURSE FACILITATOR
8.05	WELCOME COURSE LEADER	MANAGER
	COURSE PARTICIPANTS EXCHANGE EXPERIENCE	ALL
8.25	PROGRAMME	COURSE FACILITATOR
8.30	NUTRITION OF THE TEA PLANT FERTILIZERS AND MANURES INTRODUCTION AND METHOD OF DELIVERY	COURSE FACILITATOR
	OBJECTIVES	FACILITATORS
8.40	ELEMENTS ESSENTIAL FOR PLANT GROWTH	COURSE FACILITATOR
8.50	FERTILIZERS AND MANURES TYPES OF:- 1. FERTILIZERS COMMONLY IN USE 2. MANURES COMMONLY IN USE 3. SOURCE OF FERTILIZERS AND MANURES	PARTICIPANTS
9.15	PRESENTATION AND DISCUSSION EACH GROUP	ALL
9.45	TEA BREAK	ALL
10.05	FERTILIZERS: COMPOUNDS STRAIGHTS	FACILITATORS & PARTICIPANTS
10.30	MAJOR NUTRIENT CARRIERS NITROGEN PHOSPHATE POTASH	ALL
10.45	MAJOR NUTRIENTS N, P & K FUNCTIONS DEFICIENCY SYMPTOMS REMEDIES	ALL
11.00	MINOR NUTRIENTS: ZINC, COPPER, MAGNESIUM AND SULPHUR FUNCTIONS DEFICIENCY SYMPTOMS REMEDIES	ALL
11.10	SOIL AMENDMENTS SULPHUR ALUMINIUM SULPHATE	ALL
11.15	TREATMENT OF HUTSITES	ALL
11.30	FERTILIZER STORAGE	ALL

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11.45	NUTRIENT REMOVAL BY THE TEA CROP	ALL
12.00	APPLICATION RATES: MATURE TEA IMMATURE TEA PLANTING HOLES INFILLS MOTHER BUSHES NURSERY SOILS NURSERY PLANTS	
12.45	METHODS OF APPLICATION	ALL
1.00	<i>LUNCH</i>	ALL
2.00	FERTILIZER PRACTICES ESTATES AND SMALLHOLDERS	ALL
2.30	MIXING OF FERTILIZERS	ALL
3.00	TIME AND FREQUENCY OF APPLICATION	ALL
3.30	SOIL SAMPLING LEAF SAMPLING	ALL
4.00	ACTIONS ARISING FROM THE DAY	ALL
4.30	<i>END OF DAY ONE</i>	

PROGRAMME

DAY TWO

TIME	DETAILS	ACTION BY
8.00	RECAP	COURSE FACILITATOR
8.15	MANURES (Organic) GREEN MANURE COMPOST MANURE MULCH-LEGUMINOUS	PARTICIPANTS IN GROUPS
8.40	PRESENTATION AND DISCUSSION	ALL
9.40	<i>TEA BREAK</i>	
10.00	ECONOMICAL FERTILIZER APPROACH (case study)	ALL
12.00	SOCIAL ECONOMIC FACTORS INFLUENCING FERTILIZER USE AND APPLICATION	ALL
12.30	<i>LUNCH</i>	
2.00	RECAP	FACILITATOR
2.30	USEFUL HINTS ON FERTILIZERS AND MANURES DISCUSSION	ALL
3.00	CALCULATING FERTILIZER	ALL
4.15	ACTIONS ARISING FROM THE DAY	PARTICIPANTS
4.30	<i>END OF DAY TWO</i>	

PROGRAMME

DAY THREE

TIME	DETAILS	ACTION BY
8.00	RECAP	COURSE FACILITATOR
8.15	IDENTIFICATION OF DIFFERENT TYPES OF FERTILIZERS	ALL
8.30	PREPARATION FOR PRACTICALS: 1. FERTILIZER 2. CHECK EQUIPMENT, CONTAINER 4 LITRE, SPADE, KNIFE, GROUND SHEET & MEASURE 200G 3. CHECK PROTECTIVE GEAR, WATER, SOAP & TOWEL	ALL
8.35	DEPART FOR FIELD VISITS AND PRACTICALS	ALL
9.00	VISIT 1 PRACTICAL FERTILIZER APPLICATION PROCEDURES - APPLICATION METHOD TO BE DECIDED - RE-CHECK FERTILIZER, MIX IF REQUIRED, EQUIPMENT, PROTECTIVE GEAR AND THE WEATHER - APPLY FERTILIZER CAREFULLY, AVOID SCORCHING LEAVES - CHECK AGAIN EMPTY SACKS, EQUIPMENT AND PROTECTIVE GEAR BEFORE YOU LEAVE THE FIELD - RETURN IN STORE EMPTY SACKS AND EQUIPMENT - CLEAN PROTECTIVE GEAR, REMOVE ALL CLOTHES AND CLEAN BODY WITH SOAP AND TOWEL AND CHANGE CLOTHES	ALL
11.00	VISIT 2 NUTRIENT DEFICIENCIES - FIELD IDENTIFICATION AND DISCUSSION	ALL
12.00	VISIT 3 FERTILIZER STORE	ALL
	PLANNED VISIT SHEET	PARTICIPANTS
1.00	L U N C H	
2.00	PLANNED VISIT SHEET DISCUSSION	ALL
2.15	THE CONFIDENCE BUILDER	PARTICIPANTS
3.00	SHARE THE CONFIDENCE BUILDER	ALL
3.30	KEY ACTION PLAN	PARTICIPANTS
3.50	IDEA SHEET	PARTICIPANTS
4.00	COURSE ASSESSMENT SHEET	PARTICIPANTS
4.25	GUEST OF HONOUR TO CLOSE COURSE	GUEST OF HONOUR
4.30	END OF THE COURSE	

OBJECTIVES:

**AS A RESULT OF THIS THREE DAY MODULE THE EXTENSION AND TECHNICAL STAFF
WILL BE ABLE TO:-**

1. FULLY UNDERSTAND THE PRINCIPLES AND TECHNIQUES OF FERTILIZER AND MANURE APPLICATION TO THE TEA PLANT

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2. IMPROVE YIELDS AND PROFITABILITY OF BOTH CLONAL AND SEEDLING TEA BY OPTIMUM ECONOMIC FERTILIZER USAGE.

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3. DETECT NUTRIENT DEFICIENCY SYMPTOMS AND APPLY CORRECTIVE FERTILIZER MEASURES.

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4. CALCULATE MIXTURES WITH N:P₂O₅:K₂O RATIO OF 25:5:5 FROM STRAIGHT FERTILIZERS.

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SESSION PLAN 1

TIME	CONTENT	TECHNIQUES AND AIDS
5Min	INTRODUCTION	
20Min	COURSE PARTICIPANTS EXCHANGE EXPERIENCE	Q&A FLIP CHART
5Min	PROGRAMME	HAND OUT
10Min	INTRODUCTION AND METHOD OF DELIVERY OBJECTIVES	OHP/FLIP CHART
10Min	ELEMENTS ESSENTIAL FOR PLANT GROWTH	OHP/FLIP CHART
25Min	FERTILIZERS AND MANURES TYPES OF: 1. FERTILIZERS COMMONLY IN USE 2. MANURES COMMONLY IN USE 3. SOURCE OF FERTILIZERS AND MANURES.	“HUM GROUP” OR “BRAIN STORM” FLIP CHART
30Min	PRESENTATION AND DISCUSSION	GROUP PRESENTATION, FLIP CHART
20Min	TEA BREAK	
25Min	FERTILIZERS: COMPOUNDS STRAIGHTS	Q&A
15Min	MAJOR NUTRIENT CARRIERS NITROGEN PHOSPHATE POTASH	Q&A
15Min	MAJOR NUTRIENTS N, P, & K, FUNCTIONS DEFICIENCY SYMPTOMS REMEDIES	Q&A
10Min	MINOR NUTRIENTS: ZINC, COPPER, MAGNESIUM, AND SULPHUR FUNCTIONS DEFICIENCY SYMPTOMS REMIDIES	Q&A
5Min	SOIL AMENDMENTS SULPHUR ALUMINIUM SULPHATE	Q&A
15Min	TREATMENT OF HUTSITES	Q&A
15Min	FERTILIZER STORAGE	Q&A
15Min	NUTRIENT REMOVAL BY THE TEA CROP	Q&A
45Min	APPLICATION RATES MATURE TEA IMMATURE TEA PLANTING HOLES INFILLS MOTHER BUSHES	Q&A – EQUIPMENT PROTECTIVE – PLUCKING CAPE APRON, GUM BOOTS GLOVES, WATER, SOAP & TOWEL GROUND SHEET FERTILIZERS, SPADE & KNIFE

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	NURSERY SOILS NURSERY PLANTS	CONTAINER 4 LITRE TIN MEASURE 200 GRAMMES.
15Min	METHODS OF APPLICATION	
60Min	LUNCH	
30Min	FERTILIZER PRACTICES ESTATES AND SMALLHOLDERS	Q&A
30Min	MIXING OF FERTILIZERS	Q&A TOOLS
30Min	TIME AND FREQUENCY OF APPLICATION	Q&A
30Min	SOIL SAMPLING LEAF SAMPLING	Q&A THICK PAPER, AUGER POLYTHENE BAGS, PENCIL, PAPER BAGS, ADHESIVE TAPE
30Min	ACTIONS ARISING FROM THE DAY	
	END OF DAY ONE	

SESSION PLAN 2

TIME	CONTENT	TECHNIQUE & AIDS
15min	<i>RECAP</i>	Q & A
25min	MANURES ORGANIC GREEN MANURE COMPOST MANURE MULCH - LEGUMINOUS	"HUM GROUP" or "BRAIN STORM" FLIP CHART THREE GROUPS
60min	PRESENTATION AND DISCUSSION	GROUP PRESENTATION
20min	TEA BREAK	
120min	ECONOMICAL FERTILIZER APPROACH (case study)	HANDOUTS & Q & A
30min	SOCIAL ECONOMIC FACTORS INFLUENCING FERTILIZER USE AND APPLICATION	Q & A Q & A
90min	<i>LUNCH</i>	
30min	RECAP	Q & A
30min	USEFUL HINTS ON FERTILIZERS & MANURES	DISCUSSION
75min	CALCULATING FERTILIZERS	Q & A
15min	ACTION ARISING FROM THE DAY	
	<i>END OF DAY TWO</i>	

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SESSION 3.

TIME	CONTENT	TECHNIQUE & AIDS
15Min	RECAP	Q & A
15Min	IDENTIFICATION OF FERTILIZERS	VARIOUS FERTILIZERS
5.Min	PREPARATION FOR PRACTICALS 1. FERTILIZER 2. EQUIPMENT: CONTAINER 4 LITRE TIN, MEASURE, SPADE, KNIFE, GROUND SHEET. 3. PROTECTIVE GEAR: PLUCKING CAPE, APRON, GUMBOOTS, GLOVES, WATER, SOAP & TOWEL.	Q&A Deleted: L
25Min	DEPART FOR FIELD VISITS AND PRACTICALS.	TRANSPORT
120Min	VISIT 1 PRACTICAL FERTILIZER APPLICATION <u>PROCEDURE</u> - APPLICATION METHOD TO BE DECIDED - RE-CHECK – FERTILIZER, MIX IF REQUIRED, EQUIPMENT, PROTECTIVE GEAR AND WATER. - CHECK AGAIN EMPTY SACKS, EQUIPMENT AND PROTECTIVE GEAR BEFORE YOU LEAVE THE FIELD. - RETURN IN STORE EMPTY SACKS AND EQUIPMENT. - CLEAN PROTECTIVE GEAR, REMOVE ALL CLOTHES AND CLEAN BODY WITH PLENTY OF WATER, SOAP AND TOWEL, CHANGE CLOTHES.	"BRAIN STORM" Q&A
60Min	VISIT 2 NUTRIENT DEFICIENCIES – FIELD IDENTIFICATION AND DISCUSSION	Q&A
60Min	VISIT 3 FERTILIZER STORE-PLANNED VISIT SHEET	PLANNED VISIT SHEET
60Min	<i>LUNCH</i>	
15Min	PLANNED VISIT SHEET DISCUSSION	Q&A
45Min	THE CONFIDENCE BUILDER	Q&A
30Min	SHARE THE CONFIDENCE BUILDER	
20Min	KEY ACTION PLAN	
10Min	IDEA SHEET	
25Min	COURSE ASSESSMENT SHEET	
5Min	GUEST OF HONOUR TO CLOSE COURSE	
	END OF THE COURSE	

THE NUTRITION OF THE TEA PLANT: FERTILIZERS AND MANURES

INTRODUCTION:

The application of fertilizers and manures is an important component of the normal intensive production of tea. Optimum fertilizer usage, in association with other appropriate management cultural practices, should produce high and profitable yields. For the most effective use of applied fertilizer many soils need to be improved so that they include a high proportion of organic matter.

Tea is grown as a long-term crop. Nutrients in the soil become depleted leading to mineral deficiencies in the plants, severe reduction in yield, ultimately to the death of plants and degraded tea field or smallholder tea plot. Fertilizer levels may be based on the results of field experiments, analyses of soil and/or foliage, and symptoms of mineral deficiencies or toxicities. Optimum fertilizer applications vary from one region, district, division, village or field to field in accordance with local soils and climatic conditions.

The tea plant in normal conditions takes in through the root system, some of the elements required by absorbing them in solution from the soil. The soil solution is therefore the source of these elements, which must be present in such quantities that the plant can absorb as much as it needs. They are always present as chemical compounds and referred to as nutrients. The tea plant requires rainfall of about 1200mm per annum, well distributed throughout the year. Air, leaf and soil temperatures all influence the rate of growth of tea. Soil provides anchorage for roots, acts as a storehouse for tea plant nutrients and a reservoir for soil moisture. The best soil for tea is a medium light loam, deep and friable, well supplied with nutrients and with a pH range of 5.0 - 5.6.

OBJECTIVES OF MANURING

- To replenish the depleted nutrients caused by removal of crops (plucking), soil erosion and leaching
- To ensure continuous availability of nutrients to the tea plant.
- To harvest high yields.

TERMINOLOGY:

- (i) *Fertilizer (inorganic)*: A term generally applied to a nutrient carrying material of mineral like appearance.
- (ii) *Manure (organic)*: Material originating from plant or animal which is added to the soil to improve fertility.

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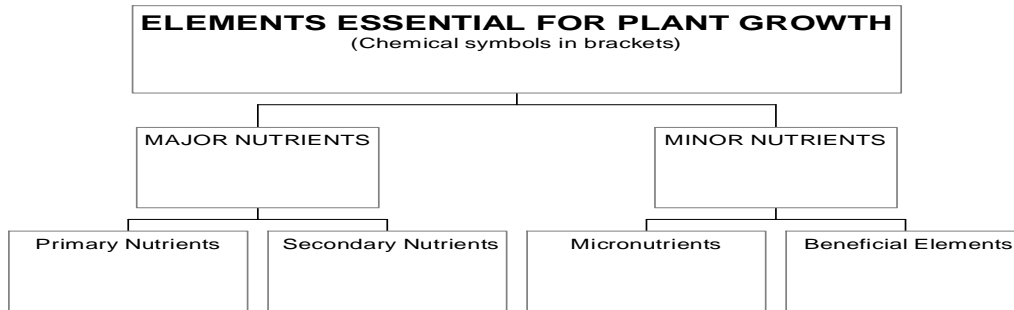
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Carbon (C)	Magnesium (Mg)	Zinc (Zn)	Aluminium (Al)
Hydrogen (H)	Calcium (Ca)	Manganese (Mn)	Silicon (Si)
Oxygen (O)	Sulphur (S)	Boron (B)	
Nitrogen (N)		Iron (Fe)	
Phosphorus (P)		Copper (Cu)	
Potassium (K)		Molybdenum (Mo)	
		Chlorine (Cl)	

Note: Other elements have been reported to be essential for, or to confer to, the growth of certain plant species. The above list covers those accepted as essential for all plants.

COMPOUND (COMPLEX) FERTILIZERS

This is a group description, denoting intimate mixtures of nutrient - carrying chemicals, manufactured in such a way that the components cannot be separated by crude, mechanical means. They are to be sharply distinguished for this reason, from physical mixtures. In their physiological action, there is little if any reason to suppose that they need differ from a physical mix of the same form of nutrients, if this is to be made. A wide range of nutrient formulae can be prepared and compound fertilizers are now usually manufactured in hard granules, which remain dry and separate under good storage conditions, and permit efficient distribution in the fields.

The range of NPK formula already familiar to the East African tea industry, and of which 25:5:5: is one, and 20:10:10 is another containing nitrogen in two forms, ammonium and nitrate, often in the ratio 2:1. Phosphorus is present as water-soluble phosphate. Potassium, as in all the potassic fertilizers dealt with in these notes, is water-soluble. Sulphur, if present, is usually in the elemental, insoluble form. It is not known that the forms of these nutrients have any influence on their value for tea. Usually, calcium is not present. Compound fertilizers, which contain ammonium-nitrogen, will acidify the soil.

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STRAIGHT FERTILIZERS

These are chemical compounds which are made and sold as individual fertilizers. Each may contain more than one nutrient, but this does not arise because of deliberate mixing during manufacture, and the ratio of nutrients in the purified fertilizer is only able to vary very little, or not at all. They can be formulated as powders, crystals, pellets or granules.

(i) Sulphate of ammonia (or ammonium sulphate - 21%N and 24%S)

This contains two nutrients, nitrogen 21%N and sulphur 24%S. All the nitrogen is in the ammonium form and the sulphur is present as sulphate. The fertilizer is usually sold as dry, free flowing, small white crystals. The dry crystals are compatible with other fertilizers in this list, except that granular fertilizers in general are difficult to mix with any other material apart from powders. Sulphate of ammonia is a valuable sulphur containing fertilizer, usually stable in the store and handling well in the

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field. Acidifies the soil strongly. Non-hygroscopic. No volatilisation loss. Conversion factor (cf) = $\frac{100}{21} = 4.76$ (1kg N = 4.76kg Ammonium sulphate). Unit cost of N highest.

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(ii) Ammonium sulphate nitrate (26%N and 12%S)

This is a chemical compound, not a mixture, and contains two nutrients, nitrogen at 26%N, and sulphur at 12%S. The ratio of ammonium - N to nitrate - N is approximately 3:1 and the acidifying action is therefore slightly less than for sulphate of ammonia. The sulphur is present as sulphate.

(iii) Urea (42 - 46%N)

A compound of nitrogen, carbon and oxygen containing 42-46%N. This form of nitrogen decomposes under the action of a soil-borne enzyme, and is converted to ammonium bicarbonate. This compound is volatile, and if it is formed while urea is still on the soil surface, there is a risk of a serious loss of ammonia gas to the atmosphere. For this reason, care in the choice of weather conditions at the time of application is vitally important. Urea is formulated as small, hard pellets, which gradually absorb moisture from the atmosphere. If storage conditions are damp and the sacks are damaged, or if the urea pellets (or prills) are mixed with other fertilizers, the urea may become very sticky indeed. Highly hygroscopic. Acidifies the soil to a lesser degree than the ammonium fertilizers.

Poor keeping quality cf = $\frac{100}{46} = 2.2$ kg Urea). Unit cost of N cheapest.

(iv) Concentrated superphosphate (or Triple superphosphate 40-50% P₂O₅)

This covers a group of products, variously called "double" or "triple superphosphates." Phosphate rock is treated with phosphoric acid, to give water-soluble products of varying composition, phosphorus at 40 to 50% P₂O₅, calcium at approximately 14% Ca, and little or no sulphur. They are formulated as hard granules, which should be used in preference to powdered forms.

(v) Single superphosphate (20% P₂O₅, 10-12% S and 20%Ca)

This is manufactured from phosphate rock and sulphuric acid, and is an intimate mixture of calcium phosphates and calcium sulphate (gypsum). Contains three nutrients, phosphorus at 20% P₂O₅, sulphur at 10 to 12% S and approximately 20% calcium (Ca). The composition varies according to the choice of materials and technology. A small proportion of the phosphate is citric-soluble, the remainder being water-soluble. These proportions are usually stated by the manufacturer.

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(vi) Phosphate rock (up to 30% P₂O₅ and Ca)

Deposits of various types of phosphoric minerals exist in East Africa, although they have not yet been used in the raw state in our tea, their potential use should be mentioned. The composition varies widely, phosphorus, up to 30% P₂O₅ and calcium being the two main nutrients. They are insoluble in water, but when finely crushed, they dissolve slowly in the soil, especially where the pH is low, temperature and rainfall are high. Conditions in our tea soils are favourable to a reasonable rate for the release of phosphate. Requires placement at 15 - 20 cm depth in soil. cf = $\frac{100}{30} = 3.3$ (1kg P₂O₅ = 3.3kg Rock phosphate)

(vii) Di-ammonium phosphate 18-20%N and 48 to 50%P₂O₅

Contains two nutrients, nitrogen at 18 to 20% N and phosphorus at 48 to 50% P₂O₅. All the nitrogen is in the ammonium form and the phosphate is water-soluble. This compound dissolves readily and acidifies the soil quite strongly. It is usually formulated as hard granules and is a useful source of nitrogen and phosphorus.

(viii) Muriate of potash (or potassium chloride 50-60% K₂O)

The potassium content ranges from 50 to 60% K₂O (Note: although chloride is an essential element, it is required in minute quantities and is so plentiful in agriculture that its presence in fertilizers is not taken into account in their evaluation). Muriate of potash is readily soluble, and is formulated as a fairly dry, coarse powder. Impurities may cause it to be moist, and difficult to handle. Normally, it will mix well with other fertilizers. cf = $\frac{100}{60} = 1.67$ (1kg K₂O = 1.67kg MOP) Unit cost cheaper.

(ix) Sulphate of potash (or potassium sulphate 48-52% K₂O and 15 to 17%S) Of similar origin to the muriate, this salt contains two nutrients, potassium at 48 to 52% K₂O and sulphur at 15 to 17%S.

Both nutrients are water-soluble. In appearance and properties this compound is similar to muriate, except for the possible value of sulphur. Unit cost highest.

(x) Magnesium sulphate (Epsom salts or Kieserite)

Magnesium is not yet used as a general fertilizer nutrient in East African tea, but it should be included in the present list. Both these compounds are magnesium sulphate. Epsom salts contains 10% magnesium (Mg) and Kieserite 17% Mg. The sulphur contents are 13 and 23%S respectively. Epsom salts can be used for foliar application.

(xi) Gypsum (or calcium sulphate 23% Ca.)

The calcium content is 23% Ca. And the sulphur content 19%S. Gypsum is only slowly soluble in water, cannot scorch tissues, and may be a useful source of sulphur under certain circumstances. It should be bought in a powdered form.

NITROGEN CARRIERS (commonly in use)

- Sulphate of ammonia (SA) ($(NH_4)_2 SO_4$) - contains 21%N as ammonium and 24% sulphur. Cheap and readily available. Acidifies the soil and is a valuable source of sulphur.
- Ammonium nitrate (AN) (NH_4NO_3) – contains 35.5% nitrogen, half as ammonium, and half as nitrate. The advantage of higher nitrogen are nullified by the deliquescent nature of the material, it is therefore, not suitable in a pure state for tea plantations.
- Ammonium sulphate nitrate (ASN), a mixture of SA and AN with 26% nitrogen. Not deliquescent can therefore be handled more easily than AN.
- Calcium ammonium nitrate (CAN), a mixture of AN with limestone (calcium carbonate) to neutralize the acidifying effect, nitrogen 25%. The adverse effect of calcium in CAN must be borne in mind.
- Urea $CO(NH_2)_2$ - concentrated nitrogen 46%N. Mild acidifying effect. Highly soluble in water. Decomposes at high temperatures. Very effective for foliar application. Contains an impurity, biuret, which is toxic to plants in sufficient quantity.

PHOSPHATE CARRIERS (commonly in use)

- Single superphosphate (SSP), contains 20% water soluble P_2O_5 , 11% sulphur and 21% calcium.
- Double superphosphate (DSP) or Triple superphosphate (TSP), no sulphur, about 1% calcium and 45 - 51% water soluble P_2O_5 . Deleted: S
- Dicalcium phosphate (DCP), contains 35-40% soluble P_2O_5 , upto 1% sulphur and about 23% calcium. Suitable for very acid soils. Deleted: P
- Di-ammonium and mono-ammonium phosphate (DAP & MAP), both have the added advantage that they also contain N. Use usually confined to mixtures or compound fertilizers.
- Reno or rhenania phosphate is alkaline 27% P_2O_5 and 29% calcium.
- Ground rock phosphate 20% - 35% P_2O_5 with calcium between 20% - 39%. Deleted: ¶

POTASH CARRIERS (commonly in use)

- Potassium chloride or muriate of potash (KCl or MOP) contains 60% K_2O and 47% chlorine.

- *Sulphate of potash* (K_2SO_4 or SOP) contains 50% K_2O and 18% sulphur usually more expensive than MOP. Unit cost high. $cf = \frac{100}{50} = 2$ (1kg (K_2O) = 2kg Potassium sulphate).
- *Nitrate of potash* (KNO_3 or NOP) combines potash 44% with nitrogen 13%.

MAJOR NUTRIENTS (MACRO-NUTRIENTS) FUNCTIONS AND DEFICIENCY

SYMPTOMS

- **Importance of Nitrogen:** Adequate nitrogen in the soil is important for the optimum growth of plants, all their vital processes are associated with the presence of nitrogen. Nitrogen functions effectively in the structure of proteins, vitamins, hormones and chlorophyll. The presence of adequate nitrogen in plants is revealed by luxuriant and vigorous leafy growth and consequently by high crop yield.

Deficiency Symptoms:

- (i) Lighter than normal green colour in young flush, eventually becoming quite yellow.
- (ii) Mature foliage changes from dark green to lighter green as deficiency becomes severe.
- (iii) Auxiliary buds do not develop
- (iv) Crop **yields** decline. (There can be other reasons for this)

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NOTE:

- (a) Some bushes (e.g. clone 6/8) may have yellow or creamy white leaves – this is **genetic**.
- (b) Sometimes, whole areas may pale for several weeks then return to normal – this is seasonal (**low temperature**).
- (c) Water logging can often cause a paling of leaf.

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genetic

- **Remedy of nitrogen deficiency**

Apply 50-150kgs N/ha as sulphate of ammonia depending on affordability if the yellow colour of the leaves is the result of inadequate applications of nitrogen.

- **Importance of Phosphorus**

Phosphorus stimulates new root and wood formation in tea plants and produces rapid and vigorous growth, and sometimes improves disease resistance. Phosphorus is essential for cell division because it is a constituent element of nucleoproteins which are involved in cell reproduction processes. It takes part in reactions involving carbohydrate synthesis and breakdown.

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Deficiency symptoms

- a. An absence of gloss on the leaf surface. They appear dull and matt.
- b. Excessive dieback of young and old woody stems, particularly after pruning.
- c. A lack of response to nitrogen.

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Remedy of phosphorus deficiency – Phosphatic fertilizers should be used at a rate of 60kg P_2O_5 /ha. An undisturbed mulch of prunings and leaf fall on the soil is essential.

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- **Importance of Potassium**

Potassium helps to maintain the balance between respiration and transpiration. This balance helps the plant to economise in the use of water and reduces the tendency to wilting. It regulates the effect of excess nitrogen in plants. It contributes to the hardening of the supporting tissues and consequently leads to a stronger structure. Potassium is required indirectly for chlorophyll formation and aids in the transportation of carbohydrates in plants. It produces increased vigour and disease resistance.

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Deficiency symptoms

- a) Plants do not branch freely
- b) Stems remain thin and weak
- c) Poor recovery from pruning, poor callusing
- d) Defoliation of maintenance layer leading to a carpet of fallen leaves below the bush and very scanty foliage.
- e) Remaining leaves often affected by brown blight

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Remedy of potassium deficiency

Apply sulphate or muriate of potash. Rate according to the severity of deficiency. From 100 to 400 K₂O per ha.

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TRACE OR MINOR NUTRIENTS (MICRO-NUTRIENTS) FUNCTIONS AND DEFICIENCY SYMPTOMS

• ***Importance of Zinc***

Zinc is necessary for normal chlorophyll production and growth. It plays an important part in metabolism. Because it is difficult for the tea bush to mobilise sufficient quantities from the soil, it is applied by knapsack sprayer to the foliage.

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Deficiency symptoms

- a) Failure of youngest tissue to develop
- b) Little leaf and rosetted shoots, small narrow shoots are produced, one fifth of normal length, crowded at the tip of the shoot with two-sided distribution.
- c) Leaves pale and sickle shaped, curving sideways.
- d) Leaves wavy edge or up folded.
- e) Loss of crop
- f) Vague chlorosis

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Remedy of zinc deficiency

Correction by foliar application of zinc oxide or zinc sulphate. The application should be at the rate of 5kgs zinc sulphate per ha in 100 litres of water, every six months. Correction may increase yields by 10-15%.

• ***Importance of Copper***

Copper is an essential constituent of the enzyme polyphenol oxidase which is vital for fermentation. Takes part in the synthesis of chlorophyll and some vitamins.

Deficiency – Causes poor fermentation, which reduces the quality of the final product.

Remedy – A foliar application of copper sulphate will remedy the deficiency, at the rate of 5kg copper sulphate crystals per hectare dissolved in 280 litres of water.

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• ***Importance of Magnesium***

Essential part of the constitution of chlorophyll
Plays an important part in the movement of phosphorus.
Plays part in the production of carbohydrates, proteins, fats and other compounds.

Deficiency symptoms

Lower leaves bright yellow with a conspicuous inverted dark green “V” down the midrib.

Remedy – Apply potash fertilizers or magnesium sulphate (Epsom salts)

Sulphur – The sulphur deficiency known as “tea yellows”

- **Importance** - Takes part in the formation of chlorophyll.
 - Acidifies the soil
 - Takes part in oxidation
 - Included in the composition of amino-acids, proteins and enzymes.

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Deficiency symptoms

Leaves become yellow between the veins, which remain green.

Leaves of new growth become smaller and the internodes distance becomes shorter.

Leaves become more yellow, scorch and then fall off.

New shoots are stunted and ultimately the stems die back from the tip.

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Remedy

Apply a fertilizer with a high sulphur content, sulphate of ammonia 24% S.

SOIL AMENDMENTS - Generally, the optimum range of soil pH for tea is 5.0 - 5.6. Soils of pH 6.0 and above are considered unsuitable for growing tea and require correcting with acid material.

Sulphur: The element is a yellow powder, or lumps and can be used in tea growing as a soil amendment, to reduce the acidity of too alkaline soils. Although it has an obvious fertilizer value, other compounds are usually preferable where sulphur is simply required as a nutrient. Sulphur is not soluble in water, so it must be broken up and distributed evenly over a depth of soil. Sulphur is easily crushed to a sufficient fineness by spreading the commercial lumpy material on a hard floor and rolling a heavy concrete culvert section or similar object over it. The sulphur should not be ground in any type of mechanical mill, as it will catch fire. Sulphur must be thoroughly mixed with the soil from the planting holes (hole size 45cm diameter by 75cm deep), before the soil is returned to the holes. Quantity of sulphur depends on the soil pH.

The length of time to be allowed between sulphur application and planting depends on the amount of sulphur, allow at least two months for each 115g of sulphur used.

Aluminium sulphate: This compound is primarily used for acidifying soil, its sulphur content 14% S, may be of incidental value as a nutrient. The sulphur is water soluble, and aluminium sulphate even in high concentration, does not damage tea roots. The usual formulation is as lumps (described as "kibbled") which are very hard and difficult to crush. Unless reduced to small crumbs the lumps may take months to dissolve in the soil. A weight of 450g of aluminium sulphate has the same effects as 115g of sulphur.

TREATMENT OF HUTSITES

Hut site: An area of soil at one time used as an enclosure for livestock or human habitation. The soil is, in consequence, alkaline or only feebly acid so the pH level is too high for tea.

General: Soil testing must be carried out whenever patches of tea are noticed to be growing poorly, and if the symptoms of high pH are present. Suspect a hut site:-

- (i) If sedges are apparent
- (ii) If the tea is stunted, with short internodes, small-distorted leaves, tip die back.
- (iii) If pieces of charcoal or of pot are seen on the soil surface.

Sampling technique and labelling

- (i) A minimum of three holes per hut site should be sampled.
- (ii) Samples of soil from three levels 20, 40 and 60cm should be taken with an auger and must be kept separate. The samples from the three (or more) holes should be bulked. Thus there will be three (or more) sets of top soil in a bag marked "A" 20cm and similarly three (or more) sets of samples of middle soil in a bag marked "B" 40cm and three sets of samples of soil in a bag marked "C" 60cm. These samples must be clearly marked "Hut site sample" and any relevant information of identifications clearly shown.

Treatment

- (i) Hut sites and Infills - Planting.
Soil of pH 5.9 or lower will not be treated. Soils of pH 6.0 or above will be treated as follows:-

- Planting holes 45cm wide by 75cm deep will be dug.
- Sulphur must be thoroughly mixed with soil from the hole before the soil is returned to the holes. The quantity of sulphur required depends on the pH as below:-

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Soil pH values	Sulphur per hole (g)
5.9 - 6.4	115
6.5 - 6.9	225
7.0 - 7.4	340
7.5 and higher	450

Note that if only a few plants are to be put in, the holes may be filled with good forest soil brought in from the boundary.

- (ii) *Established Area.*
When tea is growing but not thriving on hut sites, aluminium sulphate may be applied. 350g per square metre should be applied every three months, for a year.

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FERTILIZER STORAGE

Fertilizer stores must be dry, secure, well ventilated, conveniently sited and of suitable size. They must be served by an all weather road, must be kept clean and tidy. Fertilizer sacks must be stacked on wooden battens or stones, leaving space for air to circulate round, and especially below each stack. Proper records must be kept of all fertilizer sacks in the store and issues recorded accordingly.

Fertilizer is a highly desirable commodity, so no chances can be taken over security. Fertilizers are corrosive, metal containers coming into contact with fertilizers must be thoroughly washed with water or damage will result.

HARVESTABLE CROP REMOVAL OF NUTRIENTS

NUTRIENT	CONTENTS ON DRY MATTER BASIS	YIELDS 2000KG MT/ha	YIELDS 5000 KG MT/ha
		ANNUAL REMOVAL	ANNUAL REMOVAL
Nitrogen Nitrate NO ₃ or Ammonium NH ₄	3.5 - 5% Nitrogen	70 - 100kgs N/ha	175 - 250kgs. N/ha
Phosphorus H ₂ PO ₄ in the ionic form	0.20 - 0.25% Phosphate	4-5 kgs P/ha	10 - 12.5 kgs P/ha

Potassium Ionic K ⁺	1.75 - 2%K	35 - 40kgs K/ha	87.5 - 100kgs K/ha
Calcium	0.5 - 1%Ca	10 - 20kgs Ca/ha	25 to 50kgs Ca/ha
Magnesium	0.05 – 0.25% Mg	4 – 6 kgs/ha	10 - 15kgs Mg/ha
Sulphur	0.15 - 0.25%S		

Source TRFK Annual Report

FERTILIZER APPLICATION RATES

i. **Mature tea:** The use of a compound fertilizer formula close to 25:5:5:5 referring to the percentage of N, P₂O₅, K₂O and S respectively, as the basis of a mature tea fertilizer programme is recommended by TRFK. This formula may be achieved:

- By the use of a compound fertilizer
 - By mixtures of straight fertilizers
 - By alternating compounds with straight fertilizers
- This may be done either within an annual programme, or in certain cases on a cycle basis.

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If little or no regular fertilizer application has been made, levels of 50, 100 and 150kgs N/ha per annum are suggested by TRIT for the first three years respectively. The full yield benefit may not be seen within the first few years of increasing fertilizer doses. Note that, if full fertilizer benefit is to be realised, other tea cultural management practices must be applied correctly.

ii. **Immature (Young) tea:** Young tea is considered by some people to be between 1 - 5 years from field planting. The plants need fertilizer to maintain their health and extra fertilizer to encourage their developing strong root and branch systems in order to support vigorous cropping at maturity. (First year is 12 months after planting.)

Amount of nitrogen to apply each year to young tea

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Clonal plants

Year from planting	One wet season	two wet seasons
First year	3 x 40kgs/ha	4 x 30kgs/ha
Second year	2 x 90kgs/ha	3 x 60kgs/ha
Third year	1 x 300kgs/ha	2 x 150kgs/ha
Fourth year	1 x 300kgs/ha	2 x 150kgs/ha
Fifth year	1 x 300kgs/ha	2 x 150kgs/ha

Source: Tea Growers Handbook (TRFK 1986)
TRIT AR 1999/2000 EXP.N14

Note: Lower rates of 62.5, 100 and 150N/ha may be applied in first, second and third year respectively, depending on the inherent soil fertility and affordability.

- iii. **Fertilizer placement in planting holes** - Single super phosphate which contains sulphur is mixed with the soil at rates which vary according to the size of the holes

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Size of planting hole depth x width	Amount of SSP per hole
30cm x 12½cm	15g
45cm x 22.5cm	30g
50cm x 25cm	40g
60cm x 30cm	54g

Source: *Tea Growers' Handbook (TRFK 1986)*

Fertilizers must be thoroughly mixed with the soil from planting holes. Where soils have carried grass or unfertilised arable crops, di-ammonium phosphate should be used instead of SSP or TSP. Do not use NPKS 25:5:5:5: on its own in the planting holes. Avoid residues from factories or farms as they may have alkaline or high pH value. Also avoid ash from burning organic matter and fresh animal droppings and urine.

- iv. **Fertilizer for infills** - Nitrogen, Phosphate and Potash fertilizers must be used in the planting hole in proportion to the size of the hole. A hole 50cm diameter by 60cm deep will need 115g diammonium phosphate and 115g sulphate of potash. Apply NPKS 25:5:5:5 to each plant at the rate of 50g per plant, three months after planting and thereafter as applied to the rest of the field.

- v. **Fertilizer for mother bushes** - Mother bushes are tea bushes which are used as a regular source of supply of cuttings. Usually pruned at intervals of five to seven months, all the prunings are taken to the nursery to be made into cuttings. Mother bushes should be given twice as much fertilizer, of the same kind, per annum as would be applied to plucked bushes of the same age. Fertilizers should be applied two or three months after each prune in at least two doses each year. If it is anticipated that there will not be rain then fertilizer should be applied immediately after pruning the mother bushes. The branch and shoot material left over should be taken back to the mother bushes and placed on the soil surface as mulch. Mother bushes for pluckable shoots propagation should be fertilised same as mother bushes for conventional method.

- vi. **Fertilizer in nursery soils** - Dependent on the type of vegetation and soil, but a mixture of sulphate of ammonia, TSP and muriate or sulphate of potash (S/A: TSP: MOP 3:4:1) 2kgs to one cubic metre of topsoil could be used. It is suggested that no fertilizer should be mixed with the sub-soil which is placed at the top 7.5cm of the polypots in which cuttings are planted. However, in some subsoil, single super-phosphate may be mixed thoroughly at a rate of 600g per one cubic metre of subsoil as single super-phosphate or 300g per one cubic metre of subsoil as triple superphosphate. Great care must be exercised before fertilizers are used in nursery soils.

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- vii. **Fertilizers in nursery plants in polypots** - Once plants have started to put on growth, rooted and polythene sheet removed, 100g of diammonium phosphate should be applied every fortnight to each bed. The fertilizer should be put on in liquid form by thoroughly dissolving it in water, and application should be followed by a light watering to clean the leaves and prevent scorch. OR a weekly application of NPKS fertilizer in solution 1g per square metre in 1.3 litres of water.

If the soils are known to be deficient in sulphur, every alternate application should be of sulphate of ammonia at 1g nitrogen per square metre i.e. 5g of sulphate of ammonia per square metre in 1.3 litres of water.

METHODS OF APPLICATION: There are different methods of fertilizer application used in tea. The total amount of fertilizer to be applied to each farmer plot of the tea field must be calculated in advance to ensure that there can be no misunderstanding. Methods of fertilizer application commonly used in tea are:-

- i. The fertilizer should be *sprinkled in a diffuse ring*, about 5 - 10cm wide, around the plant leaving a ring of at least 10cm in diameter around the base of the stem unfertilised.
- ii. The fertilizer can be *broadcast by hand* between adjacent bushes and spread evenly over the whole surface. This must be carried out with the highest degree of efficiency. Care must be taken to ensure that foliage is not scorched by fertilizer.
- iii. The foliar application of fertilizer using a knapsack sprayer. Example zinc oxide, copper sulphate or magnesium sulphate solutions. Also diammonium phosphate thoroughly dissolved in water and applied to clonal nursery plants using a watering can.
- iv. Fertilizer *placement in the planting hole*. This is applied to the soil dug from the hole, mixed thoroughly and returned into the hole before and during planting of young tea plants.
- v. Fertigation - Fertilizer is thoroughly dissolved in water which is used for irrigation of tea at the same time.

Note: The fertilizer aerial application by aircraft is very efficient but very expensive and not commonly used.

CURRENT FERTILIZER PRACTICES ON DIFFERENT ESTATES AND SMALLHOLDER TEA FARMS AND HOW THEY MAY BE IMPROVED UPON

Distributing fertilizer evenly in mature tea is far from easy, and the handling properties of fertilizers are important. Some may have names similar to a familiar fertilizer, but the properties may differ. Guidance should be sought from the Tea Research Institute of Tanzania before purchase is made of a new product whenever a tea planter is in doubt.

Different Estates and smallholder tea farms use different procedures of fertilizer application, some of the practices not suitable. The following procedures are suggested:

- Use right type of mixture appropriate to age of tea
- Calculate correct quantity per area and per bush
- Follow the right method of application
- Keep the fields of tea free from weeds before fertilizer application,
- Apply fertilizer when there is adequate soil moisture
- Always stock the required quantity for one season (application).

Improvements: Fertilizers are expensive; their application must be given the greatest attention, even if it means slight additional expenses to get the work done properly. Fill a container with 5kgs fertilizer, walk between two rows of tea while broadcasting fertilizer in a measure enough for one bush. After emptying the 5kgs container count the number of bushes covered, then calculate area to be covered with available fertilizer.

BULKING (MIXING) OF FERTILIZERS:

Mixing of fertilizer should be done in the field immediately before application. Pre-mixing in the store can lead to the breakdown of the fertilizer, and should not be attempted. Change from one type of nutrient formulation to the other will not affect crop response. However, the following conditions should be noted:

Two granular or one granular fertilizer and one coarsely crystalline may be difficult to mix evenly. Inclusion of a powdered fertilizer may help to bind the various sized particles.

The fertilizers must be turned over several times to achieve a proper mixture. Do not mix ammonium sulphate nitrate and urea with other fertilizers. Do not crush granular fertilizers for the sake of mixing.

TIME AND FREQUENCY OF APPLICATION: Fertilizer application must not start until the main rains have begun. If urea is used, the rains must be well established or the fertilizer may be wasted. No fertilizer should be applied to areas suffering severe drought stress (leaf scorch or defoliation), until the tea has recovered. Immature area should be left until mature tea is completed. Pruned tea should be fertilised at about the time of tipping. Tea under severe nutritional stress should receive a curative fertilizer application as soon as practicable. Plan a fertilizer programme which allows efficient and even distribution of the fertilizer. Fertilizer split application has no effect on the overall crop. A fertilizer application programme must be worked out well in advance, including allocation on a field by field basis, type of fertilizer, rates, labour and early procurement of requirement. *Example in the case study fertilizer programme in these notes.*

SOIL SAMPLING TECHNIQUE: Ten samples in a grid pattern should be taken at random from each half hectare, these samples to be taken with an auger of 4cm diameter which will be marked at 20, 40, and 60cm. The top of the bit should be gently pressed into the soil and the handle turned gently until the 20cm mark is reached. The tool is then pulled out with the soil sample lodged in the convolutions of the bit. The sample should be peeled off and placed in a polythene bag containing a piece of thick card on which details should be written in pencil (not ballpoint).

There will be ten sets of top-soil in a bag marked 'A', 20cm and similarly ten sets of middle soil in a bag marked 'B' 40cm and again ten sets of bottom soil in a bag marked 'C' 60cm. The samples from the three levels can be taken from the same site number but must be kept separately, taking care not to contaminate one sample with another. The ten soil samples from each level will be bulked thoroughly to obtain at least 1 1/2 kg representative sample by repeated quartering of each depth.

Details should be written on labels in pencil, one label to be inserted inside the bag and another label stapled to the outside of the bag with details:

Soil information sheet	
Company/Plot owner.....	site number.....
	Depth of sampling.....
Estate/District.....	Date of collection.....
Division/Sub-scheme.....	Object of testing.....
Field number/village.....	

Records must be kept for analysis results for future reference.

LEAF SAMPLING TECHNIQUE: Sample at least 100 bushes from half hectare, taking the uppermost mature leaf in the plucking table, which is hard, dark and quite full size. Each plot must be sampled on the same day. Dry the leaf as far as possible in shade on clean surface but do not crush it. Put the leaves into a clean paper bag and seal with adhesive tape. Do not use staples or pins. Do not use polythene or cloth bags.

When sampling avoid the few rows, which adjoin roads, paths or large vacant patches. After fertilizer, manure or mulch has been applied, wait for several weeks before sampling. Do not sample banjhi shoots or free growing shoots on the edge of the plucking table.

Leaf Sampling Form

Company/Plot owner.....	Clone number.....
Estate/District	Date collected.....
Division/Sub-scheme	Object of testing.....
Field number/village.....	

Note: Take a separate sample from the weaker area if bush vigour is uneven within a plot. This may give valuable information.

Source: Tea Growers' Handbook (TRFK 1986)

MANURE (Organic) - A source of plant nutrients originating from plant or animal residue which is added to the soil to improve fertility and structure. Organic manure is applied to tea as green manure, compost manure, cattle manure or mulch.

(a) **Green manuring** - Is the process of incorporating in the soil, plant material in the green state. This undergoes quick decay and adds to the soil organic matter in bulk and appreciable quantities of nitrogen, phosphorus and potassium.

A newly opened forest land produces heavy yields of crop, but after several years of continuous cropping, the yields decrease due to the decrease in organic matter content. To maintain fertility, the lost organic matter must be restored to the soil. In the absence of a sufficiency of humus, artificial fertilizers (inorganic) are bound to be less efficient. Green material to be incorporated into the soil can either be grown on site or may be brought from outside. If a crop is to be grown on the land, should be a leguminous crop, as it has the power to fix atmospheric nitrogen through the medium of the bacteria present in its root nodules. A non-leguminous crop, if grown on the soil, will take its nitrogen requirements from the soil, later give back to the soil the same nitrogen or perhaps a little less than it took up.

The factors which govern the decomposition of green material in the soil are:-

- The physical state of the soil - the rate of decomposition of green material put into the soil depends chiefly on the moisture content of the soil.
- The micro organic population of the soil - these organisms are responsible for the decomposition of the green material incorporated into the soil, they finally produce nitrates.
- The composition of the plant material - immature portion of plants and young tender plants contain more readily decomposable constituents such as sugars and proteins in large quantities, these decompose very readily and lead to nitrification in the form of nitrates. Over mature or woody material are not desirable as they impede the process of decomposition. A crop specially grown for green manure should be cut down just before it flowers. *Crotalaria* spp and *Desmodium* spp are normally suitable, also leaf fall and prunings provide green manure.

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(b) **Compost (humic) manure** - Plants and animals residues which have been specially treated and undergone the biological decomposition process before being applied to crop. The residue are available as green material, dung, urine impregnated earth, vegetable, animal residues and garden or line refuse. Compost provides nitrogen, phosphoric acid and potash, also ensures the improvement of the texture and tilth of the soil. Compost when properly prepared is comparable in fertility to cattle manure and it is possible to make about five times of its bulk in compost with a given quantity of cattle manure. Compost can be made in either heaps or in

pits. A good balance of material is necessary for the maintenance of optimum conditions of temperature, moisture and aeration throughout the period of manufacture. Suitable rate of application is (10 tons per acre) or 25 tons per ha. It is advantageous to arrange that application be made a few months after pruning in order to incorporate as much leaf fall as possible with the compost.

- (c) **Cattle manure** - This is cow dung or sheep/goat droppings used without any improvement. A minimum of (5 tons per acre) 12.5 tons per ha will replenish the humus content of the soil satisfactorily. Nitrogen content varies from 2% to 3% according to the type of fodder on which the cattle are fed. Dry cattle manure has lost much of its value.
- (d) **Mulch** - Is any material used to cover the soil surface.
Beneficial effects of mulch.
- Prevent soil loss
 - Reduce evaporation of moisture from the soil
 - Protect the soil from the beating action of the rain, wind and the scorching or a baking effect of the sun.
 - Reduce soil temperatures during drought
 - Increase humus content of the soil which supports an active micro fauna which speed decomposition converting nutrients to an available form.
 - Suppress weed growth
 - Supplies extra nutrients to the tea
 - Improves soil structure and fertility
 - Improves the uptake of nutrients like phosphorus
 - Increases yield of young tea (kg Mt/ha)

Table 9.17 Effects of mulch on yield of young tea (yield in kg Mt/ha)

	1963/64	1964/65	1965/66
No mulch	155	347	826
With mulch	360	600	1259

Source: Tea cultivation to consumption

Sources of mulch

- Prunings and leaf fall of tea
- Napier grass (*Pennisetum purpureum*)
- Guatemala grass (*Tripsacum laxum*)
- Weeping grass (*Eragrostis curvula*)
- Oats (*Avena sativa*)
- Maize stalks (*Zea mays*, L)
- *Crotalaria anagyroides*
- Lupin.

EXPERIMENT

Effect of farmyard manure, enriched manure and NPKS fertilizer on tea CHEM 4F:
Comparison of farmyard manure with NPKS 25:5:5:5 on clonal tea (TRFK AR 1999)

The initial objectives of the experiment planted 1982 was to find out the "effects of substituting (SSP) with farmyard manure (sheep manure) in the tea planting holes on four different clones." Two types of clones, i.e. high and low soil pH tolerant, respectively, were compared. The two type of manure did not

show any effects on the young tea plants in terms of yields and leaf nutrient contents, up to the end of 1984.

As from 1985, the NPKS 25:5:5:5 was surface applied in the plots that had received (SSP) in the planting holes, while those that had received sheep manure continued to receive it but as surface application so as to compare the effects on yields, soil chemical properties and nutrient contents of either sheep manure or NPKS 25:5:5:5 fertilizer on four clones of tea. Whereas the long-term application of NPKS or nitrogen fertilizer are known to acidify the soil, similar application of the sheep manure is known to alkalise the soil making it unfavourable for the growth of tea. Determining how long the sheep manure can be applied to tea before observing adverse effects on production is important for growers who have animal manures within their farms and may want to use the manure on tea.

The main treatments (clones) are:

High soil p/H susceptible

- (i) Clone $6/8$
- (ii) Clone $31/8$

High soil pH tolerant

- (i) Clone $STC\ 5/3$
- (ii) Clone $TN\ 14/3$

The sub treatments (types of manure) are:

- (i) NPKS 25:5:5:5 at 150kg N/ha
- (ii) Sheep manure at 150kg N/ha.

Effects of sheep manure and NPKS (25:5:5:5) on the yields of clonal teas.

The annual yields are shown below Table 82. This year, the NPKS fertilizer showed yields that were higher than those of the sheep manure but the differences were not significant. The clonal differences were also observed with $STC\ 5/3$ showing yields, which were significantly lower than the other clones.

TABLE 82 CHEM 4F. Effects of sheep manure and NPKS fertilizer on the yields (kg Mt/ha) of clonal tea January - December 1999 (TRFK AR 1999).

MANURE TYPE

Clone	NPKS (25:5:5:5)	Sheep manure	Clonal mean
6/8	4932	4736	4834
31/8	4830	4455	4643
STC 5/3	3482	3520	3501
TN 14-3	4986	4923	4954
MANURE MEAN	4557	4409	
	Clone	manure	clone x manure
C.V.(%)	12.8	4.4.	4.4
LSD (P=0.05)	571	NS	NS

- The annual yields January - December 1998 $STC\ 5/3$ yielded significantly lower than the others. The NPKS fertilizer showed yields which were significantly higher than those of the sheep manure treatment.
- The annual yields January - December 1997 $STC\ 5/3$ yielded significantly lower than the other clones. The NPKS fertilizer showed higher yields than the sheep manure.

- The annual yields January - December 1996 STC ⁵/₃ yielded significantly lower than the other clones
The yields of the tea was not significantly affected by the manure treatment in line with the common observation that tea does not respond to nitrogen fertilizer during the year of prune.
- The annual yield January - December 1995. STC ⁵/₃ yielded lower than the other clones, clone ⁶/₈ yielded significantly lower than ³¹/₈ and TN ¹⁴/₃ both gave similar yields. This year there was significant interaction between the clones and the two manures with clone ³¹/₈ giving lower yield, in the presence of the sheep manure compared to NPKS applied while all the remaining clones did not yield differently with the two manures, implying that clone ³¹/₈ would not tolerate high soil pH compared to the other clones.
- Annual yields January - December 1992.
Pruned beginning of year and yields recorded from April to December 1992 clone 31/8 which is a high yielder, gave significantly lower yields than clone 6/8 which yielded higher than any other clones. Sheep manure treatment yielded significantly higher than the NPKS treatment.

Source: Tea Research Foundation of Kenya Annual Report 1999.

SMALLHOLDER TEA GROWERS' IMPROVEMENT OF YIELDS FROM (150 - 500KGS MT/HA) TO MORE THAN 1000KGS MT/HA IN FOUR YEARS TIME USING THE ECONOMICAL FERTILIZER APPROACH

- Fertilizer is an important and expensive component of tea production (green leaf)
- Fertilizer levels may be determined by analyses of soil and foliage or the presence of symptoms of mineral deficiencies or toxicities.
- Optimum economical fertilizer application levels vary from plot to plot.
- Optimum economical fertilizer usage must be associated with other appropriate tea cultural practices.

CASE STUDY: Assuming that a plot of tea rectangular planted in 1970, one acre (0.405 hectare), at a spacing of 4^{ft} x 3^{ft} (1.2 x 0.9m), giving a plant population of 3630 plants per acre (8975 plants/hectare) was abandoned in 1990, after Mzee Mwakarobo died, tea bushes have since overgrown, infested with weeds, pests and diseases. The one-acre plot of tea was abandoned over 10 years ago according to Nyakyusa taboo. Tupege (the late Mwakarobo's wife) wants to rehabilitate the one acre plot of tea because she is now allowed by Nyakyusa socio-culture to own it after the long mourning. Tupege wants expert's advice to find out whether the plot of tea will be sustainable. She intends to do all field operations including plucking with her grown up son, two daughters and a daughter in law, this will be regarded as family labour. In the plot of tea, 435 plants are dead completely, need digging out and replacing with good high yielding clonal plants. She can only afford the replacement of 435 plants if you help on the nursery side to raise these plants at the lowest possible cost of shs.20/- per plant, including cost of cuttings. Fertilizers diammonium phosphate and muriate of potash cost Shs.13,000/- and 12,000/- respectively. These two types of fertilizers to be used in the planting hole for infills at 115 grammes of each per hole. Then 50grammes of NPKS 25:5:5:5 per plant after six months in the field, thereafter, as applied to the rest of the field. The cost of NPKS 25:5:5:5 is 14,500/- per bag of 50kgs. Green leaf of good quality plucking is bought by the Katumba factory at shs.70/- per kg, transport is offered by the factory and charged at shs.10/- per kg of green leaf, this does not change.

You advice that her fertilizer regime for the next four years will be forecast to be muriate of potash K₂O 60% for the first year of rejuvenation pruning and NPKS for the next three years as below:-

FERTILIZER PROGRAMME

<i>Area ha 0.405</i>	<i>Year of Rehabilitation</i>	<i>Fertilizers</i>				
		<i>Type</i>	<i>Kgs/ha</i>	<i>Total kgs</i>	<i>Total bags @ 50kg</i>	<i>Grammes/bush</i>
3195	First 2002	Muriate of potash	125K ₂ O	84	2	31
3630	Second 2003	NPKS 25:5:5:5	75N	122	2 1/2	34
3630	Third 2004	NPKS 25:5:5:5	125N	203	4	56
3630	Fourth 2005	NPKS 25:5:5:5	150N	243	5	69

Production from the one-acre plot of tea, which now belongs to Tupege and her family, is projected for four years as follows:-

ANNUAL YIELDS AND GREEN LEAF PRICE

<i>Year</i>	<i>Kgs green leaf</i>	<i>Shs. Per kg.G.L.</i>	<i>MT/ha</i>
January - December 2002	500	70	278
January - December 2003	1000	70	556
January - December 2004	2000	70	1111
January - December 2005	5000	70	2778

YEAR PLANTED 1970
REHABILITATION OF ONE ACRE (0.405 HA) OPERATING BUDGET - I

Year	Item No.	Operations	M' days	Shs.@	Shs. Total
2002	1	Sickling	5	1100	5500
	2	Jembe weeding	10	1100	11000
	3	Rejuvenation pruning 15cm 3195 bushes		15	47925
	4	Digging for infills 60cm deep	10	1100	11000
	5	(a) Cutting 435 stakes 2m long (b) Cost of plants 435		10 20	4350 8700
	6	Staking	2	1100	2200
	7	Holing 50cm wide x 60cm deep	5	1100	5500
	8	Placement of fertilizer in planting hole 435 115g DAP and 115g MOP	1	1100	1100
	9	Transport of plants to the field	4	1100	4400
	10	Planting (carrying and restaking)	5	1100	5500
	11	Soil and water conservation measures (Microcatchments and mulching)	5	1100	5500
	12	(a) Bringing infills into bearing Tipping-in at 50cm - five rounds (b) Tipping-in mature bushes at 50cm	25	1100	27500
	13	NPKS Fertilizer applications on infills 50g per bush (435 bushes)	1	1100	1100
	14	(a) Plucking 500kg green leaf (b) Transport of 500kg green leaf to factory		20 10	10000 5000
	15	Potassium (K ₂ O) application 3195 bushes x 31g	2	1100	2200
	16	Weed control - Handpulling (infills) - Herbicide spraying - Grammoxone 5ltrs @	12 6	1100 1100 5572	13200 6600 27860
	17	(a) Diammonium phosphate 1 bag of 50kg (b) Muriate of potash 60% 1 bag of 50kg (c) NPKS 25:5:5:5 1/2 bag (d) Muriate of potash 60% 2 bags of 50kg		13000 12000 14500 12000	13000 12000 7250 24000
Sub Total:-			93		262,385
OPERATING BUDGET - II					
2003	1	Plucking 1000kg of green leaf		20	20000
	2	Transport of 1000kg of green leaf		10	10000
	3	NPKS application 3630 bushes @ 34g	2	1100	2200
	4	Weed control - Handpulling - Herbicide spraying - Grammoxone 5ltrs @	12 6	1100 1100 5572	13200 6600 27860
	5	Soil and water conservation measures (microcatchments & mulching)	5	1100	5500
	6	NPKS 25:5:5:5 2 1/2 bags @ 50kg		14500	36250
Sub Total:-			25		121,610

OPERATING BUDGET III					
2004	1	Plucking 2000kg of green leaf		20	40000
	2	Transport of 2000kg of green leaf		10	20000
	3	NPKS application 3630 bushes @ 56g	2	1100	2200
	4	Weed control - Handpulling	12	1100	13200
		- Herbicide spraying	6	1100	6600
		- Grammoxone 5lts @		5572	27860
	5	Soil and water conservation measures (micro catchments & mulching)	5	1100	5500
	6	NPKS 25:5:5:5 4 bags @ 50kg		14500	58000
Sub Total:-			25		173,360
OPERATING BUDGET IV					
2005	1	Plucking 5000kg of green leaf		20	100000
	2	Transport of 5000kg of green leaf		10	50000
	3	NPKS application 3630 bushes @ 69g	2	1100	2200
	4	Weed control - Herbicide	6	1100	6600
		- Grammoxone 5 lts @		5572	27860
	5	Soil and water conservation measures	2	1100	2200
	6	NPKS 25:5:5:5 5 bags @ 50kgs		14500	72500
Sub Total:-			10		261,360

ANNUAL REVENUE AND EXPENDITURE ON 0.405HA

<i>Year</i>	<i>Plant Population</i>	<i>Production</i>	<i>Shs.</i>	<i>Annual Expenditure</i>	<i>Shs</i>
		<i>Total Green Leaf at shs.70 per kg.</i>			
2002	3195	500	35,000	Operating Budget I	262,385
2003	3630	1000	70,000	Operating Budget II	121,610
2004	3630	2000	140,000	Operating Budget III	173,360
2005	3630	5000	350,000	Operating Budget IV	261,360
			595,000		818,715

ANNUAL REVENUE AND EXPENDITURE ON 0.405 ha

Expenditure Shs. 818,715
 Revenue Shs. 595,000
 Difference 223,715
 =====

Explanation to the farmer Tupege

Advantages

1. She will have a tea field of 100% stand and healthy bushes.
2. Cost of weeding will be very low as the tea covers the ground.
3. Will have better yields hence profits in ensuing years from 2006 +
4. The tea plot will continue giving permanent employment to her member of the family.
5. Sale of green leaf will generate constant income.

Advice

1. Continue with good cultural practices i.e. weeding, proper plucking, maintain a fertilizer regime of 150N/ha per annum ensuring that the ratios of N P & K are well balanced and maintained. Follow a four-year pruning cycle
2. Be patient with tea, do not give up profit will be realised in year 2006, that is, family labour will be fully paid for.
3. Properly looked after tea will live for over a hundred years

SOCIAL ECONOMIC FACTORS GOVERNING FERTILIZER USE AND APPLICATION

a. **Removal of prunings** - Prunings present a valuable organic mulch and must not be removed from the field under any circumstances for the following reasons:-

- i. They are the equivalent in nitrogen of 130kg per hectare for the wood and 90 kg per hectare for the twig over a four-year pruning cycle. Total removal can reduce yields by up to 20%
- ii. The surface layer of prunings prevent soil erosion.
- iii. Prunings suppress weed growth, and insulate the soil in periods of drought.
- iv. The surface layer of mulch conditions the soil surface and helps the uptake of fertilizers, especially phosphates.

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The use of prunings as a source of firewood must be strongly discouraged, village government should be persuaded to enforce by-laws. Disciplinary action should be taken on the Estates to employees found removing prunings from the field, which may lead to summary dismissal. However, every Estate and smallholder has a need for firewood. There must be enough for domestic use by resident and nearby homesteads to ensure that tea prunings are allowed to remain in the field.

b. **Misallocation of fertilizer** - Some of the smallholder tea farmers have a tendency of applying some of the fertilizer meant for the tea fields to some other crops like maize. This must be totally discouraged. On the large Estates, employees steal or damp fertilizer meant for tea fields, tight security must be in operation during the whole period of fertilizer application from storage to field until there has been some rain.

c. **Belief**: In some villages where tea is grown, there are wrong beliefs that fertilizer causes skin disease and that fertilizer use in young tea fields may cause the tea bush to dry up and die. Smallholder tea growers need to be made aware of proper cultural practices and correct fertilizer handling by training them on the subject of fertilizers in tea.

d. **Economics of fertilizer use in tea** - Fertilizer use in tea is the most expensive expenditure after plucking and irrigation. All aspects of fertilizer programme must be given the closest possible attention by Estate management, extension workers and smallholder tea planters. Field experiments, soil and leaf analysis should be carried out before a meaningful, economic, optimum fertilizer regime is recommended. The application of optimum fertilizer levels would give the most economical yields and also the best quality. It is therefore important that the most economical type of fertilizer, accurate calculations and application are made in accordance with requirement.

RECORDING AND CALCULATING FERTILIZER USE

i. **Recording** - Records should contain enough detail for the nutrient additions to be known. Ensure that it is clear whether weight recorded refers to fertilizer as a whole or to one of the nutrients.

- Referring to fertilizer as a whole: 200kg/ha of compound 25:5:5:5 NPKS
- Referring to one of the nutrients: 150kgN/ha, as 20:10:10 NPK

Record the exact date of application: 31/12/01, and indicate whether the quantity is applied per hectare or to the whole of a plot.

ii. **Calculating fertilizer** - Nutrient content in fertilizers are normally stamped on the sacks and expressed in percentage (%) N25% P₂O₅ 5% K₂O 5% and S 5% or NPKS 25:5:5:5 or S/A 21%N 24%S.

Examples of common calculations

1. How much double super-phosphate (DSP) with P₂O₅ content of 42% is required to supply 50kg of P₂O₅. $\frac{100}{\% \text{ of nutrient}} \times \text{weight of nutrient required} = \text{weight of fertilizer}$

$$\frac{100}{42} \times 50 = 119 \text{ kg of double super-phosphate}$$

The general form of the calculation can be used for similar conversions for other fertilizers.

2. How much sulphate of ammonia, quoted at 21%N, would be required to give the same weight of N as 500kg of a NPK 25:5:5 fertilizer

$$500 \times \frac{25}{21} = 595 \text{ kg of sulphate of ammonia}$$

3. To make a mixture with an N: P₂O₅: K₂O ratio of 25:5:5 from straight fertilizers and to apply at 120kg/ha of N, using sulphate of ammonia (21%N), single superphosphate (20% P₂O₅) and muriate of potash (60% K₂O).

Calculate the quantity of sulphate of ammonia as in example 1:-

$$\begin{aligned} &= \frac{100}{21} \times 120 \text{ kg/ha of fertilizer} \\ &= 570 \text{ kg/ha of sulphate of ammonia} \end{aligned}$$

For the single super-phosphate, the formula is:

$$\begin{aligned} &\frac{100}{20} \times 120 \times \frac{5}{25} \text{ kg/ha of fertilizer} \\ &= 120 \text{ kg/ha of single super-phosphate} \end{aligned}$$

Similarly, for the muriate of potash, the formula is:

$$\begin{aligned} &\frac{100}{60} \times 120 \times \frac{5}{25} \text{ kg/ha of fertilizer} \\ &= 40 \text{ kg/ha of 60\% muriate of potash.} \end{aligned}$$

(The ratio $\frac{5}{25}$ is governed by the proportions of N to P₂O₅ and to K₂O in the compound fertilizer)

A total of 730 kg/ha of mixed fertilizer.

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4. Concentration of solutions.

For all practical purposes, a 2% solution of fertilizer means:-

- 2kg of fertilizer in 100 litres of water or
- 2kg of fertilizer in 22 gallons of water or
- 2lb of fertilizer in 10 gallons of water

EVALUATING YIELD RESPONSE OF TEA TO FERTILIZER BY USE OF "THE PAIRED-PLOT TECHNIQUE."

The paired-plot technique is a *simplified experimental approach*, which can be used by the grower without the expense and limited applicability of a small number of formal experiments. There is a possibility of gaining information relevant to the conditions within the grower's own tea.

The paired-plot comparisons could examine the following questions:-

1. If present annual fertilizer applications are over 150N kg./ha, the economics of this practice should be tested. One plot in each pair would continue with the level of N as at present, while the other plot would receive N at a rate either 20% above or 20% below the normal. The levels of other nutrients would also change in such a comparison if a compound fertilizer is used to supply nitrogen.
2. If little or no fertilizer is used a grower may wish to be assured of the value of an increased application of nutrients.
3. There may be a wish to effect immediate economics, by using N only, as opposed to the more usual NPKS compound fertilizer. Supplement by leaf analysis, this could be a straight forward comparison for paired-plot.
4. The effects of increments of a single nutrient could similarly be studied, for example potassic fertilizer added to the soil, or zinc compounds sprayed onto the foliage.

More than two plots can be chosen for comparison within one experiment, with more than two treatments under test. A plot can be of any size, but must be as representative as possible of the whole unit. There is no need for the plots to be of the same size, but the area of each must be accurately calculated. Factors which may influence the response to experimental treatments are:- Soil type, local climate, age of tea, jat, spacing, pruning styles, age from pruning, plucking rounds and standard of plucking, shade trees or windbreaks and topography. Once the experimental treatments have been applied, the plots must be managed as similarly as possible in all respects. Treatments should be applied on the same day. Plucking should fall on the same day. And recording must be accurate.

USEFUL HINTS ON FERTILIZERS AND MANURES

- It is not possible to determine the optimum economic fertilizer levels from nearby established estate records for smallholder tea farmers.
- Levels of fertilizer application may be based on the results of the following factors:
 - Field experiments
 - Analysis of soil
 - Analysis of foliage
 - The presence of symptoms of mineral deficiencies
 - The presence of symptoms of toxicities

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Loss of nutrients from a field or plot of tea may be due to:-

- Removal of crop (plucking)
 - Removal of prunings (as firewood)
 - Soil erosion
 - Drainage of excess water containing nutrients in solution.
 - Decomposition of gases.
 - Uncontrolled weeds absorb substantial quantities of nutrients temporarily available to tea and may be permanently removed if the weeds are removed during weeding.
-
- Assumption is made that the optimum economic fertilizer level is the point on the curve where the marginal rate of production (MRP) equals 2 to 3kgs made tea.
 - The age of the tea influences the optimum fertilizer level more than any other factor. N should be increased with age of tea.
 - Rarely does the climate affect the optimum economic fertilizer levels and therefore it is "not advisable to adjust rates according to climate factors.
 - Management factors that influence the optimum economic fertilizer level are **down pruning and irrigation**. Adjust N levels accordingly.
 - The response to N is strong with most clones, the optimum economic fertilizer level will have to be determined by examining the effect increasing N levels have on quality of made tea.
 - High fertility areas require less fertilizer than low fertility areas.
 - Once the tea is mature, the inherent soil fertility status no longer has any effect on the response of N.
 - Having a different fertilizer regime dependent on the stage in the pruning cycle is no longer valid.
 - Splitting the fertilizer alters crop distribution.
 - Splitting the fertilizer does not make any difference in yields.
 - The benefit effect of split applications under irrigation is significant increase in total crop and a higher crop in the dry season, when teas of better quality are made.
 - Split application where there is no marked seasonal variation in crop distribution.
 - There are interactions between N and P, between N and K, and sometimes between P and K. These interactions make it necessary to ensure the three major nutrients are applied in a balanced ratio.
 - **Calcium** - Not important in tea at present. In future it may be used to remedy the high acidity of the soils, because of the continued use of high levels of nitrogen. (limestone added to ammonium nitrate).
 - Base N levels in young seedling tea up to the 15th season on the inherent fertility of the soil.
 - There is no difference in the N response between China, Indian, Assam hybrids and polyclonal tea.
 - The response of mature and young clonal tea to N will be linear.
 - If N levels are reduced, an immediate fall in crop can be expected.
 - As there is no difference in response between the four commonly available N carriers, the choice of which to use should be based on cost effective considerations.
 - Under irrigation split fertilizer application $\frac{2}{3}$ Main application and $\frac{1}{3}$ Irrigation application.
 - It would be wise not to apply urea in hot, dry conditions or heavy rainfall.
 - Three basics of Nutrition Management:
 - Attend to details of all fertilizer operations
 - The keeping of records.
 - The collection of samples for soil and leaf analysis.
 - Fertilizers are expensive and the yield is very closely related to the levels of nutrient applied. Errors in calculating can be **very costly**.

- Errors in calculating are due to:- Partial metrication.
 - Not checking the nutrient quantity in the fertilizer being used, content usually printed on bag N, P₂O₅ or K₂O
 - Work being done by untrained staff.
- Increase the age of young tea by two to three years when calculating N requirements for tea under irrigation and split the application (5% to 15% increase of fertilizer).
- If irrigation is withdrawn revert to dry land levels.
- Seedling tea responds to increasing levels of NP & K in the classic manner common in agriculture where "the yield increment diminishes for each unit increase in nutrient, the diminishing return continues up to a point beyond which the yield of made tea becomes negative. This point is known as turn over point (*TOP*). The incline of the curve and the position of *TOP* are the two parameters that can be used to determine the optimum economic fertilizer levels in seedling tea.
- Quality declines with high rates of nitrogen even if the source of nitrogen is organic.
- Organic manure can marginally improve black tea quality (liquor colour)
- Sheep manure alkalises the soil.
- A fertilizer programme should not be influenced by the use of organic materials
- Effects of increasing levels of fertilizer application lead to increased yields.
- Tea receiving correctly balanced fertilizer will produce a reasonable product of good quality and the economic return will be maximized

GLOSSARY

- Acidity* - The activity of hydrogen ions in both the solid and aqueous phase of soil. It is measured and expressed as pH value.
- Acid soil* - A soil with a pre-dominance of hydrogen (H^+) and aluminium ions (Al^{+++}) in proportion to hydroxyl ions (OH^-); A soil with a pH value less than 7.
- Alkali* - Hydroxides and carbonates of alkali metals, example, sodium and potassium. The pH of dilute aqueous solution is more than 7.
- Alkaline soil* - Any soil that has a pH value above 7.
- Amendment* - Any chemical that is added to the soil for altering the reaction (pH).
- Chlorophyll* - Green pigments present in the chloroplasts of plants and are necessary for photosynthesis.
- Chlorosis* - Unhealthy condition due to deficiency of chlorophyll as shown by yellowing of the plant
- Deficiency* - Abnormality caused by the insufficiency of an essential nutrient element
- Die-back* - Drying of shoots or branches from the tip, backwards.
- Humus* - Organic matter that has undergone complete decomposition in the soil
- Hutsite* - An area of soil at one time used as an enclosure for livestock or human habitation. The soil is in consequence alkaline or only feebly acid so the pH level is too high for tea.
- Hygroscopic* - Substance capable of absorbing water vapour from the air.
- Macro-nutrient* - A nutrient required by plants in relatively large amounts.
- Micro-nutrients*
or
Trace elements Essential plant nutrients required in minute quantities
- Mulch* - Any material used to cover the soil surface to prevent soil loss during wet weather, to reduce evaporation from the soil, to increase the humus content of the soil.
- Necrosis* - Death of tissues in localised areas.
- Pathogen* - An organism capable of causing disease
- Photosynthesis* - The process whereby the plant uses the energy of sunlight to convert carbon dioxide gas from the air into food.
- pH* - The scale for measuring the degree of acidity or alkalinity.
- Plasmolysis* - The shrinking of the cell contents away from the cell wall due to loss of water, caused by locally heavy concentration of fertilizer in the soil water.
- Rosetting* - Short bunched growth of shoots
- Toxicity* - Abnormality (symptoms) caused by the excess of an essential nutrient in the plant organ.
- Volatilisation* - Conversion of a chemical substance from a liquid or solid state to a gaseous or vapour state.

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PROFICIENCY EVALUATION

NAME _____ Location _____ Date _____

Please answer the following questions.

- 1. a) What is **f**ertilizer?----- Deleted: F

b) What is manure? -----

- 2. a) Why do we apply fertilizers on immature tea? -----

b) Why do we apply fertilizers on mature tea? -----

- 3. a) Mention three major **n**utrients essential for plant growth? Deleted: N
i)-----
ii)-----
iii)-----
- b) Mention three **m**inor **n**utrients essential for plant growth: Deleted: M
i)----- Deleted: N
ii)-----
iii)-----

- 4. a) What are **c**ompound **f**ertilizers? -----

b) Mention two compound fertilizers commonly used in tea.-----

c) These compound fertilizers contain nitrogen in two forms. -----

- 5. a) What are straight fertilizers? -----

b) Mention five straight fertilizers commonly used in tea?
i)-----
ii)-----
iii)-----
iv)-----
v)-----

- 6. a) Mention three fertilizers that are nitrogen carriers.
i)-----
ii)-----
iii)-----
b) Mention three fertilizers that are phosphate carriers.
i)-----
ii)-----
iii)-----
c) Mention two fertilizers that are potash carriers.
i)-----

- ii) -----
7. Mention two functions of nitrogen in the tea bush?
i) -----
ii) -----
8. List four deficiency symptoms of potassium.
i)-----
ii)-----
iii)-----
iv)-----
9. Copper is an essential constituent of the enzyme polyphenol, which is vital for

10. a) The sulphur deficiency known as -----

b) Name a fertilizer you would use to remedy the above sulphur deficiency

11. a) What is a hut site? -----
b) Suspect a hut site if: -
i) -----
ii) -----
iii) -----
12. Why do we take soil samples for analysis three reasons only?
i) -----
ii) -----
iii) -----
13. A fertilizer store must have the following qualities: -
i) -----
ii) -----
iii) -----
iv) -----
v) -----
vi) -----
vii) -----
14. What formula of a compound fertilizer is recommended when considering a mature tea fertilizer programme? -----

15. If little or no regular fertilizer application has been made, what levels are recommended in the first three years?
i)-----
ii)-----
iii)-----

16. Down pruned fields in the year following the prune do not respond as well as other areas, what rates of nitrogen are recommended?-----

17. When is the right time to apply fertilizers? -----

18. Write down methods of applying fertilizer to: -
i) Mature tea -----

ii) Immature tea -----

19. Write down details on labelling leaf sample-----

20. Why do we need to keep leaf analysis results? -----

21. What is manure (organic) -----

22. Mention five beneficial effects of mulch
i)-----
ii)-----
iii)-----
iv)-----
v)-----
23. How do we refer to: - (during recording for future reference)
i) Fertilizer as a whole -----
ii) One of the nutrients -----
24. How much sulphate of ammonia quoted as 21% N would be required to give the same weight of N as 500kg of NPK 25:5:5 fertilizers? -----

25. You want to make a mixture with N: P₂O₅: K₂O ratio of 25:5:5 from straight fertilizers and to apply at 120 kg/ha of N using sulphate of ammonia 21% N, single super phosphate 20% P₂O₅ and muriate of potash 60% K₂O.
i) Calculate the quantity of sulphate of ammonia.
ii) Calculate the quantity for the single super phosphate
iii) Calculate the quantity for the muriate of potash
iv) Calculate the total of mixed fertilizer.
26. You have inherited one hectare of a tea field from your late uncle Juma. The tea field has not received any fertilizer for the past five years, though other management cultural practices (pruning, plucking and weeding), have been carried out and green leaf sold to the factory. There are a few negligible deaths of bushes, which do not justify infilling as the ground is well covered.

The following information is available, some from your late uncle's records and some from the extension officer:-

1. Year planted 1980, spacing 1.2m x 0.9m, area one hectare, population 9000 plants, clone 207.
2. Tea was brought into bearing by pruning at 30cm six months from field planting, pruned at 35cm after 2 years and at 40cm after 3 years. Thereafter, pruned on a 4 year cycle 5cm above previous prune.
3. Tipping was carried out at 20cm, 15cm and 10cm in subsequent years.

In 1996 fertilizer was last applied to the plot of tea at a rate of 400kgs as NPKS 25:5:5:5. Total annual production for that years was 10,000kgs green leaf. Since then, fertiliser, has not been applied and production has gradually declined to 2000kgs green leaf in 2001.

You are advised that production will improve if you resume a fertilizer regime of NPKS 25:5:5:5.

Resumption of fertilizer application

<i>Year</i>	<i>N/ha 'annum'</i>	<i>Production</i>	<i>Price shs.</i>
1 st pruned	50	4000	70
2 nd	100	8000	70
3 rd	100	10000	70

You have a choice to make from the following list of fertilizers. Prices include transport to your place.

Urea 46%N at	Shs.10,000 per bag of 50kgs
S/A 21%N 24%S at	Shs. 6,000 per bag of 50kgs
ASN 26%N 12%S at	Shs. 7,000 per bag of 50kgs
NPKS 25:5:5:5 at	Shs.14,500 per bag of 50kgs
SSP 20% P ₂ O ₅ 12% at	Shs. 6,000 per bag of 50kgs
MOP 60% K ₂ O at	Shs. 8,000 per bag of 50kgs

PLANNED VISIT

PARTICIPANT.....DATE.....

1. EXAMINE EACH OF THE FOLLOWING ASPECTS OF THIS FERTILIZER STORE
2. SCORE EACH ONE ON THE SCALE 1 - 10
3. COMMENT ON EACH ASPECT

	ASPECT	SCORE 1- 10	COMMENT
1.	DRYNESS		
2.	SECURITY		
3.	VENTILATION		
4.	CONVENIENTLY SITED		
5.	SUITABLE SIZE		
6.	SERVED BY AN ALL WEATHER ROAD		
7.	RECORDS (HAVE BIN CARDS AVAILABLE)		
8.	CLEANNES AND TIDINESS		
9.	WELL STACKED AND EASY TO CHECK STOCK		
10.	FERTILIZER SACKS STACKED ON WOODEN BATTENS OR STONES		
	MAIN AREA FOR IMPROVEMENTS		

NOTE: THE SCALE 1 - 10 (1 POOR - 10 EXCELLENT)

ACTION ARISING FROM THE DAY

PARTICIPANT.....DATE.....

ACTION WHICH I INTEND TO IMPLEMENT	WHO ELSE SHOULD BE INVOLVED	BY WHEN

PROGRAMME ASSESSMENT

**NUTRITION OF THE TEA PLANT
FERTILIZERS AND MANURES**

VENUE.....DATE.....

Please tick at the appropriate point on the scales

A. CATERING

Suggested Improvements: Very Good..... Good..... Adequate..... Poor.....

B. ACCOMMODATION: Very Good..... Good..... Adequate..... Poor.....

Suggested Improvements.....

C. For you, were the subjects/topic discussed:

TOO ADVANCE **TOO ELEMENTARY**

D. What were your feelings about the pace of the course?

TOO FAST **TOO SLOW**

E. COURSE OBJECTIVES

Please turn over for this section

	Very Relevant	Relevant in part only	Not at all relevant	Not quite sure
Were the subject	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Were there any subject which

- a) You felt could have been Omitted - if so which?.....
- b) You felt could have been Included - if so which?

F. PROGRAMME PRESENTATION ETC.

Please rate these	Excellent	Very Good	Good	Poor
Aspects of the programme				
PRESENTATION	4	3	2	0
TRAINING AIDS	4	3	2	0
HAND-OUT MATERIALS	4	3	2	0
GROUP WORK/CASE STUDY	4	3	2	0
ADMINISTRATION	4	3	2	0
VENUE FACILITIES ETC	4	3	2	0

G. If you were to improve this course what one thing would you change and why (Please write in).

H. What is your overall Assessment Very Good Good Adequate Poor

COURSE EVALUATION

Please fill in this evaluation form so that we can assess whether we have met the objectives for the course. Mark how good the course was in helping you better to: -

1. Fully understand the Principles of Fertilizer and manure application to the tea plant
Very Good Good Fair Poor Very Poor
2. Fully understand the techniques involved in the Fertilizer and Manure application of the tea plant
Very Good Good Fair Poor Very Poor
3. Improve yields of both clonal and seedling tea by optimum economic fertilizer usage
Very Good Good Fair Poor Very Poor
4. Detect nutrients deficiency symptoms and apply corrective fertilizer measures
Very Good Good Fair Poor Very Poor
5. Calculate mixture with N: P₂O₅: K₂O ratio of 25:5:5 from straight fertilizers.
6. Have you any other comments on the course, which might help for future planning.

References for further reading on the subject of Nutrition of the tea plant fertilizers and manures

1. *TEA – CULTIVATION TO CONSUMPTION*
Edited by: K C Wilson
M N Clifford
First Edition 1992
2. *TEA GROWERS' HANDBOOK*
The Tea Research Foundation of Kenya
4th Edition 1986
3. *TEA GROWERS' HANDBOOK*
The Tea Research Institute of East Africa
3rd Enlarged Edition 1969
4. *JOHNSON'S NOTE BOOK FOR TEA PLANTERS*
By R.J. Johnson
3rd Enlarged Edition 1955
5. *TEA*
By T. Eden
Second Edition 1965
6. *TEA*
By Barclays Bank DCO 1967
7. *TEA GROWERS' HANDBOOK*
The Tea Research Foundation of Central Africa
First Edition April 1990
8. *T.T.U. WORKING DOCUMENTS NO.1 & 2 - 1999*
9. *TEA RESEARCH INSTITUTE OF TANZANIA*
Annual Reports 1997/98 and 1998/99
Annual Report 1999/2000
10. *TEA RESEARCH FOUNDATION OF KENYA*
Annual Reports 1983 – 1999
11. *REHABILITATION OF ABANDONED TEA FIELDS*
TRIT TRAINING MODULE NO.1
October 2001