TEA RESEARCH FOUNDATION OF KENYA

TEA GROWERS HANDBOOK

5th Edition

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THE TEA BOARD OF KENYA

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Preface

This handbook is a compilation of the Tea Research Foundation of Kenya's (TRFK) recommendations for tea production. It is intended for use as the standard book of reference for tea growers in Kenya.

This is the fifth edition of the handbook. The first, second and third editions were produced in 1965, 1966 and 1969 respectively by the Tea Research Institute of East Africa (forerunner institution). The fourth edition was produced in 1986 by the Tea Research Foundation of Kenya. This fifth edition contains much new information derived from the results of the Foundation's research projects. The information in the previous editions, has been revised.

The work of revision and re-writing has been completed by the senior staff of the Foundation except where separate acknowledgement is made. In addition, most Kenyan producers and tea officers have made their own special contribution to the text. Consequently the handbook now emerges as a unique testimony to that willingness to share experience for the benefit of everyone "in tea" in Kenya which characterises our progressive and expanding tea industry.

J. K. RUTTO

DIRECTOR

THE TEA RESEARCH FOUNDATION OF KENYA

July 2002

TRFK vision for the year 2010
TRFK will be the center of excellence undertaking innovative research on tea improvement and development aimed at the generation and dissemination of appropriate, effective, and efficient technologies for the benefit of all stakeholders in Kenya.

Mission Statement
The mission of TRFK is to generate and disseminate, through innovative research (conducted with the participation of stakeholders), effective and efficient tea production, processing and value adding technologies for enhanced productivity and development of high quality tea products which can compete profitably and sustainably in the market. The Foundation will give due cognizance to the important aspects of sustainability and conservation of environment, natural resource base and human health.

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Chapter I

LAND PREPARATION

(a) **Site selection and other basic considerations**

Among tropical crops there is none that demands such precise requirements as tea does, if a paying yield is to be obtained. Tea requires a climate with specific limits of certain attributes, a soil with special characters, a proper clearing and preparation of land prior to planting. It is therefore of paramount importance that in selecting a site for tea, due consideration should be given to climatic and soil requirements of the tea plant before a decision is made on whether the area is suitable for tea. A point to remember is that tea, once planted, could last for up to 100 years and beyond.

When considering whether to plant tea, disappointment and unexpected expense can be minimised if the sites under consideration are critically examined. It is always advisable to consult the Tea Research Foundation of Kenya, or your nearest Tea Officer or an officer of the Ministry of Agriculture.

(i) ***Climatic factors***

Tea is thought to have originated within the fan-shaped area extending from the Assam/Burma border in the west to China in the East; and south from this line through Burma and Thailand to Vietnam. This is an area of monsoon climate with a warm wet summer and a cool dry (or less wet) winter. From the main centres of cultivation in South East Asia tea has been introduced into many other areas of the world, and is now grown in conditions, which range from Mediterranean type of climate to the hot humid tropics. Commercially viable plantations have been established as far North as Turkey and Georgia (42°N) and as far south as Argentina (27°S) and between sea level and about 2500 m in altitude. Tea has even been reported to be cultivated below sea level in Iran.

Despite the generally wide range of climatic conditions found in the different areas of the world where tea is now grown, the following requirements must be met for it to be commercially viable.

(ii) ***Rainfall***

1. *Minimum requirements*

The minimum annual rainfall considered adequate for the successful cultivation of tea is about 1200 mm without irrigation. It is impossible to judge whether rainfall is adequate on the annual total alone as distribution of the rainfall is of prime importance.

Water is removed from the soil by tea roots and lost from the leaves by evapo-transpiration at a rate which varies from 120 mm to 180 mm per month depending on the prevailing weather conditions. Ideally therefore water should be available to the roots in amounts which are of this order each month. Where there are prolonged periods when rainfall is less than the water lost by evapotranspiration, the plants must rely on stored ground water. The more even the rainfall distribution, the less likely is the tea to be adversely affected by drought.

The amount of water lost by evapotranspiration will be increased by wind and hot weather and reduced by low temperatures and long periods of mist or cloudy weather. Throughout Kenya, tea requires at least 1400 mm of rain annually to compensate for the loss. Where distribution of rain is uneven, it is possible that in months of high rainfall a large proportion is lost by drainage and surface run-off, and in these conditions a higher rainfall is necessary.

When considering rainfall, it must be remembered that in the extremely dry years, the rainfall may be only two-thirds of the long term average, and such dry years may occur once in every ten years. It is important to note that such a pattern may or may not occur.

2. *Maximum requirements*

Provided that there is no danger of water logging, i.e. the drainage of the soil and the height of the water table are all satisfactory and erosion and run-off are under control, there appears to be no maximum limit under which tea cannot be grown successfully.

3. *Irrigation*

If irrigation is intended to be used or is found desirable on consideration of the climate, the availability of water must be investigated. This must take into account flow of rivers, as low flow is likely to coincide with the maximum demand for irrigation. The need for and the practicability of storage in a dam and the cost of irrigation must be considered (see breakdowns page 93).

(iii) ***Temperatures and altitude***

Temperatures

Regardless of whether or not other climatic factors are favourable, tea, like other plants, does not grow when temperatures are either too low or too high. There is evidence that air, leaf and soil temperatures all influence the rate of growth of tea.

1. *Air temperature*

In some of the most northerly tea areas such as Georgia, China, Japan, Turkey and Darjeeling, snow sometimes falls during winter months and air temperatures fall below freezing point; notwithstanding this, tea survives the winter months. However, it is considered that temperatures below freezing are inimical to tea especially when followed by a rapid rise in daytime temperatures (as is usual after a night frost) leading to leaf scorch. It is also suspected that, in general, minimum air temperatures below 13°C are likely to bring damage to foliage. Research has shown that various tea clones exhibit different responses to air temperature in what is known as base temperature for shoot extension and development. These base temperatures can be described as threshold temperatures below which shoot extension and development ceases. It is also considered that mean maximum temperatures greater than 30^0Care likely to be accompanied by humidities so low that cessation of active growth is inevitable.

2. *Leaf temperature*
Research findings have shown that net photosynthesis of the tea leaf rises steadily with increase of leaf temperature up to 35°C and then declines sharply, ceasing when the leaf temperature reaches 40°C. It has also been shown that when ambient dry bulb temperatures are 30 - 32°C, that of tea leaves in full sunshine reaches 40 - 45°C.

3. *Soil temperature*
Soil temperature is in many instances of greater significance to plant life than air temperatures. In Kenya it has been shown that soil temperature influences the growth rate of tea and hence yield. The optimum soil temperature within the feeder-root depth of the soil is 20 - 25°C.

Altitude
Temperatures are inversely related to altitude, i.e. the higher the altitude, the lower the temperature. It has been found in Kenya that, within certain limits, there is a negative linear relationship between yields of tea and altitude at which it is grown. Using long term average yields data of tea estates situated at different altitudes from 1500 m to 2250 m a.m.s.l. and equation has been calculated which suggests that the average annual tea production falls by 200 kg made tea per hectare for every 100 m rise in altitude. The decrease in yield can be more when considering high yielding clones, which are sensitive to temperature changes. This fall in tea production with rise in altitude is directly attributed to fall in air, leaf and soil temperatures.

It is therefore important to take note of this information when considering a site for tea planting.

(iv) ***Soil factors***
Tea may be grown in soils of diverse origin. However, in Kenya good tea soils are those of volcanic origin of Kericho, Kisii, slopes of Mt. Kenya etc. These soils are well-drained and are red, brownish red or dark red in colour. In the current FAO-UNESCO soil classification system, Nitosols (Nitisols) are the predominant soil type for tea in Kenya.

Tea is known to demand, perhaps more precisely than any other crop, soils with special characters if economic yield is to be obtained. This means that although tea can be grown commercially in different areas in different soil types, certain conditions must be fulfilled in each case if tea is to succeed as a profitable crop.

The most important soil factors to be considered when selecting a site to be planted with tea are: indicator plants and physical and chemical characteristics of the soil.

(v) ***Tea indicator plants***
The vegetation on the area is a very useful guide. If the area is already cultivated the condition of the crops can give some indication of the fertility status of the soil. Analysis of natural vegetation where this is largely of one species can sometimes give some guidance.

One characteristic property of the tea plant, its ability to accumulate aluminium, gives rise to a very convenient method of recognising a potential tea area. There are a number of natural species of plants which have a similar property. The presence of one or more of these in an area is a sure indication that the land is suitable for tea. These plants have some general characteristics: large flowers with prominent stamens and parallel leaf veins (Melastomes), changeable flowers (coloured varieties of *Hydrangea macrophylla*), beautiful foliage (tree ferns and club-mosses) or bright blue fruits (*Symplocos* spp., *Lasianthus* spp., *Psychrotria* spp.).Other plants which are commonly associated with good tea are:

Shrubs
Triumfetta macrophylla, Vernonia auriculiferra, Pauridanta holstii. The spectacular melastone, *Dissotis irvingiana*, is very often seen in waste land, road cuttings and quarries in Kericho district, Sotik and Cherangani.

Herbs
Borreria princeae is rampant on banks and grassy wastes competing quite successfully with couch and Kikuyu grasses. It is a troublesome weed in tea, resistant to most herbicides. Closely related species of *Borreria* are found in all tea growing areas of Kenya.

Ferns
Pteridium acquilinum (Bracken) is often regarded as a good indicator of tea land. However, it also thrives on infertile, very acid soils and in areas which are too dry for tea. Mention must be made of living fossil fern, *Marattia flaxinifolia,* the most ancient of all ferns which is also cosmopolitan in distribution and is particularly common in ravines in tea growing areas of Kenya. This fern has huge fronds, rather like a palm tree, or ciycada, on the backs of which are comparatively large, pod-shaped fruits or spores sacks.

Trees
Newtonia buchanani and *Albizzia* spp.
When considering small areas, the vegetation on adjacent land is important. For instance tea must not be planted within 30 m of *Eucalyptus* trees, as their roots compete with tea roots for available water. Smallholders, particularly, must bear this in mind.

(vi) ***Other considerations***
1. *Site history*
The previous history of the area is important. Cropping in the past may have affected the soil. Continuous raising of food crops without adequate fertilizers can reduce the fertility of the soil without a major effect on the pH. This can be of value on a very rich soil, but on a more normal tea soil, growth will be poor without heavy fertilizer application. There is a greater risk of nematodes on cultivated land, and *Armillaria* on forest clearings.

2. *Slope and aspect of the land*
The slope of the land is critical. On steep land the risk of severe soil loss by erosion is high and control measures become costly. Normal estate operations become more difficult as the land becomes steeper. These points must be carefully considered when the slope of the land exceeds 20%.

3. *Accessibility*
Access for bringing in material and removal of leaf can be expensive in some conditions. Water is essential for domestic, factory and nursery use even if irrigation of planted tea is not intended. A factory needs fuel, which means either fuel trees must be planted or access road for fuel tankers to reach the factory must be provided and be adequately maintained.

4. *Physical characteristics.*
A deep well-drained soil is essential for successful tea growing. The "available depth" of the soil in which tea roots can grow freely is very important for a successful tea area. It is considered that, for tea, 2 m (6 ft) "available depth" should be taken as minimum. It is necessary, if tea soil selection is to be done with any confidence, that a soil profile pit be dug in representative sites to open out, at least to this depth, and the various soil horizons examined as to their suitability for successful tea growing. An unsuitable sub-soil for tea can be due to several factors, such as a section of temporary or permanent high water table, i.e. water logging within shallow depth of the soil. It is always very difficult to provide efficient drainage for these sections particularly after tea is established. It is therefore important that the sections should be identified and dealt with prior to planting tea. Soil profile pits dug during wet seasons in the suspected sections would reveal the degree of the problem.

The most common and perhaps the most neglected cause of unsuitable sub-soil is impediment caused by *hard-pan of clay, murram, gravel* or *rocks*. In new areas which are still under natural forest vegetation, areas with unsuitable sub-soil due to these factors are easy to identify visually because more often than not the natural forest vegetation will not have penetrated the area. Instead, they will be covered by shallow rooting vegetation which in most cases will be grasses. Nevertheless, if they are not identified visually, soil profile pits dug in representative sections of the area to be planted to tea should reveal their presence. Unless it is possible to loosen the hard-pan, these areas should be avoided at the time of planting tea.

(b) **Sampling soils**

(i) ***Chemical characteristics***

It is known that successful tea soils are acid in reaction. It is therefore very important that the acidity of the soil be investigated and only those areas found to have suitable pH are planted with tea without any pH correction treatment.

Samples should be taken as described below and tested for pH (see page 7).

A soil of pH between 4.0 and 6.0 is, in general, suitable for tea. The best soil for tea (other factors not limiting) is in the range of pH 5.0 to 5.6. As soil pH decreases below 5.0 deficiency of the base nutrients (potassium, magnesium, calcium etc.) and phosphate are likely to become troublesome. In soils of pH above 5.8, there are often problems of establishing tea and it is recommended to treat soil pH at planting (see page 139).

(ii) ***Sampling procedure***
A single sample might be very unrepresentative of the field from which it is taken. Several samples should be taken from a field. Ten small pits should be dug in a grid pattern over each half hectare. About 50g of each of the topsoil (0 - 20 cm), middle soil (20 - 40 cm) and bottom soil (40 - 60 cm) from each pit should be put in three bags viz. ten sets of top soil in one bag marked “A”, ten sets of middle soil in one bag marked “B” and ten sets of bottom soil in one bag marked “C”. Mix the samples in each bag thoroughly.

For topsoil only it is not difficult to dig ten pits to a depth of 20 cm and take a slice of soil about 2 cm thick from each side of the pit using a garden trowel. These slices, put into one bag, will give about 1½ kg of soil for laboratory investigation.

For subsoil sampling, using an auger can save much time and effort. This tool should be the ordinary carpenter’s type 3 to 5 cm in diameter. The best size is 4 cm diameter and total length to 60 cm. The twist bit of the auger is 20 cm long and is just the depth of a normal topsoil. A file mark should be cut at 20 cm and 40 cm above the top of the bit.

To take a sample with an auger, first make the surface firm by trampling, then press the top of the bit gently in and turn the handle until the whole of the bit is in the soil. Then pull the tool out with the soil sample safely lodged in the convolutions of the bit. Peel off the sample carefully into a polythene bag which contains a piece of thick paper on which is written the site number and depth letter. The “A” sample can very easily be taken with one auger dip, and is uncontaminated provided the tool is clean. The “B” sample is obtained by inserting the auger tool in the same hole, turning the handle until the 40 cm file mark is reached, and then pulling up and removing the sample in the convolutions of the twist bit as above. When pulling up the “B” sample it is almost impossible not to have some topsoil dropping into the hole. In order to remove this, the auger is inserted and drilled about 5 cm, pulled up and the soil discarded. The “C” sample can be taken quite cleanly. Contamination of the “B” and “C” samples with topsoil can be reduced to a minimum if the outer part of the soil in the twist bit is scrapped lightly with a knife.

The soil sampler then goes to the next hole site with the same three bags and drills for samples and puts in the three bags. The procedure is repeated for the ten holes marked previously in a grid over each half hectare. Bags should be securely closed with a strong string.

Systematic sampling of a field or estate by the above procedure is well worth while because the laboratory results can be plotted on a plan to serve as a guide for planting and fertilizer programming.

Hutsites should be sampled in the same way with proportionately fewer holes for the smaller ones but not less than three holes per hutsite.

(iii) ***Deeper samples***

It is often desirable to obtain samples from depths lower than 60 cm. This can easily be done with longer augers. By cutting off the 4 or 5 cm bit 15 cm above the top of the twist and welding this to 120 cm of 12 mm diameter steam or water pipe, augers of any length up to 6m can be made by connecting with ordinary threaded rings; the handle is fitted into a standard threaded T-joint with a cross member of 4 cm diameter. Handles should always be of smooth hardwood and should project not more than 25 cm from either side of the auger. Tapering towards the tips gives an easier grip and additional strength.

Screw augers work extremely well in red clays derived from volcanic rocks in East Africa. Gritty soils derived from quartz schist may give trouble by holding back the auger, but if this is pulled up every two centimetres then a reasonable sample can usually be obtained.

(iv) ***Bags***

Cloth bags are unsuitable because if the soil is wet the dressing in the bag contaminates the soil; if the soil is dry then dust passes through the cloth and contaminates the samples touching it. Bags made of polythene tubular film of 250 or 300 gauge and 30 x 23 cm lay-flat diameter, heat sealed at the bottom, are ideal.

Samples should not be air-dried before sending to the Tea Research Foundation, they should be sent as soon as collected and not left around in an office or store to be further contaminated by alkaline cement and wall dust. Supplies of suitable bags can be obtained from TRFK for a fee. These bags are used once only, and if necessary can be used in the final storage of the sample for reference purposes.

(v) ***Labels***

Details should be written on labels in indelible ink or pencil, and the labels tied or stapled on the outside. The same details should also be written on a slip of paper inside the bag.

(vi) ***Surveys***

Take your sample on a grid with ten auger holes per half hectare. Large estates could reduce the work by taking sample areas out of each field and then going back to do problem fields in detail. In uniform soils, if the results from, say, five sample areas show that the "C" and "B" samples do not vary significantly from the "A" sample, then only the "A" sample need be taken, but a composite sample from ten sites is essential in the first sampling.

(vii) ***Results***

The TRFK will determine pH values on soil samples (see page 162).

(c) **Soil pH testing**

There are various types of electronic instruments available for pH testing. These instruments measure pH directly and are accurate to 0.1 of a pH unit. They are best used in a fixed position in a laboratory or soil testing room and require some skill to use reliably.

"Pocket" instruments are obtainable in which the electronics are fairly robust. As the voltage measured is small, faulty contacts can give incorrect pH readings.

The following are required for soil pH testing:

Apparatus

pH meter with glass and calomel electrodes (or combined electrode); small beakers, i.e. 50 or 100 ml; short stirring rods and distilled water.

Reagents

Standard buffer solutions of pH 4.00 and 7.00 (buffer tablets can be purchased commercially prepared to these); saturated KCl (about 40 g per 100 ml of water).

Procedure

Each pH meter will have its instruction manual giving procedural steps to be followed in getting ready for pH testing. Please read these instructions very carefully. Remember that the glass electrode is fragile and subject to breakage and excessively rapid deterioration if not properly cared for. It is also expensive to replace.

Before making pH measurements of a soil, prepare a soil suspension by placing a volume of approximately 40 cc of soil in a 50 cc beaker (the beaker should be about 70% filled with soil in lieu of weighing). Add distilled water to the soil without stirring until water wets the entire soil. When the soil is completely wet, the soil is stirred with a rod and drops of water added until the soil is a "thin paste" that just barely flows together to close around a hole left by the rod. The soil is now ready for the pH measurements.

The glass and calomel electrodes are inserted in the water-saturated soil, and pH measurement is made. The glass electrode is moved about to ensure removal of water film around the electrode, and the pH reading is again taken. When the reading is constant or nearly so, the pH value is recorded.

The following precautions will help:

1. The electrode is not allowed to remain in the test solution or suspension longer than necessary, especially if more alkaline than pH 7.0 (i.e. a pH greater than 7.0).
2. Immediately after testing, the electrode is washed off with a strong stream of distilled water from a wash bottle.
3. For storage after cleaning, the electrode is suspended in distilled water and the system is protected from evaporation. Drying out of the electrode must be avoided.
4. Failure of the glass electrode pH meter is indicated when, after standardisation, it gives a slow response to large pH changes. The glass electrode is immersed in pH 7.00 buffer, then in the original pH 4.00 standard buffer. Readings of pH values a few tenths higher than the specified pH values of the standard after as little as 60 seconds equilibration indicates "etching" or an over-age glass membrane.

(d) **Clearing and preparation of land for planting**

Soil samples should be taken and tested to determine the suitability of the soil for planting with tea (see page 5).

(i) ***Clearing***

After the site has been chosen, the area for planting should be marked out. Sites will vary from district to district and in each case the amount of clearing will depend on whether the vegetation is heavy to medium forest or simply grassland.

Gradients of 20 per cent or more should be avoided where possible and gradual slopes should be preferred in order to keep erosion to a minimum. In planting flat areas careful checking is necessary to confirm that the land can be adequately drained, or problems of water-logging may arise later.

Most of the smallholding tea growers in Kenya are currently confined to grasslands; such areas are abundantly available and more economical to prepare than forest land. Clearing long grass, such as Napier grass, can sometimes be done mechanically by a gyramor flail attached to a suitable tractor or by hand, with gangs of labour using pangas (machetes) and jembes (hoes). Short grasses can be effectively dealt with by ploughing and harrowing. When clearing mechanically, the necessity for burning off the vegetation does not arise. Napier grass stems should be pulverised with the flail so that they do not tangle the plough and harrow at later stages of the clearing operation.

When a light vegetation covers the land, the modern type rotovator mounted on a suitable tractor can be put to work without any prior clearing of vegetation. Three rounds of rotovating are adequate and land is generally ready for lining out. Clearing by this method has been found to be effective against couch grass. The rotovator blades tend to throw the roots to this surface where they can be left to dry out or be removed by hand. The maximum depth to which these machines can cultivate is about 25 cm.

Trees on forest land clearings should be first ring-barked or frilled in order to kill the trees before clearing (see page 14). The trees should be felled after they die and the roots removed as completely as possible. The fallen timber is removed. If a bulldozer does this, it will even out most of the holes from which the roots have been removed, but it may be necessary to fill in some of the deeper holes to allow free passage of the ripping equipment.

It is a very bad practice to bulldoze or dump timber and trash from a clearing on to land that will be needed for planting with tea in future. This will raise the pH of the soil of the land on which the trash is dumped, there will be heavy weed growth and probably a high casualty rate in the newly planted tea. Burning timber and plant debris can also produce large patches of spoiled land on which the tea will not establish. Dumping and burned trash must be confined to areas unsuitable for tea planting.

Between each stage of these operations, it is advisable to clear away from the site all pieces of “couch” grass and free roots which become exposed. The ripping operation which follows should be done at least twice, the second ripping being across the first. After each operation, hand forking should be done, to reduce the risk of losses from *Armillaria* disease in the tea in future years.

The main danger from *Armillaria* is generally from stumps and roots left by the ripper below forking depth. Thus it may pay to dig these out by hand when they are seen in a hole from which a tree has been uprooted. This latter operation must precede bulldozing as these holes tend to become covered while bulldozing. During bulldozing care should be taken to ensure minimum *disturbance and removal of fertile topsoil*.

The final ripping before planting must always be across the gradient, never up and down the slope.

After clearing, the land should be ploughed and harrowed a number of times to break down the clods of soil from around the grass roots. The grass roots are then left on the surface to dry out. This operation can be done by gangs of labour with jembes, especially in cases where there are heavy layers of Napier grass roots. In forest land, ripping and subsoiling is normally required to prepare the land for lining out while in grassland and wattle trees, land ploughing and harrowing, or hoeing for small growers, is normally required to prepare the land before lining out.

(ii) ***Sub-soiling***

Subsoiling, when necessary, is the next operation, and should normally precede lining out, or, if contour planting is envisaged, both can be combined (see page 65).

By placing the subsoiling tines at the required spacing, staking can be done by following behind the tractor and placing marking stakes at the required planting distances. In some instances the marking of the line spacing has been eliminated and the planter merely plants along the sub-soiled line at the require spacing.

If subsoiling is not considered necessary or possible, lining is carried out as a separate operation. Two 30-metre chains and an adequate number of marking stakes are all that are required for this operation.

(iii) ***Terracing*** (see Figures I:1 and I:2)

Before starting graded terracing, any holes remaining from which large trees were uprooted will need filling. Next, cut-off or down drains should be sited. Should there be a hollow or depression in the area for planting, this will be the best site for a cut-off drain. Other cut-off drains can then be measured from this, bearing in mind that no graded terrace should have water flowing in one direction for more than 300m. Shorter distances are better as an insurance against heavy storms. In the event of a road being planned across the top of, or through the area, culverts must be placed so that they discharge water into a cut-off drain.

The “O” or starting line is then chosen, and points marked at the correct distances along this from which terraces will run laterally. An “O” line will be necessary between each two down drains, or between a drain and a road where it is decided to spill terrace water on to a road and this road is more than 300m from a drain. A road tracer is considered accurate enough to mark out graded terraces, but if neither this nor a surveyor’s level is available, a small spirit level which will fit on to a cord may be used.

Using a road tracer, “shots” of 15m are recommended and marking stakes should be put up at this distance across the field, the road tracer having been set to give a fall of half per cent, or more in areas of particularly high rainfall and on steep slopes (see page 12).

Each graded terrace is marked out from the “O” line to the nearest drain, or to a road if the roadside drain is to take water from the terraces.

Where a terrace crosses depression and there is no run-off drain there, it is necessary to take short shots and so follow the contour accurately.

When a spirit-level is used, shots of 7m are most suitable as it is not practicable to keep the string taut over longer distances. The string can be fixed to the top of two 1-metre high thin stakes, one being “V” notched 3cm into the top to give the required fall. The spirit level should be placed midway between the stakes. When marking out is completed or enough work done to merit a start on making terraces, the tractor and terracer should start on the first terrace from the top of the field. Terraces can be done by hand, but tractor-made terraces are far more satisfactory as they are compacted by the tractor during making.

It is best for terraces to be made alongside and above the marking stakes, as the tractor driver then has a guide when he is making terraces.

The trough of the terrace should be at least ½ m deep and 2 m wide. When each terrace has been completed it should be checked with whatever instrument was used to mark it out, taking shots of 7m working in each direction from the “O” lines, and all high spots dug out by hand.

On slopes steeper than 20 per cent, the vertical interval can be maintained at 2 m and terrace banks made narrower. It is imperative that the banks, of necessity made by hand, are well consolidated and a cover crop of oats or love-grass is planted immediately. The cover crop should be broadcast over the whole field. Holing and planting operations for the tea largely bury this crop and a second, inter-row crop should be planted immediately following the tea planting.

In situations where the slope of the land is steeper than 20 per cent, the fall of the terraces from the “O” line should be increased from ½ percent to 1½ per cent.

Following this, down-drains (cut-off drains) are put in, care being taken to see water from the terraces will flow into them. Drains which are to be grassed should be wide and shallow; concrete or stone drains are better. Drains must be adequate to take water from heavy storms off the terraces. Terraces must be accurately made; a badly made terrace is more dangerous than no terrace at all.

A useful guide for making terraces is given in Table I:1. In practice, the slope of the land may be constantly changing from the top to the bottom of a hill and so the average gradient is normally used. Only when the slope changes by more than 5 per cent need a new distance between terraces be determined.

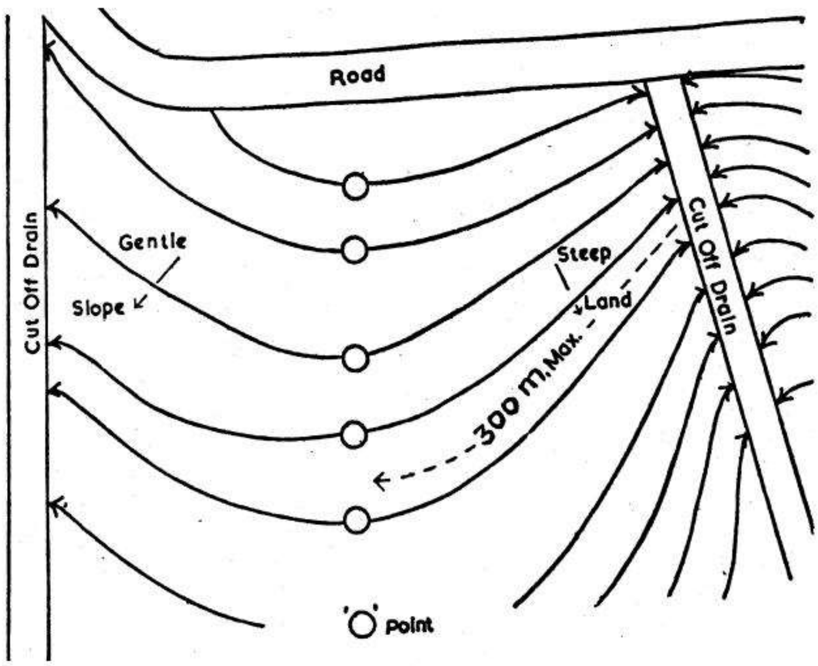


Fig I.1

Method for marking terraces

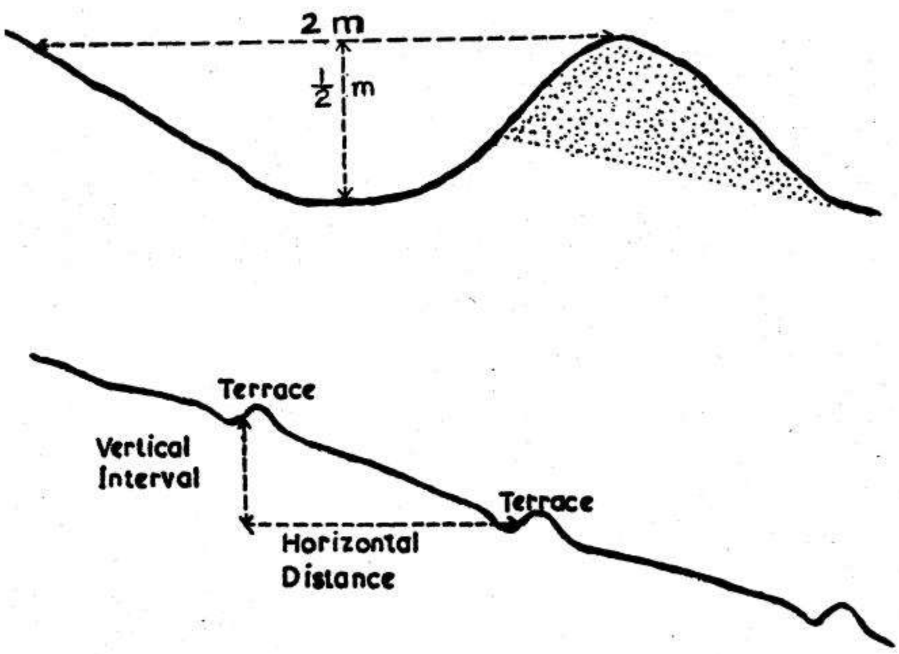


Fig.I.2

Formation of terraces on sloping land

Table I:1. *Distances between terraces relative to slope*

Angle of slope (°)	Slope (%)	Vertical interval (cm)	Horizontal distance (m)	Ground distance (m)
1°	1.7	74	42.51	42.55
2°	3.5	88	25.08	25.09
3°	5.2	101	19.25	19.28
4°	7.0	114	16.34	16.38
5°	8.7	128	14.59	14.64
6°	10.5	141	13.42	13.49
7°	12.3	155	12.58	12.68
8°	14.0	168	11.96	12.08
9°	15.8	182	11.47	11.61
10°	17.6	195	11.08	11.25
11°	19.4	209	10.76	10.96
12°	21.3	223	10.49	10.72
13°	23.1	237	10.26	10.53
14°	24.9	251	10.06	10.37
15°	26.8	265	9.90	10.24
16°	28.7	279	9.75	10.14
17°	30.6	294	9.61	10.05

Calculations

1. % slope $= 100 \tan\theta = \dfrac{\text{Vertical interval (cm)}}{\text{Horizontal distance (m)}}$

2. Vertical interval (cm) $= (7.62 \times \%\ \text{slope}) + 60.96$

$= \text{approximately } \dfrac{(38 \times \%\ \text{slope})}{5} + 61$

3. Horizontal distance (m) $= \dfrac{\text{Vertical interval (cm)}}{100 \tan\theta}$

$= \dfrac{\text{Vertical interval (cm)}}{\%\ \text{slope}}$

4. Ground distance (m) $= \dfrac{\text{Vertical interval (cm)}}{100 \sin\theta}$

5. The area, measured in hectares, enclosed by a 100 m length of ground between two terraces is found by dividing the distance between the terraces by 100 (e.g. at a 9° slope, the horizontal area is 0.1147 ha and the ground area is 0.1161 ha).

Lining or marking out for planting is the next step. For this a 30-metre surveyor's chain is best and sufficient supply of half-metre stakes will be needed. First a line of stakes is put along the middle of the terrace faces and lining starts from these lines. Take the line along the face of the first terrace and that along the face of the second, and from the first, work upwards, using whatever distances between the lines of tea decided upon. As terraces never run parallel, there will be some short lines or lines that cannot be taken to the end, and by the above method these will come between the terraces, which is a help towards soil conservation. After lining the first two terraces, the same system is used until the field is finished (see Figure I:3).

An alternative and more convenient method is to mark out the lines for planting so that they are parallel to every second terrace. Taking every second terrace is reached. In this way the short lines will run into every other terrace which can be used as a path or road convenient for starting and finishing any operations through the lines of tea later (see Figure I:4).

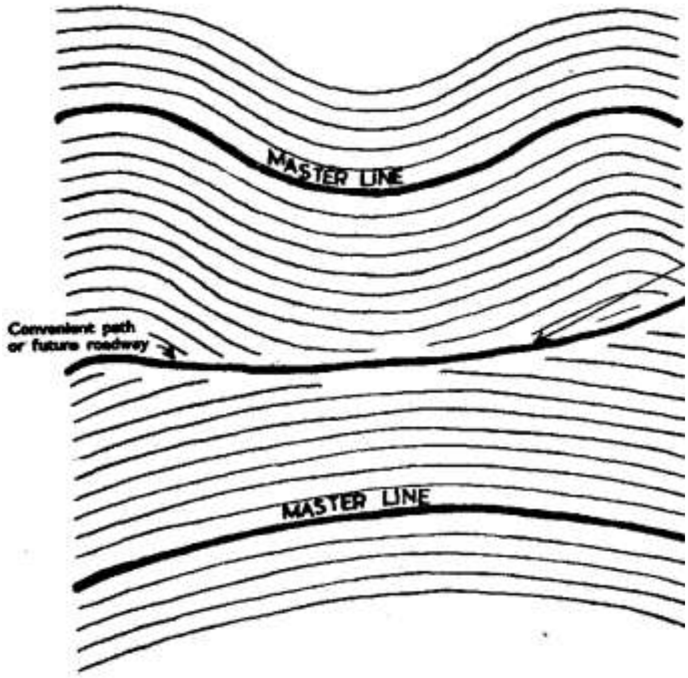
(iv) ***Field drainage in low-lying areas***

Terraces and cut-off drains are adequate for sloping land (see plates 1 & 2). Low-lying areas need a system of parallel channels leading into a main drain or channels laid out in a herring-bone pattern. Whichever method suits the conditions, the main drain must be in the lowest part of the area, it must have a fall of at least 1 per cent to ensure disposal of water and channels leading into it must also have their fall.

Should the area have a high water table and be liable to water-logging, then drains must be adequate to lower the water table sufficiently to prevent water-logging. This may entail quite deep drains and a problem of subsoil disposal.

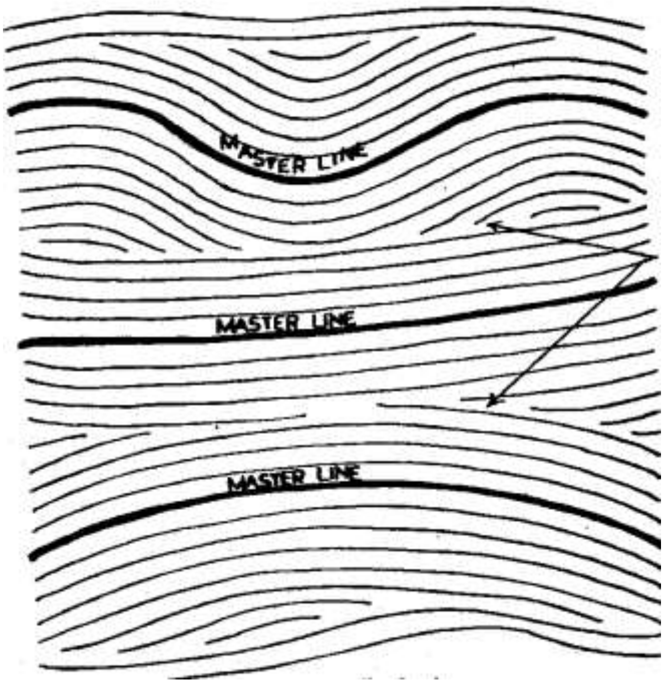
e) **Killing trees**

The aboricide 2,4,5-T has been effective in killing trees but has been withdrawn from the market in Kenya. The TRFK has not yet tested another chemical for killing trees. An alternative is "frilling" (ring-barking), that is, the bark is cut with a panga all round the trunk and pulled away without removing or cutting the pulled bark to remove it from the tree (see Figure I:5). The TRFK cannot, from experience, quote the time any particular species will take to die. The majority of species may take two to three years to die. This slow dying reduces the food reserves of the roots and this will reduce the risk of *Armillaria* infection following removal of tree (see page 170).



"Point rows" meet in every second bund. The other bunds are taken as master lines.

Fig I:3
Lining for planting: First method



"Point rows" in between bunds. Each bund is taken as master line for half the rows above and half below the bund

Fig I : 4
Lining for planting: Second method

Plate 1 *Soil and water conservation.*

Main drain prepared before grassing but with the field staked ready for planting.

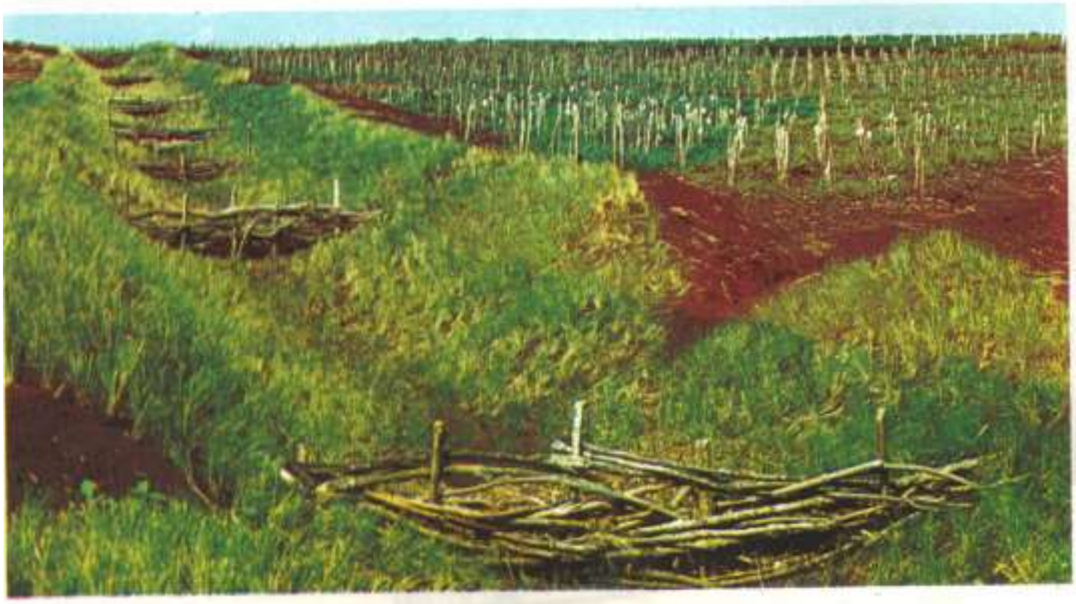


Plate 2 *Main drain grassed with* **Eragnostis curvula** *to protect it from erosion*

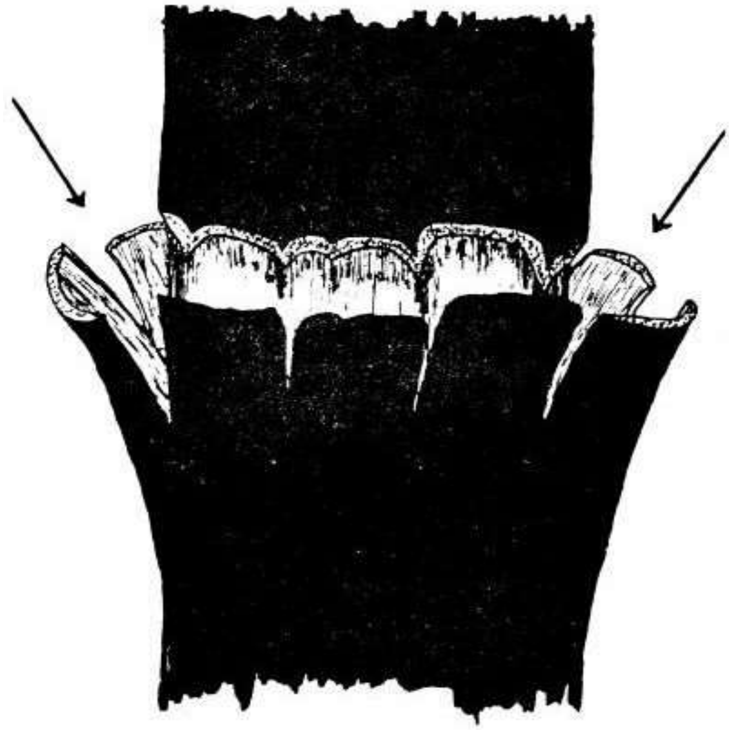


Fig. I : 5

Frilling tree trunks

Removing dead shade trees

When shade trees in mature stand of tea have been killed by ring-barking, their removal presents special problems. The normal procedure is to fell the trees by sawing or chopping through the trunk as close to the ground level as possible, sawing off the branches before felling so as to reduce the damage to the tea bushes to a minimum. The branches and trunk are cut into sections and hauled out through the tea.

There is no need to remove the complete root system of the trees if they have been successfully and completely killed.

After cutting, the exposed surface of the trunk which remains in the ground should be covered with soil to a depth of 10 cm. This will hasten the decay of the wood by cellulose-destroying fungi and bacteria from the soil. The species of termites which live on dead stumps and roots are harmless to growing tea.

It should be realised, however, that even this method is seldom completely effective against *Armillaria*. It is normal to find a few bushes dying from *Armillaria* in the years following the removal of shade trees, particularly in the fields where the trees had grown very large before being killed.On no account should attempts be made to remove living shade trees by this method. If this is done, the roots left in the ground become permeated by *Armillaria*. So if shade trees are felled before they die, and living roots are left in the ground, a high incidence of *Armillaria* deaths in the surrounding tea bushes will inevitably follow during the next two years.

See also the chapter on diseases control on page 170.

f) **Land management after clearing**

(i) ***Preparing land for planting***

Persistent herbicides should not be applied to cleared land prior to planting unless the land is not to be planted with tea for at least three months. Doses of up to 7 kg active ingredient of each chemical per hectare can be used (Karmex - 8.75 kg).

Couch and other grasses can be removed by Round-up® (Glyphosate) at 6 litres per hectare. Tea can be planted six weeks after such treatment, not earlier.

All vegetation should be burnt off by applications of paraquat (Gramoxone®). Repeated applications will discourage deep-rooted plants; Kikuyu grass can be killed by repeated applications of Gramoxone. Doses up to 1.4 litres, with 280 ml of Teepol®, per hectare can be used. Cover crops such as Oats and Guatemala grass are recommended.

Land treated with persistent herbicides cannot therefore be planted with a cover crop before tea is planted.

(ii) ***Tea following wattle***

After felling, wattle stumps become infested by parasitic fungi especially of the general *Fomes* and *Ustulina* which are the causal agents of brown root rot and charcoal stump rot diseases of tea. By the end of the third year after felling the wattle roots and the fungi themselves will have been attacked and destroyed by harmless fungi and other bacteria from the soil micro flora.

If tea is to be planted on land which has previously carried wattle trees and wattle stumps are to be left in the ground, then a minimum period of three years must elapse between felling the wattle and planting tea, if very heavy losses from root diseases are to be avoided. This time interval can be reduced if the wattle trees are frilled before felling but it is understood that this practice destroys wattle bark.

There is strong evidence that wattle trees greatly improve land intended for tea, when the recommended three-year interval is followed. In smallholding areas it is suggested that farmers plant row crops such as beans and potatoes during the three-year period.

g) **Road making**

Roads on tea estates are a major and expensive item. Lime can be used to produce a road-bed which is much more durable than good murram. Some of the trunk roads reconstructed in Kenya have been made by this method, with a thin layer of tarmac to provide a better wearing surface.

All types of soil can be stabilised provided sufficient lime is used. The method is to mix lime evenly with the surface layer of the road while it is fairly dry and then grade the surface. Wet the surface until it is fairly tacky but not saturated and then roll it.

The surface so formed will remain solid in most weather conditions. The major form of loss will be as dust blown off in dry weather. If the surface does get pitted it can be re-graded, wetted and rolled. This can be repeated indefinitely so long as lime is present.

The important parts of the operations are:

1. Thorough mixing of the lime with the soil.
2. Adequate but not excessive wetting; it does not need to be so wet that it sticks to the roller
3. Very thorough rolling.

The amount of lime required will vary with the soil. On big road contracts, the soil type is tested to avoid wasting lime (see below). Table I:2 gives the quantities of lime required for estate roads.

Table I:2. *Lime quantities for road stabilisation*

Soil type	Lime percentage	Kg of lime per metre length of road, 3 m wide, mixed to a depth of 10 cm
Murram	5	18 kg
Red soil	10	36 kg
Black cotton soil	20	72 kg

The lime to be used is slaked or hydrated lime; the lowest grade available being adequate.

(i) ***Grass roads***

Care must be taken in the choice of sites for these roads as they are unreliable for transport in wet weather, and are apt to cut up and transport may bog down on them. Boundary roads and intermediate roads are the only suitable sites for this type of road surface.

One of the best grasses for this purpose in Kenya is Kikuyu Grass, *Pennisetum clandestinum*, because:

1 It is frequently available in large quantities and is easy to plant

2 It is vigorous and forms a dense mat which can be kept tidy by mowing without reducing the vigour of the grass.

When conditions are right for planting, disc harrow the road one or two rounds to give a tilth which will speed the operation. After harrowing, lines 15 cm to 30 cm apart (according to the amount of planting material available) are opened down to 8 cm or 10 cm deep. The closer these lines are, the quicker cover will be achieved.

These lines should follow the road alignment and not cross it. If lines are planted across the road a corrugated surface may develop and be very noticeable in a vehicle. Light watering after opening up lies for planting will help the grass to root. It is recommended that phosphate be added to these lines at the rate of 55 kg P_2O_5 per hectare to aid the establishment of the grass.

The grass should be planted in the lines, covered with soil and firmed down. It is better to leave ends of grass sticking out to reduce erosion until the grass is established.

It is not necessary to have a lot of growth on grass roads. Roots are what are needed, and roads should be kept closely cut and the edges trimmed.

Natural regeneration and establishment of indigenous grasses, followed by frequent close cutting is sufficient to establish adequate grass roads in many parts of Kenya.

(ii) ***Grass verges***

These are recommended on roadside banks and along the sides of drains, as they prevent the bank from eroding and exposing the roots of tea bushes. A single, thin line of grass planted between the metalled road surface and the edge of the adjacent drain is useful in preventing the loss of murram and gravel by washing into the drain. It is necessary, however, to have a good camber on the road and periodically to clear the debris away from the grass and back to the middle of the road so that water can pass freely through the grass into the drain and not form rivulets down the road.

Love grass (*Eragrostis curvula*) and Dallis grass (*Paspalum* sp.) are recommended for these purposes. Kikuyu grass (*Pennisetum clandestinum*) is effective but needs constant attention to keep it from spreading into tea and road, and is therefore not recommended. *Eragrostis curvula* is easy to establish as it is a prolific seed producer and germination from seed is very high. Unless turfs of this grass are available for splitting and planting, seed should be planted in a nursery five or six months beforehand.

For planting, turfs are dug up and split into small pieces, trimmed and dibbled in, the closer the better as this will give quicker cover. Two or three grains of superphosphate in each hole into which grass is to be planted will improve establishment. The area planted should be hand weeded after planting to delay weed germination until the grass is established.

The grass chosen must never be planted nearer to tea than 60 cm or it will adversely affect the growth of the tea.

Khus Khus (*Vetivera zizanioides*) grass is sometimes used to reduce erosion because of its dense mated root system. It tends to grow in clumps, forming gaps in the row through which erosion channels form, and also competes severely for soil water with adjacent tea rows in dry weather.

(iii) ***Road drainage***

The run-off from murramed roads is proportionately greater than that from fields. Drains must discharge into existing or intended cut-off drains, and not into planted areas.

The directions of flow of a roadside drain to the nearest culvert should be at an even fall. Should the fall at any place become less, silting will occur at this point and water may cross the road and spill into the clearing.

Culverts should slope from the upper to the lower side of the road and should have a trap at the upper end to collect silt and trash. This trap should not be less than 1 metre square and its floor 30 cm below the culvert; the trap should be cleared out from time to time.

Cut-off drains must be of sufficient capacity to deal with the discharge from road drains and culverts should not be less than 40 cm diameter. The best type of cut-off drain is that made of precast concrete sections or stone and cement. Grass drains silt up and requires careful maintenance.

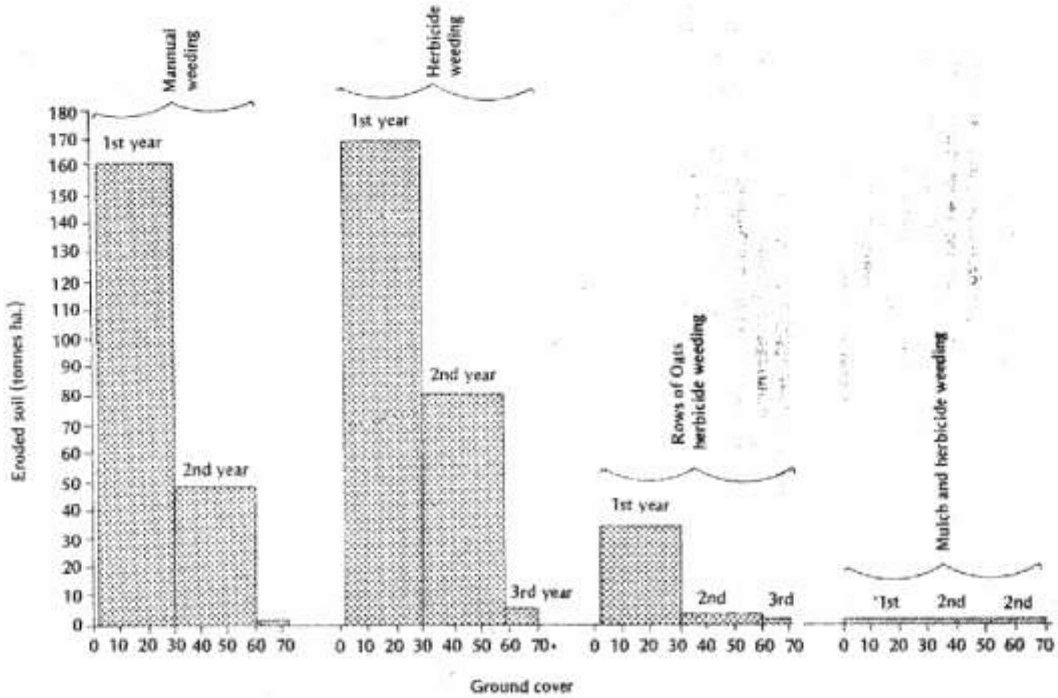


Figure 1.6: Relationship between soil erosion and percentage ground cover

h) **Erosion**

One of the factors detrimental to the establishment of young tea is soil erosion, which is more severe the more sloppy the area to be planted to tea. The danger from erosion in tea areas is greatest on land prior to and just after planting and even if this land is terraced (see page 10) there will be movement of soil between terraces during heavy storms. Mulching or planting with oats is recommended to reduce this soil movement (see pages 22 and 25).

Since the use of herbicides has become prevalent the trash due to dead weeds also helps in reducing soil erosion. Young tea is vulnerable to erosion because it has not formed an appreciable ground cover, and for this reason prunings should never be removed. An experiment was carried out in Kericho district tea zone to quantify surface run-off and soil erosion on a sloppy (10% slope) field of tea. The experiment showed that:

1. Grass mulching gave the best control of soil erosion, followed by a treatment in which oats were planted between rows of tea. Hand weeding and hoeing, which produce a surface cap of loose soil, was found to give slightly better erosion control than non-tillage treatment. (Figure I:6, above). However, hoeing is undesirable in tea fields because of the potential damage to tea feeder roots.
2. The amount of tea canopy cover was an important factor in the reduction of the amount of soil erosion.
3. The very large amounts of soil lost, 211 and 255 tonnes per hectare in the tillage and non-tillage treatments respectively during the three years following planting, shows the need for proper and adequate soil erosion control measures when land is prepared for planting and immediately after planting.

Tea bush management which encourages the early spread of the canopy, such as pegging, is a better method of reducing the amount of soil erosion than frequent pruning. In areas of high rainfall (therefore high erosion hazards), tea clones which spreads easily and quickly following planting should be preferred to those which spread slowly. Closer spacing at planting can also produce early closure of canopy. Tea planted on or near a bund of soil immediately below a terrace trench show remarkable tolerance to extended drought. These bunds (or micro-catchments) are capable of intercepting run-off water and eroded soil if properly constructed and maintained. This can be particularly beneficial in young tea plant in sloppy areas.

Water from roads must be kept out of tea areas and confined to drains. Run-off from roads may be quite high and can cause serious erosion by forming gulleys which will tend to get progressively deeper, resulting in washing off young tea or causing serious root exposure in old tea.

i) **Mulch**

Effects of mulching tea

A surface organic mulch has two types of effects on the soil: a characteristic effect from being on the surface of the soil, and a general effect it would have if it were ploughed into the soil, due to the plant nutrients set free as it decomposes.

1. *Effects on soil temperature*

In many instances, soil temperature is of greater ecological significance to plant life than air temperature. A surface mulch affects both the diurnal and seasonal fluctuations of the soil temperature. The effects of mulch depend on its type, the amount applied and its rate of decay.

A field experiment conducted at the Tea Research Foundation's station in Kericho showed that under young tea plants, grass mulches had the effect of reducing diurnal variations, but generally lowering the average soil temperature at 0 - 10 cm depth. This had a negative effect on the growth rate of young tea plants. The general high average soil temperature under the plastic mulch had a positive effect on the growth of the young tea plants.

The results of the experiment clearly showed that in high altitude areas with cool climate, low soil temperatures can reduce rates of growth and yield of tea.

2. *Effects on soil moisture and other physical aspects.*

Mulches reduce the rate at which moisture is lost from the soil by evaporation, particularly in young and newly pruned tea where a large proportion of the soil is exposed to direct sunlight and drying wind.

Mulches prevent soil from cracking. They also prevent soil from puddling by the impact of rain drops thus helping to keep the soil surface permeable. Furthermore, rain water can only reach the soil surface through the mulch as a gentle stream of clear water, which gives greater permeability than if the soil surface itself was exposed to the beating rain. Thus mulch reduces the run-off of the rain and consequently reduces the amount of soil the water can carry and increases the proportion of water that percolates into the soil. So, not only is evaporation from the surface of the mulched soil reduced, but also the amount of water infiltrating into it is increased. Hence, the water-supplying power of a soil can be considerably increased by mulching.

3. *Effects on nutrition of the tea plant.*

Organic mulch supplies extra nutrients to the tea. As the organic mulch decomposes, the plant nutrients held in it are released into the soil and become available to the plant. Experiments have shown that organic mulch is particularly beneficial when applied with inorganic phosphatic fertilizers such as single superphosphate. In the very acid soils on which tea thrives best this form of phosphate fertilizer immediately reacts with some elements in the soil forming less soluble and less mobile compounds. Unless the roots are able to reach them, they will remain unused. Improvement of the soil's physical structure, as a result of using organic mulch enables the roots to reach these tied-up phosphates. In the decomposing of organic mulch, a chemical solution is released which reacts with the insoluble phosphate compounds rendering them available to the plant. Results of the experiments conducted at the Foundation's station have shown increases in uptake of nitrogen, phosphorous, potassium and magnesium where organic mulches have been applied, including tea prunings and leaf falls.

It has been found that tea prunings in four-year cycles can return to the soil as much as 400 kg nitrogen, 25 kg phosphorous and 200 kg potassium per hectare.

It is therefore very important to leave prunings *in situ*. Removal of prunings has been found to result in a yield drop of 30 and 27% in the first and second year, respectively following pruning.

Continued application of organic mulching material high in potassium such as Napier grass has been shown to induce magnesium deficiency. On the other hand, continued application of potassium deficient material such as *Eragrostis curvula* grass can induce potassium deficiency. It is therefore recommended that remedial application of the respective mulch deficient tea nutrients be made where necessary.

When fresh plant material is applied as a mulch during wet weather, the decay of the mulch initially reduces the soil nitrogen available for use by the tea and this can lead to a marked reduction in the growth rate of young tea plants, particularly if the mulch itself has a low nitrogen content, as in the grasses. When this material is applied together with nitrogenous fertilizer, the response to nitrogen in terms of crop has been shown to be higher on mulched tea than on unmulched tea. However, it has been demonstrated that a high level of nitrogenous fertilizer applied together with a grass mulch in young tea can be harmful in some areas.

(ii) *Suitable materials*

The following materials have been found to be suitable for application as mulch. The list is not exhaustive but, while mulching tea; care should be taken not to introduce weeds in tea gardens. Prunings and leaf fall of tea

Guatemala grass (*Tripsacum laxum*)

Napier grass (*Pennisetum purpureum*)

Weeping grass (*Eragrostis curvula*)

Oats (*Avena sativa*)

Maize stalks (*Zea mays*, L.)
Guatemala grass has proved to be the most effective of all the mulching materials. However, in high altitude and colder tea areas, its growth is comparatively slower than in the warmer tea areas as it takes 18 to 24 months from planting to become sufficiently well established to stand cutting.
Napier grass should be cut and thoroughly wilted before spreading. It need not be chopped into small pieces as leaf shrinkage is minimal and rotting down is slow, thus offering a good soil cover. A mulch depth of five centimetres can be considered appropriate.
The main problem that accompanies the large-scale use of mulch is the cost of growing and applying the material. For example, to grow Napier grass to provide mulch for tea at the rate of 40,000 kg (40 metric tons) per hectare requires about one hectare of planted Napier grass for each five hectares of tea to be mulched. Mulch in the form of mature tea prunings and leaf litter, if conserved properly, will confer benefits for several years, depending on the condition of the tea at the time of pruning. This is why it is advised that tea prunings should never be removed from tea fields.
Following the application of mulch it is important that the soil is not disturbed and any weed control must be effected by chemicals or by hand pulling. Mulch is most effective when applied before the onset of the dry spell i.e. in November/December.
Weeping grass mulch is more resistant to decomposition as an additional advantage over the other grass mulches on the effective duration in conserving the soil.
In order to provide sufficient vegetative matter, oats would need to be planted continuously in the first two or three years of planting tea. A shallow (2.5 cm) trench, width of a cheel hoe, is scraped out between each contour row of tea. For less sloppy areas, the planting may be at every interval of two rows of tea. In newly cleared land, the sowing of oats should be accompanied by a light application of single superphosphate at the rate of 30 gm per running metre (or 260 kg per ha). This will assist the oats to obtain a good stand and much of the fertilizer thus used would eventually become available to the tea plants. The cutting of oats should be carried out as soon as the first signs of flowering are observed. This encourages the oats to tiller and provide mulching material from loppings obtained from the oat cuttings.

(iii) *Some negative effects of mulching of tea*
Mulching of tea may also have negative effects on tea growth. Continuous mulching has been found to induce shallow rooting as the tea roots tend to grow laterally. This causes the tea plants to be susceptible to drought.
In the cold high altitude tea areas, heavy mulching of tea can further reduce soil temperatures especially during the cold months. Low daily temperatures prevailing over a long period have been found to reduce tea growth rate.
When mulch is applied to newly planted tea, care should be taken to avoid the dry mulching material touching the young tea plants. This is important especially in areas where destructive ants (e.g. termites) are a problem where the mulching material will form a habitable medium for the ants.

Considerable damage to tea can be caused if dry mulching material is allowed to catch fire. Great care should be taken during dry weather.

j) **Cover crops**

Land which has been cleared and terraced should be covered by an easily removed crop as soon as possible. These crops include oats and *Crotalaria* sp. There are two main advantages for this:-

1. The cover crop will reduce soil erosion to a minimum at a time when, without the cover crop, the recently disturbed bare soil is most liable to erosion by heavy rain.
2. It will reduce the loss of organic matter from the soil. Without some form of cover, the organic matter in the upper layers of the soil is rapidly destroyed by the action of heat and ultraviolet rays from the sun.
   The method used to establish the cover crop will depend upon the time which will elapse between clearing the land and planting tea.

It sometimes happens that after land has been cleared and prepared for planting, planting has to be delayed. When this happens, the normal practice is to allow weeds and grass to regenerate over the area. If planting is unduly delayed, woody shrubs and trees soon become re-established on neglected soil and re-clearing becomes necessary.

These practices are no longer recommended. When a delay between clearing and planting is inevitable, the land should normally be planted to oats (*Avena sativa*) or Guatemala grass (*Tripsacum laxum*). Should it be desired to grow a food crop, either beans or Irish potatoes are suitable. Maize, sunflower or sweet potatoes should not be grown on land intended for the cultivation of tea because these are heavy feeders and thus would remove a lot of nutrients from the soil.

If the period before planting tea will be a few months, then the land must be planted with a cover crop as soon as possible.

If tea planting will follow immediately after the land has been cleared and terraced, then oats should be sown between the lines of tea as soon as possible after the tea as been planted.

In most areas the best cover is oats. This crop is simple and cheap to establish, remains in the field for up to one year, and its stubble remains for up to two years as a guard against soil erosion.

Several perennial leguminous plants can be used. Examples include *Crotalaria anagyroides* and some varieties of Lupin.

Weeds which become established among oats can be killed by spraying with herbicides which contain 2,4-D, which does not affect oats. There is no effective method of controlling weed growth in the other suggested species.

(i) *Oats*

The recommended oats variety is Suregrain. The seeds can be sown at the rate of about 170 kg per hectare; at the same time, single superphosphate should be mixed with the top 5 cm of soil at the rate of about 56 kg per hectare.

When the oats are to be broadcast, the seeds and superphosphate should be dispersed evenly over the whole area and then mixed into the top 5 cm of soil. This can be done by hand, using garden rakes, or by tractor using harrow.

If the oats are to be established after the tea has been planted, the oats and superphosphate should be spread in a shallow scrape, 30 cm wide, made with a jembe between the lines of tea. The seeds should then be covered by the soil scraped from the sides by the cheel hoe (jembe) and firmed down by foot. These broad bands of oats are sufficient in contour-planted tea, but in regularly spaced tea care should be taken to ensure that the bands of oats are, as far as possible, parallel to the contours.

In the bands, the requirement is 1.5 kg oats and 3 kg single superphosphate per 100 m of band. It will always be simpler to broadcast the oats before the tea is planted. The oats should be cut back to a height of 8 cm whenever the first signs of flowering are seen. This encourages tillering. The stubble should be allowed to remain to reduce soil erosion and the roots, as they decay, will add organic matter to the soil and will improve the aeration of the soil.

(ii) *Lupins and Crotalaria*

These should be established in the same way as oats. In some tea areas these species have been grown as miniature shade trees. This is not the purpose of these crops; they should be lopped at a height of 60 cm two or three times a year and the loppings used as mulches.

Mulching with cover crops

During wet weather, the breakdown of the mulch cut from these cover crops results in a temporary depletion of nitrogen in the soil. This can severely retard the growth of the young tea plants.

To overcome this, the cover crop cuttings and the application of nitrogenous fertilizer should coincide as nearly as possible. If the cutting is carried out when no nitrogenous fertilizer would normally be applied, it may be beneficial to make a special broadcast application of nitrogen at the rate of 10 kg per hectare.

All cover crops should be cut down at the onset of an extended period of dry weather. If left standing, they will rapidly remove water from the soil and this will exaggerate the effects of the dry weather. On the other hand, the mulch can be spread over the soil and this will help reduce evaporation of water from the soil.

In the areas where strong winds occur during the dry weather the effect of this wind on the young tea plants can be reduced by allowing a light stand of the cover crop to remain during the dry weather.

k) **Windbreaks**

Dry air takes up water from any soil and vegetation over which it passes and the stronger the wind, the faster will the water be removed from the soil by evaporation and from the vegetation by transpiration. In dry weather, this process can cause a reduction in tea yields.

In severe cases, not only may the soil dry out to such an extent that the plants suffer from drought, but even when a plentiful supply of water remains in the soil, the transpiration rate may be so high that the roots cannot supply water to the leaves fast enough. Eventually the leaves wilt and may suffer permanent damage.

The object of a windbreak is to reduce the speed of damaging winds over the tea plants. The best kind of windbreak is formed by a belt of growing trees which are taller than the tea.

The beneficial effect of a windbreak decreases as the distance from that windbreak increases, so it is necessary to have a series of windbreaks across the direction of the prevailing and most damaging wind. It has been found that on level ground, the distance between adjacent belts should be ten times the effective height of the trees in the belts. The effective height is defined as the height of the tree above the tea. The effective height of trees which are 10m tall which will protect tea plants about 1.5 m tall at most, is therefore 8.5 m so the belts of trees should be 85 m apart.

On sloping ground, the distance between adjacent belts should be less than this, but if the belts become too close the yields will be reduced by shading and by competition with the shelter trees.

(i) *Siting*

Turbulence is greatest over and around hills, up valleys and beside any obstacle in the path of the wind such as buildings, woods etc. The windbreaks should be sited so that they interrupt the wind across exposed hills and across narrowing valleys.

It is essential, therefore that the direction of the wind should be determined as accurately as possible, bearing in mind that the direction alters over small distances as a result of topographical features. It is helpful to prepare a plan of the area to be protected, showing hills and valleys and their relationships to the wind direction.

The windbreaks should then be sited at right angles to the wind, especially on windward slopes, over the top of the hills and across the valleys. Because of local changes in wind direction, these belts will not form straight lines except on flat or uniformly sloping ground. Changes in direction of the belts of trees should be gradual, so that no re-entrants are formed which can funnel he wind. Similarly there should be no gaps in the belts through which the wind can accelerate causing even more damage to the tea.

Because wind goes round the edges of windbreaks, the belts of trees should extend at least 20 m beyond the limits of the area which is to be protected.

(ii) *Composition and establishment*

1. *Hakea saligna* has proved to be the best tree for windbreaks in tea. It grows faster than tea in the first few years and eventually reaches a maximum height of about 6 m. Although all plants growing in tea will compete with the tea to some extent for soil water and nutrients, *Hakea* appears to compete less than most other species and, moreover its leaves do not taint the tea. It superficially resembles some species of Eucalyptus but in fact it belongs to a completely different family of plants.

Hakea is normally grown from seed, which should be sown under light shade. Individually they can be sown in polythene sleeves and transplanted to the field when they are 20 cm to 40 cm tall. Weak and exceptionally vigorous plants should be discarded.

The shelter belts are best planted before the tea is established, but if *Hakea* is to be planted in standing tea, care should be taken to ensure that the *Hakea* plants are not shaded by the tea as they will not grow well under shade. The belts should be about 75 m apart; the trees 2 m apart in each belt.

2 Tea itself may be used to form windbreaks especially in established tea fields. The tea plant should be allowed to run up, being trimmed to form fan-shaped trees with fans of adjacent plants in the belts touching each other forming a continuous windbreak at right angles to the wind. Adjacent belts should not be more than 100 m apart and normally 75 m apart.

3 *Grevillea robusta* may also be used as a windbreak. In the application of these trees or tea as shelter belts in tea, it should be borne in mind that the shelter trees should not constitute a complete barrier to wind flow through them. The rows of trees should only reduce the speed of strong winds thus creating an environment for good tea growth.

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Chapter II

BREEDING, CLONAL SELECTION AND PROPAGATION

TEA BREEDING

Introduction

This chapter, formerly entitled ***"Propagation"*** has been restructured into three sections consisting of breeding, clonal selection, and propagation. Breeding has been treated in more detail and clarity than before, to cover important breeding objectives, breeding and selection strategies, selection criteria, tea genetics and clonal response to environmental variation.

In clonal selection, the classical TRFK four-stage selection programme has been retained to preserve the information for users preferring the method. However, this approach is too long, usually taking about 20 years or more. Therefore, a two-stage selection programme involving progeny tests followed by full-scale clonal field trials has been introduced. The progeny trials last six years, while the clonal field trials last two pruning cycles, thus, shortening the duration of the breeding cycle considerably.

New information on grafting has been added on the propagation section.

Taxonomic classification of tea

Correct name

The correct botanical name of cultivated tea is *Camellia sinensis* (L.) O. Kuntze, regardless of varietal differences, and it consists of three distinct varieties, namely,

(i) China – *C. sinensis* var. *sinensis* (L.). Characterised by small, narrow, serrated, erect, dark green leaves. It is slow growing, dwarf and shrub-like, and originated from China.

(ii) Assam – *C. sinensis* var. *assamica* (Masters) Kitamura. This is typified by large, horizontal, broad, mostly non-serrated, light green leaves. It is the predominant variety grown in Kenya due to its high yield potential.

(iii) Cambod – *C. sinensis* var. *assamica* ssp *lasiocalyx* (Planchon ex Watt). It is a hybrid between China and Assam varieties, with semi-erect leaves. It is found in Indonesia but it is not common in Africa. The Tea Research Foundation of Kenya has introduced six clones for use in breeding and clonal selection.

Clarification of nomenclature

Originally, Linnaeus classified tea as *Thea sinensis* (1752). Later, two varieties were identified and classified by Masters (1844) as *Thea sinensis* (China type) and *Thea assamica* (Assam type). *Thea* and *Camellia* were thought to be separate genera. However, *Thea* is actually classified as a section within the genus *Camellia*, and *C. sinensis* is classified under this section. The genus resembles and interbreeds freely with tea. However, hybrids with tea do not produce suitable tea beverages. *C.sasanqua* Thumb is a wild non-tea species found in Japan. Some of the wild species are resistant to environmental stress (e.g. drought, cold temperatures, pests and diseases) and, therefore, can be used as a source of resistance genes in tea breeding.

Breeding objectives

The primary aim of the tea improvement programme is to provide growers with suitable clones with combined optimum potential in yield and quality, ideally and adequately buffered naturally against biotic (pests and diseases) and abiotic (environmental stresses e.g. drought and high soil pH), with good adaptation and stability to prevailing environmental conditions within the different tea growing zones in Kenya. The objectives of the tea improvement programme include: -

- .Breeding for combined optimum yield and quality.
- .Breeding for environmental stress, i.e. drought resistance, high soil pH tolerance, cold tolerance and adaptation to replanting in old tea soils.
- .Breeding for pest and disease resistance.

(i) *Breeding for combined optimum potential in yield and quality*

In tea production, high genetic potential in yield and quality are economically important and, therefore, constitute the main objectives of tea breeding and clonal selection. It is particularly desirable to have an optimum combination of both for maximum profitability. In Kenya, deliberate and successful clonal improvement of high yield potential has been attained, with average yield potential of 3000-4000 kg of made tea per hectare year. The improvement of clonal quality potential, however, has not received due emphasis, hitherto. This situation can be ascribed to favourable environmental conditions found in Kenya which favour high tea quality (Kenya tea is mainly high grown), coupled with high management standards, particularly consistent fine plucking, which also enhances tea quality. Therefore, there was no pressure to accord high priority to breeding for high quality potential, as there was for high yield potential, since nature and good management assured acceptable tea quality. However, environmental conditions are unpredictable, and climatic variations can affect tea quality, hence, the need and importance of consistent quality assurance by breeding for high quality potential.

It is also important to take into account market requirements and constraints to further expansion in tea production. Naturally, consumers prefer high quality tea, which, therefore, generally attracts greater market demand and higher prices, and this would be especially advantageous in the event of a glut in the world market. Moreover, expansion in production has diminished considerably both in the small scale and estate sub-sectors, making it imperative to maximise profits per unit area of land using intensive production methods, including the use of clones with high potential in yield and quality.

(ii) *Breeding for environmental stress*

Resistance or at least tolerance to environmental stress, is also important in tea improvement. The adverse effects and long term impact of the 1997 *El-Nino* related drought on tea production, clearly illustrated and emphasised the importance of using drought resistant clones. Green leaf production dropped by 10-43% among small-holders and by about 90% in some tea estates, and many tea bushes died. These effects can be mitigated using appropriate management strategies, which include the development of strong deep roots while bringing young tea into bearing, careful use of fertilizers, and correct timing and methods of pruning. However, some resistant clones are available, as was evident in research plots during the 1997 drought in which clone SFS 150 from Malawi and Tea Research Foundation of Kenya's clone 303/577 were less affected by the drought. Therefore, drought resistance forms an integral and important component of tea breeding.

Other environmental stresses, which can partly be overcome through the breeding of suitable clones, include soil pH, cold temperatures and difficulties with replanting in old moribund tea fields. In Kenya, pockets of high pH due to past settlement can be ameliorated using high soil pH tolerant clones, particularly TN 14-3. Clones STC 5/3 and TAI are also tolerant to high pH, but clone STC 5/3 has not found widespread use because it is low yielding. However, the range of improved high pH tolerant clones could be diversified through breeding. Similarly, low pH particularly below the lower limit (pH 4.0) of the normal range (pH 4.0-5.6), can also be detrimental for optimum tea growth and, hence, is also important in tea breeding. Likewise, selection of clones suitable for replanting in moribund tea fields may constitute part of the long term solution to this complex problem.

(iii) ***Breeding for pest and disease resistance***
In Kenya, tea pests and diseases can cause significant crop losses. Tea mites, particularly the red crevice (scarlet) mite (*Brevipalpus phoenicis*), can reduce tea yields by 14-30% in localised areas of the Mt Kenya region. Similarly, scale insects, especially the fried egg scales (*Aspidiotus* species) and the soft scales (*Ceroplastes* species) can lower tea yields by 5-10%. Among tea diseases, concern has heightened on stem canker (Phomopsis) caused by the fungus *Phomopsis theae*. Increased incidences of Hypoxylon wood rot and Armillaria root rot have also been noted. Breeding for pest and disease resistance constitutes the most viable control option because of the high cost, health and environmental effects associated with chemical control.

Breeding and selection strategies
Successful plant genetic improvement depends on the correct selection of breeding stocks (parents), use of controlled hybridisation, and proper evaluation of the resulting progeny for the desirable traits using reliable selection criteria.

(i) Selection of breeding stocks
Important considerations in the selection of breeding stocks include the genetic potential of the breeding stocks, and a broad genetic base (i.e. genetic lineage) of these stocks.

(a) Genetic potential of breeding stocks
Genotypic traits are hereditary and different genotypes vary in their genetic constitution, i.e. in the type of genes and alleles responsible for the phenotypic expression of specific traits. This variation forms the basis of genetic segregation and recombination, and clonal selection during evaluation in field trials.
Principally, high yield and quality form the primary goals in tea improvement, but breeding for environmental stress and resistance to pests and diseases constitute important secondary considerations which have to be incorporated as much as possible in the selection of breeding stocks.

Yield and quality are complex quantitative polygenic traits, each with many components, which are controlled by many interacting genes. The genetic constitution of a genotype is hereditary and is reconstituted in the progeny of each new generation through the segregation and recombination of alleles of the parent stocks. However, it is highly unlikely that any single parent can possess all the desirable alleles for a particular trait at its gene loci. Therefore, parents with some of the desirable traits are usually crossed to create progeny with new genetic recombinations. These F_1 populations are used to select genotypes with the desired traits and, ultimately, the optimum gene combinations for the desired traits may be assembled and accumulated through recurrent selection over several generations.

According to genetic modes of inheritance, most progeny from controlled biclonal crosses assume mid-parent values. However, allelic and epistatic gene interactions may cause transgressive segregation in which some progeny will be significantly improved than the best parent. This is important and fundamental in achieving satisfactory gains in plant breeding, hence, the importance of correct choice of parents, and the role of controlled hybridisation.

(b) Genetic base of breeding stocks

A broad genetic base is essential for the attainment of genetic advance in plant breeding: -

- To provide a large magnitude of genetic variation and, therefore, ensure high frequency of genetic recombination and generate many new genotypes (progenies) from specific biclonal (paired) crosses to be screened for desirable traits.
- To sustain future genetic advances in tea improvement.
- To minimise possible inheritance of adverse genes, e.g. susceptibility to pests, diseases and drought.
- To safeguard against genetic erosion, i.e. maintain a high degree of genetic variability in the breeding stocks and commercially cultivated clones.

It may be tempting to over-exploit genetically outstanding clones, as has happened in the past in East Africa, but the practice will erode and narrow the genetic base, thus, diminishing the level of genetic variation and posing the risks noted above.

African teas derive their genetic base from restricted, random open-pollinated (half-sib) hybrid provenances in Assam, India. In Kenya, mass selection among popular seedling populations, and subsequent breeding using a few elite parents, and replanting with a few outstanding clones, are thought to have eroded the genetic base further. In particular, clone 6/8 alone accounts for 60% of the number (45) of TRFK released clones. Similarly, only five popular clones, namely, clones 6/8, S15/10, BB35, 31/8 and TN 14-3, form the bulk of the commercial clones. The first three are susceptible to drought, while the last two are moderately susceptible; clone S15/10 appears to be susceptible to Phomopsis (stem canker) caused by the fungus *Phomopsis theae*, yet all are among popular breeding stocks in Kenya. Thus, both the genetic base of the breeding stocks and some of the commercially grown clones are restricted. This has limited genetic advances in the selection for high potential in yield and quality, and some clones derived from some of the parents, e.g. 6/8 and S15/10, are prone to Phomopsis.

It is relatively easy and rapid to characterise the magnitude and pattern of genetic variation and diversity, and estimate the extent of genetic relatedness within and between taxons using molecular techniques, Recent studies using Randomly Amplified Polymorphic DNA (RAPD) have shown that a high degree of genetic diversity and differentiation exists within and between commercial tea clones in Kenya. However, closely related clones were discerned, indicating common pedigrees, obviously due to over-reliance on a few breeding stocks, thus, underscoring the need to ascertain genetic relatedness. A similar study using Amplified Fragment Length Polymorphic DNA markers (AFLP) validated these findings among Kenyan tea clones compared to Indian clones. Therefore, a broad genetic base exists in the genetic pool of tea in Kenya, but care must be taken to use disparate parents in breeding programmes.

In recent years, the genetic base of the breeding stocks at TRFK has been broadened to include Cambod tea (*Camellia sinensis* variety *assamica* subspecies *lasiocalyx*), naturally occurring polyploids and some wild species of *Camellia*. Cambod tea clones are considered to be putative hybrids of Assam and China teas, and have shown good potential in high yield and quality in field trials in Kenya. Polyploids are relatively more vigorous than diploid clones, and this can be exploited in tea breeding and clonal selection, in addition to possible use as rootstocks. Wild species may be used to transfer any useful genes to cultivated tea e.g. resistance to drought, low temperatures.

Moreover, investigations have been initiated at TRFK to rationalise the existing gene pool through a comprehensive characterisation of germplasm accessions based on phenotypic, genetic, cytogenetic, biochemical and chemical traits. In this way, information gathered on the extent of genetic variation and pattern of genetic diversity will facilitate the identification of disparate seedling populations, clones and breeding stocks; and the exclusion of duplicates especially within breeding stocks and living museums. The germplasm will also be screened to identify sources of resistance to important biotic and abiotic factors.

(ii) ***Controlled hybridisation***

The breeding method used is also important and has to meet certain criteria to be effective. First, it must be able to assemble and accumulate all the desirable traits, e.g. high yield potential and high quality, and drought resistance, in one clone. Obviously, no single parent is likely to possess desirable genes for every trait and, therefore, parents with some of these traits need to be crossed to obtain new genotypes, some of which may possess good genetic combinations of the desirable traits.

A	B	A	B	A	B	A	B	A	B	A
B										B
A		A		B		A		B		A
B										B
A		B		A		B		A		A
B										B
A		A		B		A		B		A
B										B
A		B		A		B		A		A
B										B
A	B	A	B	A	B	A	B	A	B	A

Previous breeding schemes in East Africa and Kenya in particular, have mostly been based on mass selection in seedling tea populations and uncontrolled open cross-pollination. Mass selection is largely subjective and relatively inefficient, while the seedling teas represent heterogeneous open-pollinated genotype, which were derived from parent sources of unproven genetic potential, in which occurrence of superior genotypes is extremely low. The disadvantage of uncontrolled open-pollination (half-sib mating) is that the genetic potential of only the female parent is known, in contrast to controlled cross-pollination (full-sib mating), either by means of hand-pollination or isolated biclonal breeding populations in which both the male and female parents are known. Clearly, the best breeding option must involve controlled cross-pollination of the selected parents.

Controlled-pollination can be mediated artificially by hand or under natural conditions in isolated seed baries. In tea, artificial seed production is usually low compared to natural seed production. High seed set enhances the chances of producing elite genotypes. Therefore, natural pollination is preferable, though it may allow low levels of contamination from extraneous pollen.

However, contamination can be minimised using adequate isolation distances between biclonal seed baries, with 2-3 rows of closely spaced buffers consisting of alternating guard rows of both parents.

It is suggested that each barie should contain 16 plants, eight of each clone, and these should be surrounded by a guard row of the same two clones planted close together. Seed should be collected only from the central 16 trees.

(iii) Selection criteria

Tea is a perennial, highly self-incompatible crop, with a long breeding cycle. Therefore, tea breeding is long term and, hence, requires precise selection. Phenotypic selection (mass selection) based on morphological characteristics was used widely in past field selection programmes in East Africa, but phenotypic traits are influenced by environmental factors and the technique is subjective.

Selection criteria are usually related to the commercial product, *i.e.* harvestable yield and quality, consisting of the terminal tender shoots only. Therefore, leaf characteristics constitute the principal selection criteria in tea and, therefore, it is logical and essential that selection for high yield and quality is done concurrently, as well as for any other important agronomic characteristics, e.g. drought resistance.

(a) *Yield selection criteria*

Yield is primarily determined by shoot numbers, shoot weight and the rate of shoot regeneration and extension, which, though intrinsically genetic, are influenced by environmental factors. Therefore, their phenotypic expression varies according to environmental conditions and is generally weakly correlated.

Clonal differences in dry matter production and partitioning and harvest index may also be used to select for high yield potential. The harvest index of tea is low, ranging between 7 to 24%. Generally, however, high yielding clones tend to have greater above ground biomass and, therefore, high dry matter production and harvest index than low yielding clones. In one study, for example, clone S15/10 which is a very high yielding clone with a record yield of 11000 kg of made tea per hectare per year, also has a high harvest index (37%).

However, the use of dry matter production and harvest index in clonal selection in tea is not routinely practised, because the measurements involved are very laborious, tedious and time consuming, and, thus, are less attractive for routine practical use in large selection programmes. Similarly, morphological traits associated with high harvest index with regard to light interception, notably, leaf area index and leaf pose angle are not routinely used. However, given adequate resources, any method that complements others in clonal selection should be utilised.

(b) *Selection criteria for quality potential*

Theaflavins and thearubigins, whose precursors are the green leaf flavanols, are genotype dependent, mainly determine plain black tea quality. These flavanols consist of many compounds including (+)gallocatechin, (+)catechin, (-)epicatechin, (-)epigallocatechin, (-)epigallocatechin gallate and (-)epicatechin gallate. Caffeine, associated with the briskness of black tea, is also genetic. Total green leaf polyphenol content is positively correlated with brightness, thearubigin content, total colour and sensory evaluation of plain black tea quality. The valuation of black tea has also been found to be correlated with theaflavin content and (-) epigallocatechin is highly correlated with theaflavin level and valuation of black tea. The levels of theaflavin-3,3'-digallate and the theaflavin digallate equivalents of black tea relate strongly with sensory evaluation than with total (Flavognost) theaflavins. It has been shown that (-) epicatechin gallate, (-) epigallocatechin gallate and caffeine are strongly correlated with sensory evaluation. These findings suggest that green leaf flavanols, particularly, total polyphenol content, (-) epicatechin gallate, (-) epigallocatechin gallate; green leaf caffeine content; theaflavin content and the levels of theaflavin-3,3'-digallate and the theaflavin digallate equivalents of black tea, may be used as reliable indicators of quality potential.

Flavour indices based on the volatile flavour compounds (VFC) of black tea aroma, can also be used to predict the quality potential of tea. There are four main flavour indices, notably, *Wickremasinghe-Yamanishi*, *Yamanishi-Botheju*, *Owuor's Flavour Index* and *Mahanta*. Two of these indices, *Owuor* and *Wickremasinghe-Yamanishi* exhibit significant relationships with sensory evaluation of black tea.

Black tea quality may also be predicted using green leaf pigment composition. β-carotene and chlorophyll *a* and *b* are associated with black tea quality and show clonal variation. Therefore, visual light leaf colour may be indicative of high quality potential, and is generally preferred over dark leaf colour in routine selection. Chlorophyll fluorescence, molecular markers and near infra-red spectroscopy may also hold future promise for predicting quality potential.

Clearly, many fairly reliable selection criteria for quality potential have been developed, but like those for yield potential, are not routinely used in clonal selection. This is partly because of the need for specialised equipment and expertise, and associated high costs. However, the main reason may be the desire and selection for high yield potential *per se*, little attention being dispensed for high quality potential, which would require concurrent selection for both.

Tea genetics

Improvements in plant breeding, termed genetic gain, genetic advance or simply genetic progress, also depend on knowledge of the genetic control of pertinent agronomic traits. Yield and quality are controlled by many genes and, therefore, have complex modes of inheritance which are difficult to study and to manipulate in plant breeding. In tea, there is dire paucity of information on basic prerequisites for efficient breeding and selection strategies. These include information on the genetic control, heritability (extent to which parents pass characteristics to progeny), mode of gene action (e.g. additive, non-additive, dominance, epistasis), and combining abilities (genetic ability to recombine and express genes for specific traits, between potential parents when hybridised).

Adaptability and stability

Genotype-environment interaction trials are useful selection criteria for determining clonal genetic potential and adaptation. In Kenya, environment factors are known influences of tea yield and quality. Therefore, potential clones should be tested for environmental response at representative sites.

CLONAL SELECTION

Mass selection

Pioneer commercial cultivation of tea in Kenya was based on tea seeds obtained from northern India during the first quarter of the 20^{th} Century. These seeds originated from random open-pollinated (half-sib) natural hybrids between the Assam and China varieties from the Assam region. The seed collections were obtained as polyclonal mixtures. Several jat stocks from the original Assam hybrid seed provenances that proved adapted to East Africa, e.g. *Betjan,* and formed the basis of local selections of improved *assamica* type clones from seedling tea, through phenotypic or mass selection.

In seedling tea populations, outstanding genotypes may occur in extremely low frequencies (0.0025%) because the original provenances were not specifically selected and bred for high yield and high quality. Therefore, one seedling in 200-300 may be high yielding, or has good quality, and one seedling in 40,000-100,000 may combine outstanding yield and quality.

(i) Selection in fields of mature tea

In old fields, the natural growth habit of a bush is often masked by accidental damage, which might have occurred earlier. Similarly a large bush need not have great genetic vigour since an adjacent vacancy occurring soon after the field is planted may allow the bush to spread into the vacant space. Mature fields are therefore not ideal for selection schemes as the present appearance of the plants is not always a good indication of their natural growth potential.

Selection procedure

1 A plan of the field should be drawn showing how the rows of bushes in each row are numbered. A bush might then be numbered as 132/96, showing that it is plant No.96 in row as No.132. The plan should show the position of neighbouring fields, roads, paths, leaf-sheds and any other useful features. It is difficult to give numbers to bushes in contour planted fields, but the effort may be worthwhile.
2. Stake all bushes which, one or two days before being plucked, have a high density of pluckable big shoots.
3. Prune these bushes.
4. Inspect these bushes about four months after being pruned. Retain only those bushes which have made most regrowth and on which the new shoots are fairly even in length and evenly distributed.
5. Test fermentation by the chloroform test (see page 38).
6. Prune the bushes which pass the chloroform test, about six months after the previous pruning, and establish a 1st Rooting Trial (see page 40) with cuttings prepared from these prunings.
7. Proceed with selection in the 1st Rooting Trial and successively clonal establish the 1st Field Trial (see page 40), the 2nd Rooting Trial (see page 41) and the 2nd Clonal Field Trial (see page 41). At each stage of selection, reject those clones which are worse than the control clone in any character.

(ii) Selection in fields of young tea

The amount of growth made by seedling plants during their first two years in the field is a better guide to inherent vigour than is the size of a mature bush. Even so, soil conditions and other factors can influence this growth to a considerable extent and the selection carried out in the seedling field should be of the simplest kind, as in mature tea.

Selection procedure

1. Stake or label all bushes which have grown better than their immediate neighbours in terms of height or spread.
2. Prune these bushes. This should be the second formative prune, or should be carried out after pegging.
3. Check the regrowth from this prune and thereafter continue as in mature tea.

(iii) Selection in seedling stump nurseries

The amount of growth made by two- to three- year- old seedlings in the nursery is probably a better guide to inherent vigour than can be obtained at any later stage when the environment has exerted its influence.

Selection procedure

1. Shortly before the seedlings are to be transplanted, place the markers at intervals along each nursery bed. The length of bed between successive markers should contain 200-250 seedlings.
2. Tie a label to the top of the two tallest seedlings in each marked length of bed. Ignore the seedlings growing at the very edge of it.
3. Inspect these pairs of seedlings and retain only the one which is thicker round the stem at ground level. Alternatively, if the seedlings are pulled before this inspection has been made, retain the one with larger root. Reject the seedlings with few but very large leaves or the ones with many, but very small shoots such as those of the China species.
4. Plant these selected seedlings in a holding plot at normal spacing.
5. Select within this holding plot in the manner described for selecting in fields of young tea (see page 37). Because this plot contains only the best seedlings a larger proportion of them will be selected than in normal fields of young seedlings.

NB. To enhance selection, six months before the normal time of propagation, cut across all the seedlings which have been selected, at a height of 90cm. The regrowth is made into cuttings for the 1st Rooting Trial. Towards the end of the 1st Rooting Trial, parent seedlings may be uprooted if their clones become rejected whilst the stumps of the parents of selected clones are transplanted into a holding plot.

(iv) Special selection in nurseries

A higher rate of selection will be possible if the nursery is planted with only the best seeds. For this purpose, the seeds used should be those which sink within eight hours of the start of floatation. These should then be graded for size and only 25 per cent of the largest seeds used. In practice it would be convenient to use only those which fail to pass through a mesh of about 16mm. The selected seeds should then be planted in a normal nursery and selection carried out as described under (iii) – Selection in seedling stump nurseries.

(v) The chloroform test

(This eliminates all poor fermenters, but is itself no test of absolute quality).

1. Two fresh, fully-opened first leaves from *flushing shoots* are placed with their petioles upwards in a test tube which contains 12 drops (0.5-1.0ml) of chloroform. A 15 cm by 2.5 cm boiling tube is suitable. The tube should be tightly corked. One tube is similarly prepared for each of the bushes to be tested.
2. After about two hours (up to four hours in cold, dull weather) some of the leaves will have turned coppery brown. At this stage grade all the bushes or clones; "A" for those which have turned a rich brown, "C" for those which still show a lot of green, and "B" for intermediate.
3. Repeat this test three times on each bush or clone. Throw out all the selections with gradings only of "B" or "C", retaining those which at worst are one "A" and two "B" gradings. On these, repeat a further three times, retaining only those which after the six tests, are no worse off than four "A" and two "B" gradings. This should effect a (50-75%).

4. In later schemes use a known good fermenter as a control and grade the clones as soon as this clone reaches its optimum colour. Select only those bushes or clones which are as good as or better than the control.
5. During these tests, the tubes should be kept away from the sun but in good light. Do not test too many at once otherwise the time lag between the first and the last may become excessive; it is preferable to test material in small batches.

(vi) Rooting and field trials

The root systems of seedlings and of clonal plants from these seedlings are frequently dissimilar. The amount of work in selecting within seedlings should therefore be kept to the minimum and the main emphasis should be in comparing the clones. A standard rooting medium is usually used because if different rooting media are used the final selections could be different from those selected using the standard rooting medium.

There is no theoretical reason why a full-scale field trial should not be established immediately after the best seedlings have been chosen, but in practice this would be extremely wasteful of land and man-power. To avoid wasting land and to save the time of pluckers and recorders, a four-stage selection programme incorporating two field trials each of which is preceded by a rooting trial can be used. The final field trial is relatively small.

Soil can vary considerably over quite small areas and if the trials were to contain only one plot of each clone then the true growth potential of the clones could be masked by variations in soil fertility. To overcome this, each trial should have three or more "repeats"; in each repeat there should be one plot of each of the clones under test. Furthermore, counteract the effect of a possible general fertility gradient, which might change gradually from one end of the trial to the other, the positions of the clonal plots within each repeat should be *allocated at random*. One simple way to do this is to write the clonal numbers on small pieces of paper, shake all these together in a large tin, and then draw out the papers one by one. The first number to be drawn goes into the first plot, and so on. This operation is repeated separately for each replication in the trial. Make allowances for the positions of the plots of the control clone (see below).

The clones which are finally selected should be able to respond efficiently to high levels of fertilizer applications. Whereas one clone might appear to be the most vigorous when normal applications are made, some others might outyield it when the fertilizer application rates are increased. It is essential, therefore, that plants in the field trial plots are given more fertilizer than would normally be given to seedling plants of the same age.

(vii) Control clones

The object of selection is to find a clone which is better in every way than those which are currently available for planting. Some standard clone or clones in current use (e.g. clones TRFK 6/8 and 31/8) should therefore be included in the field trials as controls. Any clone which is better can be selected whilst any clone which is merely as good as the control clone or worse will be rejected. To gauge the advancement in comparison with seedlings, it is suggested that a common seedling jat entry should be included in each final field trial.

In field trials, there should be $\sqrt{\mathbf{n}}$ control plots in each repeat where "n" is the number of clones being tested. At the TRFK, the number of plots is taken to be the whole number below the perfect square root of "n". Thus, with 160 clones, the nearest square roots are 13 (square root of 169) and 12 (square root of 144); 12 would be chosen. In very large trials the number of control plots should be increased so that no clonal plot is farther than 10 plots away from a plot of the control clone.

However, due to general non-uniformity of fields where trials are conducted, trials are usually not too large.

The control plots should be spaced regularly throughout the trial to facilitate comparisons between the clones under test and the control clone.

In rooting trials a number of clones will be rejected. Therefore, proportionately fewer plots of the control clone are needed. In general the number of control plots in each replicate should be 2/3 √ n, where "n" is the number of clones being tested in the rooting trial.

(viii) 1st Rooting Trials

Sufficient plants of each clone should be raised in this trial to permit the establishment of the 1st Clonal Field Trial.

Procedure

1. Have three randomised replications, each with one single-line plot per clone in each repeat. A single line of 14 sleeved plants per plot is used at TRFK. This ensures that with a clone of average rooting potential, eight plants from each replication are raised for the 1st Clonal Field Trial.
2. When the plants are nearly ready for transplanting, count the survivors in each plot.
3. On the basis of total number of deaths, reject the worst one-third of the clones. Among the remainder, reject all clones which have made less growth than the control clones. The remaining clones, which will be about half the number included in the trial, will be transferred to the 1st Clonal Field Trial along with plants of the control clones.

(ix) 1st Clonal Field Trials

The object of these trials is to determine the ability of the clones to withstand transplanting and pruning, and to compare their early growth with that of the control clone.

Procedure

1. Have three randomised replications each containing plots of a single line of at least eight plants, spaced 1m square or normal estate spacing. As far as possible, plants for the first replication should be taken from the first repeat in the rooting trial, and so on. Vacancies need not be infilled in this trial immediately unless the vacancies have been caused by accidental damage.
2. The plants should be pruned at 20 cm and 40 cm (as described on page 71) or pruned at 20 cm and pegged thereafter (as described on page 80). About four months after the 40 cm prune, or soon after tipping-in in the case of pegged plants, the clones should be graded on the basis of survival and of field vigour in comparison with the control clone. Only those clones which are at least as good as or better than the control clones should be retained in the selection scheme.
3. Apply fertilizer at a rate of 50 per cent greater than that applied to seedling tea of the same age.
4. These trials can be uprooted after the growth assessment following the 28 cm prune. However, in many estates where the land is available uprooting is not done because this would mean a loss of revenue from the plants which are about to be plucked for the first time. Instead, new land is opened for new field trials.

(x) 2nd Rooting Trials

Sufficient plants of each clone should be raised in this trial to permit the establishment of the 2nd Clonal Field Trial. Usually, this stage is reached after the plants have been fully brought into bearing and are plucked for some time. However, to save time, the cuttings should be planted at about the same time as the plants in the 1st Clonal Field Trial are pruned at 28 cm. The 2nd Rooting Trial will therefore include clones which will later be rejected in the 1st Clonal Field Trial, and will be rejected in the nursery as soon as they are rejected in the field.

If possible, this trial should be replicated three times, with plots of 60 or more cuttings per clone in each replication. The number of cuttings will depend on the size of plots in the 2nd Clonal Field Trial and the success of rooting of cuttings in the nursery. Use the same procedure as in the 1st Rooting Trial.

(xi) 2nd Clonal Field Trial

These trials constitute the main test of the clones and should contain enough plants of each clone to permit miniature manufacture and tasting as well as a fairly accurate estimate of yield potential. Other factors to be considered include response to mature pruning; resistance to pests, diseases and drought; ease of plucking and growth habits. In addition, the ratio of the weight of fresh leaf to manufactured leaf should be calculated, so that weights of plucked green leaf can be converted to yields of made tea. Where possible, clones should be tested for their adaptability to various environments at this stage. Those which do not meet the required conditions are rejected.

Selection procedure

1. Similar procedure as in the 1st Clonal Field Trial is followed with a minimum of four lines, each with eight plants, for a clonal plot.
2. Infill all vacancies as and when they occur. If a clone is rejected, vacancies which occur in its plots should be infilled with plants of any vigorous clone (at TRFK plots of rejected clones are infilled with plants of the same clones to keep plots pure for research purposes).
3. Keep accurate records of yields of each plot until at least one year after the prune which follows the completion of the first three- or four-year cycle (preferably up to the end of the second pruning cycle). Tasting of the high potential clones should be carried out periodically throughout the whole of this period; if the liquoring properties fluctuate markedly from season to season or deteriorate as the pruning cycle progresses, the clone should be rejected. Usually more than one tester is used to taste the same samples.
4. Ideally, each clone should be plucked when it is ready; plucking rounds will then be found to vary from clone to clone. If this is not practicable, then all the clones should be plucked together on a short round. If this round is too short for a particular clone, no great harm is done and in any case only ready shoots are plucked, but if the round is too long for a clone, then the leaf will be left on the bushes of that clone or thrown away when breaking back and the records will show it is having a yield lower than its true potential.

(xii) Multiplication plots

These plots are used solely as sources of cuttings of the high yield potential clones. The plants should be brought into bearing by the standard method and thereafter should be pruned every five to seven months, whether or not the prunings are needed for preparing into cuttings. When no more cuttings are needed, the plants in the plots are tipped-in and plucked as other bushes. Each

bush should be given 150g of 25:5:5:5 NPKS fertilizer each time it is pruned after the final formative prune.
Pruning twice a year will eventually weaken these bushes, so if long-term propagation from these plots is anticipated one-third of the plants in each plot should be rested each year, without being plucked or pruned.

(xiii) Plot labelling

Labels in the nursery and field plots are essential, but at every stage of selection, plans of the plots must be prepared. Before starting a rooting trial, prepare a plan for the nursery plots. From this plan, place labels in the nursery, one label for each plot of each selected bush or clone. At the TRFK these labels show the replication, the plot position and the number of the clone, thus:- **A 54 6/8** means that the plot is 54^{th} in sequence in Replication A and that the clone in that plot is 6/8. A further set of identical labels is used for tying to the selected bushes in the field. The three labels on each bush (one for each nursery replication) will be transferred from there to the bundle of prunings and from there to the container of the cuttings. This container is taken to the nursery plots, the corresponding labels checked to see that they agree and, after planting, the label from the container is tied to the stake holding the plot label. At a later stage these pairs of labels are checked to see that they correspond.
At the time of planting out clonal field trial plots of 32 or more plants per plot, specially made boxes are used which contain 24 or 32 sleeved plants. The box or boxes containing plants for each plot is/are labelled, the label/s showing the field plot position and the clone; the field plots will have been labelled. After planting a plot, the label/s from that or those boxes are tied to the stake holding the plot label so that, again, the two or more labels can be compared.
It will be appreciated that in all cases the plans should be prepared well in advance of any planting. In spite of these precautions rogue plants may be found in some plots. As soon as these are recognised, they should be uprooted and replaced with the right plants.

(xiv) Records

Records should be kept to a minimum, yet at the same time it should always be possible for a new-comer to take over the schemes at short notice. Hence the records
should be well kept. The following records are the most essential:-

1. ***Field plan***. This should show how the bushes are numbered.
2. ***Chloroform test records***. One line will be required for each seedling which has been selected in the field following the assessment for recovery from pruning. The following form below can be used.

Clone	Results of chloroform test						Total grades			Result
	1	2	3	4	5	6	A	B	C	
1/12	C	-	-	-	-	-	-	-	1	R
1/26	B	A	A	B	A	A	4	2	-	S
1/42	B	B	B	-	-	-	-	3	-	R

Of the three examples shown, clone 1/12 is rejected immediately after its first test. No "C" grades are allowed. Clone 1/42 is rejected after three tests as no more than two "B" grades are allowed. Clone 1/26 has the minimum requirement for selection. The letters "R" and "S" in the last column indicate whether the clone is rejected or selected for the next stage.

3. ***Rooting trial records***. There should be a plan of the trial so that the position of each clone can easily be found. Next, there should be record sheets for recording results of the trial. The data to be recorded include the number of survivors (or the number of deaths) and an assessment of growth with "A" for better growth than the control clone, "B" for growth similar to the control clone and "C" for growth worse than the control clone. The following form can be used:-

	Repeat A		Repeat B		Repeat C		Results
Clone	Survivors	Growth	Survivors	Growth	Survivors	Growth	

4. ***1st Field Clonal Trial records***. There should be a plan of the trial. Records to be kept are the same as in the rooting trials and the same form can be used.
5. ***2nd Field Clonal Trial Records***. There should be a plan of the trial. There should be a list of all clones in the trial; on this can be noted the reason for rejecting a clone. Yield records should be kept as in the following form:-

Weight of green leaf in grams
Repeat:-

Date of plucking	Clones						

A large number of these forms will be needed. Periodically, the total yield per plot should be determined and clones obviously yielding less than the control clones should be rejected. At TRFK running total yields are calculated each month. During the first year or two of plucking, it is helpful to calculate the yield per plucked bush if there have been several vacancies which have been infilled. This becomes unnecessary once a complete cover of tea is obtained. The records of all field operations, notes of interest and analyses should be kept.

6. ***Master record***. This sheet is useful in allowing the progress of the scheme to be assessed quickly. The list should include all clones which pass the chloroform test and there should be columns for each stage of selection. In these columns, the letter "R" can be entered if the clone is rejected at that stage.

Clone	1st RT	1st CFT	2nd RT	2nd CFT		
				Growth	Yield	Manufacture

(xv) Quality assessment

The rolling system used in miniature manufacture should be similar to that which will later be used for full-scale manufacture. Thus, if CTC rolling will be used for bulk manufacture there is no point in testing the clones only by a system which includes a miniature orthodox roller and vice versa.

Whenever clonal samples are prepared for tasting, an exactly similar control sample should be included for comparison. This will normally consist of leaf from the control clone, but it is useful to include a sample of popular seedling leaf. Leaf for the control samples should be taken from bushes of the same age or same time from last prune, on the same plucking round and, if possible, from the same field as the clonal samples. During manufacture, all the samples must be given identical treatment.

If a clone proves to be outstanding, its leaf can be manufactured and sold separately, otherwise the leaf from several clones can be mixed together and even mixed with seedling leaf. The best price is sometimes obtained from a blend of several clones. In other cases the best price might be obtained from the leaf of only one of these clones.

The leaf of the various clones should therefore wither, ferment etc., at the same rate as each other and also at the same rate as the seedling leaf. Sample blends must be tasted professionally so that the best blend can be determined. Only in this way can be proved that the clonal leaf can be safely mixed with the bulk seedling leaf, and only in this way can best use be made of the various clones.

Progeny Tests

The tea plant is highly outcrossing, strongly self-incompatible and, therefore, highly heterozygous. Consequently, progenies of a cross segregate into variable fixed genotypes in the F_1 generation. This means that each progeny represents a unique genotype, and the diverse array of the F_1 population offers the first opportunity for clonal selection. This initial selection phase can be conducted mainly within the period of bringing the young plants into bearing and up to one year after first maintenance pruning cycle to assess recovery from prune.

Selection procedures

1. Raise the progeny in the nursery from viable seeds selected according to the floatation test, as sleeved plants.
2. Decenter at 15 cm (6") when plants attain a height of at least 30 cm (12").
3. Conduct chloroform fermentation tests in the young nursery plants.
4. Select the best fermenters; transplant to the field at the age of two years and plant in progeny rows at normal spacing.
5. Include parent clones, control clones for high yield, high quality, and any clones known to have resistance to biotic (pests and diseases) and abiotic (e.g. drought and high soil pH) factors.
6. Bring the plants into bearing through tipping to form a plucking table at 50 cm (20"). This should take a period of 3 years, then pluck until the first maintenance prune at 50 cm i.e. for 3 years.
7. Make early assessments of high yield potential based on general plant vigour and leaf phenotypic traits associated with high harvest index, e.g. the total number of shoots per year, shoot density and dry weight, the number of shoot replacement cycles per year, the rate of shoot regeneration and extension, leaf area index and leaf pose angle. Record also the annual yield per bush for the 3 years leading to the first maintenance prune, as a guide to the yield potential of the progeny.
8. Make early assessments of high quality based on predictions from the fermentation test and green leaf flavanols known to be associated with black tea quality. In particular, the total green leaf polyphenol content is known to be positively correlated with thearubigin content, brightness, total colour and sensory evaluation; (-) epigallocatechin gallate is highly correlated with theaflavin levels, (-) epigallocatechin gallate and caffeine are strongly correlated with sensory evaluation.

   It is also known that green leaf pigmentation, especially β-carotene and chlorophyll *a* and *b* are associated with black tea quality. Therefore, light leaf colour can be used to predict high quality potential. This can be determined using a chlorophyll measuring apparatus or judged visually.
9. Consolidate information on the assessments of yield and quality potential and select only those progenies whose performance is better than that of the control clones and the best parent. A selection pressure of the top 2-5% performers should be applied depending on the size of the progeny array and the type of trait under selection.
10. Propagate sufficient plants vegetatively for the establishment of full-scale replicated clonal field trials.

Clonal Field Trials

Since progeny tests are not usually replicated, it is difficult to separate genotypic and environmental effects, which can be done through replicated clonal field trials (CFTs). CFTs may be conducted in a four-stage procedure as described previously. However, this is lengthy usually taking over 20 years, but it can be shortened substantially by setting up and conducting selection in a single trial lasting two pruning cycles only. The rooting trials can be conducted separately.

It is known that clones differ in their growth rates, which may render slow starters to be missed in selecting for high yield potential. Usually, however, selection is not intended to capture every genotype with good potential because many genes control quantitative traits like yield and quality. Therefore, the probability of finding the best genotype with desirable alleles at all loci for all the traits is very rare. Moreover, past experience has shown that the selection of elite clones from slow starters is uncommon. Likewise, fast starters are unlikely to switch of their inherent ability in improved performance.

Selection procedures

The selection procedures are similar to that of the 2nd CFT approach described previously.

Adaptability

In Kenya, the environment influences tea yield and quality. Therefore, potential clones should be tested for adaptability at representative sites. This can be done in sub-stations at representative tea zones, and also through collaborative *on-farm* trials with growers.

PROPAGATION

Tea plants can be raised from seed, cuttings and tissue culture (micropropagation).

Propagation from seed is less common nowadays following the development of operationally easy, rapid and cheap techniques of vegetative propagation (VP), which facilitate easy production of clones. However, if required, open pollinated seed can be supplied from tea breeding seed baries. Tissue culture is rapid and economical on space. However, it is costly for use in micropropagation and is appropriate mainly for breeding. purposes.

Tea seed production

Tea seed gardens or orchards are generally referred to by the Indian word *barie*.

(i) ***Site***

Preference should be given to sites which are sheltered from the prevailing wind and which are in a sunny aspect. The soil should be fertile and 2m deep or more and have a pH of no more than 6.0 (see page 141 for the treatment of soils with high pH). The area should be cleared of all weeds, especially rhizomous perennial grasses, e.g. couch *(Digitaria scalarum)* and Kikuyu *(Pennisetum clandestinum)* grass, common in East Africa (see pages 9 & 18) before the seed bearers are planted. A field of mature tea can be converted to a clonal barie by grafting clonal scions onto the mature tea plants. When this is done, the grafted seed bearers grow faster and flower earlier than seed bearers raised from young sleeved clonal plants.

Areas liable to damage by hail should be avoided, or protective measures using high polythene nets with appropriate mesh are used for important breeding stocks during periods when hail may be prevalent. The Assam *(Camellia sinensis* var. *assamica)* type of tea takes 4-5 years to flower at high altitudes and about three years at low altitudes, but as a long term investment, the differences on the initial time to flowering should not be regarded as a major constraint. If small amounts of seed are required urgently at high altitudes, clonal seed bearers can be grown in 20-litre metal containers which has been found to reduce the time from planting to flowering. In areas prone to drought there should be provision for irrigation.

(ii) ***Shade***
Tea seed bearers should not be shaded.

(iii) ***Spacing***
The foliage of neighbouring trees should just touch at maturity. Generally, in Kenya and East Africa this means adoption of a spacing of about 6 metres triangular. Since seeds are borne mostly on the surface of the trees, close spacing reduces the total surface area and, hence, reduces the seed yield.

(iv) ***Planting***
Holes one metre in diameter and one metre deep should be dug, and the excavated soil then replaced in the holes. Standard planting holes (see page 66) should be dug in this loosened soil. Single, double or triple superphosphate fertilizer should be mixed with this soil before it is replaced round the tea plant (see page 124).

(v) ***Grafting***
Grafting involves the joining of the scion (young clonal plants in conventional nursery sleeves) of the desired seed bearer onto a rootstock of a mature plant. Four conditions are necessary for successful grafting, namely, botanical compatibility of the rootstock and scion; proper alignment of the cambiums (thin layer of tissue between the wood and the rind of a shoot from which new growth develops) of the scion and the rootstock; inducement of rapid callus growth at the graft area; and protection of this area from desiccation. Prior tests can indicate rootstocks less likely to cause rejection.

Approach grafting or chip budding may be used for mature plants and unrooted tea cuttings, respectively.

(a) Approach grafting
Approach grafting is suitable for use with mature plants. The method is simple, cheap, rapid and convenient. Up to four low branches of the selected mature rootstock plants are chosen and the rest of the branches are pruned.

The sleeves with the scion plants are buried at the base of the rootstock, or put on the ground at the base of the rootstock, and soil is put round the sleeves. The bark of the scion is pared down to the wood and pieces of bark are cut from selected branches of the rootstock. The wounds of both scions and rootstock branches must be smooth, clean and match as nearly as possible. The combined layers may be pressed together, and then the scions and the rootstock are tied firmly with polythene tapes. Experience has shown that sealing the binding by covering with grafting wax is very effective in encouraging the fusing of the scions and rootstock.

Watering daily or as needed is necessary to keep the scions' roots in their sleeves moist. Usually, it takes about three months for the scion and rootstock to bind. At this stage, the binding tapes are carefully loosened. Grafting is repeated if the plants have not joined. If grafts have succeeded, fresh grafting wax is applied. When the growth of the scions is sufficiently strong, the scions are cut off from their roots just below the grafts, while the branches of the rootstock are cut off just above the grafts.

(b) *Chip budding*
Chip budding involves uniting one bud and a small bark with or without wood to a rootstock to form composite clone. The upper portion consisting of the shoots and leaves of

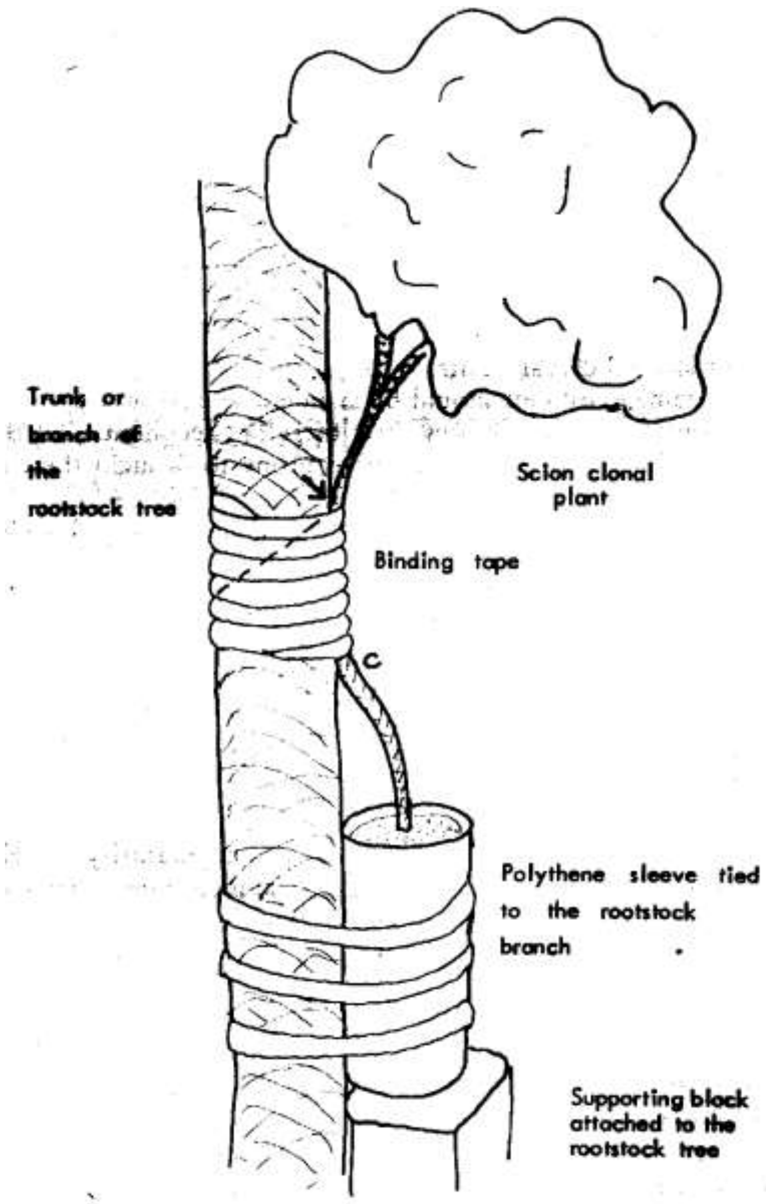


Figure II: 1 : Diagram of an approach graft

the new plant forms the scion, while the lower portion, mainly consisting of the roots forms the rootstock. The method is simple and suitable for use with unrooted tea cuttings.

The scion is made from a thin shoot by making a cut (a) with a blade below the node, followed by another cut (b), to remove a chip (c) of same size as the slot in the rootstock. After tying, the axillary bud of the rootstock is removed. The composite plant is then inserted onto a growing media and covered with a polythene tent till it takes, and hardened before field transplanting.

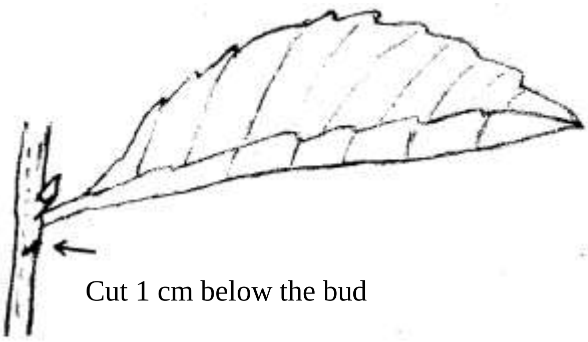
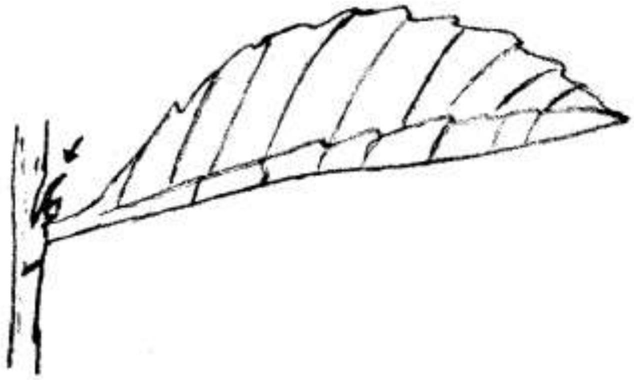
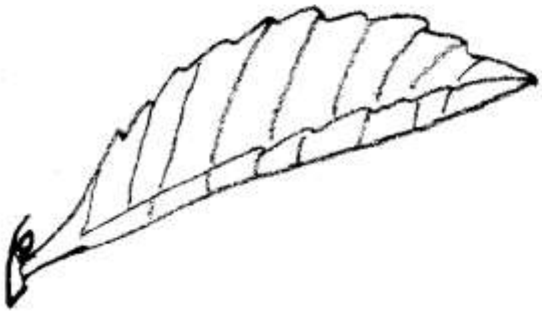


Figure II: 2(a)



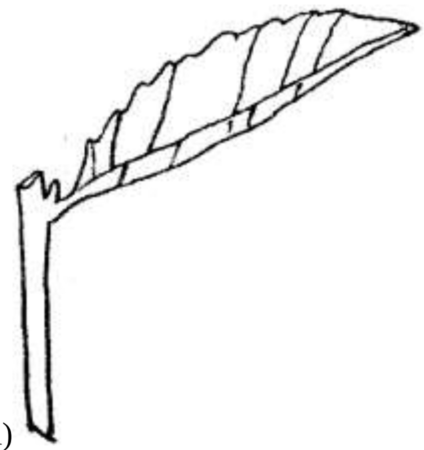
2(b)

Make a cut 1 cm above the bud, then downward behind the bud and connecting with the lower cut.



Remove the bud.2(c)

The rootstock consists of a full leaf, axillary bud and a 6 cm length stem. The top cut (Fig II:2(d) is made near the bud and should slope away from the bud. The lower cut (2) should slope opposite to the first one.



(i)

Figure II:2 (d) Preparing the rootstock

A slot of 2 cm is cut on the internodes as illustrated below.
The scion is inserted onto the slot, ensuring that the cambia are aligned properly, then tied with a polythene strip (Figure II: 2 (f).

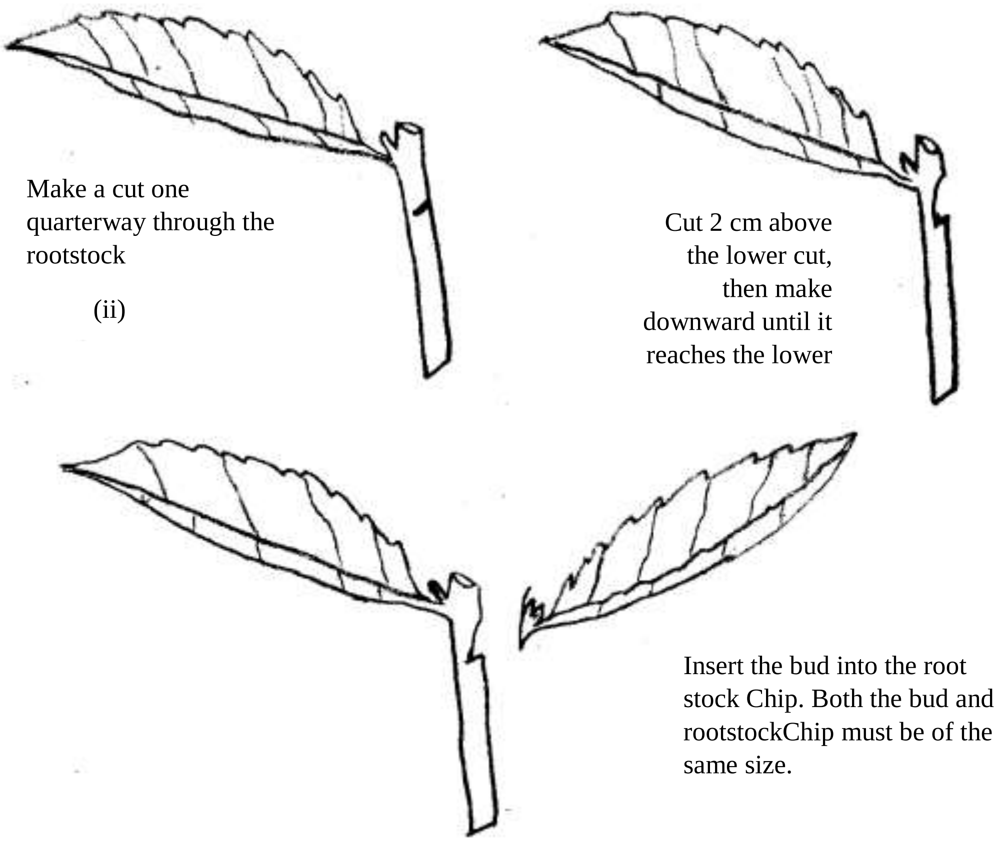


Figure II:2 (e): Insertion of bud into the root stock

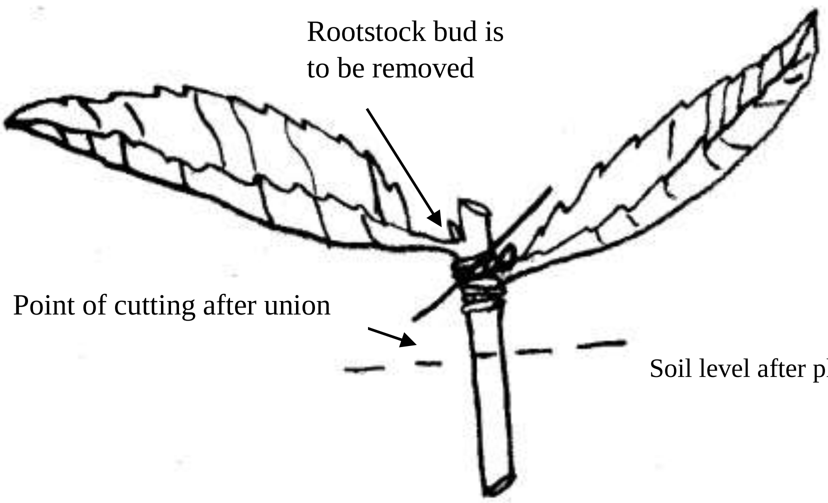


Figure II : 2 (f) Complete chip budding

(vi) ***Pruning***
Dead branches should be removed from the seed producing trees. The lowermost branches can be trimmed as needed to facilitate collection of seed from the ground. However, the seed bearers should not be pruned.

(vii) ***Weeding***
Keep the barie clear of weeds. In young baries bare ground should be planted with a shallow-rooting cover crop such as oats *(Avena sativa)*. Alternatively, lines of non-spreading grasses such as *Setaria*, Rhodes grass or Love grass (*Eragrostis curvula*) may be planted. Gramoxone *(Paraquat)* can be used to control weeds (even during seed collection as it does not affect seeds), at the standard rates, i.e. 1 part of Gramoxone in 400 parts of water plus a wetting agent. Roundup *(Glyphosate)* at the rate of 1 part in 1000 parts of water, may also be used, except during seed collection, as its effect on seed is as yet unknown.

(viii) ***Fertilizers***
Fertilizers are applied to seed bearers as shown on page 136.

(ix) ***Seed barie maintenance***
Inspect the trees several times a year and prune off branches parasitised by mistletoe (*Loranthus* spp), taking precaution to cut well below the apparent point of infection. Also prune off branches likely to interfere with seed collection, including dead or dying, and trailing branches. Irrigate seed-producing trees in dry weather if possible. Apply about 270 litres per tree every 10 days. In practice, determine (by filling a drum) how many minutes it takes to apply 270 litters through a hose-pipe; do this at various levels in the barie, as the time taken will depend on the vertical distance below the tank or source of water. Re-calibrate if a hose-pipe of different diameter is used or if the pressure of the water source changes.

(x) ***Seed collection***
Ideally, the seeds should be collected from the ground daily, and should not be left longer than two days. To facilitate collection, ensure that the ground is smooth and free of weeds. Start the season by sweeping away all the old seeds.

(xi) ***Sorting***
After collection, the seeds should be floated for 24 hours in water. As they sink, they should be removed and graded. The seeds must either be kept stirred or should form only a single layer on the surface of the water, otherwise some of the seeds might remain dry and later be rejected as floaters. Removal of the sinkers is facilitated if the floatation tank has a sloping base up which the sunken seeds can be raked.Seeds which still float after 24 hours in water should be discarded. The sinkers should be run over a 12.5mm (half-inch) mesh, discarding seeds which pass through. The large seeds should then be picked up by hand and all bad seeds discarded, e.g. the black, very pale, rotten or empty seeds. Cracked seeds should be planted immediately. Small seeds are likely to be genetically inferior and should be discarded.

(xii) ***Packing and dispatch***
Nowadays the use of seeds for planting has become rare owing to the widespread popularity of clones. However, the following procedures may be used if need be. Seeds may be packed in sacks if they will be in transit for no more than one day, otherwise they should be packed in double layers of damp ground charcoal divided by waterproof paper, in strong cardboard or carton boxes.

The charcoal should be of the best quality, finely ground and oven-dried. Immediately after it has been dried, sufficient water should be added to increase its weight by 40%. Poor quality charcoal, and oven-dried charcoal which has been left for some hours and, thus, has absorbed moisture from the air, cannot absorb this amount of water.

Damp vermiculite mixed with a fungicide can be used for small quantities of seeds (e.g. for research purposes) for despatch by post. The seeds are mixed with an equal amount by volume of vermiculite and a small amount of fungicide, packed in polythene bags, sealed and then packed in a cardboard box or carton and despatched immediately. Well packed seeds may not deteriorate for up to four weeks in transit.

(xiii) ***Storage***
If seeds are to be stored for any reason, they can be kept mixed in moist charcoal and in layers to prevent the mass of seeds fermenting (as when packed for despatch), in a cool dry place, or in slightly moist deep-dug sterile sub-soil. Seeds to be stored should be soaked in a fungicide solution (e.g. Dithane M45 at 30g/5 litres of water), or dusted with Fernasan D while the seeds are damp, making sure that the seed coats are completely covered by the seed dressing. Seeds can be stored for about four weeks (perhaps six weeks in cold, cloudy weather or two to three weeks in hot weather). Before being packed for despatch, these seeds should again be tested by floating in water for 24 hours. Any cracked or germinating seeds, as stated above, should not be packed for despatch but may be immediate planted.

(xiv) ***Forking***
A hard surface may form on the bare soil under the seed bearers. This should be broken up annually at the start of seed collection by forking to a depth of no more than 5 cm to soften the soil surface, but need not be repeated during the seed collection season.

Tea seed nurseries

(a) Seed preparation

1 *Storage*

Tea seed should be used as soon as it is received. If it has to be stored, keep in a cool, well ventilated room and allow free movement of air all round each of the containers of seed.

2 *Floatation*

Soak the seeds in water, ensuring that they do not from a thick mass of seeds floating on the surface; stir the seeds occasionally. Those which sink within 24 hours can go to the routine germinating area; those which still float after 24 hours should be given a further 48 hours to sink and should be kept separate at every stage from earlier sinkers. Those which still float after a total of 72 hours should be discarded.

3 *Bad seeds*

At all stages between collection and despatch, discard any seeds which appear black and sticky or which have a fungus growth on them.

4 *Cracking*

Place the sinkers in full sunshine, making sure that they do not dry out; sprinkle with water when necessary. They will crack rapidly. As soon as they crack plant them in the nursery. It is required that the hard seed coat is cracked slightly to allow free entry of moisture from the soil in the nursery.

In cloudy weather, the seeds can be placed on beds raised 15 cm above the surrounding soil and which have a 5 cm top layer of coarse river sand. Place the seeds on the beds in a single layer, cover with a single thickness of hessian and keep the hessian damp by watering lightly, but if necessary, frequently. Seeds may also be covered with some dry grass and must be kept damp by light watering as in the case of the hessian. Pick over the seeds daily, removing all cracked seeds to the nursery. In every case it is suggested that when 90 per cent of the seeds have cracked the remainder should be discarded. For small amounts of seeds the suggestion of retaining only the 90 per cent of the cracked seeds should not apply.

(b) The nursery

1 *Site and soil*

The site should be well sheltered from the prevailing wind, exposed to the sun so that the developing plants may benefit from the sun's warmth. In cold areas such as Kericho and upper areas of Central Kenya the site should be chosen to obtain maximum benefit from the sun, but in hot areas, some protection from the full heat of the sun will be beneficial. Low-lying areas which become very wet during the rains or which get frost during dry months should be avoided.

The nursery site should be close to a good source of water. The soil should be free draining and friable. Both the top soil and sub-soil should be tested for pH, which should be between 5.0 and 5.8 with 5.6 being optimum. If the soil pH is higher than 5.8, acidify the soil with sulphur at the time of digging the nursery beds. Table V:4 on page 142 lists the quantity of sulphur required to treat a soil of any given pH. The minimum quantity of sulphur is sufficient but results will be better if more than the minimum is used. Grind the sulphur (without using mechanical mill which may catch fire due to heat generated during grinding) and mix it thoroughly with the soil. Give the sulphur time to act (see page 141).

2 *Nursery preparation*

For seedling stumps, the nursery site should be dug over to a depth of not less than 75cm. The soil should then be roughly levelled and beds marked out; the beds should be no wider than 1½ m, and between adjacent beds there should be a path about 45cm wide. The beds should be aligned so that these paths can act as drains. Soil should be removed from the paths and placed on the beds until the beds become raised 15cm above the paths. The beds should then be raked to provide a soil of fine tilth.

For sleeved plants (see below) forking to a depth of about 30 cm should loosen the soil below sleeves. The sleeves must be supported by light walls or wire round each bed; walls are preferable as they will later shade the sleeves on the edges of the beds and prevent the roots in these sleeves from being sun-scorched.

The nursery should be provided with light dappled shade which in a high shade nursery, should be raised at least 2 metres above the beds so that it is easy to walk in the nursery. Some areas need no shade, but if there is any doubt it is safer to have the shade. The shade should be thinned out gradually so that it is completely removed three to six months before transplanting stumps. Sleeved plants can be transplanted as soon as the shade has been completely removed.

(c) Seed planting

The seeds should be planted with their "eyes" horizontal. They should then be covered by 2.5 cm of soil. For stumps, the seeds should be planted at a spacing of 12.5cm triangular. Seed planting is facilitated by having the beds very finely raked and then rolled very lightly. The seed sites can be marked by using a board through which long nails have been hammered at the correct spacing; this board is then pressed on to the bed surface so that the nails mark the soil.

(d) Nursery maintenance

1 *Fertilizers*

Fertilizers are applied to the seedlings as described on page 122.

2 *Weed control*

If plants are grown in sleeves, weeds are not usually problematic. Where seed is planted for raising stumps, weed may be troublesome in the early stages. *Simazine* has been applied to nursery beds in some places immediately after planting the seed. This should be tried first on a small scale to check that there is no adverse effect on young tea seedlings. Otherwise the weeding should be manual.

(e) Alternative methods

1 *Stump plants*

The seeds are planted directly into the nursery beds and the seedlings are allowed to grow for two to three years. They are then removed from the nursery with bare roots and their shoot systems are pruned off at a height of 10cm above the level of the nursery soil (page 67).

2. *Sleeved plants*

The seeds should be planted one per sleeve, covered with 2.5cm of soil and with the "eyes" horizontal. Sleeves of 250 gauge polythene, of not less than 10cm circular diameter and not less than 30cm in length are suitable. The soil should be as described in "site and soil" (page 53). Transplanting of sleeved seedlings is described on page 65.

3 *Seed at stake*
With this method, the seeds are planted directly into the field (at the stake marking the plant site). With ideal climatic conditions or with overhead irrigation, the method can be successful, but without irrigation the system becomes a gamble with the weather.

The system is horticulturally unsound as the seeds germinate and start growing over many hectares of field instead of in a compact nursery, so that expense involved in weeding, watering, fertilising or protection from pests and diseases is vastly increased. There can, moreover, be no selection of the best plants except by planting two or more seeds at each site or by halving the planting distance. Any of these methods, which must be followed by rouging of the weakest plants, involves an inordinate wastage of potential planting material.

Vegetative propagation
(i) *Nursery site*
The site should be similar to that of seedling stumps (see page 53). However, suitable soil to be used in sleeves can be transported to the nursery, hence the nursery site should be as near as possible to sources of suitable soil.

(ii) *Nursery soil*
Ideally the topsoil should have a pH of about 5.6 as that of seedling stumps (see page 53) but the subsoil should have a pH about 5.0. Subsoil with a high clay content has poor drainage and therefore should be avoided. Cuttings will not normally root in soils of pH above 5.5 or which contain a large proportion of organic matter (humus). They should therefore be planted in subsoil or in soil from below long established grass. The plants will grow best, however, if the roots can eventually penetrate a more fertile soil. When the topsoil or subsoil is being used for the first time it is essential that the grower should have the soils tested for acidity (pH) before filling the sleeves. Soil of pH higher than 5.5 should not be used unless it is acidified (see page 142). When the soil is acidified, allow at least two months to elapse between soil acidification and planting for each 150g of sulphur applied per cubic metre of soil.

The rooting medium for the best results depends on the type of soil used. In practice, the cuttings should be planted in 7.5-8.0 cm layer of subsoil, or grassland soil, which covers a more fertile topsoil or subsoil/topsoil mixture. Examples are known where roots have failed to grow from one layer to the other, so soil-mixtures should be tested on a small scale before the best mixture is chosen for the nursery.
For fertilizers in the cuttings nursery, see page 124.

(iii) *Stump nurseries*
Cuttings can be planted directly into the nursery beds and raised as stump plants in the same way as seedlings. Unlike seedlings, however, the cuttings form widely branching root systems. This means in practice that the cuttings must be spaced widely in the nursery (not less than 15cm apart) and when fully grown after two or three years, they must be dug or forked out carefully. Because of their bulky root systems, the number which can be transported on a vehicle is small and field planting is expensive as the planting holes must be large. Once planted, however, they can be brought into bearing by pegging (see page 80) more quickly than sleeved plants.

The nursery beds must be dug thoroughly to a depth of at least 75 cm. Walls made for example of woven bamboo laths, should be constructed round the bed and then the fertilizer should be mixed thoroughly with soil to a depth of about 25cm after first being broadcast over the surface of the soil. The application rates per square metre will be one quarter of the amount quoted in page 124 for a cubic metre of soil (e.g. 150 g single superphosphate per square metre dug into 25 cm). The soil should then be carefully levelled, covered with a 7.5-8.0 cm layer of subsoil and lightly rolled. After cuttings have been planted the bed should be covered by polythene sheeting and shade as described for sleeve nurseries (see below).

(iv) Sleeve nurseries

1 *Polythene sleeves*

The size of the sleeves will depend upon the size of plants required by the grower. Larger plants will require larger sleeves and vice versa. When cuttings are spaced widely by use of large sleeves, they have better lateral shoot growth, but with large sleeves fewer plants are raised in each bed which adds to the cost of production of each plant. Large sleeved plants are heavy and transport costs from the nursery to the field are high if distances are long. It is suggested that if plants are to be 20-30 cm (8-12in) tall at planting, which is usually reached when plants are six to eight months old, small sleeves which are 10cm (4in) lay-flat 6.25 cm (21/2 in), circular diameter 150 gauge and 25cm (10 in) long should be adequate. Larger plants than these, e.g. those used for infilling, require larger sleeves for example, sleeves with circular diameter of 10 cm (4 in) i.e. 15 cm lay-flat, 250 gauge and 35-40 cm (14-16 in) long.

Sleeves should be spot-sealed or stapled once in the middle of the bottom edge to help to hold soil in place and to effect drainage. A few holes punched near the bottom edge will help drain off excess water. Some growers have used sleeves which are sealed completely along the whole bottom edge, but this might cause drainage problems, especially where heavy soils have been used to fill sleeves. However, if ready-made sleeves which are completely sealed at the bottom edge have to be used, it is suggested that more drainage holes should be punched near the bottom edge of the sleeves and the bottom edge corners of sleeves cut off to prevent water logging.

2 *Filling sleeves*

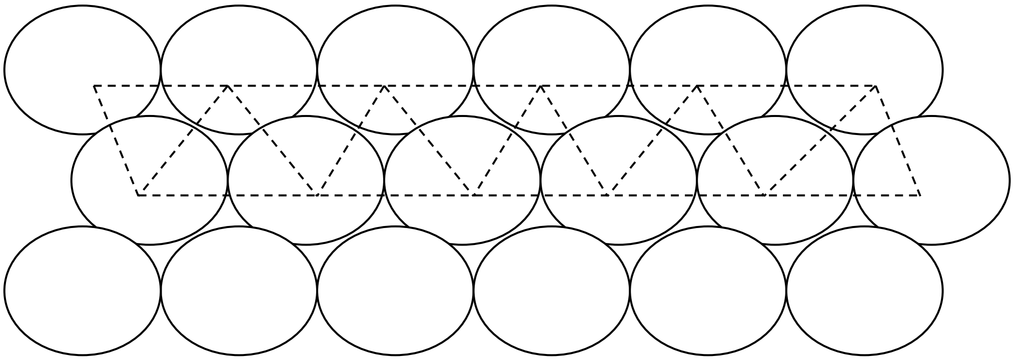
The sleeves should be filled to a height of 17.5-18.0 cm topsoil or topsoil/subsoil mixture mixed with fertilizer and the top 7.0-7.5 cm filled with subsoil only. The soil filling the sleeves should be packed fairly firm; it should not be loose nor should it be packed hard and should be damp at all times. If the soil is dry before filling the sleeves, it will run out of sleeves as fast as it is put in (where the sleeves are spot-sealed at the bottom edge). On the other hand if the soil in the sleeves is allowed to dry up, it becomes extremely difficult to wet it later. All roots and hard soil lumps or stones should be removed from the soil used to fill sleeves.

3 *Nursery construction*

The size of the nursery depends on the number of plants required by the grower and can range from a small unit of about 1000 plants to a large nursery with thousands of plants.

There are two types of nurseries, low shade and high shade. The choice of the type of nursery to construct will depend upon the availability of the construction material or upon personal preference. In both cases, nursery beds are marked out after the site has been dug over to a depth of 30 cm and levelled out.

Low shade nursery
For building walls, woven bamboo laths are convenient (Figure II: 2), but even sacking, bracken, tree branches, bricks etc. can be used for the side shade. The beds are marked as those of seedling stumps (see page 54) and the walls are constructed. The beds can be of any length, but 30 m (100 ft) is convenient for large beds. The beds should lie in a North-South direction.
The sleeves are then stacked carefully, leaving a gap of about 15 cm and 30 cm between the stacked sleeves and the side and end walls, respectively. The polythene sheeting, or tent as it is sometimes called, will be sealed into this gap. To reduce overlapping of the cuttings' leaves, sleeves should be stacked triangularly as shown below.



Triangular stacking

Fig. II:2. Low shade nursery bed constructed with bamboo laths

Hoops to support the polythene sheeting should then be placed every 1 m or less along the bed. These should be slightly curved or slope towards one side of the bed so that rain water will easily run off the surface of the polythene. The hoops should not be less than 20 cm above the top of the sleeves.
After planting and thoroughly watering the cuttings the clear polythene sheeting (250 or 500 gauge) should be stretched taut over the hoops and sealed into the space between the

sleeves and the walls. To effect this sealing, soil from the space between the beds should be lowered. The difference in level between this pathway and the top of the sleeves should be at least 15 cm.

Until young plants have about 7.5 cm long roots, they should be kept shaded under a uniform overhead shade which allows only a little dappled light to pass through. The shade can be provided by bamboo lath frames, hessian sacks, coffee drying cloth, backen woven into chicken wire frames or frames made from papyrus, maize and napier or elephant grass stems. This shade should be about 5 cm above the topmost part of the hoops in cooler areas, but in warm areas the shade should be about 30 cm above the hoops to increase the air space below the shade and, thus, reduce the temperature (smaller air spaces in cooler areas take shorter time to heat up and, hence, increase the temperature in the bed). If cuttings are grown in temperature which is too high they become extremely susceptible to fungi. cuttings are best grown in temperature of about 27^{o}C. They are also highly susceptible to fungicides unless these are applied at very much lower concentration than that which is normally recommended. If fungal disease occur, the polythene should be opened up immediately to reduce humidity of the air.

The polythene cover serves the following functions:

1. It prevents loss of soil moisture.
2. It preserves a high atmospheric humidity.
3. It increases the air temperature and keeps the temperature range inside the polythene cover low.

It therefore keeps the cuttings in ideal conditions for growth and dispenses with the need for expensive frequent hand-watering. However, it is not essential in humid weather in low and warmer parts. If no polythene sheeting is used, the shade should lie no more than 20 cm above the cuttings. Under these conditions, high shade allows drops to fall on the beds so heavily that the cuttings can be damaged or even washed out of the soil.

High shade nurseries

In a high shade nursery, walls are constructed along the outside perimeter of the nursery only and not for each individual bed. As in the low shade nursery, any material can be used for walls and shade, providing dappled light passes through it. The shade is constructed as shown below (Figure II:3).

Marking out of the beds is preceded by building the side walls and the shade. Then timber planks, off-cuts, fitos, smooth fencing wire etc. are used to hold sleeves in place. Digging trenches 20-25 cm deep to stack sleeves into is not recommended because it can lead to water-logging. Hoops are then placed over the sleeves as in the low shade nursery.

High shade nurseries are usually cooler than low shade ones and heavy drops of rain water falling through the shade may damage rooted cuttings. For the beginner, it can be difficult to manipulate the density of the shade in the nursery or parts of the nursery if plants grow at different rates (or are propagated at different times) and, hence, need different treatments. Attempts to improve the growing conditions by thinning out the shade may lead to excessive shoot growth without corresponding root growth.

When a large annual propagation programme is anticipated, it is often worthwhile constructing a high shade with permanent or semi-permanent materials. This nursery site can then be used year after year with a minimum of expense.

Figure II:3
High shade nursery

(v) ***Time of year***

No one season is better for propagation than others provided that at the time of propagation, the mother bushes are growing vigorously and are not suffering from drought or recent hail damage. Seasons of propagation will normally be decided by the need to have plants ready for the field at the start of the next planting season.

(vi) ***Mother bushes***

To obtain the best cutting material in the greatest quantity, it is necessary to prune mother bushes twice a year even if the cuttings are needed only once a year. The time of pruning depends upon the time the cuttings are to be propagated, thus, if propagation is to be in September, mother bushes should be pruned the previous February to March. The type of pruning is a straight cut-across the framework, about 2.5 cm (1 in) above the previous pruning level or at 40 cm (16 in) if bushes were brought into bearing by pegging and had not been pruned before. Any cleaning out, that is, the removal of weak and crossed branches, should be done only once a year during one of the prunes. New shoots should be ready for cuttings between five and seven months after pruning. Where the climate is cool, plants take longer to produce cuttings whilst in warmer areas plants take a shorter time. Under no circumstances should the new stems be allowed to remain on the mother bush for more than seven months as the material becomes hard and the resulting cuttings grow poorly. Mother bushes should not be covered.

When mother bushes are pruned twice in 12 months and have to provide cuttings for a number of years, the pruning level would rise quickly if adjustments are not made. It is suggested that for the mother bushes pruned between January and June the pruning height be 5 cm (2 in) above the previous pruning level, and when pruned between July and December the pruning level should be 2.5 cm (1 in) below the previous level. Thus, the pruning level rises 2.5 cm (1 in) a year. It is further suggested that the mother bushes be cleaned out during the second prune.

If mother bushes have aphid infestation, their upper foliage should be thoroughly sprayed with an insecticide (see page 176) before the prunings are taken off. NPKS (25:5:5:5) fertilizer is applied to mother bushes at the rate given on page 122.

(vii) ***Preparation of cuttings***

The cut branches or prunings for cuttings are wrapped in wet sacking and taken to a shelter near the nursery where they are immediately watered. These prunings should be kept under shade. Cuttings should be made under shade and kept shaded at every stage thereafter.

Only vigorous young shoots between five and seven months old should be used to make cuttings. The very soft tips, which can be determined by placing the stem on two open fingers and pressing in between with thumb, and the very hard lower parts of the branches where bark is forming should be discarded; if cuttings are too hard they will grow poorly and produce flowers which exhaust the food reserves in the stems and this may lead to death.

The good shoots are made into individual cuttings, each consisting of a single leaf with 3

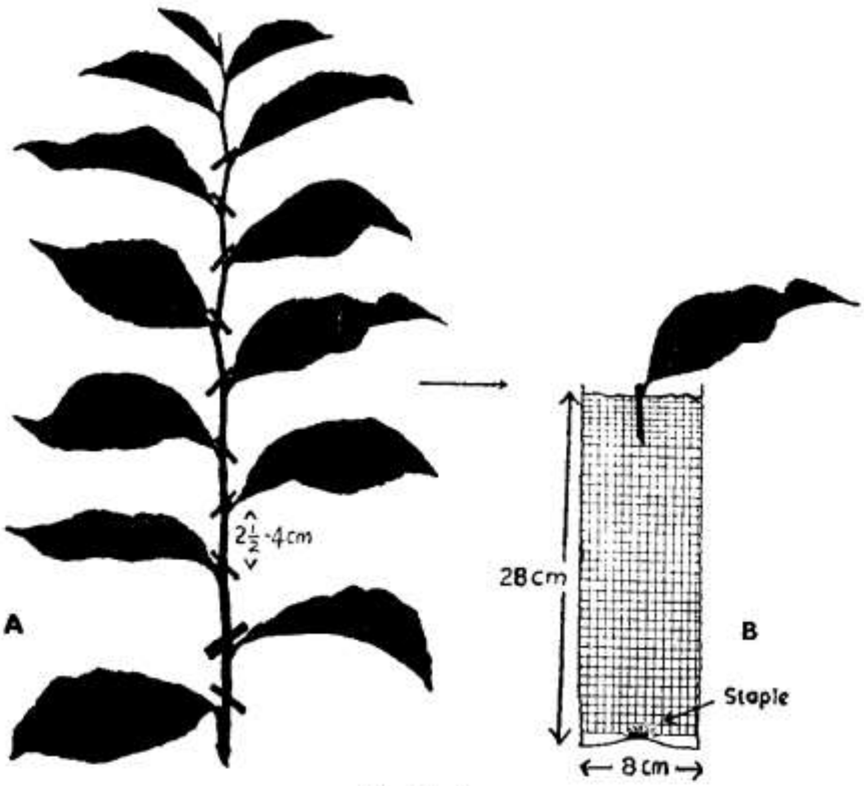


Fig. II : 3
(A) Division of a tea shoot into internodal cuttings
(B) Polythene sleeve with one cutting

to 4 cm of stem below the leaf (see Fig. II:3).

This is done by making two cuts; one just above the bud and sloping away from the bud, and second across the stem 3 to 4 cm below the bud again using a sloping cut. Cuttings are prepared by using very sharp knives. If the internodes are short, so that less than 3 cm of stem will be below the lower leaves, use cuttings with extra leaves but remove the lower leaves. Immediately cuttings are prepared, they should be placed into a container full of water, such as a basin, karai or debe. They are soaked in water for about 30 minutes before being planted. Too many cuttings should not be placed in the container otherwise the top ones will not be in the water and the bottom ones will be pressed so hard that the leaves may be damaged.

This type and length of cutting stem gives the largest number of cuttings per mother bush. Cuttings with damaged leaves should be rejected because they generally grow slowly or die if fungal diseases attack them through the wounds.

Two or three-leaf cuttings can be used but the number of cuttings per branch, hence per bush, decreases as the number of leaves per cutting is increased. Multi-leaf cuttings give more branches to the young plant and are ideal if there is plenty of material. It has been found, however, that in lower areas with high temperatures and high evaporation rates the survival of cuttings decreases as the number of leaves per cutting is increased. It is therefore suggested that multi-leaf cuttings be planted only in the high altitude areas where cuttings are sealed under polythene sheeting or where a mist unit is available. The beginner is advised to use single-leafed cuttings to start with.

Care before cuttings are planted

The time from pruning mother bushes to the time the branches are delivered to the cutting preparation shelter or shade should be as short as possible. Branches should not be exposed to direct sunlight as leaves would scorch easily or wilt due to loss of water. Compressing branches will damage the leaves and, therefore, wrapping branches in a hessian sack too tightly, or having too large a heap of branches when the branches have to be transported by vehicle should be avoided.

(viii) ***Planting cuttings***

If a leaf or its bud touches the soil they may be attacked by fungi; the leaf then falls off and the cutting dies. Thus, cuttings are planted in the sleeves so that the leaves do not rest on the soil surface and the bud is just above the soil level. Where the cuttings' leaves are naturally deflexed (bending backwards instead of upwards), the stems should be inserted into the soil at an angle so that the leaves are clear of the soil. During planting, fingers should not touch the top or bottom cuts of the stems as the sweat from the fingers may affect survival. The cuttings are kept moist during planting by frequent watering.

When the whole bed is completely planted, the cuttings and the soil between the sleeves and the walls (outside the sleeves in the case of high-shade nurseries) are thoroughly watered. Watering should be done gently as strong jets may displace cuttings. The clear polythene sheeting is then stretched taut over the hoops and sealed into the soil, all round the bed. To help stretching and sealing the polythene sheeting, a few turns of sheeting are made round pieces of wood at both ends of the bed (see Fig.II.4) and after stretching the polythene sheeting, these pieces of wood are buried length wise in the soil. Immediately afterwards, the beds must be shaded in the case of low-shade nursery.

Care after planting cuttings

All beds should be inspected at least once a week. If only a little condensation is found on the under surface of the polythene sheeting, it suggests that the soil in the sleeves is becoming dry due to either inadequate watering or that the sheeting is torn or that the seal is poor. These faults should be checked and the aim is to have a heavy condensation inside the sheeting, sufficient to prevent out a clear view of the cuttings inside. The beds should be regularly checked for weed growth, insect pests and diseases and treated as necessary. Weeding should always be by hand pulling. Chemical herbicides should not be used. After each opening or after the faults in the polythene sheeting are corrected, the beds are watered thoroughly and covered again.

Fig. II : 4
Stretching polythene cover over the hoops to cover the cuttings.

If the nursery becomes too cold or the growth of cuttings is slow due to heavy shading, the shade should be thinned slightly. In the cooler areas the shade should cut out about half the daylight, but in hotter areas a more dense shade may be necessary. During dry weather the soil around the polythene should be kept damp. Mist units have been used in VP nurseries successfully but they are expensive and there is a possibility of losing many cuttings if there is a power failure. Occasionally there are pests and diseases in the nursery. For control and prevention, see page 170.

(ix) Hardening-off

When plants grow under polythene sheeting and shade, they are soft and will scorch and many of them will die if the polythene sheeting is removed too quickly without a hardening-off period. Generally, there are two main methods of hardening-off plants, though there could be variations on the methods.

1. *Hardening-off in low shade nursery*

Note: During the first four weeks of hardening-off, the polythene is gradually opened as described next. But throughout this period the lath shades or other types of shades are kept in place and not removed.

As soon as the new shoots are about 20 cm (8 in) tall, the polythene sheeting should be raised on the side away from the direction of the prevailing winds, at intervals of 3 m (10 ft) along its length. Each opening is held up by a stake and the rest of the polythene remains sealed in the soils so that a series of small vents are formed.

The number of vents is doubled one week later by raising the polythene sheeting at 1.5 m (5 ft) intervals. During this time, the soil in the sleeves should not be allowed to dry and watering is done through the vents by a hose pipe. In the third week, the polythene on the vent side is rolled up completely to the top of the hoops thereby leaving one side of the bed covered.

At the fourth week, the polythene sheeting is removed completely, washed thoroughly, dried and carefully stored under cover for further use. The polythene sheeting should not be left exposed to the sun for any length of time during storage because it will be damaged.

Two weeks after removal of the polythene sheeting the shade frame is raised 30 cm (1 ft) on one side only and supported by stakes. Thereafter, it is raised 30 cm (1 ft) every week for three weeks after which it can be completely removed. Plants are ready for transplanting after the complete removal of the shade. Plants must be watered as necessary and fertilizer applied weekly until they are transplanted.

2. *Hardening-off in high shade nursery*

Plants grown in high shade nurseries can be hardened off in the same way as under low shade up to the stage of removal of the polythene sheeting.

An alternative method involves loosening the polythene sheeting at both ends of the bed and leaving the polythene sheeting loose on the ground for a week. One week later, the polythene is rolled up at both ends and left that way for a week so that air may circulate. Then the polythene sheeting is rolled up 30 cm (1 ft) at each end and a week later it is rolled up 120 cm (4 ft) at each end. This weekly opening continues to increase by 1.2 m (4 ft) per week until the whole bed is uncovered. The polythene sheeting is then washed, dried and stored as before. Care should be taken that the soil in the sleeves does not dry up during the hardening-off periods. After the polythene sheeting is removed, fertilizer application is started and continued as for the low shade nursery.

After removal of the polythene sheeting, the shade and side walls are thinned gradually by removing some of the covering material, a little every week, until all material providing the shade and covering the walls is completely removed after about four weeks. If the weather changes and dries suddenly and plants start scorching, the hardening-off should be postponed or the beds re-covered. When the weather improves the hardening-off is resumed.

If the plants have to remain in the nursery for a long time after the removal of the polythene sheeting, the removal of shade and wall-covering material can be postponed until about a month before the transplanting is anticipated. Then the removal of the wall-covering and shade material is gradual, exactly as described above. Watering of plants is carried out as necessary. Leaving the shade and wall material in place reduces evaporation and, hence, reduces the frequency of watering.

There could be many other variations of hardening-off plants, but whatever method is used, the hardening-off should be gradual to give the young plants time to acclimatise themselves to their new conditions and be able to withstand any adverse weather which may set in later. If plants are hardening-off during a cloudy period, the hardening-off time can be shortened without the danger of scorching. The grower must, however, be on guard for sudden changes of weather.

(x) ***General information***

The cuttings must be completely protected from dry soils and dry air until they are rooted, because they lose more water through transpiration than they can take from the soil. Until rooted, they require dappled light which reduces evaporation, but there is enough light for normal growth. Excessive darkness prevents cuttings from developing and encourages excessive callusing, whereas full sunlight will kill them.

(xi) ***Size of new plants at transplanting time***

Some growers prefer large plants. It is suggested that plants with one shoot 20 cm (18 in) tall, or 15 cm (6 in) if decentred, or with two or more shoots 15 cm tall and with roots which have reached the bottom of sleeves (25 cm or 10 in long) are ready for transplanting in a new clearing. Plants which reach 30 cm (1 ft) tall in the nursery should be cut-across (decentring) at 15 cm. For in-filling, it is suggested that plants should remain in the nursery for about 18 months and be pruned at 15 cm (6 in) when they reach a height of 30 cm (1 ft) and again at 20 cm (8 in) when they reach a height of 35 cm (14 in). This pruning will encourage low branching. If at transplanting infills have long soft shoots, they should be transplanted during dull weather or be shaded lightly.

Chapter III

ESTABLISHMENT

(a) Field planting

Planting should be avoided in excessively wet weather to prevent soil from puddling around new plants. The ideal planting time is when the soil is damp, rather than wet, and the weather is cloudy. Once the rains have started, planting should normally commence as soon as the soil is found to be damp to a depth of at least one metre.

Planting holes should be dug beside the lining stakes. The holes should all have the same diameter so that the centres of the holes, where the tea plants will be, are at an even spacing. The excavated soil should form a single heap beside the hole.

In some estates, a subsoiler tine or tines are used to make a channel in which tea is subsequently planted and this can, in certain conditions, cause problems. On soils of clay type which have not been ripped both ways, when an abnormally wet year is experienced, water logging in channels may occur with disastrous results to newly planted tea. Run-off from terraces is far greater in immature tea areas than in mature tea areas, particularly at planting time when the land is normally clear of weeds and inter-row crops are not yet established. Such run-off may uproot plants in the channels.

In areas where the rains follow a hot dry season, the period between holing and planting should be as short as possible to avoid filling in of the holes which inevitably leads to bad planting. In practice, lining and staking should be carried out prior to the rains and holing should be left until immediately before planting i.e. after the first rain has fallen. This has the advantage that in the event of a hot dry spell occurring a few weeks after the onset of heavy rains, the plants are less likely to dry out.

Ideally, where there is enough labour, the planting gang should follow immediately behind the holing gang. Leaving holes open for several days should be avoided, as either the soil dries out in dry weather or puddles in wet weather. In very heavy clay soils, this exposure can however be an advantage, causing the smoothed sides of the holes to crumble enabling the plant roots to easily penetrate.

(i) Planting sleeved rooted cuttings, or clonal plants, and seedlings

1. Removing from the nursery

Sleeved plants are ready for transplanting when the roots have reached the bottom of the sleeves and also have at least 20 cm (8 in.) of top-growth. At the time of transplanting, the cylinder of soil in sleeves should not be dry.

The plants must be handled carefully to avoid cracking the cylinder of soil and perhaps breaking the roots, and for the same reason, they should be stacked carefully and tightly on any vehicle taking them to the field. Containers should be made which hold reasonable number of sleeved plants for one or two men to carry. At TRFK these containers (boxes) are filled in the nursery, stacked on a trailer and taken to the field, and then carried from the trailers, each man carrying one container (one container carries either 24 or 32 standard sleeves of 6.25 cm diameter). A number of containers can be carried on a wheelbarrow. This avoids all unnecessary handling of the sleeves.

The sleeves should be protected from direct sunshine at all times until planting is completed to prevent damage to the roots.

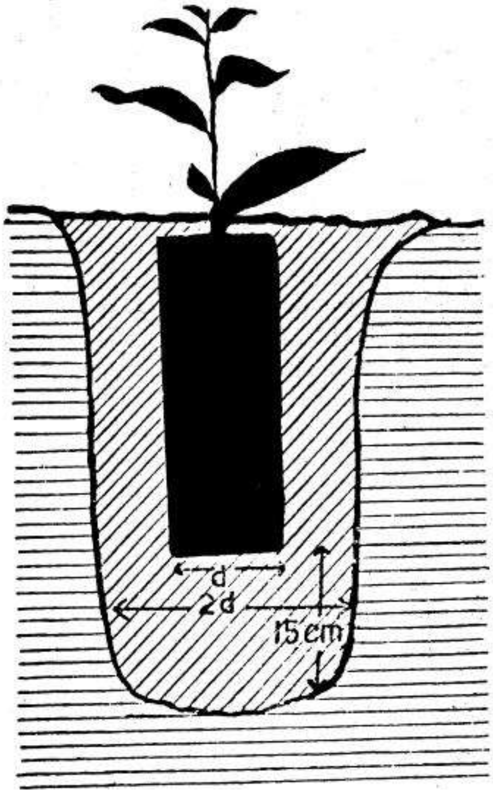


Figure III:1
Cross-section of planting hole for selected rooted Cuttings or seedlings
d= diameter of the sleeve

2. Holing

The holes should be 15 cm to 20 cm deeper than the length of the sleeves and double their diameter (see Figure III: 1), though the minimum should be 25 cm. For standard 25 cm long x 6.25 cm diameter sleeves the holes will be 40 cm x 25 cm. To reduce damage of young plants by chafer grubs, holes may be sprayed with Dursnnnnnnnban (Gladiator) (see page 179).

3. Planting

The soil in each standard hole should be mixed with 30g of single superphosphate (see Fig. V:1 on page 127). In larger holes, apply single superphosphate in proportion to the volume of the hole (see page 124). Place 20 cm depth of soil/fertilizer mixture in the hole and slice the polythene tube with a sharp knife at the side and at the bottom, taking care not to cut any roots but retaining the sleeve around the cylinder of soil. Place the plant in the hole and add more soil round it. Gradually remove the polythene and complete filling of the hole. Firm down the soil with hands, and then feet, until the top of the plant's cylinder of soil is covered by 1-2 cm of field soil, making the site flush with the rest of the field. Failure to give this covering may result in an exposed soil cylinder drying out rapidly in dry or sunny weather. Exposed roots at the top of soil cylinders also reflect poor planting a few weeks or months after planting. Such roots should be covered immediately with soil surrounding the plant and firmed down.

4. Shading

No shading is needed if the plants have been adequately hardened off in the nursery. In all circumstances, if plants are not well hardened off at transplanting, the plants in the field should be given the same density of shade as they had in the nursery at the time of removal, but in the field this shade should be of a kind which will soon break down, such as bracken fronds stuck into the soil.

5. Planting sleeved seedlings

The Foundation recognises the usefulness of competition of seedlings in the nursery and thus recommends that only the most vigorous seedlings should be transplanted. The recommendation is that if tea seedlings are to be planted, the seed should be planted evenly in the nursery directly in the beds. In 24 to 36 months after planting, about 75 per cent of the most vigorous seedlings should be transplanted. The rest of the weak seedlings should be discarded. When seedlings are raised in sleeves, the competition between plants is non-existent or is reduced, and it is probable that some weak plants will be transplanted to the field. Such plants will show their weakness years after transplanting when competition sets in. For this reason, the Foundation does not recommend that seedlings be raised in sleeves. However, if there is a good reason to raise seedlings in sleeves then they should be transplanted in the same way as sleeved rooted cuttings (see above).

(ii) Planting seedling stumps

From the late 1960's most of the planting in Kenya has been carried out with sleeved clonal plants. During this time seedlings have only been raised for experiments or for infilling in the fields.

1. Selection

In a seedling nursery, the more strictly *the plants can be selected, the better will be the resultant stand of tea*. From any one bed, approximately 25 per cent of the plants are rejected on the basis of poor stem girth, poor root size or poor height. *The rejected plants will be genetically weak and should not be retained for a further period to increase is size.* Weak patches of seedlings due to poor soil can be left for a further year if necessary, *and the best of these plants should be selected as above.*

2. Removing seedling stumps from the nursery

Tea seedlings are ready for transplanting as stumps when they are 1 cm thick at the collar, provided that they have built up adequate food reserves in their roots by being unshaded for at least three and preferably six months.

In many nurseries, it is easiest to remove seedlings by pulling them from the soil by a vertical pull. In this case, the seedlings should be pulled first and then pruned 10 cm above what had been nursery soil level (see Figure III:2). In poorly prepared nurseries, direct pulling causes many of the roots to break. In these soils the seedlings should be pruned to 10 cm above the soil level before they are dug out. To make the uprooting easier, the seedlings should be uprooted after the onset of the rains when the soil in the nursery has been wetted to a depth of not less than one metre.

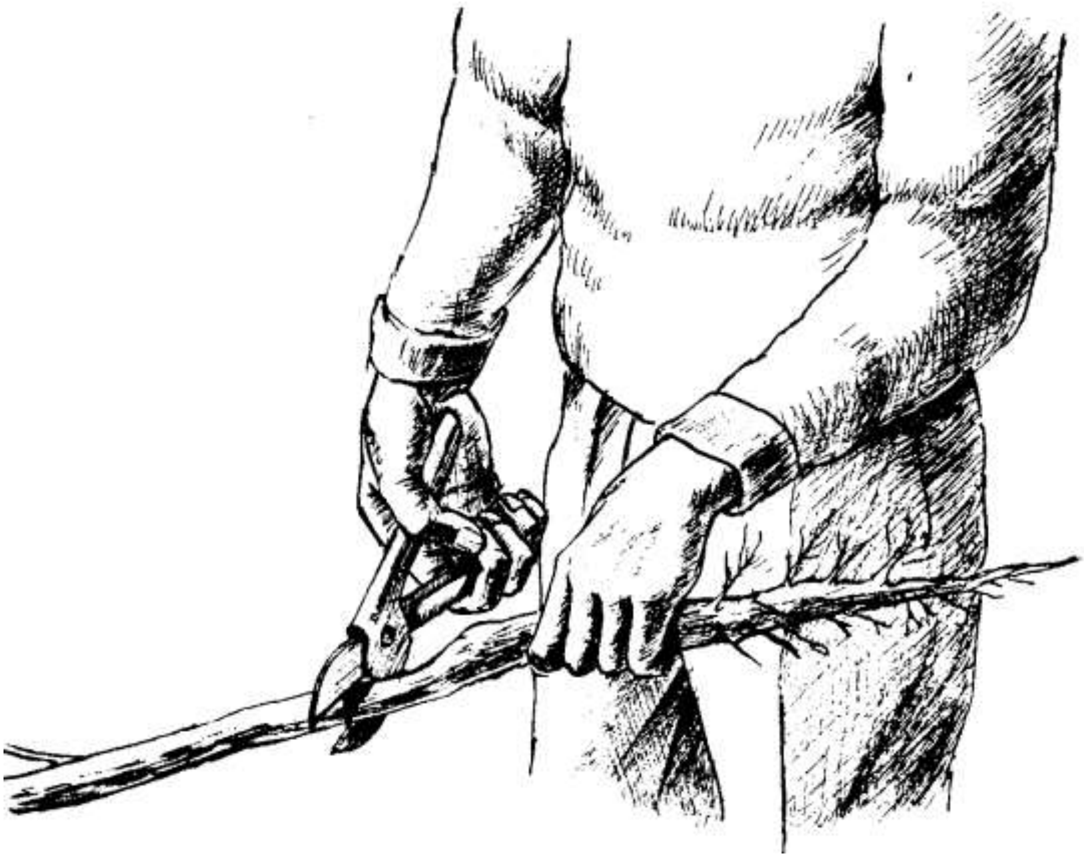


Figure III:2
Seedling stump preparation

All seedlings should have their roots cut to a length of 45 cm and any thin laterals removed. Some nurseries produce only wide-spreading root systems, often because of shallow digging during nursery preparation or because of inadequate watering during dry weather. The roots of such seedlings should not be cut back drastically, otherwise much of the root food reserves will be removed.

If necessary, the prepared stumps can be stored in a cool building after being washed free of soil and wrapped in polythene in bundles of 20. Storage in mud baths should be avoided except for periods of a few hours (up to a day). In wet cool weather, stumps can also be covered with prunings and stored in nursery beds for a day or two.
At no stage should the stumps be exposed to strong sunshine or be allowed to dry out.
Planting holes should be 15 cm deeper than the depth of the roots (see Figure III:3).

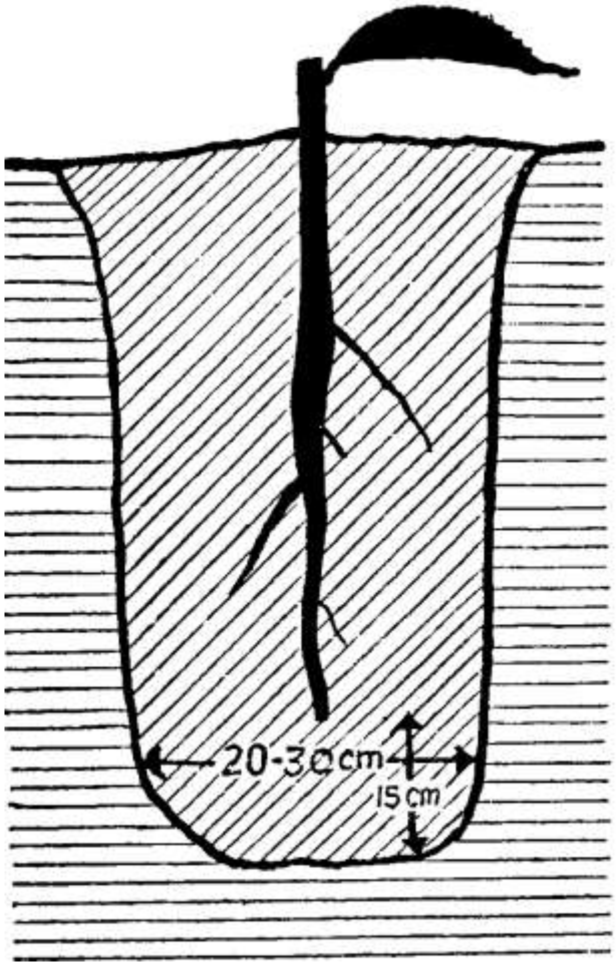


Figure III:3
Cross-section of planting holes: stump planting.

At the Foundation, where seedling stumps with 45 cm of roots are used, the holes are dug to a depth of 60 cm and a width of 20 to 30 cm; the first 20 cm of the holes are excavated by a jembe (hoe) or fork jembe and the rest by another gang or the same gang using pangas or coffee diggers.

Do not use steel spikes (*Alavangas*) except in newly loosened deep soils, as they tend to form smooth-sided holes which restrict root growth and may enclose pockets of air or water. In clayey soils, the sides of the holes should be roughened with a fork or allowed to crumble by action of the weather. Mix 60g of single superphosphate (or 30g of double or triple superphosphate) with the excavated soil.

The stumps should be kept shaded or wrapped in sacking in bundles of 50 until they are actually placed in planting holes (see Figure III:4).

The stumps should be kept damp. For this purpose, watering cans can be used. The stump should be held in the centre so that the top pruning cut is 7 cm above the field level and the excavated soil the replaced firmly, though not rammed, around the stump in the hole. The soil around the stump should be slightly higher than the field soil to allow for settling, otherwise a depression may form which could lead to waterlogging in wet weather. Never plant a stump at the side of the hole as this restricts root development.

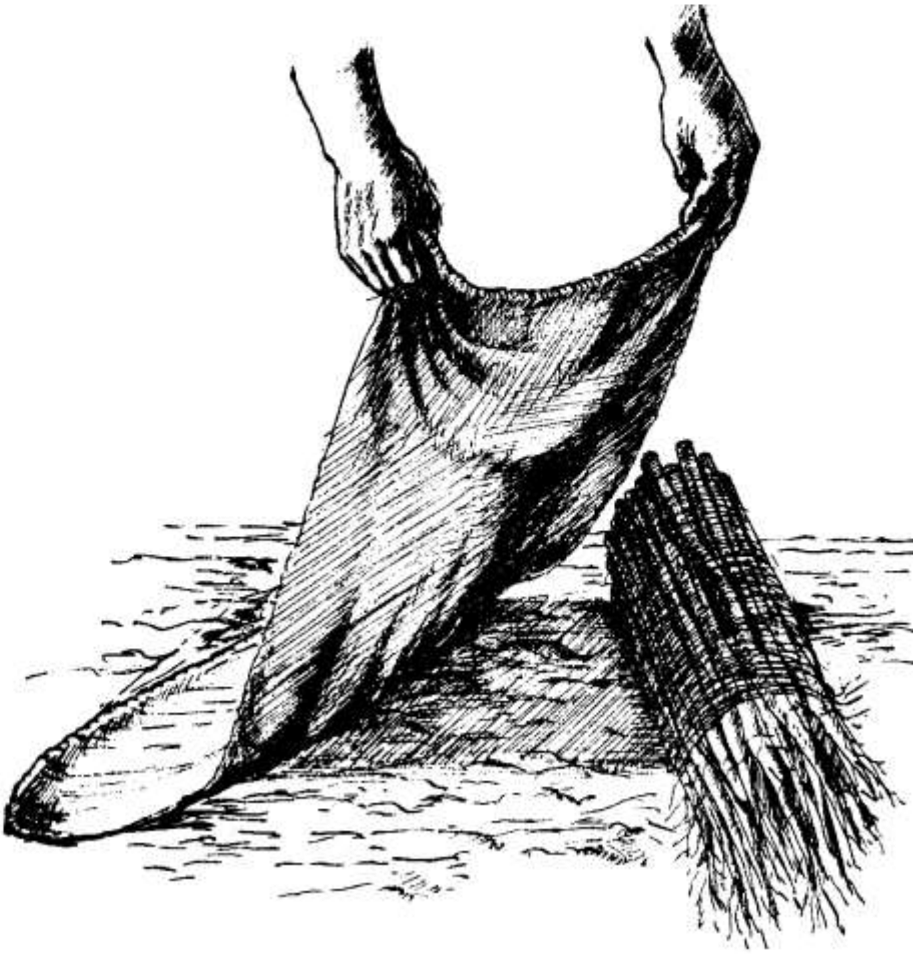


Figure III:4
Seedling stumps being shaded before planting.

After planting, the marking stake should be placed at an angle over the plant. This guards against the plant being trampled on or damaged during weeding, and act as a check that the planting has been carried out correctly.

3. Shading
In the nursery, the foliage of the seedlings heavily shades the basal 10 cm of stem. After transplanting in hot sunny weather, this stem is liable to be severely scorched so some shading should be provided. The best shade is obtained from three or four bracken fronds stuck in the soil and bent over about 10 cm above the top of the stump. This gives a light, dappled shade which gradually breaks down, thus providing a gradual hardening off of the stem of the tea stump. Leafy branches of any tree, including prunings of the seedlings at the time they are made into stumps, or woody weeds may be similarly used. Each stump should be shaded immediately after it has been planted. During wet, cloudy weather, shading is unnecessary. Bud-break from the stumps may be delayed if the shading is too dense.

(iii) Planting clonal stumps
The programme will be exactly the same as for seedling stumps, except that the tendency for clonal stumps to have a wide-spreading root systems will mean that they will more often need to be forked out of beds, fewer can be held in any given container (e.g. wet

sacking) and the planting holes will have to be wider. As the width of the planting hole is increased, so the amount of superphosphate applied should be proportionately increased (see Table V:1, page 107).

Fertilizers used in planting holes are given on page 124).

b) Bringing tea into bearing

During the establishment of tea on an estate or smallholding, there is a period when financial returns may depend upon the speed and efficiency with which the young tea is brought into bearing. The system adopted should result in economic production of an even stand of healthy bushes obtaining their optimum yield potential as soon as possible and maintaining this optimum yield.

The lower parts of the branch of the bush will form the permanent frame which will remain largely unaltered throughout the life of that bush or until the bush is down or collar-prune to rejuvenate it. This frame must therefore be low, strong and should have a good spread. A system of bringing tea into bearing which enables plucking to be started very early might seem at first to be satisfactory but might prove to be poor in the long run if the system restricts root development or encourages more shoot and less root growth so that the plants are susceptible to drought, or if it results in narrow framed bushes which only slowly form a complete ground cover and which will again give low yields when next pruned.

Any operation designed to form a permanent branch system, from the time the plants are in the nursery to the time they are tipped-in to form a plucking table in the field, is defined as “bringing tea into bearing”. Three systems of bringing tea into bearing have been developed which result in the formation of good permanent frames. These are pruning, pegging and tipping. Any of these methods will be subject to modifications depending upon the kind of nursery plant which has been raised and its characteristics.

(i) *Pruning*

Whenever a shoot on a tea plant is removed, axillary buds are stimulated to develop for a distance of about 10 or 12 cm below the cut. This stimulus occurs if soft apical shoots are removed, as at tipping-in to form a table, during regular plucking, or if thick stems are cut, as during hard pruning and during preparation of stumps from the nursery. Any axillary shoot which develops outwards contributes to the spread of the bush.

All forms of pruning remove photosynthetic tissues, such as leaves and green stems, from the plant. The manufacture of carbohydrates and assimilation of nutrients from the soil and air is consequently reduced by an amount dependent upon the severity of the prune. New shoots which grow after this stimulus can develop only at the expense of the reserves which already exist in the plant, and particularly in the roots, at the time of pruning.

While these reserves are being used up, root growth stops. The rootlets only start growing again when the food reserves have been replenished and this cannot start until the new shoots become efficient. The plant is therefore short of reserves and its root development restricted for many months after a hard prune. It is essential that the bushes are given time to replace these reserves and to extend their root systems before any further pruning or even plucking takes place.

If the interval between successive prunes, or between pruning and plucking, is too short, then recovery from prune will be delayed, the root systems will be restricted and in extreme cases, branch dieback or even death of the plant can occur.

The timing of successive formative prunes is dependent upon the growth rate of the plants, which will vary from plant to plant and from district to district, and upon seasonal variations in weather conditions. It appears that a branch is at a suitable stage for pruning when red striated wood has been formed and the stems, at pruning height, are about 1 cm thick. The one exception to this rule is when sleeved plants are given their first prune, i.e. pruning or decentering them at 15 cm when they are 30 cm tall.

Experiments have shown that stumps, whether clonal or seedling, should be given no more than two formative prunes in the field unless only one or two stems develop from the original stump. Sleeved plants should be given no more than three prunes, the first of which is very light.

It must be noted that tipping-in and plucking have effects similar to, though less severe than, those produced by pruning. The growth stimulus is constantly being diverted to new buds on or just below the plucking table so that the bush spreads rapidly at this level. If the tipping-in level is high, then a relatively narrow lower frame which is left when the bush is next pruned will support a wide plucking table.

(ii) *Pegging*

In this system, the shoots which develop from a stump or after the first light prune of a sleeved plant are bent downwards and pegged so that they radiate outwards and upwards from the main stem. These pegged branches form the basis of the permanent frame which is added to the vertical shoots that develop from axillary buds along the branches. The development of these axillary buds is encouraged by pegging the branches so that they slope uniformly and slightly upwards; it is retarded or even prevented if the branches are pegged so as to be horizontal or to slope downwards. If the branches are pegged so that they curve upwards at first and then downwards towards their tips, the axillary buds will generally develop only along the upward-sloping portion near the main stem.

Further encouragement to development of the axillary buds is given if two terminal leaves and a bud are removed from the pegged branches at the time of pegging. The removal of two leaves and a bud is based on the premise that there are growth hormones in young tissues at the tips of shoots which encourage terminal growth and inhibit lateral or axillary bud growth. This phenomenon is known as apical dominance. The removing of two leaves and a bud at the time of pegging branches removes the axillary buds' inhibitors and thus encourages their growth. Tipping-in to form a table of young tea or tea recovering from pruning is based on the same principle.

It has been found that the best time to peg is when the branches are about 60 cm tall and have just started to develop reddish bark where they join the main stem. At this stage the majority of the stems are not brittle if plants have been growing vigorously and therefore will not break or split when pegged.

Tipping-in the vertical shoots should be carried out at a low level so that axillary shoots which consequently develop can contribute still further to frame formation. Some large-leaf Assam-type plants produce very vertical shoots; such plants may benefit from a light prune at about 35 cm before being tipped-in.

Pegging does not involve the removal of leaves and green stems, so that the root reserves do not become depleted and there is no check on root growth. Plants brought into bearing by this method have a larger frame and better developed root systems than those brought into bearing by pruning. Because of this, pegged plants can be tipped-in and plucked sooner than the pruned plants and, because of the extra spread resulting from the pegging, they produce much higher yields for at least the first pruning cycles. The cost of pegging is greater than that of most pruning systems but this is likely to be out-weighed by the value of the higher yields and by lower weeding costs which result from the more rapid attainment of a complete canopy cover of tea.

The ground should be cleared of weeds just before pegging starts so that no further weeding will be needed for the next three months. After this, the pegged branches will remain in position even if the pegs are removed. In fact pegs, especially metal ones, should be removed at about this time to avoid girdling of the branches by the pegs.

Pegging has been found to be very successful, if done correctly and at the right time, in areas with high rainfall which is well distributed. However, in marginal areas with less rainfall and also in areas which are prone to long droughts of more than three months, pegging is not recommended. Since pegging does not involve the removal of leaves and green stems, during the long dry periods, the pegged plants lose a lot of water from the soil through transpiration. When the moisture is exhausted around the roots, plants suffer from drought and may become weak, die or be attacked by diseases associated with plants suffering from drought stress such as *Phomopsis theae*. On the other hand, pruning in such areas removes or reduce transpiring surfaces, i.e. leaves and green stems, and this conserves moisture. Hence in marginal and drought prone areas, plants should be brought into bearing by pruning. However in such areas, leaving plants to grow freely during rains also helps in developing a better rooting system since plant roots grow in proportion to the shoot.

(iii) ***Tipping***

This system entails tipping shoots (three leaves and a bud) of tea plants at gradually increased heights. There is great danger that root growth will be reduced in marginal areas or in areas prone to long droughts so that ultimately the root system is too small for the large branch system; plants like these may be highly susceptible to droughts.

(iv) ***Bringing stump-plants into bearing by pruning (see figures III:5,6 and III:7)***

The first prune of the stump-plants is done when plants are removed from the nursery and are pruned at 10 cm from the ground level or collar (see fig. III:2).

1. Prune all the shoots at a height of 20 cm from ground level when most of these shoots are 1 cm thick at that height (see fig. III:5).
2 Prune all the shoots at a height of 40 cm when most of these shoots are 1 cm thick at that height (see fig. III:6). With the spreading type of plants this prune may not be necessary and if it is not done, the bringing into bearing of the plants is hastened.
3 Tip-in for three rounds at a height of 50 cm (previously tipping-in was done at 60 cm) by removing shoots as soon as they have developed three leaves and a bud above that height.
4 The prunes at 20 cm and 40 cm are known as formative prunes. Do not tip or pluck the bushes between the formative prunes as this will slow the bringing to bearing stump-plants.
N.B. Each prune should be a straight cut across the whole frame of the bush (see fig. III:7). The cut on each stem should slope slightly to prevent rain water from remaining on the cut surface and possibly causing die-back. Cleaning-out should be restricted to removing crossing-over branches, the weaker of the two branches lying on the ground. Always use a sharp knife for pruning to avoid breaking or splitting pruned branches.
5 When most of the bushes are being pruned at 20 cm, those with only one or two shoots should be cut-across at a height of 15 cm when these shoots are at least 1 cm thick at this height. They should later be pruned at 28 cm and again at 40 cm when most of the shoots are 1 cm thick at these heights. Tip-in at 50 cm.

Figure III : 5

Pruning a seedling stump at 20 cm

Figure III:6

Pruning at 40cm

Figure III:7

Bringing into bearing by the standard TRF pruning method.

Diagrams of bushes immediately after pruning at 20 cm and 40 cm and after tipping at 60 cm.

(v) ***Bringing stump-plants into bearing (see Figure III:8).***

1 Clear all weeds from the ground before pegging starts.
2 Prepare wooden pegs 40-50 cm long from suitable material. Wire pegs can be used
3 Peg the shoots when they reach a height of not less than 45 cm and not more than 60 cm, and when the bark near the base of each shoot has turned reddish-brown.
4 Shoots which are too short for pegging on this first round can be pegged later when they have reached a height of 60 cm together with other shorter shoots. It should not normally be necessary to carry out more than two rounds of pegging.

5 Use one peg per shoot and arrange the shoots so that they are evenly spaced round the stump. It is not necessary to peg more than five branches per plant; there should not be fewer than three. Where planting is rectangular, shoots should not be pegged between plants within a row but should be pegged into space between rows (see Figure III:9).
6 The peg should be closer to the centre of the plant than the branch tip and the pegged branch should slope upwards along its *whole* length. Remove two terminal leaves and bud from each pegged shoot.
7 Tip-in to form a table at 45 cm for at least five rounds by removing shoots as soon as they have developed three leaves and a bud above that height.

NB. Some clones and some seedlings produce few shoots which often have long internodes. Such plants should be pruned, after pegging, at a height of 35 cm and tipped in at 45 cm as above.

8 When most of the bushes are being pegged, those with one or two shoots should be pruned at a height of 15 cm when these shoots are at least 1 cm thick at this height. The new shoots which develop after this prune should be pegged as above when they reach a height of 50 cm to 65 cm. Tip-in at a height of 50cm. An alternative is to peg the one or two shoots when ready for pegging. New shoots arising near the bases of these shoots should then be pegged when 60 cm to 65 cm long.
9 At the end of the first pruning cycle, three or four years after tipping-in, these pegged bushes should be pruned at a height of 40 cm, i.e. 5 cm below original tipping level.

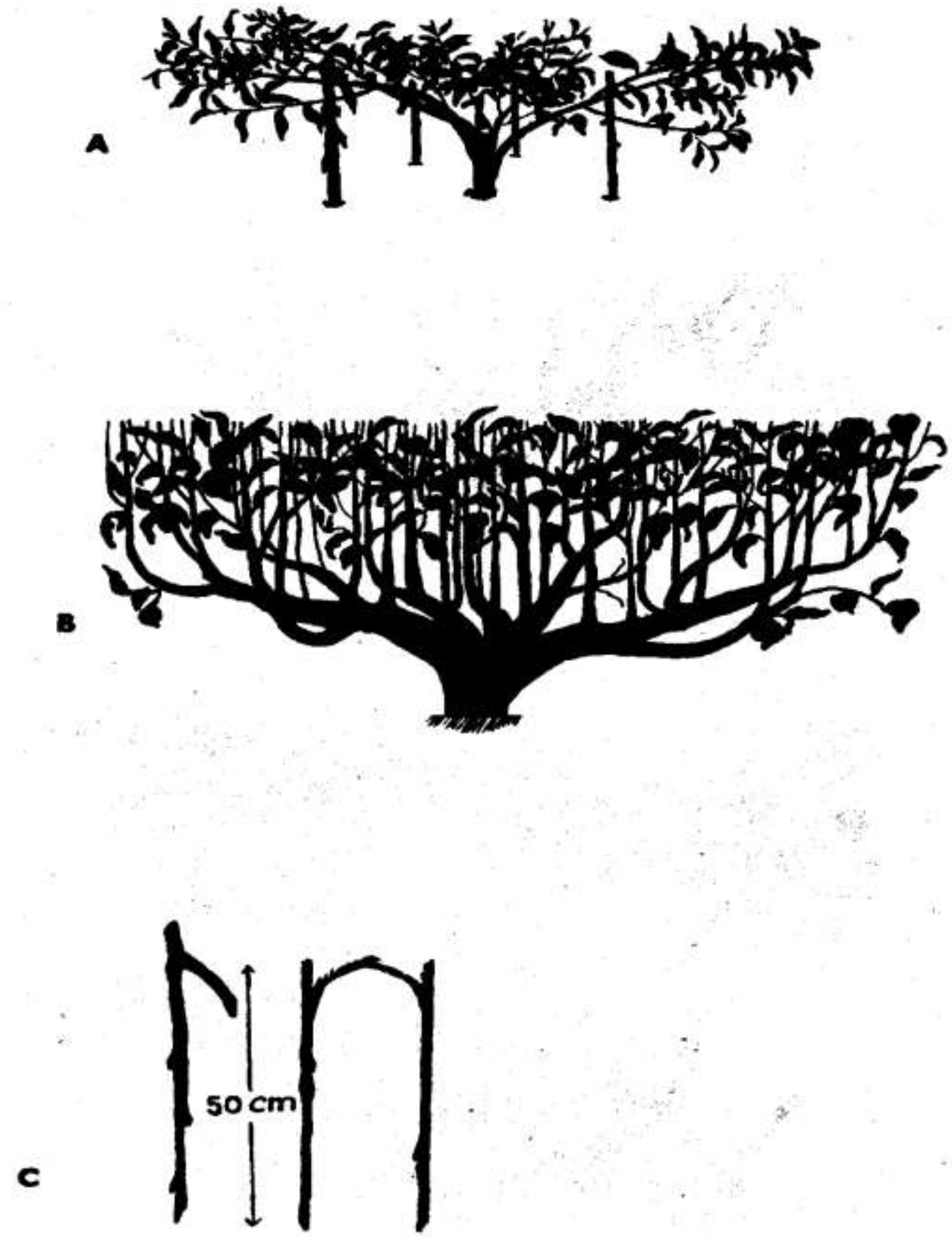


Figure III:8

The pegging system of bringing into bearing

(A) Newly pegged bush (B) The same bush after tipping (C) Two types of peg

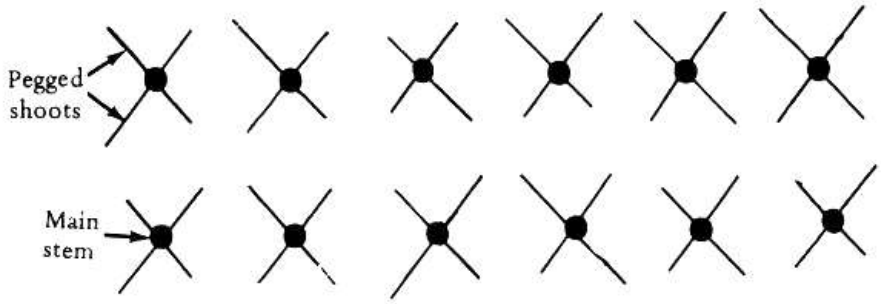


Figure III: 9 Arrangement of pegged branches

(vi) ***Bringing sleeved clonal plants into bearing by pruning.***

Young sleeved plants do not normally possess sufficient root reserves to support the development of new leaves and shoots, so these plants should be pruned only if they possess some leaves below the pruning level.

Most clonal plants tend to develop a strong main stem. This central growth should be checked at an early stage so that strong lateral branches can be encouraged to develop. The earlier this operation is carried out, the lesser will be the check to plant growth and the sooner will the lateral branches develop strongly. In some districts or in some clones, it has been found that a "thumb-nail" prune, which removes the apical bud and its first leaf, is sufficient to stop central growth and divert the plant's nutrients to axillary shoots, but in most areas, this operation is ineffective and the axillary bud immediately below this pruning level takes over as a single main central shoot, i.e. assumes apical dominance.

The most successful method is to prune the central stem or stems, but not lateral shoots, at a height of 15 cm when the plant is 30 cm tall. The plant can subsequently be given a cut-across prune at higher levels if need be. The system described below is that which is used at the TRFK and has been found to be successful in most tea districts.

1. Decenter at 15 cm when the plants are 30 cm tall, but only if there are at least three leaves on the plant below 15 cm; if there are fewer than three leaves below 15 cm, the pruning level must be raised until at least three leaves are left on the plant.
2. Prune *all* the shoots at a height of 28 cm when most of these shots are 1 cm thick at that height
3. Prune *all* the shoots at a height of 40 cm when most of these shoots are 1 cm thick at that height.
4. Tip-in for three rounds at a height of 50 cm by removing shoots as soon as they have developed three leaves and a bud above that height.

N.B. The best system will vary from clone to clone and some vigorous clones may be brought into bearing successfully with fewer prunes than in the system.

(vii) Bringing sleeved clonal plants into bearing by pegging

A vigorous tea stump normally produces three to five shoots which are ideally suited to pegging. A sleeved clonal plant normally produces a very vigorous main central shoot with comparatively weak laterals. Such plants are not suitable for pegging at this stage. The strong laterals which develop after the first decentering at 15 cm can, however be pegged successfully.

1. Decenter at 15 cm when the plants are 30 cm tall, but only if there are at least three leaves on the plant below 15 cm; if there are fewer than three leaves below 15 cm, the pruning level must be raised.

2. Peg the shoots when they reach a height of not less than 50 cm and not less than 50 cm and not more than 65 cm, and when the bark near the base of each shoot has turned reddish brown.
3. Shoots which are too short for pegging on this first round can be pegged later, when they have reached a height of 65 cm, together with other shorter shoots.
4. Pegging, shoot-tipping and subsequent tipping-in should be as described for pegged tea stumps (see page 79). Tip-in at a height of 50 cm.

N.B. Plants which have insufficient lower-foliage to be decentred and plants which respond to decentering by producing one (single stemmers) or two lateral shoots, should be pegged when they become 45 cm tall. New shoots will normally then develop from the base of the pegged branch, and these can in turn be pegged later in other directions. If the pegged main shoot or shoots snap, do not cut off the broken part; if it is not completely broken it will supply assimilates to the other parts of the plant.

(viii) ***Bringing sleeved seedlings into bearing.***

Methods of bringing sleeved seedlings into bearing have not been studied at TRFK because raising seedlings in sleeves is discouraged, but practical experience on many estates show that good frame formation can be initiated by removing the top few leaves and apical bud from these plants when they are 25 cm tall. Lateral branches which may have developed should not be pruned at this stage.

Subsequent to this early light prune, the seedlings can be brought into bearing by pruning or pegging in the same way as sleeved clonal plants.

(ix) ***Bringing tea plants into bearing by continuous tipping.***

This system entails tipping the shoots at gradually increased heights. There is a great danger that root growth will be reduced so that ultimately the root system is too weak to support the large branch system; plants like these may be highly susceptible to drought in marginal areas.

1. For both stump-plants and decentred clonal plants, tip at a height of 20 cm, and again at 30 cm and 40 cm, for two rounds by removing shoots as soon as they have developed three leaves and a bud above those heights.
2. Tip-in at a height of 50 cm for at least five rounds by removing shoots as soon as they have developed three leaves and a bud above that height. Regular plucking follows this.

NB The tipped shoots may be processed into made tea if the third leaves and their stems are broken off and discarded. If there is a delay in tipping plants at 20 cm or if only a few shoots have developed, the shoots should be snapped at that height but not cut off. These will supply assimilates to the other parts of the plant and help in the growth of new axillary shoots.

Anything which affects the spread of plants also affects bringing into bearing. One of these is potassium deficiency, which is described on page 145.

(c) ***Replanting***

Uprooting old tea bushes and replanting with improved clonal or seedling plants becomes imperative where tea yields are very low despite the application of optimal cultural practices. Replanting procedure involves uprooting and removal of the moribund tea stumps. This is followed by construction of terraces, cut-off drains and waterways as soil conservation measures, then cover cropping with oats and soil conditioning crops such as Guatemala grass for up to two years in order to rehabilitate the soil. Finally, the field is replanted with suitable high yielding, good quality clonal plants.

Research is still continuing in trying to understand the problem of moribund/old tea soils and as soon as information is available, growers will be informed accordingly.

Replanting is a major capital development which is very expensive and should be considered only when the tea become completely uneconomic to maintain.

Chapter IV

FIELD MANAGEMENT AND FARM RECORDS

(a) **Plucking, pruning, skiffing and tipping-in mature tea**

(i) ***Functions of the leaves***

The economically important part of the tea bush consists of the terminal tender shoot, made of the succulent stem and one to three leaves and a bud, which protrude above the plucking table or surface.

The tea bush, like all other green plants, obtains its food primarily from the atmospheric carbon dioxide, which diffuses into the plant through small pores or stomata on the leaf surface; and from water which is absorbed by roots and passes up the stem into the leaves. In the presence of chlorophyll (the green pigment in the leaves) the carbon dioxide and water react to synthesize sugar in the process called photosynthesis which is dependent upon light. If there is insufficient light photosynthesis will be reduced or even stop all together.

An efficient plant manufactures more sugar than is needed for current growth. The excess sugar is converted into starch and stored mainly in the roots. The stored starch is available for use by the plant in an emergency such as when new shoots are produced after pruning, or when the rate of photosynthesis drops at night; during periods of very hot, dry weather; during very cold weather or when only old and inefficient leaves are present on the plant.

(ii) ***The maintenance foliage***

The production of new shoots after pruning, skiffing or plucking is dependent upon the plant's starch reserves. If the existing foliage on a skiffed or plucked plant is highly efficient, the starch that is used will be replenished quickly. But if it is inefficient the amount of stored starch decreases every time the bush is plucked to the point when shoot production could cease whenever the plant is subjected to sub-optimal growing conditions. It is therefore essential that the tea bush is allowed to retain at all times an adequate amount of efficient foliage. On a plucked tea bush this foliage is called the maintenance foliage or layer.

If the maintenance layer is too shallow or too sparse then the rate of sugar production may be too slow to permit the accumulation of starch reserves. Therefore, after pruning, a deep and dense layer of green leaves must be allowed to form before plucking starts. While depth of the layer depends on the height at which plucking starts above the level of the lowest leaves, the density of the layer depends upon the number of shoots which will have developed before plucking starts. Tipping in practice, increases this density. It has been found that less than 5 per cent of sunlight penetrates below 15 cm of the maintenance layer. Therefore, a maintenance layer 25 cm deep is adequate.

Once an adequate maintenance layer has been formed and plucking has started the maintenance foliage gradually becomes senescent and dies. It is therefore necessary to keep adding new efficient leaves to the layer. This is achieved gradually by leaving a new leaf on the bush whenever a shoot is plucked above the plucking table, or in steps by missing out one or more plucking rounds and restarting plucking at a higher level.

(iii) ***Plucking***

The object of plucking is to provide the factory with leaf that is suitable for processing. The factory management is accordingly responsible for deciding on the type of leaf suitable for manufacture. On the other hand, it is the responsibility of the field organisation to provide regularly the type of leaf required by the factory in order to achieve and maintain a good standard of tea making. Therefore the whole of the plucking operation should be centred on the absolute necessity of maintaining a regular flow of standard leaf to the factory.

Two groups of terms are used in describing plucking standards. The first pair of terms relates to the type of shoot that is sent to the factory: -

'Fine' plucking is the removal of one or two leaves and the bud. 'Coarse' plucking is the removal of three or more leaves and the bud.

The second pair of terms relates to the amount of new foliage left on the plucked shoot above the plucking table: -

'Light' plucking leaves some new foliage above the previous plucking level.

'Hard' plucking means that the shoots are plucked right down to the previous plucking level so that new maintenance foliage can hardly develop.

It is possible to combine the pairs of terms to obtain four basic types of plucking:
Fine and light, fine and hard, coarse and light, coarse and hard. In general the finer the plucking the better the overall quality of the made tea.

Light plucking ensures that the adequate depth of maintenance foliage is present on the bush, but if the plucking is too light then the plucking table rises rapidly and the potential crop is thus wasted by leaving pluckable leaf on the bush. On the other hand, hard plucking cannot be continued indefinitely as at some stage new maintenance foliage must be permitted to develop on the surface of the bushes.

The leaf standard set by the factory must not be too rigid, but should indicate the maximum permissible proportion of over-standard and damaged shoots that can be accepted. No plucking can be entirely "two leaves and a bud". There will be always be a number of 3+ bud shoots, banjhi shoots, broken shoots and detached leaves.

During plucking, soft banjhi shoots must be plucked as soon as they rise above the plucking table; if left they might become too hard at the next plucking round. Thus hard banjhi shoots should not normally be found above the plucking table, but if they do occur they must be plucked and discarded (breaking-back) unless the banjhi state is caused by drought. Banjhi shoots below the plucking table should not be plucked. They are part of maintenance foliage and are useful as their leaves are efficient at manufacturing the sugar, which is utilised by the rest of the bush.

It has been observed in the Kenya highlands that a normal leaf on a pluckable shoot takes 8 to 9 days to expand fully from the growing bud. Therefore a young growing shoot with only one normal leaf and a bud takes the same period to reach a pluckable stage of two leaves and a bud. Since most shoots to be plucked in the subsequent round would have emerged from below the plucking surface, the duration of 8 to 9 days, or multiples of these, may be used as guides for fixing the plucking round lengths.

The length of the plucking round should be adjusted according to the rate of growth of bushes. Once pluckers have been trained as to what kinds of shoots to leave on the bush then the management must check samples of plucked leaf every plucking round. If it is found that too large a proportion of immature shoots have been plucked then the plucking round should be lengthened, and if there is too large a proportion of over-mature shoots then the round should be shortened.

To assist the pluckers maintain a flat plucking table on the bushes, they should be provided with long straight sticks or "wands", which can be placed across several bushes and pushed down gently so that they are just at the plucking level. On sloping fields the wands must be placed parallel to the slope and not the contour. Failure to do this leads to "step-plucking" when each contour row of tea has a horizontal surface partly shaded by the row immediately above it on the slope.

Breaking-back is only necessary when the plucking round is so long that after the standard shoots have been plucked, the stubs of these shoots bear several leaves above what should have been the plucking table. The pluckers then have to break these stubs off at the plucking table and throw them away. This is a waste of both leaf and manpower and the operation should be avoided during peak periods of leaf production.

(iv) ***Leaf collection and transport***

No matter how good the plucking and the manufacturing might be, good quality tea cannot be manufactured unless the plucked leaf arrives in the factory in perfect condition. Bruised leaf will immediately start to ferment, so it is important that the leaf should be plucked into baskets of an adequate size so that it does not have to be compressed and that, if transferred to other containers for transporting to the factory the latter containers are not so large that the leaf is compressed by the weight of other leaf above it. If sacks are used they should never be packed tightly, piled on top of each other or sat upon. They should be stacked in single layers or hung from hooks.

The interval between plucking and delivery at the factory should be kept as short as possible, otherwise leaf on the outside of the containers might become dry in comparison with that in the centre, resulting in uneven withering in the factory. At no time should plucked leaf be left lying in the sun, as this will lead to rapid deterioration of the leaf.

Leaf containers should be kept clean and should not be rested on soil, since dirt picked up this way is liable to taint the tea while the pieces of grit included with the leaf can damage machinery in the factory.

(v) ***Pruning***

1. Normal pruning

Under normal plucking the table rises gradually with time at the rate of about 20 cm annually. After 3 to 4 years from pruning the table reaches an unmanageable height (120-150cm) and plucking is considered cumbersome, leading to reduction in plucker productivity. At this stage it is necessary to prune the bushes down so that plucking can be started at a lower level.

The duration of successive prunes of the pruning cycle may vary with locality due to differences in climate, the jat of the tea or clone, the style of plucking adopted and the nutrient status of the plants

The pruning level should be raised gradually. A rise of 5 cm each time has been found satisfactory. Pruning at the same level each time leads to the formation of large knots of callous tissue or clubs.

The pruning should be a straight cut-across parallel to the slope of the ground (see Figure IV:1). The pruning cut on each stem should slope slightly so that rainwater drains off the cut and does not remain to induce branch dieback.

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Figure IV:1

Pruning a mature tea plant

2. Lung pruning

In this type of pruning, a number of branches are left on the bush unpruned until the bud-break stage of re-growth when they are then removed. Research has shown this type of pruning to aid in faster recover and contribution to the overall yield has also been noted especially where rim-lung pruning is used. In rim-lung pruning the branches to be left are those on the periphery of the bush, and arranged such that adjacent rows of tea would have lungs on one side to enhance plucker productivity. Twelve branches are recommended per bush, until tipping-in time.

3. Down or height-reduction pruning

After a number of pruning cycles, the pruning level may be so high that the plucking table reaches an unmanageable height too soon. It is then necessary to lower the pruning level from the maximum of 70 cm down to 45 cm and start off a new series of pruning cycles. This low prune is often called a "height-reduction" prune or a "down" prune. During the down pruning operation, attempts should be made to remove all diseased, dead and knotted branches

As a guide to pruning at the correct height, a stick clearly marked or notched at the pruning height, should be placed vertically in the centre of the bush and two or three branches pruned at the indicated height. Due to a possible change in ground height, either because of accumulation of organic matter or soil erosion, it is recommended that this height be checked against the previous pruning cuts and adjustment made to achieve the required pruning height. The rest of the branches are then pruned at the correct height, using the already-pruned branches as a guide. The pruning stick can be pushed into the bush at the level of the already-pruned branches, adjusted so that it is parallel to the ground, and used as a guide for pruning the rest of the bush.

On sloping ground the prunes should use a horizontal stick with two upright sticks fastened to it at a distance apart equal to the distance between the rows of tea and with the height of the horizontal stick equal to the required pruning height. This frame is then placed over the bush with one of the upright sticks higher up the slope than the bush and the other upright on the slope below the bush. The horizontal stick will then be parallel to the ground slope and at the correct pruning height.

When pruning is carried out during hot sunny weather the newly exposed stems may be damaged by sun-scorch. This damage is started within minutes and can be prevented effectively by placing some of the prunings over the pruned bush immediately after that bush has been pruned. Covering the bushes a day after pruning may be too late as the sun-scorch damage may have occurred. When the pruned bushes have recovered and the new shoots are vigorously growing and touching the prunings, the latter are removed and placed on the ground.

The prunings must never be removed from the field. They help to suppress weeds, prevent soil erosion, improve soil structure, and on decomposition they release large amounts of plant nutrients into the topsoil where the nutrients become available to the pruned bushes. Whereas there is no clear experimental evidence as to the best time of pruning in Kenya, it is considered that the most suitable time for pruning is probably towards the end of the peak growing period. In Kenya the latter coincides with the start of the dry season or the start of the cool season (July & August).

Pruning should be done while there is still adequate moisture in the soil. The prunings then form a mulch that reduces the loss of water by evaporation from the soil. The lack of foliage on the bushes means that transpiration will be minimal until there will still be enough water in the soil to support the bushes' continued growth until the end of the dry season.

The speed of recovery from pruning of a bush depends on the plants' starch reserves in the roots. Since the starch reserves are withdrawn during the dry season to sustain the rest of the tea bush, the end of the dry season is a bad time to prune.

(vi) ***Skiffing***

This is a very light pruning operation whereby the bushes are cut across using a pruning knife, at some level within the maintenance layer. Skiffing may be done to level off the plucking table when the bushes have developed domed surfaces which result generally from poor plucking on the sides of the bushes until such a time as the outer shoots reach the same height as the central shoots.

(vii) ***Tipping-in***

The object of tipping-in after pruning is to produce a dense and upper level surface to the bush so that efficient plucking is possible and to leave an adequate depth of maintenance foliage on the bush. Normal plucking should not be started until a sufficient depth and density of maintenance foliage has formed to ensure the replacement of all the food reserves used up in the development of new shoots after the bushes were pruned.

After pruning, the new shoots originate at different heights on the stems and form an uneven surface above the pruning level. Plucking on such uneven table is difficult and inefficient. Tipping-in at a fixed height above the pruning level enables all shoots emanating from the pruned bush to be plucked initially at a uniform height and thus establish a smooth table.

Tipping-in should start before the shoots go banjhi at a height of about 25 cm to 30 cm above the pruning level. In practice, it has been found that the best tipping-in height is 10 cm above the pruning level. During tipping-in, shoots that have developed three leaves and a bud above the tipping-in level should be plucked off at the tipping-in level. On sloping ground, the tipping-in level should be parallel to the ground since the bushes would have been pruned parallel to the slope of the ground.

Aids to tipping-in (see Figure IV:2) are similar to those mentioned previously for pruning. An alternative method is to use a cord stretched tight between two upright sticks at the required tipping-in height. The sticks should be pushed firmly into the ground to a standard depth. A strip of strong rubber fastened to the cord is useful in maintaining tension, but no more than ten bushes at a time in a row can be dealt with by this method.

At least three rounds of tipping-in, at the same level, should be carried out on pruned bushes and five rounds on pegged bushes before normal plucking is introduced. During the second and subsequent tipping-in rounds, the plucker may be aided by use of a short stick marked or notched at the tipping-in height above the pruning level. A string tied at the top end of the measuring stick is further tied around the left hand wrist. Any moment the plucker is not certain of the tipping-in level of a shoot, he quickly uses the marked stick by placing it vertically onto the nearest previous tipped-in or pruned stalk.

It is important that tipping-in is not delayed. Undue delay means that the buds just below the tipping level will become mature and will therefore take longer to develop into new shoots. **Never tip-in with a knife.**

The branches of pegged bushes slope upwards and are usually tipped-in directly, without pruning. On such bushes, the question of tipping-in above the pruning level does not arise. Instead, the average height of pegged branches is assumed to be 25 cm in the case of initial single or double-stemmed plants which have been given an extra prune at 10 cm. The average height of the branches of pegged sleeved plants is assumed to be 30 cm so that tipping-in is carried out at a height of 50 cm.

Figure IV:2
Tipping

(b) Rehabilitation of moribund tea plants

A moribund tea plantation is one whose production has stagnated or shows a decline in spite of optimum cultural practices. It has been observed that tea stands aged over 50 years and having more than 25 per cent vacancies are usually moribund and therefore require drastic action to bring the field back to full production.

(i) *Causes of moribund state in tea*

Tea yield stagnation has been shown to be due to weakened bushes and gaps resulting from deaths of some of the bushes. The major causes of plant population decline are pests (e.g. Mosquito bug or *Helopeltis* spp., Spider mites, nematodes and moles) and diseases (e.g. *Armillaria mellea*, *Phomopsis theae* and *Hypoxylon serpens*). Non-pathological causes of tea bush weakening and death include lightning, removal of prunings, soil mineral deficiencies, drought, weed competition and inter-row cultivation which damages feeder roots.

(ii) *Rehabilitation methods*

In order to establish the need for rehabilitation of moribund tea areas, it is necessary to monitor the yield level and the percentage of gaps in individual fields. Under optimal cultural practices, annual yield levels of less than 1000 kg made tea per hectare from tea fields older than 50 years may be used as a guide to initiate a rehabilitation programme. The gaps should constitute at least 25% in the field.

Two rehabilitation methods which have been applied in other tea growing countries and are under intensive evaluation in Kenya are described below:

1. *Rejuvenation pruning*

This involves hard or deep cutting back of tea bushes at a height of 10-15 cm above the ground in order to remove old, diseased, gnarled and knotted branches low down. This enables new growth which leads to vigorous new framework of a tea bush. Interplanting with high yielding, good quality clonal plants within the rows of the originally wide-spaced plants and also infilling the gaps may increase the subsequent productivity of the field.

2. Replanting

See Page 82.

(c) Hail damaged tea

Most of the tea growing areas west of Rift Valley in Kenya experience hailstorms which may cause some crop loss through leaf damage and subsequent skipping of one or more plucking rounds, depending on the severity of the hail damage.

Tea plants recovering from pruning may use most, if not all, of their root reserves in developing new foliage. A repeated loss of foliage by hail will have at least the following effects:

1. The plant utilises root reserves in developing new shoots.
2. There is a loss of maintenance foliate.
3. A crop loss is expected as a result of torn off tender leaves and skipping of one or more plucking rounds.
4. The broken-off leaf acts as a mulch on the soil and its decay may temporarily cause reduction in the amount of nitrogen available to the tea plant. In the long run, however, the minerals released from the decayed broken-off foliage may be available to the tea plants.
5. Scars caused by hail stone injury on tender stems may develop into large cankers on the bush frame and these may be entry points for disease pathogens. No shoots develop from the cankerous areas of the bush.

Very severe hail damage results in the dying back of shoots and reduction in the number of dormant buds which can develop into new shoots. In these cases it is best to skiff the tea plants below the level of maximum damage. This skiff might reach the severity of a light prune if the damage was very bad, or might serve the purpose of merely levelling the table if the hail damage was light.

The action taken after hail damage must allow the redevelopment of adequate maintenance foliage. Therefore a period of light plucking or even of complete resting of the bushes by skipping at least one plucking round must be allowed.

(d) Infilling

In a field of tea some plants die due to various causes such as bad weather, mechanical damage, pests and diseases. The longer the delay in replacing these plants the more difficult it will be to raise the infills into high-yielding plants. It is therefore important that infilling in new fields or in mature tea is completed as quickly as possible after planting or pruning. Only the most vigorous clonal plants should be used for infilling to enable them to compete with the surrounding bushes.

Tea plants which die as a result of attack by *Armillaria* should be uprooted immediately and moved away from the field for burning. A new planting hole 1 m in diameter and 60 cm deep should be made at the time of the dead bush's removal. All pieces of diseased roots found during this process should be carefully removed, while taking care not to damage the roots of adjacent bushes. Should larger pieces of old root remaining in the ground from forest trees be exposed during the excavation, they should carefully be removed down to a depth of 100 cm and burned.

For replacing plants which die from causes other than *Armillaria* a hole double the size of a normal planting hole, i.e. a hole 50 cm in diameter and 60 cm deep should be prepared, removing all pieces of roots which are found. A hole larger than normal is necessary so that roots of neighbouring older tea plants are cut through and thus do not compete with the roots of the infill plant before it is well established.

(i) *Raising infills in the nursery*

In order to ensure that vigorous plants are available for infilling it is necessary either to select the best plants from a standard nursery or to prepare nursery for the plants which are to be used as infills. The best plants for use as infills should be large sleeved-plants of a vigorous clone and which have undergone one prune in the nursery. To keep multiplication plots only pure plants of the same clones as the multiplication plots should be used as infills.

Cuttings of the infilling clone should be planted into large sleeves (12 cm circular diameter, 35 cm length and 250 gauge), be in the nursery for about 18 months, pruned in the nursery at 15 cm when they are 30 cm tall and *transferred to the field vacancies later during dull weather.* This ensures that by the time transplanting is carried out, the infills will already have developed a good branching system so that after a further prune or pegging in the field a complete cover of tea is rapidly attained.

If seedlings in sleeves are used the same system can be followed, except that care must be taken to select the most vigorous seedlings. With seedling stumps, it will be useful to have a separate seedling nursery in which the seeds are planted at a wide spacing of 20 cm by 20 cm triangular. The seedlings are pruned in the nursery at 10 cm height when the stem base is about 1.0 cm thick and then pruned in the following year at 20 cm height at the time of transplanting into the field. At least 12 months must elapse between the two prunes to ensure that root reserves are fully replaced. During this period the seedlings should be unshaded in the nursery as full sunlight accelerates the rate at which the dormant buds on the stem start to develop into new shoots, increases the number of such shoots and enhances the rate of photosynthesis.

Fertilizer is applied to infills as described on page 126.

(ii) *Treatment of infills after planting*

For infilling within two years of field planting when the original plants are being pegged or being brought into bearing by pruning, treat the infills in exactly the same way as the older plants. When the original plants are being pruned, prune the infills at 30 cm when the main stem at that height is 1.0 cm thick and tip-in with the older plants at 50 cm.

For infilling fields which are two or more years old, cut back the sides of plants adjacent to the vacant plant site. Prune the infill at 20 cm when 1.0 cm thick at that height and tip-in at the existing level of the older plants.

In areas containing several adjacent vacancies, plant three infills for every two vacancies. After planting, keep the sides of any adjacent bushes cut back. In young fields give a 40 cm prune and tip-in at the same level as the surrounding tea bushes. In mature tea it may help to put long stakes next to infills to prevent the infills from being trampled by the pluckers or weeders.

(e) **Rain gauges**

The object of installing rain gauges is to obtain an accurate measure of the amount of water falling on a site in the form of rain and mist. Many rain gauges on tea estates fail to do this either because of the design of the rain gauge which is faulty or because the site is unsuitable.

Where consideration is being given to the irrigation of tea, the amount of water storage required and the capacity of pipes and pumps will depend upon the rainfall in the area to be irrigated. If rainfall records are inaccurate by as much as 25 per cent, which is not an uncommon error, the provisions made for irrigation might be insufficient or, alternatively, might be wastefully over-generous.

(i) *Type of rain gauge*

The Kenya Meteorological Department currently recommends the rain gauge illustrated below in Figure IV:3. The funnel is of a special design, the top being an accurately turned bevelled brass ring finished to a knife-edge precisely 12.7 cm (5 in) in diameter. To minimise out splashing, the funnel is cylindrical to a depth of at least 10 cm (4 in).

The funnel and container have soldered seams which should be inspected regularly for leaks. The spout of the funnel must be kept clear of debris.

(ii) *Siting*

The site for the rain gauge must be chosen with care as the amount of rainfall which falls on a small site can be greatly influenced by local wind eddies caused by buildings and trees and by features such as hills and valleys.

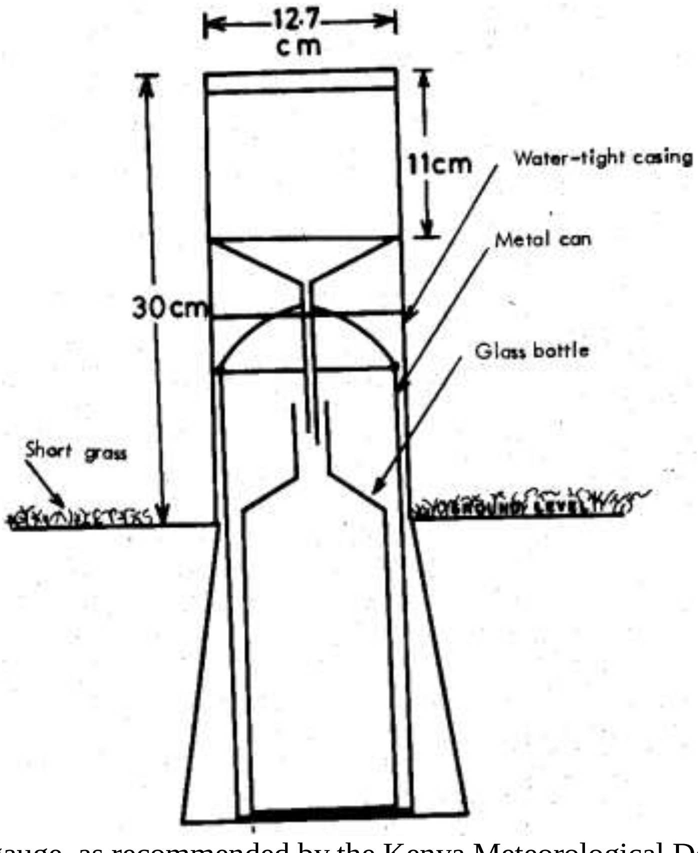
No obstruction should be nearer to the rain gauge than a distance equal to twice the height of the obstruction and, in the site itself, the surface should be level and covered with gravel or short, preferably mown grass; concrete or bare soil should be avoided. The top rim of the rain gauges should be maintained at 30 cm above the ground, with the base sunk into the ground. The rain gauge should never be mounted on a pole or pillar unless the rain gauge is sited in a field of tea, when it should be raised so that the rim is 30 cm above the plucking table.

Because rainfall can vary over quite short distances, a grower who is obtaining rainfall data to help him plan for irrigation should have one rain gauge for every 50 ha. of tea.

iii) *Recording*

Rainfall should be measured at 0900 hours daily. The collected water should be poured into a measuring cylinder which is graduated in millimetres or in tenths and hundredths of an inch. The bottom of the measure should be tapered so that small quantities can be measured accurately. When 0.05 mm (or 0.005") or less is measured, the rainfall should be recorded as a trace (Figure IV:5). When taking rainfall readings, the eye level should be at position A as shown in Figure IV:4 avoid possible parallax error. The recorded data should be in a clear and permanent form for future reference.

Figure IV:3



Standard raingauge, as recommended by the Kenya Meteorological Department

(f) **Irrigation**

Although the total rainfall in a year may be adequate for all the year round production of green leaf in most tea areas of Kenya, when temperatures permit, the distribution of this rainfall month by month is often inadequate. Most tea areas of Kenya experience both cool, wet and warm, dry seasons. The latter comes when growing conditions are most favourable and water requirement of the plant is at the maximum. Water loss by evapotranspiration soon exceeds rainfall, leading to soil moisture deficit. When this situation is prolonged a water imbalance in the plant system ensues which is followed by wilting and an immediate reduction in crop or a complete stop without crop at all. This may be alleviated or eliminated by irrigation.

Water is not the only factor controlling growth. It is useless to begin watering tea at the end of the dry season if the temperature is low. It is also useless to water tea unless the crop is provided with sufficient nutrients. If irrigation has therefore to be applied profitably, it has to be applied judiciously.

In the late 1960's tea irrigation studies were concluded at Ngwazi in Mufindi district in Tanzania. This was an area where a long dry season is experienced every year which made it possible to apply and withhold water at will during the dry season, without interference by rain.

The studies indicated that although irrigated areas out yielded the unirrigated tea, intermittent irrigation during the day resulted in larger yields than irrigating the tea every ten days. This observation had also been reported from Georgia (CIS*). The reasons for this observations were attributed to the following changes in the environmental conditions under irrigated tea compared to the unirrigated fields:

1. There was a general increase in the size of the stomata (without irrigation, the stomata tend to partially close in the middle of the day even when there was adequate water in the soil);
2. There was a reduction in sap tension, air temperature and vapour pressure deficit.

In Kenya it has been a policy to grow tea in areas where irrigation is least anticipated. But with the extension of tea growing in new marginal areas and the changes in the climatic patterns, it has been advocated that some areas could benefit from irrigation. The question is: where and when will irrigation pay? The answer to this question depends

1. The frequency and duration of the dry seasons

Obviously the more frequent and longer the dry seasons the greater the need will be for irrigation.

2. The age and vigour of the tea

Young, shallow-rooting tea is more susceptible to a short dry season than older deeper-rooted tea both of which have the same degree of ground cover. Healthy bushes will survive a dry season better than weak, sickly bushes, and they will also produce more crop when irrigated.

3. The depth, type and fertility of the soil

Tea growing on shallow and/or sandy soil, will be more susceptible to a dry season than tea growing on a deep and/or loam soil. Although irrigation will increase the availability of some nutrients, it will not by itself, make up for nutrient deficiency. Maximum returns will only occur when the nutrient status of the tea is at an optimum level.

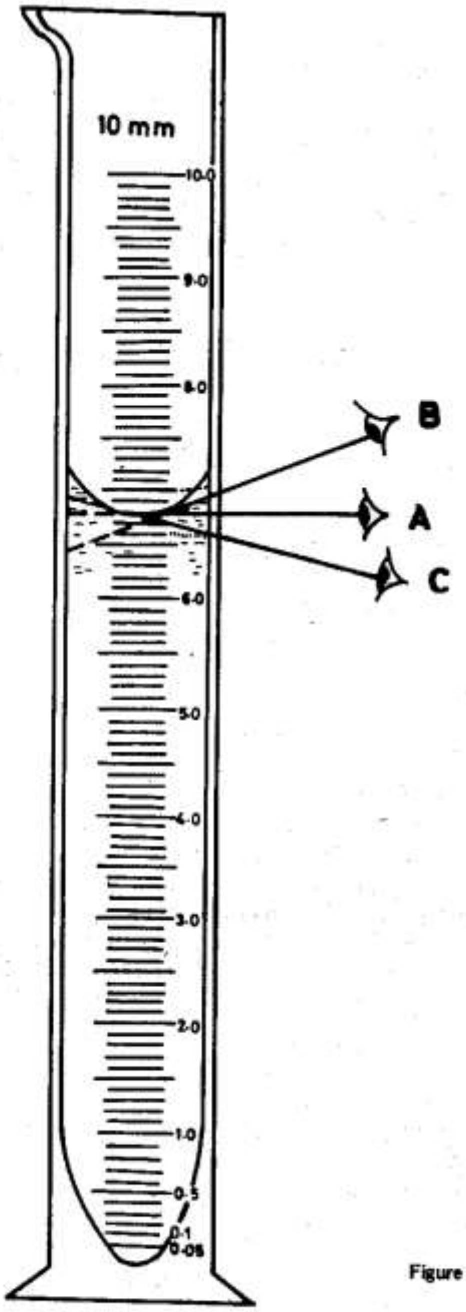


Figure IV: 4 Graduated rain measuring cylinder
Reading with no parallax error is with the eye at position A

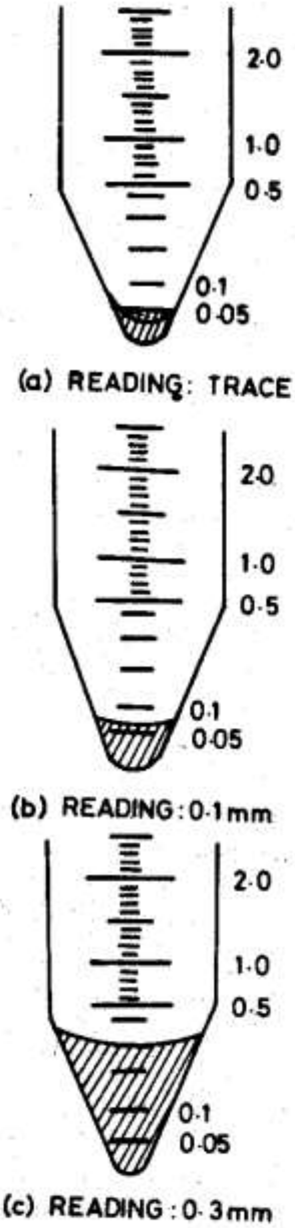


Figure IV: 5 Examples of readings from a rain-measure

4. Availability of water suitable for irrigation

Pumping water to a height or from a distance is expensive. The closer the water supply is to the tea that is to be irrigated, the cheaper will be the cost of irrigation. Remember however, that the maximum demand for water for irrigation is likely to occur when water supplies are at their lowest.

Irrigation should only be considered when other more easily controllable factors such as nutrition have been corrected. It then becomes necessary to assess each individual situation on its merits so that a rational decision on the benefits likely to result from irrigation can be reached.

In those areas where the dry seasons last six weeks or less it seems unlikely that irrigation of mature tea will pay, at least initially. Similarly, if the soil is shallow and the tea always look "sick" after a few weeks of dry weather then irrigation is most likely to pay. However, in the latter areas, irrigation of newly planted tea is likely, in the long run, to prove the most profitable enterprise. Irrigation of such tea will not only allow planting to proceed evenly throughout the year but will also, as stated earlier, raise the yield potential of those plants in succeeding years, providing of course they are always properly fertilised.

In the search for immediate short-term gains in yield through irrigation one must not lose sight of the following indirect, but equally important benefits that may result:

1. The tea crop production will be more even throughout the year with obvious managerial advantages.
2. Irrigated tea will have the capacity to respond to even higher levels of nitrogen when phosphate and potassium levels are optimum.
3. Well fertilised, irrigated tea can be plucked harder. Hard plucking may mean longer pruning cycles with increase yields.
4. Irrigation is primarily a means of supplying soil moisture if there is a deficiency. This is important in improving the health and vigour of the tea crop.

   The healthy vigorous crops are more resistant to the ravages of disease and pests than the less healthy crops. Diseases such as stem canker *(Phomopsis theae)* thrive well in droughted bushes.

   NB: Over-irrigation may negatively affect root development by encouraging shallow rooting and root exposure. If later the rate of irrigation is reduced or stopped the plants will be rendered susceptible to drought.

To obtain the maximum benefit from irrigation, the water must be applied in the correct amounts and at the correct time. The effect of irrigation should be to maintain the soil water content at some level between field capacity and the wilting point of tea. At field capacity the soil is fully moist and any additional water would simply drain downwards through the soil. At the wilting point of tea, the soil becomes so dry that any water remaining is tightly held by the soil particles and can no longer be extracted by the tea roots: the plant then wilts. As the soil dries up it cracks and in the process it may break the tea feeder roots. The actual water content at this stage will vary from soil to soil.

Irrigation should start as soon as the water content of the soil has fallen below field capacity by a certain amount. This is known as the water deficit, expressed as the depth of surface-applied water needed to bring the water content back to field capacity. It is normally estimated from two sets of information; the quantity of rain which falls on the field and the amount of water lost by evaporation from the soil and transpiration from the tea plants. These two causes of water loss are jointly termed evapotranspiration.

Rainfall data (see page 92) when properly taken and kept are essential for accurate planning for irrigation systems.
Evapotranspiration tanks designed and built as recommended by the Kenya Meteorological Department are the other essential means of estimating water loss from tea by evapotranspiration.

5. Irrigation equipment and water supply
The Foundation is not in a position to recommend any system of irrigation equipment, but in Kenya several suitable types are available.

Before an irrigation system is installed, it is essential that provision be made for supplying adequate water from rivers or dams. Care should be taken to ensure that legal requirements are met for taking water from rivers, dams or bore holes, and the advice of experts should be sought regarding the siting and construction of the necessary facilities.

There are two main systems of irrigation which can be used in tea:

1. Furrow irrigation: water is led to the plant by surface furrows which allow the water to trickle gently down the slope of the ground, percolating into the soil as it does so. This system is wasteful as much of the water drains through the soil below the furrow; many nutrients are leached from the soil; the system can be used only on suitable terrain. On the other hand, the power requirements are low as the water reaches the plants by gravity.

2. Overhead irrigation: which allows water to be applied through various designs of sprinkler equipment in accurately controlled amounts and with a minimum of wastage. However, one climatic factor affecting the utility of overhead (sprinkler) irrigation is wind, which may move the water droplets and distort the sprinkling pattern.

(g) Farm records
Keeping of good farm records is very vital in tea production for formulating good farm policies.
In Kenya, large tea estates have experienced employees who can keep good farm records, required in tea production. On the other hand, there are small scale growers whose records are kept by Kenya Tea Development Authority.
In between these types of growers, there are those with substantial hectarage of tea and in most cases they themselves manage their own tea farms. They may become under capitalised due to other competing enterprises and they depend on workers who, in most cases, do not have enough experience in tea production. The grower must be ready to supervise and inspect farm records, and should keep simple farm records if the work has to be easy.
Most farmers keep good farm records but there are those who are not sure which type of farm records should be kept and the following explanation might benefit them.
If the grower does not stay on the farm or has no time to visit the farm it is suggested that the farm records should be kept in duplicate. The original should be sent to the farm owner and the duplicate kept by whoever runs the farm. The

copy sent to the owner will enable the grower to know the progress in the farm and how the employees are working. Before giving a list of some important farm records, one thing should be stressed. The farm owner should know the area of his farm and the amount of tea in every plot. The way tea is planted; problem area (hut-sites), land topography, etc., all contribute to the differences in the amount of tea in every area planted. For example when making estimates of costs involved in the pruning work, the actual number of tea bushes should be known.

(i) ***Daily Muster Sheet - Attendance Register***

The purpose of this record is to show the daily situation of workers in the farm. The record is made daily to show the number of employees, those who did not report to work, the sick and those on leave.

Example 1

Date	Reported to work	Absent	Sick	On leave	Tota l
Type of work	(present)				
Plucking					
Weeding					
Pruning					
Etc					
TOTAL					

(ii) ***Labour Distribution Register - Attendance Summary***

The purpose of this record is to summarise the daily number of workers under different activities or items in the tea farm for the whole month. It more or less summarises and consolidates what is recorded in the Daily Muster Sheet. If properly recorded, it will show the total number of workers who did a certain job daily, and the number of days it took to complete a particular task. It will show the grower which work item is consuming more money.

Example 2

SECTION ....FOR THE MONTH OF ....

Item	Work done	Date						TOTAL
		1	2	3	4	5	6 etc	
10	Weeding	21	-	-	-	-		
12	Spraying	5						
Etc	Etc	etc						
TOTAL		26						

(iii) *Check/Muster Roll*

The purpose of this book is to record daily, on individual worker basis, days earned in the month, absent and sick days, as well as kilograms of tea plucked. Overtime hours earned daily are also recorded. This is also where monthly wages are calculated and statutory deductions such as NSSF, Union dues, etc., are recorded.

Example 3

MONTH OF ....……………. ESTATE/FARM ....……………

Date No. Name	1	2	3	4	- 10	Sub Total	11	- 20	Sub Tota l	Leaf Plucked (kg)	Days worked
1. John Run	30									30	
		1									1
2. Sam Yes	45	40								85	
3. Nick Two	36									36	
		1	A	A							1
etc etc											
Total leaf (kg)	111	40									
Total Days	-	2								151	
No. of pluckers											2
Checked by											

(iv) ***Green Leaf Sheet (Field Weight)***
This is where daily green leaf plucked by individual workers is recorded. The Green Leaf Clerk records it on plucking gang basis. The leaf recorded on these sheets is transferred daily to the Check Roll.
Example 4

Green Leaf Field Weights

NO	Name of supervisor	Weights under field numbers (kg)							Total
1	Rutto	500	-	-	-	650	-	-	1150
2	Ratemo	750				910			1660
etc	etc								etc
	Total	1250							2810

.... Leaf Clerk ....Check Roll Clerk ....…….

Checked by .... Manager/Head Clerk ....

(v) *Green Leaf Summary*

This summarises total tea plucked on one particular day. It is recorded on gang basis, and it shows the farmer the differences between factory weight and field weight, helping therefore to check performances of his pluckers.

Example 5

Daily Green Leaf Summary Estate .... Date ....…20 ......

Green leaf (kg)	Leaf Clerk	Gang Supervisor	No. of pluckers	Field No.	Factory weight	Field Weight	+ Kg -	Plucking Average	+ %
TOTAL LEAF PLUCKED									

(vi) *Green Leaf Register*

This records plucked tea on daily basis for the whole month. The sheet is arranged on field basis and its hectarage. It also shows the field and factory weights separately, and total made tea plucked from each field. From this record the grower will be able to compare productivity of his fields throughout and at the end of the year.

Example 6

Field N0. Hectares	1 10	3 12	3 12	Factory weight	Field weight	Diff. + or -	Diff. + or -	Made tea	Checked by
Date	kg	kg	kg	kg	kg	kg	%	Kg	
1.7.2000									
2.7.2000									
etc									
Total current Month									
Made Tea									
This month									
Previously									
To-date									
kg. Per ha.									
This month									
Previously									
To-date									
Estimate									

(viii) *Stores Register*

This is required to keep track of the movement of tools in the estate/farm. Any changes in the number of tools like new ones, those written-off or lost etc., will be noted here. The management should set a time interval, preferably monthly, to check these records against the actual physical count of the various tools. In this way one will know the state of his or her tools and take appropriate action where necessary.

Chapter V

FERTILIZERS AND NUTRITION

(a) **Crop nutrition and fertilizer practice**

(i) Nutrients and the factors influencing their uptake

A plant nutrient is strictly defined as a chemical element that is essential for the growth of the plant. It has been found that many species of plants require the same nutrients, and it is usual to refer to a group of elements as essential nutrients for all green-leaved plants of the type grown as agricultural crops. In section (0) a list of sixteen essential nutrient elements is given for reference. It is assumed that tea follows the general rule, and that this list applies. Thirteen of the elements are grouped as mineral nutrients, which is a convenient terminology, as all the nutrients for which fertilizers or manures may be used, fall into this group. The three remaining nutrients, carbon, hydrogen and oxygen make up the bulk of plant tissues, but are supplied by air and water, and are not discussed here.

Occasionally, it is found that elements outside the list of sixteen can improve the field performance of certain crops, without in fact being essential to the survival of that species. There is no evidence that tea is influenced in this way. Again, chemical compounds generated from more than one element have been found to influence plant growth, for example, "plant hormones" or growth regulating substances. This is by virtue of the way in which the compound is formed, and is not simply the effect of the individual elements. These considerations may affect fertilizer use for certain crops, but in the absence of firm evidence for tea, it is preferred to restrict attention to the individual nutrient elements.

Roots extract mineral nutrients from the soil, by means of physiological process, which require energy to be expended by the plant. Transport of nutrients within the plant, and their utilisation in the tissues also require energy. Efficient nutrition, in the sense of the full use of mineral nutrients, can only be thought of as one aspect of the whole complex of factors affecting plant growth such as the supply of water and air, light and temperature effects, and (for crop plants) cultural techniques. The vigour of roots, and their potential energy release, depends largely upon the supply of compounds transported to them from the leaves and the soil.

(ii) Nutrient release from the soil

Plant nutrients, and other elements, occasionally exist in solution in the films of water surrounding the soil particles, and in forms that can be absorbed immediately by a plant root. Provided that the soil mass is thoroughly filled by active roots, a plant has full opportunity to use these readily available sources of nutrients. The leaching effect of rain, which may wash nutrients below the reach of roots which are concentrated in the topsoil, is a serious factor limiting the value of the freely soluble reserves. More often, plant nutrients exist in the soil in forms which are held, more or less firmly, in chemical or physical combination with the mineral and organic components of soil. Roots need to expend more energy to exploit these reserves, the release of which can be hastened by the action of soil flora fauna, and also by chemical compounds deriving from the decay of organic matter, and from root excretions.

Some organic residues may decay so slowly that, in agricultural terms, any nutrients which they may contain are virtually unavailable to a crop. Minerals from the rocks which gave rise to the soil, contain widely varying proportion of nutrients, which are equally variable in their rate of release in forms which plant roots can use. In general, it is true to say that the absolute nutrient content of a soil, is a poor guide to the availability of those nutrients to plants.

The plant itself can influence the availability of nutrients in the soil mass, and also their exploitation. Movement of roots to sources of nutrients is often more important than the movement of nutrients to roots. Most nutrient movement in soil is downwards. If a plant has an extensive root system, which can also penetrate the soil profile in depth, it has a greater chance of removing nutrients as they are washed down, in addition to exposing a greater volume of nutrients to root action and possible release.

Tea is a crop which, under present systems of management, can bring about marked changes in soil conditions, which themselves can be expected to influence the relation between soil nutrients and root uptake. The accumulation of leaf and wood residues on the soil surface, alters the physical condition of the top-soil, and adds nutrients to the same zone. As the root system matures, lower zones in the soil profile will give up nutrients to the bush, eventually to contribute to the enrichment of the top-soil. Soil disturbance has become increasingly unnecessary, as tea has been grown to provide a closed canopy. This added protection to the soil surface lessens the rate of loss of organic matter and certain nutrients from the top-soil. The trends have been seen over the past few decades, in more than one tea-growing country, and they have begun to reverse the soil deterioration which followed the earlier planting of tea.

Much of the original tea planting in Kenya was done on virgin land or on and which carried a reasonable cover of secondary vegetation. Physical conditions and nutrient availability on the top-soil encourage good growth of the young tea, but the exposure of the soil led to a rapid loss of nutrients, other than that proportion which contributed to the development of the bush. As nutrient reserves fell, at different rates in different areas, the effects of nutrient deficiencies were recognised in the resulting debilitation of the tea. The Foundation at first concentrated its attention on remedying nutrient deficiencies, but a few years ago a change was made to an overall fertilizer policy which aimed to be flexible enough to cover prophylaxis and to guard against the possibility of further nutrient shortages limiting the anticipated rise in crop yields. The present assessment of this policy, which is the purpose of this section, is connected with the techniques available to evaluating fertilizer usage, the subject of the following sub-section.

(iii) ***Relations between fertilizer and crop growth***

Experience in Kenya has shown that it is not generally safe to expect the soil to provide sufficient nutrients for more than a short period, to support the high yields of tea which we now know can be obtained. Without supplementing the nutrient supply in one form or another, it may not even be possible to maintain yields at an economic level for more than a few years. The only practicable way of adding those nutrients which the soil reserves cannot supply, is by the use of fertilizers. Organic manures are mentioned briefly in a later section, but for reasons of economics, they could never be expected to play an appreciable part in tea nutrition. Soil application of fertilizer is, with the exceptions of zinc and copper which are dealt with towards the end of the chapter, the technique which will be considered a normal.

All the fertilizer nutrients, once they have come into solution in the soil, react to a greater extent with the soil itself, or with rainwater percolating through the profile. Studies of crop utilisation of fertilizers in general, have shown that relatively little of the nutrients applied can be accounted for in the plant as a whole. A recovery of over half of the applied nutrient is considered to be good. Loss in drainage water certainly accounts for some of the readily soluble nutrients, such as potassium and nitrate-nitrogen. Chemical reaction with soil minerals can render some phosphorus unavailable to roots. In spite of intensive research, this sort of problem has still not been solved, and fertilizer efficiency remains generally poor. It is not known in detail how efficiently tea in Kenya uses fertilizer, but there is reason to believe that this can vary greatly from one site to another. An earlier series of formal, fertilizer field experiments on tea in all Kenyan major districts showed very clearly that the degree of yield response to a given nutrient was highly variable. Of course, not all the variations would be attributable to interactions between fertilizers and soil but the integration of agricultural factors was such as to lessen the value of generalisation regarding probable fertilizer effects. Reports of these experiments will be found in the Tea Research Institute's Annual Reports from 1963 to 1979 and Tea Research Foundation of Kenya's Annual Reports from 1980 to 1996, *Tea*, Volume 2, Number 1, July 1981, and *Tea*, Volume 18, Number 1, July 1997.

One feature that was shown by several of these experiments was that the magnitude of the increase in yield tended to diminish, as the total level of fertilizer nutrient increased. In some experiments, a point was reached, where an increase in application of a nutrient did not result in any further increase in yield. This is a general finding for crops which can show a beneficial response to fertilizer application, and is known scientifically as the *Law of Diminishing Returns.* The economic implication is obvious: the value of additional crop may well at first exceed the costs of applying fertilizer, but eventually so little additional crop will be obtained for each increment in fertilizer, that no monetary gain will be achieved. The critical point, in economic terms, will change as market costs and returns change, and cannot be fixed by any biological definition. Nor is it possible to fix a biological critical point, however defined. Climatic changes influence the shape of a yield response curve, as also do methods of bush management and type of tea. Tea which is not yet mature may show different response curves as it does mature, when a larger proportion of the absorbed nutrients contributes directly to the crop, as opposed to the developing frame and root system. Finally, mature tea grown in a soil/plant system which is being continuously changed by the bush itself, may alter the fertilizer/yield relation the whole time.

The evaluation of the fertilizer by the grower depends on assessment of this sort of relation, and as current market factors make the liberal use of fertilizer less attractive, so the need for a more individual approach becomes imperative. This applies with particular force to high-yielding mature tea. Treatment of lower-yielding mature tea, as mentioned again in the next sub-section, will to a large extent, be guided by experience already gained with the better tea.

(iv) Attempts at chemical estimation of fertilizer needs

Chemical analysis of the soil was, historically, the approach which first received intensive study for many crops. The present finding is that this technique can give useful information for some crops, especially annuals, but that for others its value is limited. Tissue analysis or as it is commonly known, "leaf analysis", was introduced into agricultural research relatively recently, and has had some success, especially for some perennial crops. Taken together, it might seem that a chemical analysis approach could answer at least two important points: the potential reserves of plant nutrients in the soil, the ability of a plant to extract those nutrients. Research and agricultural experience has shown that it is not a straight forward matter, either to estimate nutrient reserves, or to explain why a given plant can vary so much in its ability to exploit those reserves over a period of time. If a nutrient is in very low supply, the chemical approach can be valuable in detecting the actual or potential danger. As nutrient supply approaches the optimum, so the precision of chemical evaluation falls. Leaf analysis has served a useful purpose in detecting gross deficiencies of certain nutrients in tea in Kenya, but it has been necessary to report its limitation where nutrition is more nearly optimum. This is elaborated in *Tea in E. Africa* Volume 13, Number 1, 1972.

Neither of these chemical approaches can predict quantitatively crop trends which might result from adjustment of a fertilizer program. Nor can they be used, with anything more than the crudest approximation, to relate nutrient removal from the field by a crop, with nutrient replacement by fertilizers. The complexity of the interaction between a plant and the soil defies simple laboratory at explanation.

A number of years ago, a scheme was introduced into one tea-growing country whereby a fertilizer-nutrient mixture, and also its rate of use, were to some extent related to the cropping level of the tea. The reasons for this need not be discussed, except to say that there was a necessity to find a starting point to guide the growers in their use of fertilizer. This rule-of-thumb guide proved to be of considerable value, in circumstances where most or all of the tea was at a low point in the yield/nutrient response curve. Many modifications were introduced, and various of these have been put into practice in Kenya. As the scientific basis of the original ideas was of the flimsiest, it is not proposed to go into detail. As long as an estimate of yield, whether obtained or predicted, is used as the basis for calculating a fertilizer program, no very great precision in fertilizer efficiency will be achieved, unless by chance.

A scientifically designed fertilizer experiment should not only fix fertilizer rates and examine the crop response which results but should try to study the effects of various nutrients and their interaction on crop response. This is complex and expensive. Attempts are therefore being made in this chapter to simply this idea, in a form which can be used by the grower without the expense.

(b**) Fertilizers**

(i) ***Definition***

The definition of the term “fertilizer” can not be precise, but is generally applied to a nutrient-carrying material of mineral-like appearance, as opposed to materials which obviously appear to be plant or animal residues. A fertilizer may be a chemical compound synthesised in a factory, or mineral mined and used either raw,

or after mechanical treatment, or an organic material which has undergone intensive alteration during a manufacturing treatment.
Whatever the origin, the purpose of fertilizer use is to carry nutrients to a crop. Soil amendments are materials which are used to alter the physical or chemical properties of the soil, without necessarily containing nutrients, but they may combine a fertilizer function (ii) c).

(ii) *Description of fertilizers*
The terminology and method of expressing nutrient contents present an often confusing picture, some terms being carried over unchanged from the earliest years of the fertilizer industry. Attempts are being made to rationalise the terminology, and it is important that the consumer should be aware of the possible alternative descriptions. It is conventional to define the nutrient in terms of percentage (of the dry fertilizer) of a hypothetical compound of that nutrient element. This is purely for convenience, and itself does not imply that the nutrient is actually present in that form. The following example will illustrate what this can mean.

Nitrogenous fertilizers are invariably quoted on the basis of the "% N" content. Nitrogen is usually present as the ammonium or the nitrate form, in those fertilizers which we are considering for tea, the symbols for the two forms of nitrogen being "NH_4^+" and "NO_3^-" respectively.

Phosphorus in fertilizer is, however, still expressed as "P_20_5". A change to the use of the element, "P", has been advocated and our reference table (Table V:I) lists percentages under both "P_20_5" and "P".

TABLE V: I Reference table of the commoner straight fertilizers and soil amendments used in tea: the quoted nutrient contents are approximate

		% of nutrient						
Name and abbreviation	**N**	**P_20_5**	**P**	**K_20**	**K**	**S**	**Ca**	**Mg**
Sulphate of ammonia: S/A	21					24		
Ammonium sul/nitrate:ASN	26					12		
Urea	46							
Diammonium phosphate: DAP	18	46	20					
Single super: SSP		20	9			10-12	20	
Triple super:TSP		40-46	18-20			0-2	14	
Rock phosphate		25-30	11-13				20-30	
Muriate of Potash				50-60	42-50			
Sulphate of potash:Sul/K				48-52	40-44	15-17		
om salts						13		10
Kieserite						23		17
Gypsum						19	23	
Sulphur						99		
Aluminium sulphate						14		
NPKS 25:5:5:5	25	5	2.2	5	4.2	5		
NPKS 22:6:12:5	22	6	2.6	12	10	5		
NPK 20:10:10	20	10	4.3	10	8.3			

N= nitrogen S= sulphur
P= phosphorus Ca= calcium
K= potassium Mg= magnesium

The phosphatic fertilizers listed (see pages 109-110) in fact contain the chemical conditions known, correctly, as “phosphate”. This term is unfortunately applied indiscriminately in agricultural circles wherever P or P_20_5 should be used. The examples set out in Section n show the need for case in using the correct term.

The phosphate compounds themselves can occur in several forms, differing among other things in their solubility. Fertilizers in current use in tea in Kenya contain all or almost all of their phosphorus in a water-soluble form. Single superphosphate has a small proportion of its phosphorus in a form which is only soluble in dilute acids: the standard laboratory analytical technique for evaluating this fraction gives to the term citric acid-soluble. Other phosphatic fertilizers may require stronger acids to release the phosphorus, and although they do decompose in the soil, they may be described as containing insoluble phosphate.

Potassium is again expressed as its oxide, “K_20”, or “potash”, and a change has been advocated to the use of “K” or “potassium” in fertilizer descriptions. Two columns are given in Table V:I to cover both descriptions.

Other fertilizer nutrients have tended to follow simpler methods of description, but it is still necessary to take care over the evaluation of *sulphur* in straight fertilizers or in mixtures. If it is present as the element, it is insoluble in water, but if as the sulphate, it may be readily soluble in water for some fertilizers, or only slowly soluble in others. Sulphur contents are usually expressed as “% S”, and Sub-section (iii), B and C pages 108-111 lists the forms in various fertilizers.

(iii) ***Fertilizers and soil amendments which may be recommended for soil application to tea***

Modern technology has permitted fertilizers to be produced in highly purified, concentrated forms, and to be stabilised in firm pellets or granules. It is still possible that less pure or convenient forms may come on to the market, and the consumer should be warned what this might imply. Distributing fertilizer evenly in mature tea is far from easy, and the handling properties of fertilizers are important. These aspects are discussed further in the following sub-sections.

A***. Compound 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 (Sub-section iv page 112). In their physiological action, there is little if any reason to suppose that they need differ from a physical mix of the same forms of nutrients, if this is in fact 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.

The range of NPK formulae already familiar to the Kenyan tea industry, and of which 25:5:5 is one, contains nitrogen in two forms, ammonium and nitrate, often in the ratio 2:1. Phosphorus is present as water-soluble phosphate. Sulphur, if present, is usually in the sulphate, soluble form. It is not known that the forms of these nutrients have any influence on their value for tea. Potassium, as in all the potassic fertilizers dealt fertilizers dealt with in this chapter, is water soluble. Usually, calcium is present at low levels of about 2%.

Compound fertilizers which contain ammonium form of nitrogen acidify the soil.

B***. Straight fertilizers***

These are chemical compounds which are made and sold as individual fertilizers. Each may contain more than one nutrient, but his 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.

1. Sulphate of ammonia (or ammonium sulphate)

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. Some powder formulations can contain free sulphuric acid and are damp. Flakes and pellets of various colours can also be offered. Their handling and storage properties vary from one formulation to another, and they may carry less nitrogen than the quoted 21% N. These variations do not necessarily mean a grade is unsuitable, but full consideration should be given to the possibility of disadvantages. The dry crystals are compatible with other fertilizers in this list, except that granular fertilizers in general are difficult to mix with any material other than powders. Sulphate and handling well in the field. It acidifies the soil strongly.

2 Ammonium sulphate nitrate

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. The older formulations were often in a soft crystalline form, which absorbed moisture from the air (hygroscopic) and became sticky. More stable granular formulations are marketed, and are the only reasonable forms for use in tea.

3. Urea

A compound of nitrogen, carbon and oxygen, containing 42 - 46% N. This form of nitrogen decomposes under the action of a soil-borne bacteria, and is converted to ammonium bicarbonate. A volatile ammonia gas can be generated from this compound, 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, the Foundation advises care in the choice of weather conditions at the time of application.

Urea is now 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. If growers wish to use it, only the prilled form should be used. Older formulations, as crystals or soft granules, absorb water very rapidly. It acidifies the soil to a lesser degree than other ammonium fertilizers.

In the case of a grower wanting to substitute the recommended compound fertilizers as a source of nitrogen with urea, the following conditions should be observed:-

i. Rates higher than 150 kg N/ha should not be applied.

ii. Application should be done during periods of adequate rainfall.

iii. If urea as a source of N has to be used continuously, the supplementary P and K should also be applied so that they do not become limiting on yield. In such a case, single superphosphate and sulphate of potash would be preferred so as to supply sulphur. Use of both of triple superphosphate and sulphate of potash or single superphosphate and muriate of potash would serve the same purpose.

4. Diammonium phosphate

Contains two nutrients; nitrogen at 18% nitrogen and phosphorus at 46%. 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, the older crystalline form being hygroscopic and releasing ammonia gas in the store. A useful source of nitrogen and phosphorus.

5. Single superphosphate

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 18% P2O5, sulphur at 10% S and calcium at 20% 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. The manufacturer usually states these proportions. Part of the calcium is readily water-soluble, but part is combined with sulphate in the slowly soluble gypsum. If single superphosphate is dissolved in water, the sediment consists almost entirely of the gypsum component. The older, powdered, formulation was liable to cake in the store and did not mix well with certain fertilizers. At present, a hard granular formulation is on the market.

6. Concentrated superphosphate

This covers a group of products. variously called "double" or "triple superphosphate". Phosphate rock is treated with phosphoric acid, to give water-soluble products, of varying composition; phosphorus at 40 to 50% P_2O_5, 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, and should be bought on the basis of phosphorus content.

7. Phosphate rock

Deposits of various types of phosphatic minerals exist in East Africa, and 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% P_2O_5 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 and temperature and rainfall are high. Conditions in our tea soils are favourable to a reasonable rate of release of phosphate. Powdered phosphate rock does not scorch foliage, bark, or roots if it comes into contact with them. Most of the other fertilizers in this list do so, to a greater or lesser extent. Do not confuse with guano, of various types, which is an animal product of very variable composition.

8. Muriate of potash (or potassium chloride)

This is mined from brine deposits and is purified to remove other salts, which are not usually deleterious. The potassium content ranges from 50 to 60% K_2O. (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. It should be bought on the basis of the potassium content and if a low-grade (less than 50% K_2O) product is offered, the Foundation should be contacted for advice.

9. Sulphate of potash (or potassium sulphate)
Of similar origin to the muriate, this salt contains two nutrients; potassium at 48 to 52% K_2O, 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 the sulphur, and also in its lesser tendency to scorch plant tissues.

10. Epsom's salts, Kieserite and magnesium oxide
Magnesium is not yet used as a general fertilizer nutrient in Kenyan tea, but it should be included in the present list. Both these compounds are magnesium sulphate. *Epsom's salts* is fully hydrated, and if heated strongly, it loses water to give the partially hydrated *kieserite.* Epsom salts crystals can lose some water in a dry atmosphere, to give a white powdery coating on the crystals. This is of no practical consequence and the fertilizer stores and handles well, remaining dry and free-flowing. Kieserite can absorb water in the store, and may cake badly. Epsom salts contains 10% magnesium (Mg) and kieserite 17% Mg. The sulphur contents are 13 and 23% S, respectively. Magnesium oxide is also available as a fertilizer with the advantage that it has a high content of magnesium (36%Mg or 60%MgO). On the basis of nutrient, it is cheaper than the sulphates.
The value of epsom salts for foliar application is discussed on page 114.

11. Gypsum (or calcium sulphate)
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.

C. Soil amendments
1. **S**ulphur (More details are given in Section k page 139).
The element itself is a yellow powder, or lumps, and can be used in tea growing as a soil amendment, to increase 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. Elemental sulphur is decomposed in the soil by micro-organisms, releasing sulphuric acid. This is a slow process, and roots can be damaged if they come into contact with high concentrations of decomposing sulphur. For other precautions which have to be taken when dealing with sulphur, see Sub-section (iv), below.
2. Aluminium sulphate (Not to be confused with alum) (see Section k for more details

This compound is primarily used for acidifying soil, and its sulphur content, 14% S, may be 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 they are reduced to small crumbs, or finer, the lumps may take months to dissolve in the soil.

3. Brimstone90 is a new amendment material for lowering high soil pH which is under test. It contains 90% sulphur and its main advantage compare to sulphur is ease of handling. It is also said to have high swelling properties when it comes into contact with moisture (about 32 times its volume) at the same time releasing active sulphur.

D. *General notes*

The above list contains fertilizers and soil amendments which are already familiar to the tea industry. New compounds and modifications of existing fertilizers are being developed and may come on to the market from time to time. Some may have names similar to a familiar fertilizer, but the properties may differ. This can be a confusing field, and reference should be made to the Foundation for guidance.

One omission from the list calls for explanation. Calcium ammonium nitrate is not recommended for use in tea. This is a mixture ammonium nitrate and calcium carbonate, and when the granules are moistened a chemical reaction can take place between the two components, ammonia being volatilised. A serious loss of nitrogen could be envisaged in this way, if the fertilizer is allowed to lie on the soil surface until sufficient rain washes the ammonium nitrate into the soil.

For some crops, it is known that the form in which a nutrient occurs in a fertilizer, its association with certain other fertilizer components has a marked effect on the efficiency of utilisation of that nutrient. In this context, considerations of solubility in the soil, and risk of scorching tissues, are taken into account in framing the fertilizer recommendations for tea in nurseries and in the first year in the field. Otherwise, few stipulations are made concerning the form in which nutrients are applied, as long as fertilizers from the above list are selected.

It is again stated that calcium ammonium nitrate is not approved as fertilizer for tea in Kenya.

(iv) Mixing and storing fertilizers

In the current situation where compound fertilizers are available at varying formulations and competitive prices, it is not envisaged that farmers would like to make their own mixtures. In addition, there is a commercial company (MEA Ltd), which specialises in the bulk blending of fertilizer and can produce any "formulation" desirable by the farmer. However, since the situation may change, the information on mixing of the fertilizer will be given.

1. Mixing

Economic considerations may arise in the future, which encourage the grower to mix straight fertilizers, rather than to use the convenient compound fertilizers. Or, to alternate the use of a high-analysis compound which may be available at a favourable price, with a straight fertilizer so that the final nutrient output conforms to the planned programme. This point is dealt with in a later sub-section (page 133).

No practicable difference in crop response is likely to be associated with a change from one type of nutrient formulation to the other, with two provisos. A few points of guidance are given.

Two granular fertilizers, or one granular and one coarsely crystalline, may be difficult to mix evenly. Inclusion of a powdered fertilizer may help to bind the various sized particles. Commercial organisations which market fertilizer mixtures on a large scale, may use non-fertilizer binding agents, as they are concerned to prevent the components from separating out during transport to consumer. The grower mixing his fertilizers on the spot does not have to go to these lengths. Examples of the efficiency of mixing are:-

Good: muriate or sulphate of potash, with sulphate of ammonia crystals.

Moderate: granular superphosphate with either of the two potash fertilizers.

Sulphate of ammonia crystals could also be added to the mix..

Poor: Crystalline sulphate of ammonia with granular superphosphate.

A mixture which may appear to be dry and free flowing, immediately after mixing, may not be suitable for use in mature tea, where it will run a risk of being wetted. Ammonium sulphate nitrate and urea, for example, are best to mixed with other fertilizers. If applied alone, the bags being opened in the field, they can usually be spread before they become sticky.

Home-made mixtures should be spread in the tea as soon as possible, to avoid the risk of caking or absorbing too much in the store. In general, granular fertilizers should to be crushed to make them easier to mix with other fertilizers. Their handling properties might deteriorate, to the point of giving a mixture which readily became sticky in the field.

Warning: if lump sulphur is to be crushed, for any purpose, no metal equipment or implements should be used. *A small spark can ignite sulphur dust, which burns violently.* Wood or concrete rollers should be used on a concrete or very hard floor.

2. Storage

It is wisest to assume that all plastic bags are damaged, and to keep the store dry. Jute or paper bags are more liable to absorb moisture, and special care should be taken to stack them on battens or stones, leaving space for air to circulate round, and especially below, each stack.

None of the fertilizers listed are dangerous, with the exception of the fire risk of sulphur. This applies only to sulphur itself. Fertilizers containing elemental sulphur intimately mixed, are perfectly safe. Some grades of ammonium sulphate and diammonium phosphate, are liable to evolve very small quantities of ammonia gas. The small may be objectionable in a small, unventilated store, but no danger is attached.

These notes on mixing and storage apply only to the fertilizers listed above. Growers may buy fertilizers for other crops which may not be compatible with some fertilizers in our list, for example, liming materials, which are not recommended for tea. If in doubt about mixing, contact the Foundation or other specialists. Also, consider the practicability of applying different fertilizers at different times, avoiding the necessity for mixing. This point is dealt with in Sub-section i (iv).

(c) Foliar application of nutrients

Leaves and young bark can absorb nutrients from solutions, suspensions or dusts of nutrient-containing chemicals which are applied to their surface. Depending on the particular nutrient, it can be transported elsewhere in the plant with greater or lesser efficiency. Tissue surfaces are physically and chemically active, and react with a variety of applied chemicals. Theoretically, a crop could be supplied with sufficient mineral nutrients through its foliage, to maintain its full development. In practice, the expense of applying sufficient solution of suspension to the foliage, restrict the agricultural use of this technique to the tackling of special nutritional problems.

Tea has been found to absorb a number of nutrients efficiently, when solutions or suspensions (in water) are applied as droplets to the upper surface of the leaf. During spraying, droplets will also lodge on the green bark of the youngest branches, and rain will wash some of the chemical deposits into the leaf axils. These notes apply only to the use of nutrient sprays, applied in relatively low volume to give a cover of small droplets without reaching the stage of run-off. Wetting agents and stickers are not essential for nutrient sprays applied to tea, and even in seasons of heavy rainfall the agricultural effectiveness of foliar sprays can still be worthwhile. Field tea can be sprayed during intensive sunshine, with not increase in the risk of scorching from concentrated solutions. Indeed, dull and humid conditions have sometimes increased scorching by certain solutions. Further guidance on this aspect is given below.

Where a rapid cure of a nutrient deficiency is required, especially for nutrients which are needed in low concentration in the tissues, foliar nutrition can be a useful technique. Where a nutrient deficiency arises because soil conditions do not permit efficient up take by the roots, foliar nutrition may become the best or only means of restoring balanced nutrition. The cure of zinc deficiency in tea, for example, has so far not been practicable through soil application of zinc compounds, but foliar spraying offers a rapid and efficient means of control. A similar finding has been made for copper deficiency in tea in Malawi.

Spraying solutions or suspensions of zinc compounds on to the foliage of tea, has been shown to be a very effective and practicable agricultural control measure.

The Foundation's recommendations are based on the results of experiments where hand-operated knapsack sprayers were used. Motorised-knapsack and aerial spraying can give a similar type of spray distribution, and results may be expected to be similar to those obtained from ordinary knapsack application. Dusting may present other problems, especially if the dust falls on to dry leaf which is then subjected to heavy rain within a few hours. The Foundation has no experience of the efficiency of the dusting technique.

Choice of zinc compound for foliar application

Two commercial zinc fertilizers have been tested and, weight for weight of zinc, have been found to be equally effective. Their properties in other respects differ, and may influence the choice.

Zinc oxide: 70% zinc

The oxide is insoluble in water, and a finely powdered "Spraying-grade" formulation must be used. Even so, spraying equipment with a built-in agitating device would be an advantage, to keep the oxide in uniform suspension.

Zinc oxide does not scorch tea foliage, and it is only necessary to use enough water to achieve a uniform distribution of the spray. This quantity has been found in practice to vary according to the equipment used, but may range from 20 to 200 litres per hectare.

Zinc sulphate: 22 to 24% zinc

The form recommended is the heptahydrate. More concentrated, partially hydrated forms are sometimes offered, but they can be difficult to dissolve under field conditions.

The heptahydrate is usually formulated as small, free-flowing crystals, which dissolve in water readily. The solution is sufficiently acidic to corrode metallic parts of spraying equipment, which must be washed thoroughly after use to reduce the rate of damage.

Tea is rather exceptional, in that up to a 5% concentration of zinc sulphate in water can be sprayed on to foliage of all ages without scorching. Inefficient mixing of the solution in the field is always a risk to be allowed for, and a solution more dilute than 5% would be preferable. Even dilute solutions can scorch if directed at foliage with too great a force from a motorised knapsack sprayer. The underside of a tea leaf has been found to be more susceptible to zinc sulphate scorching than the upper surface. The underside of the flush leaves, which do receive some spray droplets, are hairy and the droplets (which do not contain wetting agents) do not normally penetrate to the leaf surface itself.

(i) Recommended programmes for the routine application of zinc: Knapsack equipment

1. *Tea in plucking*

Either

Zinc oxide

Method: light foliar spray

Rate: 3 kg per hectare in 20 to 200 litres of water

Timing: repeat at approximately six-month intervals (see (ii) below)

Or,

Zinc sulphate

Method: light foliar spray

Rate: 10 kg per hectare in no less than 200 litres of water

Timing: repeat at approximately six-month intervals (see (ii) below)

2. *Young tea*
If regular plucking has not yet been established, and if zinc-deficiency symptoms are considered to warrant treatment, the above spray solutions and programmes can be adopted. In such a case there will be considerable wastage of the spray and, because a young plant has a small total leaf-surface area, an attempt should be made to cover each leaf with droplets (see (ii) 5). Do not spray so much solution that it runs off each leaf. It is not possible to state quantities which will be required per hectare, because of the various sizes of bushes according to age. The ratio of zinc sulphate to water must follow that given above (i) 1.

(ii) ***A guide to be timing of zinc foliar sprays***
1. It has been established that, if zinc-deficiency symptoms can be recognised in an area of seedling tea, there is a strong likelihood of an increase in yield if zinc is sprayed. This applies even though few affected shoots are detectable, and provides a valuable safeguard against the risk of incurring a major loss of crop before the cause becomes apparent to the grower.

2. For all practical purposes, the effect of one zinc application can be said to extend for less than six months. This pattern may permit a selection of spraying dates, to avoid increasing crops unduly during peak-cropping periods.
Experiments have shown that repetition of the zinc sprays, as set out in the programmes in (i) 1, causes similar yield trends. If the initial spray was made to tea suffering severely from zinc deficiency, it would be expected that the resulting increase in yield would be larger than those resulting from subsequent sprays. Apart from this, no evidence has yet been seen to suggest any progressive diminution in response.

3 Absorption of the zinc compounds, whether from the soluble sulphate or the insoluble oxide, into the leaf tissue is presumed to be influenced by the physiological activity of the leaf. Spraying should be done when the bushes are in a reasonably active state of growth. Leaf damaged by drought would not be expected to absorb nutrients efficiently. Bushes which were moderately damaged by hail have been shown to respond to zinc sprays, but if the damage has resulted in loss of whole leaves it would be preferable to wait for new foliage to develop.
In some districts of Kenya, a programme of two zinc sprays within one year one year will only be feasible if the phrase "at approximately six-month intervals" is given a very flexible interpretation. Seasonal considerations, for scientific as well as for agricultural reasons, must guide the actual dates of spraying.

4. Experimental evidence has shown that yield response can vary considerably in the few months after spraying. During cooler, lower-cropping periods, greater proportional benefits from the zinc have been recorded. This finding may not be of universal application, but there is at least preliminary evidence to support the idea that a zinc spray does not simply increase crops during rush periods.

5. Distribution of the spray should aim to give an even cover of small droplets on the leaves in the plucking table. Absorption through the upper surface of the leaf, and presumably through the green bark of the youngest shoots also, is clearly quite

efficient. The volumes of water quoted would not allow for spray liquid to run off the foliage.
Young tea, which presents a rather different problem, has been dealt with in (i) 2.

6. Spray residues may be more resistant to the action of rain if they have dried on the leaf surface before rain falls. Although experiments have suggested that this is not a problem of major importance, it would be prudent to avoid spraying during seasons of predictably heavy rain.

7. Where the overall spray programme permits, spraying should be done just after an area is plucked. Again, this is not a major problem, as discussed further in Sub-section (iii).

8. The first spraying in a pruning cycle should be timed to fall during a reasonable season, as discussed in (ii) 3, towards the end of the first quarter of the cycle. Observation of the occurrence of symptoms suggests that it would rarely be worthwhile to spray any sooner after tipping than this.
The characteristic pattern of yield response (ii) 2 suggests that spraying within about three months before pruning might not have time to produce a worthwhile yield increase.

9. The rates of use of zinc have been based on experimental data, but they replace far more zinc than is taken off in the crop. The question of a possible accumulation of zinc, to undesirable levels, has been and is continually under consideration. To-date, no evidence has come to light which suggests that a problem yet exists.

(iii) ***Considerations of zinc effects on human health and on manufacturing properties***

1. Zinc is not a toxic element, unless ingested in large quantity, but both zinc oxide and zinc sulphate are freely available in pharmaceutical preparations for external application to humans. It would be difficult to envisage a risk of toxicity to spray operators, even if they were grossly careless in handling the compounds.
To-date, little concern has been shown by official organisations over the zinc content of tea. Analyses have shown that residues on the flush plucked in the first round after spraying, do not add too greatly to the normal zinc content of the leaf. Thereafter, zinc contents of the flush have been found to show no appreciable relation to zinc spray treatments. The possibility of long-term accumulation of zinc will be studied as experiments continue.

2. No evidence is yet known to suggest that either manufacturing technology or tasters' valuation have been influenced by zinc spraying.

(iv) Combined sprays

It is natural to consider the practicability of adding other compounds to the zinc sprays, but care has to be exercised. A few guides are listed, to illustrate the nature of the problems.

1. *Copper additives*

Copper spraying has already been practised for several years, in a limited number of districts in Kenya where poor fermentation has been observed.

Copper sulphate may be added to a zinc sulphate solution, but not to the zinc oxide suspension, provided that the concentration of copper sulphate remains below 0.5%.

The Foundation has not experience of the value of copper-zinc mixtures as related to the cure of copper deficiency, but the cure of zinc deficiency appears to be efficient. Before using any mixture, growers should contact the Foundation for advice on experimental use, and it would be prudent to write to the manufacturers of the products, explaining precisely what is intended.

2. *Fertilizer additives*

By this term is meant compounds containing plant nutrients other than zinc or copper.

The zinc oxide suspension is readily destroyed when other chemicals are present, and in general it would not be advisable to consider mixing.

Zinc sulphate can react with the water-soluble phosphates in certain fertilizers, and the sediment may cause trouble in the equipment. Urea and either muriate or sulphate of potash may be mixed with zinc sulphate.

The use of sprays of other nutrients, has been restricted largely to visual observation of the cure of nutrient deficiency symptoms. At present, there appears to be little reason to consider this technique of applying those nutrients, to tea in Kenya. However, interest is sometimes expressed and suggestions for experimental use of nutrient sprays are given.

Urea, 46% N, is useful source of nitrogen. The risk of scorching foliage is very variable, for reasons which are not known, but a 2% solution (2kg urea in 100 litres of water) should be treated as a normally safe maximum concentration.

For other nutrients, suitable fertilizers and normally safe concentrations are: Diammonium phosphate 1%, primarily for its phosphorus content; sulphate of potash at 2% (muriate may be used, but the risk of scorch is greater); 10% epsom salts for both magnesium and sulphur.

If maximum output of nutrient per unit area is required, the volume of spray should not exceed that which just begins to cause the droplets to run together and drip off the leaf. This condition might well result in less nutrient-containing solution remaining on the leaf, than if the droplets had remained separate. Hand or motor-operated sprayers may be used. A spray delivered with considerable force from a motor sprayer is more liable to scorch the foliage. If the spray is properly directed, so that the mist from a motor sparer drifts across mature tea it may be found that more concentrated solutions than those listed can be used with less risk of scorch.

A motor sprayer would be wasteful for young tea, before a plucking table has been established. Foliar spraying might be considered as a means of applying small, but worthwhile, doses of nutrients to very young plants (Section h). In order to make full use of the limited leaf-surface area, a spray of fine droplets should be directed at all the leaves; again, run-off should be avoided as far as possible.

Proprietary nutrient mixtures, solid or solutions, are on the market, and may contain chemicals other than the simple fertilizers listed above. None have been intensively tested by the Foundation, and there is no immediate intention of doing so. Their effectiveness may be similar to corresponding mixtures of fertilizers. However, some contain special chemicals, which may enhance effectiveness under certain conditions, or which may require careful attention to detail if damage is to be avoided. The manufacturers' instructions should be followed.

The Foundation's recommendation to water fertilizer solutions on to nursery plants (Section f), does not constitute foliar nutrition. The solution is thoroughly washed off the foliage, before it has dried, because the risk of scorching small plants is to be avoided. Nutrients can be added to irrigation water, and, in overhead systems, some nutrients will be absorbed through the foliage. Most of the added nutrient will, of course, fall on the soil. This would be important if zinc or copper were the nutrients concerned, as it would mean that considerable wastage occurred.

Addition of nutrients to foliar sprays of insecticide or fungicide, infrequent operations in tea in Kenya, is at first sight a possibility. This should not be done, unless approval has been given by the manufacturer of the insecticide or fungicide, or by the Foundation. Some of the formulations are very sensitive to the presence of strong chemicals such as fertilizers, and their effectiveness may be destroyed.

For growers wishing to experiment, the Foundation will offer detailed advice. In general, growers should take precautions to filter solutions of fertilizers which are packed in jute bags, before filling the sprayers. Fibres are very effective at blocking the nozzles. Equipment must be washed thoroughly, immediately after use, as some of the chemicals likely to be used have a corrosive action on metals.

(d) Organic manures, composts and mulches

(i) Definitions

It is necessary to include a section on organic sources of plant nutrients, using the word "organic" in a restricted, agricultural, sense to denote materials which retain obvious signs of their plant or animal origin. Organic materials which have undergone manufacture, may not fit this definition.

Manure

Traditionally, the term "manure" has been applied to animal, rather than plant, residues, or mixture of both, but it is usually now used to describe a broad group of organic residues, with a sufficient content of plant nutrients to be worth using for that purpose alone.

Compost

This refers to mainly plant residues which have been specially treated before applying to a crop. The treatment is basically storage, in such a way as to cause decomposition. The process of decomposition leads to a rise in temperature of the organic mass. This is done to kill weed seeds or vegetative propagules, pests and disease organisms. Animal residues, soil, or fertilizers may be added, to hasten the biological decomposition.

Mulch

This describes materials, inorganic as well as organic, which are allowed to lie on the soil surface. Manures and composts can be used as mulches. A growing plant itself is not described as mulch.

(ii) Nutrient availability
Organic materials which are or can be applied to crops, vary enormously in their nutrient content, but are never as concentrated as the commonly used fertilizers. Materials differ greatly from each other and the treatment applied to each batch before application can also have effect. Exposure to rain can easily remove much of the nitrogen and potassium, and organic wastes from manufacturing processes may have only a small nutrient content. Even if a chemical analysis could be done, on each batch of material just before carrying to the field, this might still give an incomplete picture of nutrient efficiency. Nitrogenous compounds, for example, vary in their rate of decomposition in the field, and some which are estimated in the laboratory analytical technique, may be virtually unavailable to crops. Chemical analysis, if done, should be taken as a guide to the maximum supply of those nutrients, if ideal conditions prevailed for their release to crops.
Organic nitrogen compounds decompose at varying rates, and under certain field conditions this may be advantageous, compared to the rapid release of nitrogen from fertilizers. Organic compounds themselves can exert marked effects on soil conditions, which may in turn improve the availability of the nutrients to a crop. In poor soils, these benefits may be considerable. They can rarely be predicted, and there is no simple way of assessing a potential "fertility improvement" properly of an organic material, to guide the grower as to its worth. Testing the product in the field is the only reliable guide.

(iii) ***Nutrient losses***
Some organic materials, when used as a mulch, may decompose to form gaseous nitrogen compounds which are permanently lost from the field. This process is less likely to occur when the material is buried in the soil.
Organic materials which decompose rapidly or which are very low in certain nutrients, may cause a temporary loss of those nutrients from the soil. Nitrogen and to a lesser extent phosphorus, are the nutrients which are most affected, being required by the microbes, which bring about the decomposition, for their own tissues. When the process has reached its final stages, nutrients which have been locked-up by the increase in the microbial population, can again be released to the soil as the excess microbes themselves decompose. In the meanwhile, the crop may have suffered severe nutritional set-back. The Foundation warned against these risks, and the point is discussed further in Section h. Addition of nitrogenous fertilizer may avoid the worst risk, of inducing nitrogen deficiency in the crop.
Tea prunings, left in the field as a mulch, do not cause these problems. Soft green plant material in general should not be applied soon after cutting, unless fertilizer nitrogen is also added. Sawdust and some factory wastes may be so low in nutrients that their use as organic manure becomes of doubtful value, even if inorganic fertilizer nutrients are added.

(iv) ***Toxic effects***
Organic materials are not necessarily "safe". This warning is all the more needed, because a variety of products can be offered to the grower, as "manure". Apart from the danger referred to in (iii) above, there are other risks.

Residues from factories or farms may have alkaline or high pH value. Such materials are best avoided in young tea, and must certainly not be put into planting holes. Ash from burning organic matter is invariably of a high pH. The pH value of a material can be determined readily and promptly, and is an analysis worth doing where doubt exists. The Foundation will carry out pH determinations.

Manufacturing processes may add toxic materials to the wastes, and growers should insist on an analysis and an assurance from the manufacturer that a product is a safe in this respect.

Fresh animal droppings and urine can contain high levels of chlorides and ammonium compounds, which could damage young tea.

(v) ***The effect of organic materials on soil conditions***

This aspect, which may be the most important benefit conferred by organic materials in general, will be mentioned briefly.

Mulch

A much can modify soil temperature and moisture status, usually with benefit to the crop. A very thick mulch in the drier seasons however, may absorb light rains, to the detriment of the crop. Some mulches carry a fire risk, which should be check by the provision of gaps.

Placing organic materials in the planting hole is risk. Only well rotted composts or matured animal manures should be used, and care must be taken to mix the material with soil in the bottom of the hole, packing it firmly before the tea is planted. Organic matter, used as a mulch, or incorporated into the soil, usually improves the structure, in the sense that the soil forms aggregate which improve aeration and moisture retention together. The humus content of the soil, the highly degraded organic matter which is in intimate association with the mineral skeleton of the soil, is not necessarily increased. The opposite may occur, when organic materials are worked into the soil. The stimulation given to soil microbes can lead to a loss of the original soil humus, as well as the added organic matter. Mulching is often preferable to digging in organic materials, for the purpose of increasing soil humus.

(vi) ***The incidence of pests, diseases and weed infestation***

Mulches can often be used as effective suppressor of weed growth, but many types of organic material, whether used as a mulch or buried in the soil, can introduce weeds. Pests or disease organisms may also be introduced, or conditions in a much may be favourable to the build-up of organisms already present in the field. Compost must be properly prepared at high temperature, to reduce such risks.

(vii) ***General***

The Foundation does not recommend that a fertilizer programme should be influenced by the use of organic materials, in any of the above ways. The nutritional properties of each type of material, and of each batch within a given type, vary so greatly that general advice cannot be given. Qualified approval is given to the use of organic materials for their physical effects, subject to provisos as set out above, and the Foundation will advise as best as it can, if detailed queries are sent in.

SPECIFIC FERTILIZER RECOMMENDATIONS FOR VARIOUS TYPES OF TEA

(e) Fertilizers for mother bushes

Mother bushes are tea bushes which are used as regular sources of supply of cuttings. They are usually pruned at intervals of five to seven months and, when pruned, all the prunings are removed to the nursery to be made into cuttings.

Large amounts of nutrients are removed with these prunings; not only with the softer parts which can be made into cuttings and which probably contain similar amounts of nutrients to those removed by plucking, but especially with the hard parts which will not be made into cuttings but which contain larger quantities of nutrients than would be removed from plucked bushes.

Removal of nutrients from plots of mother bushes is consequently at a much greater rate than from similar areas of plucked tea, and they should therefore be given more fertilizer to keep them in a state of vigorous shoot production. Mother bush health not only affects the numbers of cuttings produced by the bushes, however, and it is known that bushes which are weak because of lack of nutrients (or because of pests, diseases, hail, drought, cold and the like) produce cuttings which strike less easily and which grow more slowly in their nursery than those from bushes which produce vigorous shoot growth after pruning.

Optimum amounts and kinds of fertilizer to be applied to mother bushes will vary from place and from clone. As a rule of thumb, it is recommended that 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 (see Mature Tea, Section i).

The fertilizers should be applied in at least two doses each year. If they are pruned every five to seven months, then the applications can be made two or three months after each pruning. But the time of application is not as important as ensuring that the fertilizer is applied, and when small numbers of bushes are being pruned each day it can be helpful to apply fertilizer to each bush immediately it is pruned. Also if there are chances of forgetting to apply fertilizer or if it is anticipated that two or three months after pruning there will not be rain, then the fertilizer should be applied immediately after pruning.

If practicable, any branch and shoot material left over after the cuttings have been prepared should be taken back to the mother bushes and placed on the soil surface as a mulch.

(f) Fertilizers for nurseries

(i) ***Seedling nurseries***

Placement

Seedlings have not responded to fertilizers which have been mixed with the nursery soil in experiments, and therefore fertilizer placement in seedling nurseries is not recommended.

If the nursery soil has a pH greater than 6.0, advice should be sought from the TRFK.

In areas where soils are known from past experience to be deficient in sulphur, sulphate of ammonia should be applied to the seedlings as described below.

Applications after germination

In areas where the soil is known from past experience to be deficient in sulphur, the seedlings should have fertilizer applied every four months starting as soon as the seedlings are 15cm tall. Every second application should be with sulphate of ammonia at the rate of 16g/m^2 ; the alternate applications should be with an NPK compound fertilizer (or mixture of straight fertilizers) with nutrient ratios 5:1:1, or more concentrated in P and K, and either with or without additional sulphur. This fertilizer should be applied at a rate to provide about 4g/m^2 of nitrogen (e.g. 16g/m^2 of 25:5:5 NPK, or 20g/m^2 of 20:10:10 NPK) on each occasion. An alternative is to apply diammonium phosphate at the rate of 7g/m^2.

In other areas, apply an NPKS fertilizer of a 5:1:1 ratio, or more concentrated in P and K, every four months starting as soon as the seedlings are 15cm tall. Each application should supply about 4g/m^2 of nitrogen. If the NPK fertilizer does not contain sulphur, every second application should be with sulphate of ammonia only, at the rate of 16g/m^2.

While the seedlings are short, the fertilizers can be applied in solution from watering cans at the rate of 1.3 litres/m^2, followed immediately by an application of water to wash the fertilizer from the foliage. Later it will be found more convenient to sprinkle the dry fertilizer over the surface of the soil, care being taken to spread the fertilizer evenly and to keep it off the seedlings, stems and leaves as far as possible.

N.B. Most supplies of NPKS are completely soluble in water. Sulphate of ammonia is also in water. Diammonium phosphate usually contains an inert-filler which will block sprayer jets if the solution is not decanted or kept well stirred.
Diammonium phosphate contains no sulphur and therefore where it is used, sulphate of ammonia should be applied in its place every third round to avoid the problem of sulphur deficiency.

(ii) ***Cutting nurseries***

General

Percentage strike and rate of growth of cuttings not only vary from clone to clone, but the performance of any one clone in the nursery is dependent upon the physical and chemical properties of the rooting medium, upon the amount and kind of fertilizer mixed with the rooting, medium, upon the combination of rooting medium and fertilizer, and also upon such factors as the density of shade in the nursery, the kind of cutting planted, the state of health of the mother bush, the time of year of propagation, and upon several other factors.
Only very general recommendations can therefore be given, and the optimum rooting medium and fertilizer treatment must be determined for each clone by experiments in each nursery site.

Placement

Cuttings should be planted into a layer of subsoil, 7.5cm thick, which contains single superphosphate mixed in at the rate of 600g/m^3 or 300g/m^3 of double/triple superphosphate.

Beneath this subsoil "cap", the rooting medium can be made richer by mixing in some topsoil and additional fertilizer. The optimum subsoil/topsoil mixture must be determined by experiment in each nursery; and it is important to ensure that the surface of this lower rooting medium is not so firmed and smoothed that there is a sharp boundary between it and the subsoil cap. There should be a transitional layer between the two.

The following fertilizers are suggested for mixing with this lower part for the rooting medium:

Forest soils	Single superphosphate	(600g/m^3)
	Sulphate of potash	(300g/m^3)
Grassland soils	Single superphosphate	(600g/m^3)
	Sulphate of potash	(300g/m^3)
	Sulphate of ammonia	(300g/m^3)
Exhausted soils	Diammonium phosphate	(600g/m^3)
	Sulphate of potash	(300g/m^3)

Applications after rooting

Fertilizers should not be applied until the cuttings have roots which are at least 10cm long. In practice, it is usually simplest to begin the applications as soon as a start has been made to removing the polythene sheeting which covers the nursery beds. The fertilizer should contain nitrogen, phosphate and potash.

These applications not only benefit the plants in the cutting nursery by improving their rates of growth, but he nutrient reserves which build up both in the plants and in the rooting medium are of great value to the plants for several months after they are transplanted to the field.

A simple and effective treatment is to make weekly applications of NPKS fertilizer in solution; 1g/m^2 of nitrogen in 1.3 litres of water. An immediate application of water should follow, to wash the fertilizer solution off the leaves of the young plants.

In districts where soils are known from past experience to be deficient in sulphur, every alternate application should be of sulphate of ammonia, also at 1g/m^2 of nitrogen (i.e. 5g/m^2 of sulphate of ammonia in 1.3 litres of water), which should also be washed off with water afterwards. Sulphate of ammonia and NPKS fertilizers are not foliar feeds and if they are left on the leaves to dry they might cause scorching.

When the plants are to remain in their nursery for long periods (e.g. over 12 months), the frequency of application can be reduced. Apply NPKS solutions as above for three months and then change to 4g/m^2 of nitrogen in 1.3 litres of water every month.

Proprietary foliar compounds can be applied if desired; they should not be washed off the leaves. These compounds are expensive.

N.B .The applications recommended above should not normally be exceeded. In many nurseries it will be unnecessary to make such frequent application, and judgement on the part of the grower is needed.

(g) Fertilizer placement in planting holes

If tea plants have been properly maintained in their nursery then, at the time of transplanting, they will contain reserves of N, P, K and S in their tissues and (in the case of sleeved plants) in the soil round their roots. These reserves help the plants to grow well after transplanting until the first field applications of fertilizer are made.

Nevertheless, in most parts of Kenya the transplants will establish and grow more quickly if superphosphate is mixed with the soil in the planting holes. Single superphosphate is preferable to double superphosphate because it contains sulphur, and should be mixed with the soil at rates which vary according to the size of the holes, as follows:

Size of planting hole **(Dept x Width)**	*Amount of single,* *(Superphosphate per hole*
45cm x 22.5cm	30g
50cm x 25cm	40g
60cm x 30cm	54g

Fertilizers must be thoroughly mixed with soil from planting holes (see Figure V. 1) on all soils except very rich and hutsite soils (pH 5.7 and other) (see Table V. 4).

Soils which have previously carried grass or unfertilized arable crops require nitrogen as well as phosphate, hence diammonium phosphate should be used instead of single or double/triple superphosphate. Do not use NPKS 25:5:5:5 on its own in the planting holes. The high nitrogen content can be harmful to young plants. If it is the only nitrogenous fertilizer available, it may be used in small amounts together with additional phosphate and potash in the quantities shown in Table V: 2.

Areas known to be deficient in potassium need a potash fertilizer in addition to the phosphate and inorganic nitrogen where tea follows grass.

In areas where the soils are known from past experience to be deficient in sulphur, gypsum should be mixed with the soil in planting hole in addition to single superphosphate. The application rate of the gypsum should be the same as for the single superphosphate. Other sulphur-containing fertilizers (see Table V. 1) should not be used.

Fertilizer for infills

In order to ensure that infills become established quickly, nitrogen, phosphate and potash fertilizers must be used in the planting hole in proportion to the size of the hole. Thus for a hole 60cm diameter by 60cm deep, use 115g diammonium phosphate and 115g sulphate of potash. Three months after planting NPKS 25:5:5 should be given to each plant to each at the rate of 50g per plant; and thereafter as applied to the rest of the field.

(h) Fertilizers for young tea

i) ***General***

Young tea is defined, for the purpose of this chapter, as being of any age from the time of transplanting to the time of pruning at the end of its first cycle of about three-years' plucking. During this period of about five years, the plants not only need fertilizer to supply nutrients to maintain their health, but extra fertilizer to encourage their

Fig. V:1
Mixing fertilizers with the soil from a planting hole

developing strong root and branch systems which will support vigorous cropping at maturity. Young tea plants therefore require at least as much fertilizer, for their size as when in full cropping.

The fertilizer should be a compound or mixture providing N, P, K and S in the proportions 5:1:1:1, or more concentrated in P and K, as for mature tea. (Section I).

Weeds and crops growing between the rows of tea plants will deprive the tea of nutrients, and so lead to reduced rate of growth by the young tea plants. It is therefore especially important in young tea that the soil be kept clear of weeds and that other crop plants grown in the tea are provided with fertilizer additional to that applied to tea.

Any convenient nitrogenous fertilizer should be applied broadcast to the soil surface, so as to provide nitrogen at the rate of 12kg/ha, immediately before mulch is first applied to a field. This is to compensate for the temporary loss of nitrogen from the soil while the mulch breaks down.

TABLE V: 2: Rates of fertilizer application: The application listed under (a), (b) etc. in each section are alternatives

Planting hole 20cm x 45cm				Planting hole 30cm x 60cm
Forest soils with pH below 5.7	a	Single superphosphate 30g	a	Single superphosphate 60g
	b	Double superphosphate 15g	b	Double superphosphate 30g
Grassland or pH below 5.7	a	Diammonium phosphate 15g	a	Di-ammonium phosphate 30g
	b	Sulphate of ammonia 15g Single superphosphate 30g.	b	Sulphate of ammonia 30g double superphosphate 30g
Soils in which potassium ia deficient and all soils into which tea is being replanted	a	Sulphate or muriate of potash 15g. di-ammonium phosphate 15g.	a	Sulphate or muriate of potash 30g di-ammonium phosphate 30g
	b	Sulphate or muriate of potash 15g. sulphate of ammonia 15g, single superphosphate 30g.	b	Sulphate or muriate of potash 30g, sulphate of ammonia 30g, single superphosphate 60g
	c	Sulphate or muriate of potash 15g, sulphate of ammonia 15g, double superphosphate 15g	c	Sulphate or muriate of potash 30g double superphosphate 30g
	d	NPK 25:5:5 12g, sulphate or muriate of potash 14g, single superphosphate 22g	d	NPK 25:5:5 24g, sulphate or muriate of potash 28g, single superphosphate 44g
	e	NPK 25:5:5 12g, sulphate or muriate of potash 14g, double superphosphate 11g Sterameal 60g	e	NPK 25:5:5 24g, sulphate or muriate of potash 28g, double superphosphate 22g Sterameal 120g
Organicfertilizer for all soilsw pH below 5.7				
		Alternatively, farmyard manure or other available material may be used. The amount to be used will depend on the analysis of the analysis of the material		

Triple superphosphate can be used at the rates quoted for double superphosphate.

(ii) First-year tea

1. Stump plants

Transplanted seedlings and clonal stumps are leafless and have bare roots. They cannot respond efficiently to fertilizers until they have developed new roots and shoots. Fertilizers should not be applied to stump plants, therefore, until about six months after transplanting.

The first application at about six months and subsequent ones at about eight-week intervals should each provide 2g of nitrogen per plant. Applications should not be made during periods of drought.

Thus there should be three or four applications in the second half of the first year, to give a total of 8g nitrogen per plant. In some districts it might be necessary to reduce the interval between successive applications to as little as four weeks; the last application can be increased to 3g nitrogen per plant; but no further adjustment should be made, even if some applications have to be omitted.

Spread the fertilizer round each plant in abroad ring, never less than 10cm wide. The fertilizer must not be allowed to touch the plant's stem, and the ring should therefore be extended from 5cm from the plant stem to just beyond the spread of the shoots. The fertilizer should be dibbled into the soil to a depth of 5cm. If necessary, move back any mulch so that the fertilizer can be applied, and replace it afterwards.

2. Sleeved plants

Sleeved seedlings and clonal plants have leaf shoots and active roots, and can respond to fertilizers which are applied six weeks after transplanting. Delay beyond this time is unnecessary and can reduce the growth potential of the plants, but the growth of plants of this age be checked by applications of even as little as 12g of NPK fertilizer.

The plants should therefore be given small but frequent applications. Each application should provide 1.5g nitrogen per plant. The first application should be six weeks after planting and subsequent ones at about eight-week intervals during the remainder of the year, to give a total of about 9g nitrogen per plant. Applications should not be made during periods of drought. In some district it will be necessary to reduce the interval between successive applications to four weeks and to increase the last application to 2g nitrogen per plant, but no further adjustment should be made even if some applications have to be omitted.

The fertilizer should be dibbled into the soil in a broad ring round each plant, but not touching the plant's stem, as described above for stump plants.

Some growers might find it more convenient to spray the foliage of these young plants with proprietary foliar nutrient compounds. In addition, poorly established plant might respond more rapidly to foliar applications than to ground applications of the more usual fertilizers. The Foundation will be placed to offer advise to growers who wish to test this technique.

(iii) Second-year tea

During the second 12-month period after transplanting, both stumps and sleeved plants should be fertilized in the same way; both will benefit from having several small applications rather than a single large application.

The total application during the year should supply about 120 kg/ha of nitrogen. This can be given in three applications of 40 kg/ha of nitrogen or (in areas with two wet seasons) in four applications of 30 kg/ha of nitrogen. It the plants are seen to be growing very vigorously, this can be increased to four applications of 40 kg/ha of nitrogen at about three-month intervals. Do not apply the fertilizer during periods of drought, and do not have less than eight weeks between two successive applications.

(iv) Tea in its third, fourth and fifth years

In areas which have a single rainy season the fertilizer can be given in a single application, preferably at the start of the rains (see Section i). In areas with two distinct rainy seasons it is preferable to give two half-applications, one at the start of each rain season. Fertilizer should not be supplied during periods of very heavy rainfall, as some of the nutrients will be lost by surface run-off.

The fertilizer should be broadcast over the soil surface, avoiding the area immediately around the plant's stems, and should provide a total of about 180 kg/ha of nitrogen in the third year after planting and about 230 kg/ha of nitrogen on the fourth and fifth years.

If the plants are seen to be growing very vigorously, the applications can be increased according to the observed vigour of the tea, as indicated in Table V.3.

Larger applications than those given in the table can be made if the tea plants are seen to be growing very vigorously. Lager applications can also be made if the plants are growing in soils which have become impoverished because of erosion, lack of fertilizer in earlier years, cropping with other species before the tea was planted, grazing, or a long history of being under uncultivated grass. In both these situations, the amounts in the table can be increased by about 25 per cent in the second and subsequent years.

TABLE V.3: Amounts of nitrogen to apply each year to young tea

	Seedlings		Clonal plants	
Year from planting	1 wet season	2 wet seasons	1 wet season	2 wet seasons
1st (stumped)	4 x 2g/plant	4 x 2g/plant	4 x 2g/plant	4 x 2g/plant
(Sleeved)	6 x 1.5g/plant	6 x 1.5g/plant	6 x 1.5g/plant	6 x 1.5g/plant
2nd (all plants)	3 x 40 kg/ha	4 x 30 kg/ha	4 x 40 kg/ha	4 x 40 kg/ha
3rd (all plants)	1 x 180 kg/ha	2 x 90 kg/ha	1 x 200 kg/ha	2 x 100 kg/ha
4th (all plants)	1 x 230 kg/ha	2 x 115 kg/ha	1 x 250 kg/ha	2 x 125 kg/ha
5th (all plants)	1 x 230 kg/ha	2 x 115 kg/ha	1 x 300 kg/ha	2 x 150 kg/ha

(i) Fertilizers for mature tea

(i) Type of fertilizer

There is much to be said for the adoption of a standard nutrient formula, as long as it is realised that this is done for convenience. No one formula could be the most efficient for all types of tea culture, under our range of soils and climates. Following the initial use of nitrogen and sulphur in our tea, in 1963 the Foundation recommended the consideration of phosphorus, followed within a years by the addition of potassium to the list of desirable fertilizer nutrients. Eventually, this led to the adoption of a single-formula compound fertilizer, 25:5:5:5 referring to the percentage of N, P_2O_5, K_2O and S respectively. This formula is now considered to be rather low in potassium for some areas as, depending on the rate of use of fertilizer, less potassium may be replaced than is removed. Under present economic conditions, it has been decided to accept this possibility, and to rely on the chemical analysis of leaf to follow changes in the potassium status of the bush. The use of supplementary fertilizers is an accepted part of our general fertilizer advice.

The Foundation continues to recommend the use of a fertilizer formula approximating to 25:5:5:5, as the basis of a mature-tea fertilizer programme.

This formula may be achieved,

(1) by the use of a compound fertilizer

(2) by mixtures of straight fertilizers

(3) by alternating compounds with straight fertilizers. This may be done either within an annual programme, or in certain cases on a cycle basis (see iv). As an example, the compound fertilizer 20:10:10 may be used to supply half the nitrogen requirement, with sulphate of ammonia to supply the balance.

It is emphasized that economic considerations should be taken into account when making such decisions.

(ii) Rate of use of fertilizer

For higher-yielding tea, growers are invited to test the yield/fertilizer relation under their own ecological and cultural regimes, and the new "Paired-Plot Technique" is fully explained in Section m. This would mean in practice, that fertilizer applications averaging above 200 kg N per hectare per annum should be also tested.

Experiments of a more formal nature have shown clearly that the relation between crop obtained and level of fertilizer nutrient applied, cannot be written down in a form that has general advisory applicability. A rule-of-thumb recommendation that served its purpose in earlier years, by relating the quantity of fertilizer advised to anticipated yield, is no longer adequate to meet the more exacting needs of the present.

Advice for lower-yielding tea (not immature, developing bushes) can be based to some extent on our experience of he response shown over the years by what is now high-yielding tea. If little or no regular fertilizer application has been made, level of 90, 150 and 200 kg/ha of N per annum are suggested for the first three years respectively. The full yield benefit may not be seen within the first few years of increasing fertilizer doses. Provided the cultural management allows adequate frame and foliage to develop, and aims to lessen or prevent root damage, the bush should eventually build up a capacity to convert increased fertilizer nutrients into increased crop. Once poor tea has shown an improvement, the paired-plot technique can be considered, in the fourth or late years of such a rehabilitation programme, to determine if it is economic to exceed the annual dose of 150 kg N.

(*iii) Time of application of fertilizers*

Insufficient experimental evidence has accumulated to support firm advice on this point, but the following suggestions can be given. Tea under severe nutritional stress should receive a curative fertilizer application as soon as practicable. One provision is that, if nitrogen is the nutrient which is deficient, fertilizer application should wait until the grower can be sure that rain will follow within a few days. Phosphatic and potassic fertilizers run little, if any, risk of loss by chemical or biological means if they remain on the soil surface in dry weather.

Normal fertilizer applications should avoid prolonged cold or wet seasons, and if they are made during dry weather they should be delayed until it appears that rain will fall within a few days.

The first application in a pruning cycle should be the time of tipping, whether the normal fertilizer or a supplementary fertilizer to remedy mild deficiency is concerned. It is assumed that all prunings will be left in the field and decomposing pruning-leaf and soft twig will return nutrients to the soil, making it unnecessary to add to this before tipping. It is also noted that there is risk of the nitrogenous fertilizer components reacting with a fresh mulch, possibly resulting in lowered efficiency of this nutrient. The more highly weathered mulch at tipping time could be considered to be safer in this respect.

The timing of the last application in a cycle would depend on the anticipated cropping pattern in the last few months. An interval of less than six months before pruning may be too short for full benefit of the fertilizer to be shown.

Severe nutrient deficiency can retard recovery from pruning. More than one nutrient is known to have this effect. If the cause is detected in time, it would be preferable to make a fertilizer application before pruning, rather than after. The time interval before pruning should be several months, and if the vigour of the bush is very poor, pruning could well be delayed until there is evidence of improved growth.

Once a bush is in reasonably balance nutrition, there is no evidence to show that heavy application of a fertilizer nutrient can improve recovery from pruning.

It is realised that practical considerations may overrule some of these suggestions. The first consideration should always be given to planning a fertilizer programme that allows efficient and even distribution of the fertilizer.

(iv) Split applications

No evidence is available to support a recommendation to split an annual fertilizer allocation for mature tea. Purely practical considerations may, however, make this an attractive proposition. Such experimental evidence as does exist, suggests that the overall effect crop would be small if any.

A programme based on a high-analysis compound fertilizer plus a straight fertilizer could conveniently be planned so that the fertilizers were allocated to different seasons. If so, it is advised that the multi-nutrient fertilizer be applied before the main cropping season. Also if it can be conveniently arranged, the same fertilizer should be allocated to the last application a cycle.

Splitting the annual fertilizer programme may be adopted in order to lessen the risk of increasing already excessive crop in certain seasons. If this is done, the overall efficiency of the fertilizer may be reduced, in terms of quality of crop produced.

(v) Relations between fertilizer uptake and cultural treatments

Cultivation, the practice of deep hoeing, to control weeds, also destroys a large proportion of the finer roots of the tea. In itself, and quite apart from any possible relation to nutrient uptake from the soil, this is considered to be harmful to the bush. Undoubtedly nutrient uptake is hindered, but it not possible to say that one nutrient is affected more than another is. Formerly, it was conjectured that phosphorus uptake was great reduced. In fact, the results of the Foundation's field experiments show a greater yield response to phosphatic fertilizer before mechanical weed-control ceased, than was recorded after. Vigorous disturbance of the top-soil may be expected to increase the leaching of nitrogen and potassium to lower layers, thus leaving an impoverished top-soil into which the new roots have to grow.

The Foundation's fertilizer recommendations apply equally to tea growing in disturbed or undisturbed soil.

Mulch: It is well established, for other crops, that mulch (Section d) can influence the nutritional status of the crop plant. Reports showed that more than one nutrient could be affected. Evidence on this point, for tea in Kenya, is beginning to accrue, and the results show clearly that it is not possible to associate just one nutrient with the beneficial effects of mulch, which have been recorded in certain experiments. This is a highly complex line of study, and until the position is clarified, our general fertilizer recommendations are uninfluenced by considerations of mulch effects, with two provisos. The possible harmful effect of mulch in young tea, and in mature yea soon after pruning, is dealt with in Sections h and i.

Recovery from hail damage. In some districts this problem has to be considered, as a possible factor affecting a fertilizer programme. Experiments in fields, which have been severely damaged, have now shown that recovery appeared to be as good in tea in poor nutrition, with respect to various nutrients, as in tea that had received heavy applications of nutrients.

The Foundation no longer recommends a special application of NPK fertilizer to follow immediately after severe hail damage, with an assumed purpose of assisting bush regrowth.

There would also seem to be no basic reason to postpone an already planned fertilizer application, if this were found to fall due within a few weeks after a hailstorm. Only if the severity of damage was such that twigs had been destroyed, would it be prudent to delay the fertilizer until appreciable bud-break had appeared.

Relation to drought effects. Experiments have shown that fertilizer can help to maintain a higher level of cropping into a drought, until the soil water reserves are exhausted. Fertilizer nitrogen is beneficial in this respect, but no recommendation is made to supplement the normal fertilizer programme because the anticipated additional return of crop would be low.

Similar remarks apply to the recovery of bushes damaged by drought.

Relation to shade. A certain amount of experimental evidence has been obtained in Kenya, to suggest the potential yield response to fertilizer is reduced if the tea is interplanted with shade trees.

(vi) ***Relations between fertilizer use and manufacturing properties***

This will be covered under tea manufacturing section. (see page 212)

(vii) ***The role of nutrients other than NPKS***

Apart from zinc and copper, which are dealt with in pages 115 and 118, respectively, no other nutrients are at present considered to be necessary additives to our general fertilizer programmes. A brief discussion of the part played by certain nutrients would seem to be necessary, to put the contents of this present Chapter into perspective.

1. Calcium. Confusion has often arisen over the part played by calcium in the nutrition of tea. It is essential to the growth of all plants. Soils which are of too high a pH, or too alkaline, for tea to grow properly usually do contain high levels of **calcium**, but it is not necessarily only the calcium content which raises the pH, or is solely responsible for the harmful effects on the tea.

Chemical analysis of leaf has shown, in more than one experiment, that the use of high-calcium fertilizers has not depressed the uptake of other nutrients appreciably. This is an important point, which has a bearing on our current recommendations for the use of single superphosphate and gypsum, both containing calcium, in large quantity for young tea (Sections f and g). Several years ago, calcium ammonium nitrate was found to be of low efficiency for tea, under certain conditions. The supposition then was that its calcium content had upset the balance of mineral nutrition. This was never substantiated by chemical evidence, and should be considered not proven. A more likely reason for the poor performance of this fertilizer has been given in Section

2 Magnesium. Many species of woody perennial crops show magnesium deficiency symptoms in their juvenile stage. If the symptoms (an easily recognised yellow pattern working in from the leaf margins to near the mid-rib remain on the lower leaves of young tea, there is reason to believe that overall growth is not greatly affected.

If symptoms are seen high on free-growing shoots, or on mature leaves in the plucking table, curative measures are probably worthwhile. For this purpose, magnesium fertilizers must be used, and the Foundation will advise on request.

It is not likely that levels at which other fertilizer nutrients are used in tea, will induce magnesium deficiency in reasonably fertile soils. In some other agricultural systems high levels of potassic fertilizer have occasionally reduced magnesium deficiency. For tea, the fact that the rate of use of potassium is, by general standards, not high is no reason to suspect an interaction between potassium and magnesium under our conditions.

3 Manganese. Although this is an essential nutrient for all crop plants, in very low concentration, there are cases where its presence in larger concentration may prove toxic. This has been found in many crops and has occasionally been suspected in tea, where leaf contents of manganese can reach extremely high levels. No proof of toxicity has been established, and it is known that tea of the greatest vigour can apparently maintain this state while still absorbing manganese in high quantity. This point is mentioned again in the next sub-section, on soil acidity.

(viii) Soil acidity in relation to fertilizer use

It is known that much of our tea in Kenya is growing in soil of high acidity, and pH values as low as 3.7 are not uncommon. According to the conventional way of denoting acidity by the pH scale, the greater the acidity, the lower is the pH number. All the nitrogenous fertilizer that we are likely to be able to use are acidifying in their reactions within the soil. The soil itself exerts a buffering effect, and at high acidities this serves to limit the level to which the pH value will fall. No evidence has yet been found, to suggest that such high acidity can directly damage tea. This problem and others dealt with in this section on secondary fertilizer nutrients, has been studied in several tea-growing areas of the world, without any firm conclusions being reached.

An important practical consideration is the cost of any soil-amendment treatment which would be needed to reduce the acidity appreciably, even if the optimum pH value of a field soil were known. This is not known, even approximately, and this aspect of the problem is usually rejected in favour of another approach. Under highly acid soil conditions, the loss of certain nutrients may be aggravated. Potassium, calcium and magnesium may be washed out more readily, while phosphorus may be fixed chemically, in forms of low availability to plant roots. Manganese on the other hand, may come into solution in excessive amounts. If tea culture has to cope with highly acid soils, general fertilizer programmes will have to be based on the understanding that specific problems may still arise for several nutrients. Intensive tea culture will be expected to accelerate the onset of individual problems.

The mulch resulting from tea prunings, or from the natural leaf-fall, is mildly acid, with a pH value in the range 5.5 to 6.5. It had formerly been supposed that such a mulch would check, or even reverse, the fall in soil pH values. Detailed investigation has shown that this is not so. Even the uppermost, very shallow, layers of soil under a heavy tea-leaf mulch have very low pH values. Mulch composed of other materials may not behave in the same way.

The Foundation's fertilizer recommendations are not adjusted to take account of soil acidity. The special cases where the soil is not sufficiently acid for tea to grow properly, are dealt with separately. Specific nutritional problems resulting from high acid soils will be treated individually, and would only influence our general advice if the extent of the problem warranted this.

(j) Fertilizers for seed bearers

To enable the best use to be made of fertilizers, the fertilizers should be applied to the soil into which the roots of the seed bearers will grow, and not only to the soil in which the roots are already established.

The area of application should form a circle round the seed bearer. The radius of this circle should be increased annually until neighbouring circles meet whereupon broadcast applications should be started.

Two types of fertilizer applications are suggested, one for potential seed bearers and the other for fruiting seed bearers.

(i) Fertilizers to potential seed bearers

In the first year after planting, potential seed bearers will be fertilized according to the kind of planting material used.

1. Seedling stumps

Start applying NPKS 25:5:5:5 fertilizer to the plants six months after planting (or in the rainy season following the planting season). During the second half of the first year after planting make three applications each of 6g of fertilizer per plant (i.e. 1.5g of N per plant) in a broad ring round each plant, no nearer than 10cm from the stem and extending to 30cm from the stem.

2. Sleeved clonal plants

In the areas with one long rainy season make six applications of NPKS 25:5:5:5 fertilizer to the plants during the first year after planting. Each application should be 6g of fertilizer per plant as for seedling stumps. These applications should be made at weeks 6, 14,22, 30, 38 and 46 after planting. In areas with bi-modal pattern of rainfall (two rainy seasons a year) the applications should be made three times, at monthly intervals from six weeks after planting, during the wet season.

The fertilizer is applied in a broad ring round each plant; no nearer than 10cm from the stem extending to 30cm from the stem.

In the second year after planting, fertilizer at the rate of 30g of NPKS 25:5:5:5 per plant is applied four times to each plant. It is suggested that in areas with one long rainy season the four applications should be in June, September, December and March. In areas with two rainy seasons it is suggested that there should be two applications in March-May and two in September-November, but the period between two applications should not be less than six weeks. Fertilizer is applied in a broad ring round each plant; no nearer than 10cm from the stem and extending to 40cm from the stem.

In the third and subsequent years, two applications are made per year (one in April and one in October), each of 180kg of N/ha. These applications should at first be made separately to each tree in an annular area bounded by two circles round the tree. The area of this annulus will increase as the plants grow larger; it will be related to "r" (the mean radius of trees, from the stem to the edge of the shoot system, as determined from a fair sample of the trees in the barie). The inner boundary of the annulus will be a distance of $r/_3$ from the stem (inside this circle o fertilizer will be applied); and the outer boundary will be a distance $4r/_3$ from the stem. Hence the area of annulus will be 5.236 (r^2).

The amount of nitrogen to be applied within the annulus is found from the equation A = 90 (r^2 where A is in grams and r is in metres.) For example, the amount of NPKS 25:5:5:5 fertilizer will be 360 (r^2) grams per plant on each of the two occasions each year.

The mean tree foliage radius must be determined before each of the periods of application.

These data are summarised below:

Distance (in metres) from trees stem				
Edge of foliage	*Inner edge of annulus*	*Outer edge of annulus*	*Amounts (grams) per tree on each occasion*	
"r"	*r/3*	*4r/3*	*25:5:5:5*	*N*
0.50	0.17	0.67	180	45
0.67	0.22	0.90	240	60
0.75	0.25	1.00	270	68
1.00	0.33	1.33	360	90
1.25	0.42	1.67	450	112
1.50	0.50	2.00	540	135
1.75	0.58	2.33	630	158
2.00	0.67	2.67	720	180

When the outer edges of neighbouring annuli meet, the fertilizer should be spread broadcast over the whole barie (excluding an area extending to 50cm from the trunk of each tree) at the rate of 180kg of N/ha twice a year, in April and October.

3. Grafted seed bearers

The spread of the roots of grafted mature plants is related to the spacing of the plants before grafting. Therefore the fertilizer application to the grafted seed bearer the first two years after grafting should be related to the spacing of the plants before grafting rather than the size of the scions. The rate fertilizer in the first two years after grafting should be the same as that of third year of sleeved clonal plants, i.e. 180kg/ha of N, applied twice a year. This fertilizer should be applied in an annular area bounded by two circles round the tree. The inner ring should not be nearer than 10cm from the stem and the outer ring should stretch to half-way between the grafted plant and the bigger distance between the neighbouring plants before removal, that is if the spacing of plants before grafting was 1.2m x 0.91m, then the outer ring from the stem should be 0.6m. Where the spacing was 1.5m x 0.75m, then the distance between the stem of the grafted plant and the outer ring should be 0.75m.

After the second year the area of the annular ring will be related "r" as shown above.

Once the trees begin to bear fruits, the fertilizer rates should be changed accordingly, as shown below.

(ii) ***Fertilizer to fruiting seed bearers***

Fruiting seed bearers will need less N, but more P and K, than trees that are not yet producing fruits. They should be fertilized twice, in April and October. On each occasion they should be given the following:

N : 125kg/ha in the form of NPKS (or NPK) fertilizer

P_2O_5 : 60kg/ha in the form of NPKS (or NPK) and single, double or triple superphosphates.

K_2O : 60kg/ha in the form of NPKS (or NPK) and sulphate or muriate of potash.

An alternative is to apply NPK 20:10:10 fertilizer, based on the same of N as given above.

These fertilizers should be applied in the same way as described above for seed bearers before fruiting. These *nutrient* applications can be summarised thus:

Distance (in metres) from the stem			*Amounts (grams) of nutrients per tree on each occasion*		
Edge of foliage (r)	*r/3*	*4r/3*	*N*	*P_2O5*	*K_2O*
1.00	0.33	1.33	60	30	30
1.25	0.42	1.67	100	45	45
1.50	0.50	2.00	140	70	70
1.75	0.58	2.33	190	90	90
2.00	0.67	2.67	250	120	120
2.25	0.75	3.00	320	150	150
2.50	0.83	3.33	390	190	190
2.75	0.92	3.67	470	225	225
Formulae for application rates per tree			$(62.5r^2)$g	$(30r^2)$g	$(30r^2)$g
Broadcasts rates			12.5g/m^2	6g/m^2	6g/m^2

The above amounts of nutrients must be multiplied by the appropriate factors to convert them to amounts of fertilizer. Thus:

25:5:5:5 NPKS	multiply N amount by 4.0
20:10:10 NPK	multiply N amount by 5.0
Single superphosphate	multiply P_2O_5 amount by 2.5
Double (triple) superphosphate	multiply P_2O_5 amount by 2.5
Sulphate of potash	multiply K_2O amount by 2.0
Muriate of potash	multiply K_20 amount by 1.7

(k) Treatment of hutsites and soils of pH higher than optimum

(i) Tea establishment

Tea thrives best in soils of pH between 5.0 and 5.6. Tea is difficult to establish in soils of higher pH. Many clones have been found to grown poorly in soils of high pH. Soil pH can be reduced in a number of ways, if it is necessary to do so, as follows:

1. Leaching

Soil kept clear of vegetation and exposed to high rainfall will lose nutrients over a period of time and the pH will fall, but this may take several years if the soil is of very high pH and contains an abundance of bases. To keep land absolutely clear of vegetation is expensive, and the soil is likely to be severely eroded.

2. Cropping

If plants with a high base nutrient requirement are grown, the amount of base nutrients in the soil is reduced. This has been done on hutsites using Cannas, Napier Grass or Guatemala Grass. In these special circumstances a food crop, even maize, can be used; the best tea areas on some rich volcanic soils (e.g. Mount Elgon, where the pH is normally about 6.0) are those which have been used for maize for many years. Less rich soils can be exhausted by extensive cropping and require fertilizer before they will grow good tea. Soil tests will establish the soil status.

This method is relatively slow; several years may be necessary. It also requires careful management as every piece of vegetable growth must be removed from the site. Any leaves etc. which fall on the site and rot down merely return to the soil nutrients which were removed by the plant prolong the process. Judicious use of sulphate of ammonia may hasten the process by promoting growth.

3. Sulphur

Sulphur acidifies soil relatively quickly and experiments have shown that it improves the rate of growth of tea bushes very considerably.

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. *Do not* try to grind sulphur in any type of mechanical mill - ***it will catch fire!***

For field planting, dig holes 46cm in diameter by 76cm deep at the site of each bush. A tractor-operated post-hole digger can easily do this where a tractor can be put on the land. The crushed sulphur must be thoroughly mixed with the soil from the holes before the soil is returned to the holes. The quantity of sulphur required depends on the pH, as follows:

pH	Sulphur per hole
5.9 to 6.4	115g
6.5 to 6.9	225g
7.0 to 7.4	340g
>7.5	not worthy treating

Sulphur takes time to reduce the pH of the soil, and this must be allowed for when planting. Stumps planted before the sulphur has reduced the pH sufficiently will die. The length of time to be allowed between sulphur application and planting depends on the amount of sulphur; allow at least months for each 115g of sulphur used. Sleeved plants can be planted sooner after sulphur application in some soils, but only if experience shows that this is safe in any particular soil.

The soil replaced in the holes will take time to settle down. If there is sufficient interval between application and planting the soil will have settled. However, sleeved plants are planted very shortly after application, maintain the soil level around the plants so that the plants are not growing in depressions after the soil has settled. Also inspect regularly to ensure that the soil has not settled and left the roots exposed.

4. Sulphate of ammonia

This chemical acidifies soil quickly. However, experiments have shown that if it is mixed with soil before planting it reduces the rate of growth of tea, both stumps and potted plants, and has been known to kill plants. Therefore, do not attempt to improve hutsites by treatment with sulphate of ammonia prior to planting.

5. Aluminium sulphate

This chemical will acidify soil without adverse effects on tea. It is very soluble in water, and easily available as it is used for varying water supplies. 450g of aluminium sulphate has the same effect as 115g of sulphur.

(ii) ***Treatment of tea established on hutsites***

Where tea is growing but not thriving on hutsites, the best treatment is to apply aluminium sulphate: 450g per square metre placed on the ground every three months for a year is usually adequate. The chemical should be spread as evenly as possible. The commercial material is usually in the form of large, very hard lumps and breaking these is difficult, but they dissolve quickly in soil moisture. The lumps will have to be spread as evenly as possible. It is sometime possible to buy the "kibbled" grade of aluminium sulphate; this is preferable as it has been broken down to small pieces.

Sulphur should not be applied as a surface dressing to sites already planted with tea.

Sulphate of ammonia is beneficial because it acidifies the soil in addition to providing nitrogen. However, very large quantities are needed to reduce the pH of hutsite soils quickly. It is quicker and cheaper to use aluminium sulphate to reduced the pH and use sulphate of ammonia purely as a nitrogen source.

In most cases where tea has been established using sulphur or aluminium sulphate as described above no problems arise later. The reduction of pH due to leaching usually ensures that the tea roots are able to continue growing outside the treated soil of each planting hole. A further safeguard is to apply nitrogen as sulphate of ammonia.

Occasionally the tea roots will into grow into untreated soil, and as a result growth is slowed down and plants may die when they have been in the grown for about a year. This usually happens where the pH initially has been very high. When the initial pH is over 7.0, the pH of the untreated soil between planting holes should be measured 6 months after planting. If it is over 6.5, the whole area should be treated with aluminium sulphate, 450g per square metre, with applications at three-monthly intervals until tests show that the pH is below 6.0.

(iii) ***Nurseries on high pH soils***

The nursery should be established in an area with suitable soil pH, hence it is necessary to have soil pH tests of the various areas on the farm until a suitable area is identified. Where it is necessary to reduce the pH of the soil of a nursery where the plants are already growing, aluminium sulphate can be watered on. Apply at the rate of 30g per square metre at monthly intervals.

If soil of high pH is to be used for a stump nursery, sulphur must be dug in the soil over the full depth of 75cm. The amount of sulphur depends on the pH; the quantity required and the time which must elapse before planting are listed in Table V: 4. The minimum quantity is just adequate for seed nurseries but results will be better if more sulphur (up to the maximum) is used.

For vegetative propagation, the soil must be mixed with the maximum quantity of sulphur given in Table V.4 and left for at least the minimum time before cuttings are planted. However, the best and easiest way is to transport to the nursery soil of suitable pH from another part of the farm estate.

TABLE V: 4: Treatment of high pH soil for nursery use

Sulphur addition, grammes per cubic metre

	Minimum		**Maximum**	
pH	*Sulphur*	*Minimum time between treatment and planting (weeks)*	*Sulphur*	*Minimum time between treatment and planting (weeks)*
5.0	-	-	-	-
5.1	-	-	60	1
5.2	-	-	115	2
5.3	-	-	170	3
5.4	-	-	225	4
5.5	-	-	285	5
5.6	-	-	340	6
5.7	-	-	395	7
5.8	-	-	450	8
5.9	60	1	510	9
6.0	115	2	565	10
6.1	170	3	620	11
6.2	225	4	675	12
6.3	285	5	735	13
6.4	340	6	790	14
6.5	395	7	845	15
6.6	450	8	900	16
6.7	510	9	960	17
6.8	565	10	1,015	18
6.9	620	11	1,070	19
7.0	675	12	1,125	20

(l) Symptoms of nutrient deficiency and excess

(i) Abnormalities caused by incorrect availability of a single nutrient

When tea plants become grossly deficient in specific nutrients, their foliage and stems may be altered in appearance. Some of the effects which nutrient deficiencies produce are described below.

It is now known that the symptoms which are described appear only when the plants become quite badly deficient; the tea plant can tolerate quite large deviations from normal in its nutrient supply for long periods before the first visible signs of deficiency begin to appear in the foliage.

When crops become deficient in essential nutrients without such deficiency being recognizable from their external appearance, they are said to be suffering from "hidden hunger".

Much mature tea in Kenya that was considered to be of normal appearance has been found to have hidden hunger for one or more of the major nutrients, i.e. nitrogen, phosphate and potassium.

Producers who identify the symptoms here described with the condition of their own tea plants should appreciate that their tea will already have passed beyond the early stage of hidden hunger and will now be suffering from a gross nutritional disorder which requires immediate remedial action.

Producers whose tea appears normal will still benefit from recourse to the Foundation's new nutrition advisory service (see Appendix V page 243) because

indications of hidden hunger for specific major nutrients are only revealed by sequential foliar analysis. In all case where symptoms as described below have been relieved by the treatments recommended in this Section, subsequent foliar analysis will enable nutrient supplies to be fully corrected.
Many of the symptoms described are quite common in tea plants that are recovering from a drought. As the feeding roots begin to grow again, they cannot explore adequate amounts of soil to absorb all the nutrients needed by the plant. It is only when they have branched considerably and the absorbing surfaces have multiplied, that the symptoms fade as the roots absorb adequate nutrients.

Nitrogen deficiency

This first shows as a lighter than normal green colour in the young flush. The youngest leaves become progressively lighter in colour until they may be quite yellow.

The mature foliage may remain dark green if for any reason the rate of nitrogen uptake by the feeding roots fall below the amounts required by the plants or ceases, the lower mature leaves also become progressively lighter in colour (see plate Nos. V: i & V: iv).

The axillary buds do not develop, and as a result fewer and fewer new shoots appear. The crop declines quickly as more severe deficiency develops, until it reaches a low level of some 400 to 600 kg made tea per hectare, at which level it may remain indefinitely.

Gross nitrogen deficiency shows up more clearly on unshaded tea than on shaded tea; at sub-normal levels of nitrogen content an unshaded one which contains the same amount of nitrogen. Tea, which is grossly deficient in nitrogen, yields less badly under shade trees than it does in the open, but tea receiving nitrogen yields better in the open than it does under shade trees. Close examination of individual bushes in deficient places will reveal this effect clearly; leaves lower in the maintenance layer, which are receiving less light, are greener than those at the top of the bush. Where one leaf lies across another and is touching it, the area of the lower leaf covered by the upper leaf is noticeably greener than the exposed part.

Some bushes may always have extremely yellow or creamy-white upper leaves no matter what fertilizers are applied. These bushes are genetically unsuited to life in unshaded conditions and only under deep shade would their leaves become green.

Sometimes, in whole areas of tea, the foliage of many of the bushes turns paler for several weeks and then recovers its normal green colour. The cause of this phenomenon is not known.

Nitrogen deficiency is to some extent seasonal, in that anything which checks the growth of the feeding roots as they explore the surface layer of the soil will induce a yellow appearance in the youngest leaves at the top of the bush. This is because as soon as the growth of the roots is checked, the rate of nitrogen uptake falls. Thus, for example, the foliage will turn yellow quite early in the dry weather, and will become progressively more and more yellow as the surface layers of the soil dry out and the feeding roots die back. Similarly, when the soil is cold, the rate of root growth is very and the rate of nitrogen uptake falls, even though there may be adequate nitrogen available for uptake in the soil.

Another example occurs when the feeding roots become waterlogged; they die back rapidly and, as no nitrogen is being absorbed, the leaves quickly turn yellow.

Remedy

1. If the yellow colour of the leaves can be ascribed to a temporary reduction in the rate of nitrogen uptake by the roots such as a drought or cold weather, no amendments to the normal fertilizer programme are necessary.
2. If the yellow colour of the leaves is the result of inadequate applications of nitrogen, apply 150 kg nitrogen per hectare as sulphate of ammonia.

Phosphate deficiency

Symptoms show on mature leaves as an absence of gloss on the surface. Affected leaves
appear dull and matt, by comparison with normal leaves, which are very shiny and appear to have been polished. Note however, that this glossiness washes off in heavy rain.

Symptoms also show on the frame of the bush as excessive die-back of young and old woody stems. This effect is usually ascribed to "sun-scorch' (see Plate V : xi), but is quit distinct from it; in gross phosphate deficiency the branches, particularly the smallest ones, die back from the ends which have been cut when pruning.

All mature tea plants which have not got an undisturbed layer of mulch formed by decomposing leaves and pruning on the surface of the soil in which they are growing, have phosphate deficiency.

The effect of phosphate deficiency is to reduce the capacity of the plant to respond phosphate uptake by the feeding roots in the surface layers of the soil and mulch promotes a bigger response to applications of nitrogen.

Remedy

Broadcast an approved phosphatic fertilizer (see pages 109-110) over the surface of the soil under the bushes at a rate of 60 kg P_2O_5 per hectare. This treatment is ineffective unless a no-cultivation system of weed control is used and there is an undisturbed mulch of pruning and leaf-fall on the soil.

Where tea is to be planted in an area where phosphate is known to be deficient, incorporate phosphate in the planting-hole (see page 124).

Potassium deficiency

In some areas, the nutrient status of the soil is such that the plants suffer from potassium deficiency from the day they are planted unless corrective measures are taken. Such plants do not branch freely and then stems remain thin and weak; they have difficulty in producing starch reserves and recovery from pruning can be very slow; the spread of the frame is often restricted.

The plants must be handled very carefully and it is advisable to bring them into bearing by pegging so that there is no loss of the starch reserves and nutrients that they have accumulated with difficulty. After plants have been tipped in, the first few rounds of plucking should be very light. (See Plates V: i, V: v, V: vi, V: vii, V: viii, V: ix, V: x).

Plants that are suffering from potassium deficiency yet which are plucked hard before they are ready will lose starch reserves, will develop weak frames and may ultimately become completely moribund, neither growing nor dying.

The onset of severe potassium deficiency in mature tea is first indicated by progressive defoliation of the maintenance layer. Large quantities of fallen mature leaves are seen under the bushes. If the branches of an affected bush are shaken one of two mature leaves usually fall off whilst still green and fresh. Leaves remaining on the bushes are often severely affected by Brown Blight, *Colletotrichum coffeanum* (Plate V: xvi).

As the condition develops, more and more of the mature leaves are lost until it is possible to look down through the maintenance layer and see the soil surface below the bush. At this stage the crop can fall to about 400 kg made tea per hectare.

Meanwhile the new leaves become progressively smaller and smaller, and eventually each shoot contains only six to ten small leaves with no leaves below them. The bush becomes banjhi and remains so for most of the time, producing a flush only once or twice a year. The crop falls to as low as 200 kg made tea per hectare, after which the practice in the past has been to abandon the tea.

Remedy for mature tea

Immediate application of sulphate or muriate of potash should be made as soon as the first signs of gross deficiency appear according to the scale in Table V.5.

TABLE V: 5: Potash fertilizer applications to cure deficiency symptoms

Symptom	Kg sulphate or muriate of potash per hectare
Growth ceases at the sides of the bushes	100
Side branches thin, bark white	150
Mature leaves defoliate. Irregular recovery from prune	200
Young leaves progressively reduced in size	300
Normal plucking ceases	400*

**Carry out a cut-back prune before applying the fertilizer*

The frame of the bush exhibits characteristic features, as follows:-

(a) The bark is silvery-white, not brown as it is in normal tea. The growth tends to be stronger in the centre than at the edges of the plants. The practice of "centering" bushes with pruning knives to try to induce more vigorous growth at the sides of the bush is ineffective with plants that are receiving inadequate potassium.

(b) Profuse branching of the shoots takes place and a dense mat of thin branches forms just below the plucking table.

(c) Lateral shoots are slow in forming at the sides of the bushes that gradually assume a cylindrical or columnar appearance, with straight sides, and the bushes do not meet in the rows.

(d) Recovery from pruning is very irregular and slow.

Remedy for young tea

If NPK or NPKS fertilizer is applied to young tea as recommended by the TRFK potassium deficiency may be corrected to some extent. However, if NPK fertilizer is not applied during bringing tea into bearing and the potassium deficiency is noticed on young tea, it is recommended that the deficiency be corrected by applying K_2O at the rate of 30 kg per hectare in the form of either muriate or sulphate of potash.

Zinc deficiency

Zinc is one of the limited of elements that are essential to the growth of plants, and deficiency of it can cause serious retardation of growth. The importance of zinc in agriculture was recognised over forty years ago, and deficiency problems have since been reported in many crops. It was not until 1960 that zinc deficiency was recognised in tea. Since then, the deficiency has been confirmed in tea in many parts of the world including Kenya.

The findings from controlled experiments and from commercial zinc applications to tea plantations have to-date presented a rather uniform picture of agronomic aspects of the problem. Recommendations set out in this section are based largely on observations made in Kenya, supplemented by data from the original investigations in Sri Lanka where appropriate. As and when further information becomes available, changes may be made in our advice.

Symptoms

Method of diagnosis

Visual symptoms

Zinc deficiency in a number of tree and bush crops, has been shown to give rise to highly characteristic patterns of malformation of young leaves and shoots. Tea shows the same general development of these symptoms, which are not readily confused with those caused by other nutritional imbalances, or by non-nutritional factors. For many crops and for most nutrients, appearance of recognisable symptoms may mean the nutritional disorder has reached an advanced stage, with the implication that crop growth has been severely inhibited. In zinc deficient tea, observation of the occurrence of symptoms, and of the pattern for response to zinc treatment, has made the diagnosis by recognition of visual symptoms to be regarded as a reliable method for agricultural purposes. It is feasible for he agriculturist to recognise zinc-deficient shoots before the deficient has reached a severe stage (See Plate V: xii and Figures V: 1, V: 2 & V: 3).

Chemical analysis

During the original investigations that led to the recognition of the zinc deficiency syndrome, it was found that chemical analysis of leaf gave a results which were conflicting or even misleading. The Foundation does not make use of leaf analysis for zinc for diagnosing zinc deficiency.

The zinc deficiency syndrome

Under conditions of zinc deficiency in tea, there is a failure of the youngest tissues to develop normally. This is shown as three main patterns of malformation which are commonly seen at the tip of a dormant shoot. If such a shoot should recover from the deficiency, without any agricultural application of zinc having been made, foliage of normal size, shape, and positioning on the shoot, will develop above the permanently damaged leaves. If an application of zinc stimulates deficient shoots into making growth, those leaves already severely distorted will show little, if any, improvement.

Little-leaf and rosetted shoot

These two malformations occur together. The leaves are very small, often less than one-fifth of the normal length, and narrower in relation to their length than normal. Several are crowded together at the tip of a shoot, and the usual spiral arrangement round the stem may give way to a two-sided distribution. All the leaves arise from the same stem, but the internodes are greatly shortened, to as little as one or two millimetres in length (see Figure V: 1).

These leaves are usually pale in colour, and may also show the sickle conformation (see Figure V: 2). This little-leaf symptom appears to be the commonest of three groups, and one least likely to show a transition to normal growth on that shoot. In a bush in plucking surrounding healthy shoots may eventually overshadow and cover the retarded shoots, which retain their leaves through the remainder of the pruning cycle.

Sickle-leaf

The uppermost one or two leaves on a dormant shoot, may show the characteristic unequal development of the two halves of the leaf-blade, which gives rise to the sickle-leaf' symptom. The length of the mid-rib may not be too greatly reduced but the sickle distortion is usually observed on leaves that are markedly reduced in size, and it can be combined with the little-leaf symptom (see above).

One half of the leaf-blade remains narrow, while the other half develops to a greater extent, especially towards the base. The mid-rib is forced to curve, which leads to some resemblance to the agricultural implement, the sickle. Note: the curvature is sideways; not upwards (see Figure V: 2).

The leaf margins, particularly that on the less developed half of the leaf- blade, may show a marked waviness (see below). If so, the overall configuration of the leaf is one of smooth, even curves. It is important to appreciate this, as insect or fungus damage can cause a leaf to develop unevenly. In such cases the point of damage is usually readily detectable, and the resulting distortion is usually irregular.

A chlorotic, greenish yellow, mottling may be present towards the leaf tip, and between the smaller veins. This is usually only observed in warmer areas. Similarly, the degree of curvature may be greater in warmer areas.

Wavy-edged and up-folded leaf

This group of symptoms may be associated with the less severely developed little-leaves, and with sickle-leaf also.

The length of the mid-rib may only be little less than normal, although the leaf-blade itself is narrow in relation to the length. Both halves of the blade fold upwards along the axis of the mid-rib, until the margins almost meet. The margins are deeply waved (see Figure V: 3).

Note: this distortion is basically a folding, and must not be confused with an upward rolling of the leaf margins.

General features of the zinc-deficiency syndrome

All four symptoms can be observed on one bush, and it has not been possible to correlate any one of them with severity of the deficiency. Climate, clone and jat may exert some influence on the development of one symptom in preference to others, but the effect is small.

A noteworthy feature is the absence of dead tissue, even in the most severely stunted leaves of shoots. This serves as a useful distinction from other causes of malformation.

The transition from healthy leaves to obviously zinc-deficiency leaves on a shoot is quite sharp. Usually no more than one or two leaves show intermediate development of symptoms. Similarly, restoration of normal zinc supply by natural means, usually results in an equally sharp transition to healthy growth.

Remedy

See pages 114-118

Copper deficiency

Tea plants deficient in copper have slightly darker foliage than normal, but it is most difficult to detect the symptoms in the field. A surer sign of copper deficiency is the length of fermentation time; if the fermenting leaf takes longer than normal to change colour, copper deficiency is to be suspected.

Severe copper deficiency may inhibit fermentation; leaf severely deficient in copper does not develop a bright orange colour during fermentation and changes colour very slowly thought dark green to dark brown.

Remedy

Foliar applications of copper sulphate, at the rate of 5 kg copper sulphate crystals per hectare dissolved in 280 litres of water, have in some cases relieved symptoms of copper deficiency. It takes about 12 days from the time of application for the fermentation to improve. The full benefit lasts for about three months after which another spraying round will be necessary. Copper sulphate applied in too strong a solution burns the foliage.

Copper sulphate is of no benefit when applied to fermenting leaf in the factory; this practice is valueless and results in tea with a copper content above the minimum levels specified by international food and drug regulations.

Magnesium deficiency

Magnesium deficiency always shows first on the lower leaves which are bright yellow with a conspicuous inverted dark green "V" down the midrib, sometimes extending along individuals veins.(see plate V: xiii).

In most cases in Kenya, this symptom has appeared during extended periods of dry weather where the symptom may also appear on the first mature leaves. However, the symptom will disappear after the onset of rains. Occasionally plants are seen, particularly in China tea, which are apparently chronically deficient in magnesium; they exhibit the symptoms although other plants around them seem

normal. If the deficiency symptoms persist after the rains, remedial application of magnesium as magnesium oxide at 50 kg MgO per hectare should be applied.
Occasional plants are seen, particularly in China tea, which are apparently chronically deficient in magnesium; they exhibit the symptoms although other plants around them seem normal

Manganese excess
When tea is grown in very acid soil, large amounts of manganese are frequently found to be dissolved in the soil water, and the tea roots absorb these. The manganese is deposited in the mature leaves of the maintenance layer and accumulates in very large amounts.
Affected plants appear normal. Their mature leaves become brittle and when crushed in the hands crack easily with a rustling noise. The surface of the leaves may develop a cracked appearance.

Remedy
Allow a natural mulch to form at the soil surface. Apply animal manure during the prune year soon after tipping, if available. The rate of application should be 1 to 5 tons/ha.

Calcium excess
The young shoots and leaves are affected. The stems become stunted, and the leaves remain small, turn bright yellow and curl backwards. The edges and tips of the leaves turn black. The leaves become distorted and cracked. Soon after this the young stems begin to defoliate. The mature leaves of the maintenance layer may present a normal appearance, but in severe cases the bush defoliates completely and eventually dies. Some bushes may appear stunted in growth with the bark covered by moss and in addition they may start flowering and eventually seeding.
These symptoms appear on hutsites and also sometimes on soils of pH of Calcium Ammonium Nitrate (CAN), and they may appear on more acid soils if CAN is applied.

Remedy
If the soil pH is above 5.8, treat as a hutsite (see page 141). If the soil pH is 5.8 or lower, apply 100 kg sulphate of potash per hectare and nitrogen as NPK 25:5:5:5.

Sulphur deficiency
The sulphur deficiency disease known as "tea yellows" occurs occasionally in the various tea growing districts.
At first the leaves become yellow between the veins, which remain green. The leaves of new growth become smaller and internodal 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.

Remedy

Apply a fertilizer with a high sulphur content. Normal nitrogen applications for one year should be as sulphate of ammonia; if phosphate and potassium are also applied these should be given as single superphosphate and sulphate of potash respectively. NPK 25:5:5 with 5 per cent sulphur will not provide sufficient sulphur to cure a gross deficiency. After the gross deficient has been cured the NPKS fertilizer will maintain sulphur supplies and prevent any recurrence of deficiency symptoms. Where tea is planted into soil of pH above 5.8, treat as a hutsite (see page 141), applying sulphur or aluminium sulphate as recommended.

When planting into soil of lower pH which is known to be deficient in sulphur, use sulphate of potash and single superphosphate in the quantities recommended on page 128.

Abnormalities caused by incorrect availability or imbalance of more than one nutrient

High nitrogen, low potassium

When nitrogen fertilizers are applied to tea plants that are deficient in potassium, the plants are unable to use the nitrogen quickly. Consequently it accumulates in the leaves, and as a result the maintenance layer begins to turn a dark green colour. The young leaves of the flush then turn dark green. Where the maintenance layer has been reduced defoliation as result of severe lack of potassium, quite small applications of nitrogenous fertilizers will turn all the small leaves that remain on the bush a dark green.

This dark green colour has always in the past been thought to be the effect of lack of potassium alone, but we now know it to result from applications of nitrogenous fertilizers to tea bushes already low in potassium.

Remedy

Apply 4 bags of sulphate or muriate of potash that is equivalent to 120 kg K_2O per hectare.

Low nitrogen, low potassium

Tea plants severely deficient in nitrogen and potassium have small leaves that are yellow in colour.

Remedy

Apply 80 kg N as NPKS 25:5:5:5 per hectare, and 120 kg K_2O as sulphate or muriate of potash per hectare (4 bags of the actual fertilizer).

Low nitrogen, high potassium

Tea plants in this condition are similar in appearance to those described under "Nitrogen deficiency".

There is evidence that in some parts of Kenya, continued heavy applications of muriate of potash unbalanced with nitrogen and phosphate bring about reductions in crop.

Remedy

Apply 80 kg N as NPKS 25:5:5:5 per hectare.

High calcium, low potassium
Severe symptoms of potassium deficiency appear (see page 145). This condition arise after applying nitrogen as CAN without potassium for two or three years, or if lime is applied.

Remedy
As described for potassium deficiency (see pages 145-146). The quantities of potash fertilizer may need to be increased, or applications repeated, to offset the adverse effect of the high concentration of calcium in the soil.

Plasmolysis
In young tea, locally concentration of fertilizer in the soil water cause defoliation.
In mature tea, leaves start to scorch from the tips. Sometimes the leaf margins lose colour first. The scorch travels progressively back to the stems and then fall off. Usually the younger leaves are affected first. Following defoliation the stem tips scorch. The scorch travels progressively down the stems until they are completely dead. In most soils large quantities of fertilizer are needed to produce such an effect on mature tea, so this trouble is only likely to occur in very exceptional circumstances. In nurseries and young tea, however, much smaller quantities of fertilizer can have serious effects. Careful control of quantities of nitrogen in planting-holes will produce this effect.

Remedy
If the fertilizer can be washed out of soil before the plants die they may recover. Heavy rain can help and extra watering of nurseries may be effective.

(m) **The use of the "paired-plot technique" for evaluating yield response of tea to fertilizer**

(i) ***Introduction***
A very simple approach is described, by which the grower can test some of the relations between fertilizer use and the response of his own tea. This technique in no way obviates the need for formal scientific investigations, and is not suitable for studying all nutritional problems of tea. It may, however, overcome one of the major drawbacks of formal experimentation, which is that the results from one experiment are dependent upon the conditions influencing the bush in that site and, a point which is too often overlooked, at that time. Tea compares unfavourably with many crops, in that most fertilizer experiments are very long term, if the full scientific results of treatments are to be evaluated. The administrative problems and expense of recording the pluckings from such formal experiments are considerable if reliable results are to be obtained, and the Foundation's facilities are not adequate to cover all Kenya.
Simple, on-the-spot, experimentation can give a grower quicker answers under his own conditions, provided simple treatment comparisons are made, and provided it is realised that the answer from any one comparison will be specific in its applicability. The dynamic nature of the relation between bush vigour, and therefore potential cropping capacity, and fertilizer use has already been emphasised (Section a). This could be brought home to the grower very clearly in

his own experiments, and the ever-changing influence of economic factors could be evaluated at the same time.

(ii) ***Examples of the questions which paired-plot comparisons could examine***

A few examples are given, to show the type of question that could usefully be tackled by the individual grower.

1. If present annual fertilizer applications are over 150 kg/ha of N, the economics of this practice should be tested. One plot in each pair would continue with the level of N as at present used, while the other plot would receive N at a rate at leaf either 33% above, or 33 % below the normal (200 or 100 kgN/ha respectively). The choice will depend on the grower's estimate of the probable value of his current fertilizer practice.

Normally, the levels of other nutrients would also change in such a comparison if a compound fertilizer is used to supply the nitrogen. The Foundation will advise if a grower wishes to compensate for his, and will suggest how leaf analysis can provide complementary service.

Plate V : I: Nitrogen deficient tea. Large yellow leaves, few large shoots.

Plate V ii
Potassium, deficient tea.
Small dark leaves, profuse branching

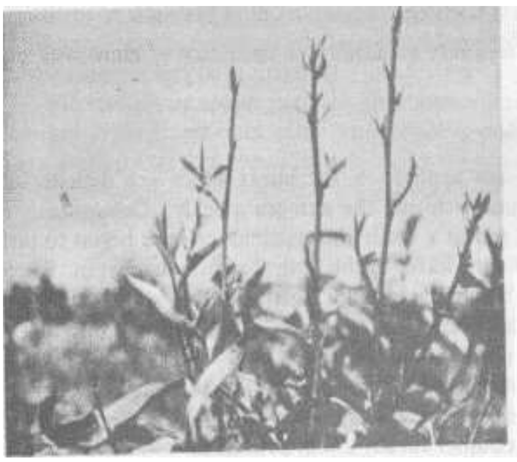


Plate V : iii
Defoliation resulting from fertilizer becoming locally concentrated on the soil surface by rain, after application to young tea

Plate V : iv
Nitrogen deficiency

Plate V : v
Potassium deficiency.
Thin maintenance layer
Mat of fallen leaves under the bush.

Plate V : vi
Potassium deficiency. Uneven
Recovery after prune.

Plate V : vii
Potassium deficiency. Strong central growth poor side branches

Plate V viii
Potassium deficiency. Defoliation, small upturned leaves

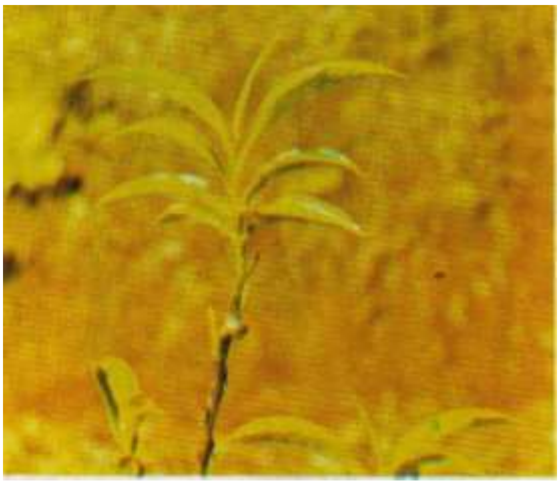


Plate V : ix
Potassium and nitrogen deficiency. Yellow, debilitated leaves, defoliation White stems

Plate V : x
Potassium deficiency.
White bark

Plate V : xi
Phosphate deficiency.
Mature leaves
Dull and brittle

Plate V : xii
Zinc deficiency. Multiple
axillary shoots, wavy edge
of mature leaf.

Plate v : xiii
Magnesium deficiency. Dark,
Inverted V along midrib of mature leaf.

Plate v xiv
Helopeltis damage on young shoot.

Plate v : xv
Brown blight on mature foliage

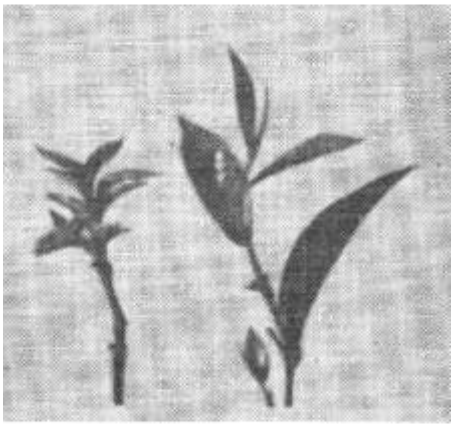
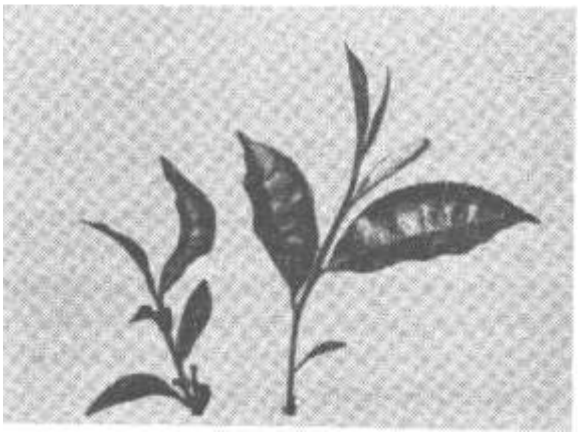


Figure V .1: Zinc deficiency of tea: the little-leaf symptom, on shoots with greatly shortened internodes; compared with a normal shoot from the same bush.

Figure V .2: Zinc deficiency of tea. A single branch showing a central little-leaf shoot, and also the sickle-leaf symptom.



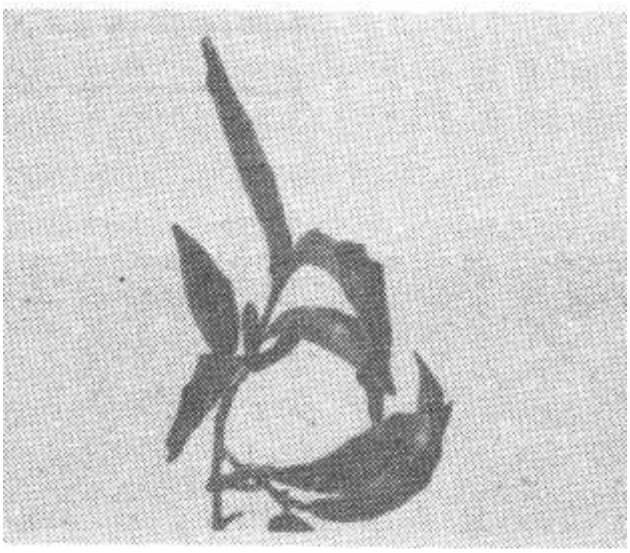


Figure V . 3: Zinc deficiency of tea. A severely up-folded and wavy-edged leaf

2. If little or no fertilizer is used, a grower may wish to be assured of the value of an increased application of nutrients. More than one nutrient may be deficient, and the increased use of fertilizer should take this into account.

Further, it may well take a considerable time for debilitated bushes to develop to the stage where they can show an appreciab

le yield response to increased fertilizer. If the Foundation is given details of the grower's agricultural problem before the experiment

is started, paired-plot comparisons can be suggested to cover the above conditions.

3. There may be a wish to effect immediate economics, by using N only, as opposed to the more usual NPKS compound fertilizer. Supplemented by leaf analysis, this could be a straightforward comparison for paired-plots.

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.

(iii) ***Advice from the Foundation***

This will be given in as much detail as possible, although officers may not be able to inspect all proposed sites. Before starting an experiment, growers are advised to contact the Foundation, and this is even more important if more than two plots are planned per experiment. The success of such a simple approach as outlined, depends on very simple questions being put to the test, and an attempt to extract too much information from a pair of plots may result in muddle.

The Foundation itself can build up a picture of fertilizer/yield relations, if sufficient paired-plot comparisons are laid down by growers and if the results are made available to us for examination. Our general advice to all growers could be strengthened accordingly.

(iv) Practical considerations in the selection of paired plots

The term "paired" is to be interpreted broadly. More than two plots can be chosen for comparison within one experiment, with more than two treatments under test. It is strongly recommended that growers consult the Foundation before attempting to lay down more than two plots in one experiment. However, a repetition of a two-plot comparison on different soils, slopes, jats, or ages from pruning for example, is a straightforward matter and will add to the value of the results.

A plot, in this context, can be of any size which is convenient for the grower to manage, but at the same time giving areas of tea which are as representative as possible of the whole unit. Too small plots, selected in particularly convenient situations may be anything but representative of the remaining tea. There is no need for the plots to be of the same size, but the area of each must be accurately calculated.

The underlying philosophy of this ultra-simple approach to experimentation, is that trends in yield would be assumed to be due to the experimental treatments. It is therefore obvious that the plots should be as similar as possible before the experiment starts. Factors which may influence the response to experimental treatments are: soil type, local climate, age of tea, jat, spacing, pruning style and age from pruning, plucking rounds and standard of plucking, shade trees or windbreaks and topography.

Many of these difficulties could be overcome by marking out plots within one field. Before the experimental treatments are started yields of the separate plots would be required for at least six months, covering the main cropping season, and preferably for a full year. During this pre-treatment period, the plots would be managed similarity in all respects. Greater precision could be expected, if several plots were marked for this preliminary comparison, eventually selecting the most similar ones for the experiment.

If separate fields are to be used, there will be more difficulty in meeting the requirements similarly. However, there could be the advantages of easier management, and the fact that yield records may be available for considerable period, permitting an immediate start to the experiment.

Whatever selection is made, once the experimental treatments have been applied, the plots must be managed as similarly as possible in all other respects. The treatments themselves should be applied on the same day. Plucking should fall on the same day, or at least follow the same length of round. If small plots are marked out, and are plucked on the same day, the order of plucking must be changed at each round, to avoid unfairly biasing the results.

(v) ***Leaf analysis***

It is anticipated that chemical leaf analysis will be useful, or essential, for the fullest interpretation of some of the more obvious paired-plot scheme. A comparison can be made between the leaf-nutrient status of the tea in each plot, both before the treatment starts, and at intervals thereafter. If the plots have been selected and managed according to the requirements set out above, there will be reason to assume the relative differences in leaf-analysis trends are due largely to the differential treatment itself. This use of leaf analysis differs from that which was adopted for the original Leaf-Analysis Advisory Service. These, large and unexplained variations in leaf-nutrient content throughout the season, have limited the value of this technique as a general advisory tool. In the new proposals, the effect of seasonal variations will be of much less importance, as we are concerned with relative rather than absolute values.

Our most recent research has shown that the uppermost mature leaf in the plucking table is a more sensitive indicator of fertilizer-induced nutrient trends, than any of the younger leaves. Further, the precision of the Foundation's analytical service, for the major nutrients, has been improved in recent years to the point where it is feasible to comment on smaller leaf-nutrient differences than previously. Both these advance are likely to be valuable in helping the grower to assess the results of his experiment at the earliest opportunity; which is a most important aspect of the whole scheme.

(v) ***Leaf sampling***

The uppermost mature leaf is hard, dark and almost or quite full size, and in these respects is comparable to the lower maintenance foliage. It is the uppermost such leaf on a twig which bears, or which has obviously borne, one or more growing shoots. Do not sample banjhi shoots, or the free-growing shoots on the edge of the plucking table.

Sample at least 100 bushes, taking one leaf from each, in each of the plots. These bushes must be uniformly scattered over the whole area, but avoid; the few rows that adjoin roads, paths, or large vacant patches. If bush vigour is uneven within a plot, take a separate sample from the weaker areas: this may give valuable information.

Each plot must be sampled on the same day. Choose a season when the tea is cropping freely, but avoiding abnormal rush crops. After fertilizer, manure, or mulch has been applied, wait for several weeks.

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. Preferably dry the leaf as far as far as possible, but do not crush it, and post the bags in a firm package to:

Director,
The Research Foundation of Kenya,
P.O. Box 820,
KERICHO.

Each bag should have the plot description and site written on it, so that it is readily identifiable on its own. If a grower has started an experiment on his own initiative, a covering letter should be sent giving details. A sample of the sheet which gives detail and which should accompany each sample is shown in page 165.

Should a grower consult the Foundation before starting an experiment, special arrangements may be made for analysing samples, as far as our facilities permit, and if we consider that the scheme could provide information of value to all growers.

(ii) ***Soil analysis***

Soil analysis should really play a part in the interpretation of yield trends, and the Foundation does provide this service. Foundation will advise growers who wish to have soil analysed. The information could be valuable for future reference, and should certainly be obtained. Our interpretation of soil analysis data will necessarily be limited to begin with, but could become more useful as the volume of data accumulates, together with yield records from the experiments.

(viii) ***Soil sampling***

See page 5 (Chapter I Section b)

(ix) ***Service charges***

Due to the fact that we cannot predict the number of samples we receive from tea growers each year, it is impossible for us to estimate on how much money it will cost to carry the analyses each year. At present we charge nominal fees per sample to cover the costs of chemicals used in the analyses and the actual charge can be obtained from the foundation before or after sending the samples

(n) **Recording and calculating fertilizer use**

(i) *Estate records*

The Foundation staff occasionally find it impossible to advise on the value of past fertilizer application, because this is referred to in growers' records as "kg fertilizer". "NPK", "N", "three bags" and similar vague descriptions. Records should contain enough detail for the nutrient additions to be known, long after the grower has forgotten which fertilizer he used.

For example:-

600 kg/ha of compound 25:5:5:5 NPKS or

150 kg/ha of N, as 25:5:5:5 NPKS

Make sure that it is clear whether weight recorded refers to the fertilizer as a whole, or to one of the nutrients. the two examples above make this distinction.

Also, record the exact date of application, and whether the quantity is applied per hectare or to the whole of a plot: neither "750 kg/ha of sulphate of ammonia in 1972", or "750 kg of sulphate of ammonia on 26th June 1972: is of true value.

(ii) ***Examples of common calculations***

1. How much triple superphosphate, with a quoted P_2O_5 content of 46%, is required to supply 46 kg of P_2O_5 :

$$\frac{100 \times \text{weight of nutrient required}}{\text{\% of nutrient}} = \text{weight of fertilizer}$$

thus, 100x46/46 = 100 kg of triple superphosphate

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

2. How much sulphate of ammonia, quoted at 20% N, would be required to give the same weight of N as 400 kg of a 25:5:5:5 fertilizer:

400x25/20 =500 kg of sulphate of ammonia

3. To make a mixture with an N: P_2O_5: K_2O ratio of 25:5:5:5, from straight fertilizers, and to apply at 150 kg/ha of N, using sulphate of ammonia (20% N), single superphosphate (20% P_2O_5) and muriate of potash (50% K_2O).

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

$$= \frac{150}{20} \times 100 \text{ kg/ha of fertilizer}$$

= 750 kg/ha of sulphate of ammonia

For the single superphosphate, the formula is

$$\frac{150}{20} \times 100 \times \frac{5}{25} \text{ kg/ha of fertilizer}$$

= 150 kg/ha of single superphosphate

Similarly, for the muriate of potash, the formula is

$$\frac{150}{50} \times 100 \times \frac{5}{25} \text{ kg/ha of fertilizer}$$

= 60 kg/ha of 50% muriate of potash

(The ratio , $\frac{5}{25}$ is governed by the proportions of N to P_2O_5 and to K_2O the compound fertilizer)

A total of 960 kg/ha of mixed fertilizer.

4. Concentration of solutions

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

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

(o) Elements essential for plant growth

(Chemical symbols in brackets)

(i) *Major nutrients (macro-nutrients)*

Carbon (C)
Hydrogen (H)
Oxygen (O)

A sub-group usually referred to as mineral nutrients comprises:-

Nitrogen (N)
Phosphorus (P)
Potassium (K)
Calcium (Ca)
Magnesium (Mg)
Sulphur (S)

(ii) Trace elements (micro-nutrients)

Manganese (Mn)
Zinc (Zn)
Copper (Cu)
Iron (Fe)
Boron (B)
Molybdenum (Mo)
Chlorine (Cl)

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

THE TEA RESEARCH FOUNDATION OF KENYA

Leaf and soil sampling sheet

To be completed for each sampled field or area

Name and address of Estate or Farm

Field/Plot number. ....

Date of Planting ....

Date of sampling ....

Seedling/clonal If clonal which? ....

Last pruned: Month: ....Year....... **To be pruned next**..........(year)

Last THREE applications of fertilizer (Year and month):

Date of application 1 .... 2................ 3...............

Type of fertilizer 1............... 2................ 3...............

Quantity kgN/ha 1............... 2................ 3...............

Past three years' yields

.... **kg mt/ha 19**...........**kg mt/ha 2000**..........**kg mt/ha 2001**.

Weeding: herbicide or jembe? ………....... Prunings left on the field ? ……….......

Has mulch or organic manure, etc. been applied Type/quantity ....

Weather conditions in 6 months before sampling (tick the applicable one):

Rainfall -about normal / above normal / below normal

Temperature -about normal / about normal / below normal

General weather comments ....

Hail damage in the last 6 months? Yes/No: If yes, how severe? ....

....

Area represented by sample: Ha..... **or if small, number of bushes**: ....

Slope of land: level / moderate / steep (tick the applicable one):

Analysis required: pH only / complete soil nutrients / leaf nutrients / any additional nutrient e.g. trace nutrients:.................................

Give any other relevant information that may be useful..................

....

Date............................ **Signed** ....

TABLE V:6 AMOUNTS IN GRAMS OF FERTILIZER TO BE APPLIED PER PLANT FOR DIFFERENT PLANT DENSITY PER hectare/acre OR spacing in feet)

Rectangular planting, No of plant or spacing in feet	6730/ha or 2722/acre **4x4**		8611/ha or 3485/acre **$5x2^{1}/_{2}$**		10766/ha or 4356/acre **$4x2^{1}/_{2}$ or 5x2**		13448/ha or 5445/acre **4x2**	
Fertilizer rate kgN/ha	100	150	100	150	100	150	100	150
	Amount of the actual fertilizer in grams (g)							
NPKS 25:5:5:5 or ASN 26%	60g	90g	45g	70g	40g	55g	30g	45g
NPKS 22:6:12:5	70g	100g	50g	80g	45g	65g	35g	50g
NPK 20:10:10 or S/A 21%	75g	110g	60g	90g	45g	70g	40g	55g
Rectangular planting, No of plants or spacing in feet	2989/ha or 1210/acre 6x6		4306/ha or 1742/acre 5x5		5383/ha or 2178/acre 5x4		8975/ha or 3630/acre 4x3	
NPKS 25:5:5:5 or ASN 26%	135g	200g	90g	135g	75g	110g	45g	65g
NPKS 22:6:12:5	152g	230g	105g	160g	85g	125g	50g	75g
NPK 20:10:10 or S/A 21%	165g	250g	115g	175g	95g	140g	55g	85g
Triangular planting, No of plants or spacing in feet	6139/ha or 2484/acre $4^{1}/_{2}x4^{1}/_{2}$		7768/ha or 3144/acre 4x4		9676/ha or 3916/acre 4x3		13896/ha or 5624/acre 4x2	

TABLE V:7 **APPROXIMATE NUTRIENT CONTENTS IN TERMS OF BAGS OF FERTILIZER (Kg N, P_2O_5, K_2O and MgO)**

Fertilizers	Number of bags of fertilizer (50 kg each)										
	1	2	3	4	5	6	8	10	12	15	16	20
S/A (KgN)	10	20	30	40	50	60	80	100	120	150	160	200
NPK 20:10:10 (KgN)	10	20	30	40	50	60	80	100	120	150	160	200
NPKS 22:6:12:5 (kgN)	11	22	33	44	55	66	88	110	132	165	176	220
NPKS 25:5:5:5 (KgN)		25		50		75	100	125	150		200	250
SSP single super (Kg P_2O_5)	10	20	30	40	50	60	80	100				
TSP Triple super (Kg P_2O_5)	25	46	70	92								
KCl Muriate of potash (Kg K_2O)	30	60	90	120	120							
$MgSO_4.7H_2O$ Epsom salt (Kg MgO)		15		30		45	60	75				
$MgSO_4.H2_O$ Kieserite (Kg MgO)	15	20	45	60								

TABLE V:8 **FERTILIZER MEASUREMENTS USING KIMBO TINS FOR PLANT DENSITY ABOUT 8611/HA OR 1.22m by 0.91m (3485/acre or 5x2½ feet spacing)**

Fertilizer type, actual weight and rate applied	Size of the kimbo tin and weight of fertilizer		
	2kg tin	1kg tin	½kg tin
S/A 21%	2700g	1350g	700g
No of bushes at 150 kgN/ha	30	15	7
NPK 20:10:10	2500g	1250g	650g
No of bushes at 150 kgN/ha	30	15	7
NPKS 25:5:5:5S	2400g	1200g	600g
No of bushes at 150 kgN/ha	35	17	8
NPKS 22:6:12:5	2400g	1200g	600g
No of bushes at 150 kgN/ha	30	15	7
Urea 46%	2000g	1000g	500g
No of bushes at 150 kgN/ha	53	26	13
SSP 18% P_2O_5	2600g	1300g	650g
No of bushes at 50 kgP_2O_5/ha	80	40	20
TSP 46%	2800g	1400g	700g
No of bushes at 50 kg P_2O_5/ha	220	110	55
DAP 18%N, 46% P_2O_5	2500g	1250g	600g
No of bushes at 50 kg P_2O_5/ha	200	100	50
Muriate of potash(KCl) 60% K_2O	3100g	1500g	750g
No of bushes at 100 kg K_2O/ha	160	80	40


BRIMSTONE90
Agricultural Sulpur 0-0-0-90
Improves Crop Yield
Free Flowing (4mm diameter pastilles)
Restores Soil Fertility
Blends with other fertilizers
Treatment for High Alkaline/Saline Soils
Offers Season Long Sulphur Nutrition
Disperses Quickly Upon Contact
with Moisture in the Soil
Tea Research Foundation of Kenya, Osho Chemicals & Kapchorua Tea Estate Company have evaluated Brimstone90 as a successful pH lowering amendment for the satisfactory growth and development of Tea.
Produced in Saudi Arabia by:
National Est. for Agricultural & Industrial Sulphur
P.O. Box 3891 - Dammam - Saudi Arabia - 314881
Tel: +966 3 8121009 Fax: +966 3 8121002
neais@sahara.com.sa http://www.neais.com
Distributed in Africa by:
OSHO CHEMICAL INDUSTRIES LTD.
P.O. BOX 49916, NAIROBI, TEL: 533621/3, 532939/40, 531428
Fax: 541526 / 531429
Email: oshochem@oshochem.com
osho

CHAPTER VI

DISEASES, PESTS, OTHER ABNORMALITIES, AND WEED CONTROL

(a) ***Diseases***
(i) ***Armillaria root rot of tea***
Causal agent
The causal agent of Armillaria root rot of tea is the fungus *Armillaria spp*.

Distribution
The causal agent has worldwide distribution. It occurs in roots of most forest trees as an epiphyte though it sometimes causes root rot in some of them.

Infection and spread in tea
The primary infection seems to be invariably traceable to woody debris of stumps and roots left in the soil during the initial forest clearing or tree felling. The fungus spreads and infects tea mainly by contact of tea roots with infested root debris and/or rhizomorphs. Secondary infection occurs when roots of disease free tea come onto contact with those of already infected ones or with rhizomorphs borne on roots of already infected tea plants. Thus, over time the spread of the fungus manifests itself in the disease occurring as radial patches of diseased plants in a tea field.

Symptoms
Infected tea bushes show gradual reduction in growth, making them shorter than the surrounding healthy ones. They also exhibit yellowing, premature flowering, defoliation and eventually die. At the collar region longitudinal cracking of the stem can be observed. If the bark is lifted off the wood at the collar area a white mycelial growth of the fungus is found overlying the wood.

Prevention
Trees should be ring-barked before they are felled to prepare the land for planting tea. The ring-barked trees should not be felled until they are completely dead and the starch reserves in their roots are exhausted. If trees have to be felled when still green, their stumps and roots should be removed from the soil as much as possible. The period between ring barking and felling varies with tree species but ranges from 18-24 months.

Control

During primary land preparation, remove the tree roots and pieces of wood as much as possible. It is recommended that all dead and moribund tea bushes are uprooted and debris of their roots completely dug out and destroyed preferably by burning. This should be done as soon as the infected bushes are observed. Look for old tree roots in the soil and if found also remove and destroy. The space can be infilled immediately or at a convenient time but ensure that the hole is free from any *Armillaria* bearing plant material or the fungus.

No effective and safe chemical method for managing the disease has been found.

(ii) Hypoxylon wood rot of tea

Causal agent

Wood rot disease of tea is caused by the fungus *Hypoxylon serpens* (Pers. ex Fr.).

Distribution

The disease causes considerable damage to tea in India and Sri Lanka and has also been observed to be serious in some tea growing areas of Kenya. *H. serpens* also causes wood rot in several dicotyledonous forest trees.

Infection and spread in tea

The causal agent of the disease is transmitted by wind as ascospores and possibly as conidia. The fungus enters its host plant through wounds caused by pruning, sun-scorch, and hail damage.

Symptoms

Decline of the bush occurs due to sectorial rotting and death of the primary branches. This may result in the ultimate death of the whole bush. The rotten wood bears superficial fructifications (stromata) of the fungus that appear as irregular dark-grey to black raised patches of various sizes. These fructifications bear ascospores of the fungus in asci contained in perithecia. The dead branches are very light in weight.

Control measures

1. Try to prevent sun-scorch by shading exposed branches with prunings immediately after pruning.
2. Once the disease is diagnosed the dead and dying branches must be selectively pruned off right down to the healthy wood. This may involve heavy pruning but if it is not done the disease may progress and kill the bush.
3. Pruning cuts should be made sloping so as not to hold rainwater and thereby heal quickly.
4. After pruning, the large cuts should be painted over with a wound dressing fungicide such as copper oxychloride 50% WP in raw linseed oil.
5. Down pruning of tea should be avoided as much as possible in fields with the disease but if it has to be done, wound dressing should be done as a mandatory requirement.

(iii) Collar and branch canker

Causal agent

Collar and branch canker of tea is caused by the fungus *Phomopsis theae* Petch.

Distribution

Phomopsis theae has a worldwide distribution. The disease it causes has been reported in all tea growing areas of Kenya.

Spread of the fungus

Inoculum of the fungus that consists of its spores (alpha conidia) can be disseminated from one plant to another by wind.

Symptoms

Canker lesions develop on the stem at the collar region or on the branches. Upper edges of the lesions are usually heavily callused. Leaves on branches girdled by the lesions turn yellow and ultimately the branches die. Where the lesions girdle the main stem the whole plant usually dies.

Predisposing factors

The susceptibility of tea to infection by *P. theae* is thought to be influenced by the moisture availability to plants and water holding capacity of the soil. Formation of cankers on infected tea plants progresses more rapidly when plants are subjected to moisture deficiency stress thus drought seems to be a major factor which influences onset of the disease.

Prevention

Infection of tea by *P. theae* can be avoided by minimising injuries on the bark of tea and by mulching to avoid stress due to soil moisture deficit.

Clones of tea differ in susceptibility to the disease.

Control

Damage to tea due to the disease can be checked by pruning off badly affected branches of infected plants at least 10 cm below the lesions. The pruned off branches should be destroyed by burning and the pruned bushes treated with a protectant fungicide such as the dithiocarbamates or copper oxychloride.

(iv) Leaf spots of tea (brown blight and grey blight)

These diseases are common on tea with their lesions occurring on old tea leaves that are about to fall but their outbreaks cause severe damage only in the nursery.

Brown blight

The disease is caused by the fungus *Colletotrichum camelliae*. The fungus infects the leaves causing brown lesions that start at the margins and spread inwards. Many such lesions may coalesce thereby killing the whole leaf. The edges of the lesions are clearly defined and marked with concentric rings. The lesions initially appear yellow to chocolate brown but gradually brown to grey from the centre outward. Minute black scattered dots (fructifications of the fungus) appear on both sides of the lesions.

Grey blight

The disease is caused by the fungus *Pestalotia theae*. The fungus infects mature leaves of tea which then form brown to grey round to oval lesions marked with concentric zonation. Black fructifications somewhat bigger than those of brown blight are produced in concentric rings on the upper surface of the lesions.

Control

Control of the diseases is only necessary if it affects plants in the nursery. The predisposing factors, mainly too much shade and over watering, should be identified and corrected. This should be accompanied with application of fungicides such as Dithiocarbamates or Benlate at 20 g in 20 litres of water.

(v) ***Damping off***

Causal agent

The damping off disease is caused by the fungus *Pythium* spp. The fungus attacks the main stems of young plants near the soil surface and causes this to rot. The leaves of the affected plants may turn yellow and the plant wilts but usually the disease manifests itself as the crumbling over of the plant at the collar region.

Pythium spp is a soil borne fungus that may occur in nursery soils especially where the soil remains unduly wet for long periods.

Control

Where the disease is common the cuttings should be soaked in water containing Ridomil (metalaxyl) at a concentration of 2 g per litre. If the disease is noted after planting the cuttings young plants can be sprayed thoroughly with the fungicide at the same concentration.

(vi) Cylindrocarpon root rot

Causal agent

The disease is caused by the soil-borne fungus *Cylindrocarpon tenue*. The fungus infects the root system causing rotting of the root tissues. The surface of infected roots typically appear pink in colour. When the root of the plant is affected the plant wilts gradually and ultimately dies.

This is a rare disease of tea and is of minor importance but where it is observed the affected plants should be uprooted and destroyed.

(vii) Crown gall

Causal agent
Crown gall disease is caused by the bacterium *Agrobacterium tumefasciens*. The bacterium enters roots of plants through wounds created by physical injuries. In the infected tissue the bacterium induces excessive cell division (hyperplasia) and enlargement (hypertrophy). These lead to abnormal growth and formation of galls/tumours at the collar region of the plant. Plants with such tumours generally appear unthrifty and unable to withstand other stresses and may ultimately die.

Prevention
The disease is best prevented by avoiding physical injuries to the roots.

Control
The only method of controlling the disease is destruction of infected plants.

TEA PESTS AND THEIR CONTROL
A number of pests exist in our tea environment. The most important pests that cause economic loss to tea are included here. Appropriate control measures are also given. The approach adopted in most cases is pest management.

(i) Tea mites
Description:
Mites are minute pests, clearly seen only through a lens. They differ from insects fundamentally in having four pairs of legs in the adult stage. They live on tender plant tissues by sucking the cell sap. Mites are the most serious pests of tea in Kenya.

(a) Red crevice mite or Scarlet mite. (Brevipalpus phoenicis ***GEIJSKES).***
Distribution
The red crevice mite occurs in all the growing districts of Kenya. Serious attacks occur during dry periods in certain tea growing districts especially in East of the Rift Valley (Kirinyaga, Muranga and Meru.

Status
This pest is a sporadic that increases during drought periods. Its outbreak is serious on tea that is not correctly fertilized. In some cases overdose during fertilizer application also encourages mite attack, so adequate fertilizer are essential.

Symptoms of attack
Brown corky symptoms develop on the underside of the leaves, especially near the petiole along the main veins, and later the leaves dry up and fall prematurely (Plate VI.1). Occasionally bushes may be heavily infested. The pest is 0.3 mm long and is bright red in colour. The eggs are also bright red, and can be seen in crevices on the stem.

Control

While using Knapsack sprayer apply omite, 57% EC at 3ml/litre of water, or cybolt at rate of 3ml/litre of water. Allow a minimum interval of 14 days between spraying and plucking for manufacture.

(b) Red spider mite (Oligonychus coffeae Nietner)

Distribution

The red spider mite occurs in low numbers in most tea growing areas of Kenya.

Symptoms of attack

The upper surface of the mature leaves darken and turn brown and become scorched (Plate VI 2). Young leaves may also be attacked during drought. Severe attacks may lead to some defoliation. The mites, which are about 0.5 mm long, can be seen on the upper surface of the leaves; the front part of their bodies is red and hind part is purple. White cast skins of the immature stages can also be seen together with the small reddish eggs which are alongside the leaf veins.

The pest is found throughout Kenya especially on unshaded tea, also attacking a wide range of plants including coffee, castor and grevillea. Its natural enemies include ladybird beetles and green lacewing larvae.

Status

Very few serious outbreaks have been reported attributed to these mites.

Control

Omite 57% EC at 3ml/litre of water, Cybolt at the rate 3ml/litre of water.

Use enough water to wet the bushes thoroughly and allow a minimum interval of two weeks between spraying and plucking for manufacture.

(c) Yellow Tea Mite (Hemitarsonemus latus)

Distribution

The yellow tea mite occurs in low numbers in most tea growing areas of Kenya.

Status

Nurseries may be badly affected, especially if densely shaded. This pest attacks a wide range of plants, including coffee and cotton.

Symptoms of attack

The young leaves are curled and may be distorted. Brown corky symptoms develop between the main veins on the underside of the leaf and two brown lines parallel to the midrib may develop. The adults are 1.5 mm long and are yellow. The eggs, which are laid singly on the underside of the leaf, are covered with whitish tubercles.

Control
Spray the upper leaves with 2.7g of dicofol 18.5% wettable powder in a litre of water, or Omite 57% E.C. at 3ml/litre of water. Repeat after one week if the first spray has not cleared the attack. Allow a minimum interval of one week between spraying and plucking for manufacture.

(d) Purple mites (Calacarus carinatus Green)
Distribution
The purple mite occurs in all the tea growing areas of Kenya.

Status
The pest was first noticed in Kenya in l977 in Sotik and later found in all the tea districts. The purple mite population has been kept low by the improvement of the nutritional status of the tea bush.

Symptoms of attack
The attacked leaves turn purple or bronze in colour and numerous skin casts can be seen scattered over the surface (Plate VI:3). Both surfaces of the leaves are attacked but is more prevalent on the upper surface. Older leaves are preferred but in heavy attacks young leaves are equally infested. Defoliation may occur where the attack is serious especially on young tea. It has been observed that bushes receiving no or inadequate fertilizer are more susceptible to the purple mites.

Control
Same as for red crevice mite.

(e) Bud Mite (Brevipalpus carlifornicus)
Status
The occurrence of bud mite has been very rare.

Symptoms of attack
Newly unfolding leaves are curled and dissected to give a coarse fern like appearance. They are hardened and appear to be unfit for manufacture. The damage is caused by very small mites which attack the apical buds; they cannot be seen by the naked eye.

Control
Spray dicofol l8.5% wp at 2.7g in one litre of water; or spray with Omite 57% EC at 3ml/litre of water. No quick benefit will be seen as damage occurs at a very early

stage of leaf formation and distorted leaves therefore continue to uncurl after the death of the mites. Leave at least one week between spraying and plucking.

(ii) Citrus Aphid –(*Toxoptera aurantii)*

Aphids are minute insects, dark brown to almost black in colour and attack young tea resulting in stunted growth.

Distribution

The citrus aphid occurs in all the tea growing districts of Kenya.

Status

It is found on mature tea, but nurseries are more often attacked.

Symptoms of attack

Brown aphids measuring up to 3 mm long are found in large numbers on the youngest shoots and leaves. Affected leaves are curled backwards (Plate VI:4).

Control

Spray the affected parts of the plants with Karate 1.75 EC at 4 ml per litre of water, or spray with fenitrothion 50% EC at 2 ml per litre of water. Allow a minimum interval of one week between spraying and plucking.

(iii) Scales insects, Soft green scale-*Cocus* sp. Soft brown scale, Fried egg scales-*Aspidiotus* sp.

Distribution

The soft scales occur sporadically in all the tea growing districts of Kenya. Fried egg scales (plate VI:5) are prevalent in Tigania, Nyambene and some parts of Kericho.

Status

Certain clones of tea are preferred by scales.

Symptoms of attack

Found along the midribs of the upper and lower surfaces of the leaves (Plate VI:5), especially in newly planted tea. The leaves sometimes turn black with sooty moulds and ants may be active on affected leaves.

Control

Pruning removes most of the affected leaves and allows parasitic wasps to attack the remaining scales.

Spray with Karate at 4 ml per litre of water and mix with 25 ml summer white oil (Murfoil EC). Examine after two weeks and if necessary re-spray. Allow a minimum interval of one week between spraying and plucking. Ants that may spread attack can be controlled by spraying with Dursban 48% EC at l.5 ml per litre of water around the base of affected bushes.

(iv) Moths and Butterflies

Damage is caused by larvae, called caterpillars, with their biting-chewing mouth parts. Caterpillars usually have 3 pairs of short, joined thoracic legs at the first three segments behind the head and usually 5 pairs of fleshy prolegs at the abdominal segments of the body. Caterpillars of the family loopers (Geometridae) have only 2 pairs of prolegs (abdominal legs) beside the 3 pairs of thoracic legs.

Control

Spray the foliage with malathion 50% EC at the rate of 2 ml/litre of water or Karate at the rate of 4ml per litre of water. Allow at least one week between spraying and plucking.

(v) Common Cutworm *(Agrotis segetum)*

A common pest of young tea in all tea growing areas. The grey brownish caterpillars, which are up to 4.5 mm in length, can cause considerable damage in nurseries and newly planted fields by eating the bark of stems at ground level. This damage is later followed by extensive callusing and swelling around the collar. By day the pests hide in the soil near their hosts. At night they appear on the soil surface to feed.

Control

Cutworms can be controlled effectively by use of baiting material as indicated below; the bait may be bought or prepared. The following formula is recommended for cutworm bait preparation:

Bait enough for 1 ha.

Dursban 48% EC (Gladiator)- 100ml
Wheat bran -50 kg
Sucrose 250gms

Mix the insecticide well with the bran before molasses or sugar. Then add water and mix thoroughly. Broadcast the bait in the affected area.

N.B. If molasses is not available, sugar at the same rate may be used. A ready bait may be purchased e.g. Volaton 0.75% (a bait containing 7.5 gm phoxin per kg). Follow the instructions on the label.

(vi) Faggot worm (*Clania destructor*)

The larvae construct cases diverse in shape and size in which they live. The cases are made of bits of twigs placed parallel to each other along the length of the cases.

Nature of damage

The mouth of the case is usually surrounded by a protective mantle (Figure VI:1) with an aperture in the middle through which the larva protrudes its head and feeds on the leaves and bark of tea bushes.

Figure VI :1
Faggot worm (*Clania destructor)*

Status
The pest has been found in some tea growing areas such as Murang'a. It is however considered as a minor pest.
Control
It can best and efficiently be accomplished by hand collection
The cases of faggot worm can easily be detected on bushes and their complete removal as soon as they appear will eradicate the pest. This is a new pest and no chemical control measures have been tested.

(vii) Leaf Eating Caterpillars (various)
Control
Spray the foliage with Karate at the rate of 3 ml per litre of water or Fenitrothion 50% EC at the rate of 2 ml/litre of water. Allow at least one week between spraying and plucking.

(viii) Beetles
Cockchafer larvae (Cockchafer larva) *(**Schizonycha*** **spp***).*

Symptoms of attack
Found generally on immature tea. The leaves of young bushes wilt; on inspection, the surface of the root is seen to be damaged, especially just below the soil surface. This damage is frequently followed by extensive callus growth and swelling around

and below the collar (Plate VI:6). Cockchafer grub damage is often confused with injury caused by chemical fertilizers coming into contact with the collar of the plants.

Control

Spray the soil around the bushes with Dursban (Gladiator) at the rate of 1.0 ml/litres of water. Spraying in the planting holes before planting has also been found to be beneficial. When nurseries are affected by this pest, it is advisable to treat the soil of new nurseries which are to be established in the vicinity before the seeds are planted. Treat in the same way as above, subsequently incorporating the endosulfan with the top 10 cm of soil.

(ix) Tea Weevils

(a)* Tea Root Weevil (*Aperitmetus brunneous)

Tea root weevil (Plate VI: 7) belongs to the familly Curculionidae and attacks tea. The pest girdles the stem of the plants just above ground level, making the plant to wilt and die. The larvae feed on tap roots, gnawing along the channel of the root causing wilting, stunting and finally death of the plant.

***(b)* Nematocerus Weevil** (*Nematocerus sulcatus)*

The adult weevil feed on the leaves making characteristic notch- like damage to the leave margin.

In severe attacks the there can be almost complete defoliation. The larvae live in the soil and eat the roots, the underground stem and germinating seeds.

***(c)* Systates Weevil *(*Systates** spp)

It causes damage on the leaves creating fjord-like indentations where the adult weevils have eaten away the lamina.

Figure VI:2

An Adult weevil and damaged leaf

Symptoms

The adult weevils feed on the leaves making characteristic notch-like damage to the margin (Figure VI:2). In severe attacks there can be almost complete defoliation.

(d) Kangaita / Kimari Weevil (*Entypotrachelus meyeri)*

The adult weevil feed on the leaves making characteristic notch- like damage to the leave margin (Plate VI:8)

In severe attacks the there can be almost complete defoliation. The larvae live in the soil.

General Control

Spray the soil in the affected areas with Gladiator at the rate of 10 ml/litre of water or the foliage at l.5 ml/litre of water or with Karate 1.75% EC at the rate of 4 ml/litre of water.

Hand picking has been found to be effective where the population of weevils is not high.

(x) Nettle grubs (Stinging caterpillars) *(Parasa vivida)*

Stinging caterpillar is a pest of coffee in Kenya. Occasionally, it attacks tea.

They have tuffs of hairs or series of spines which are poisonous and painful, and their presence makes it difficult to work in an infested area. The pain persists for several days. Workers are reluctant to pluck infested tea. This pest occurs in some parts of Murang'a, Embu and Meru (South Imenti) tuft.

Symptoms

The full grown larva are pale green in colour 45 cm long (Plate VI 9). They are found in underside of leaves.

Control
Spray the affected bushes with Karate 1.75 % EC at the rate 4 ml/litre of water. Allow at least one week between spraying and plucking.

(xi) Tobacco Cricket (***Brachytrypes membranaceus)***
Young tea plants are cut off a few centimetres from the ground. Very little of the plant is eaten but any plant which is cut will die. These tobacco crickets (Plate VI 10) have assumed economic importance in some parts of Kenya (Nandi District) and has been necessary to develop proper control measures.

Control
Spray the soil around the bushes with Dursban (Gladiator) 48% EC at 10 ml/litre of water once every month from planting time for at least 3 months time. This will protect the plants from damage by the tobacco cricket. Alternatively, bait the tobacco cricket using wheat bran bait prepared as follows;

Dursban 48% EC (Gladiator)- 10ml
Wheat bran 500 gms
Sucrose -25 gms
Place the bait inside the mole cricket tunnel

(xii) Thrips
Distribution
The tea thrips have been found to occur in all tea growing areas of Kenya. The attack is serious during the dry season.

(a) Yellow Tea Thrips *(Scirtothrips kenyensis* Mound)
Yellow tea thrips (Figure VI:3) occur in most tea growing areas of Kenya. Thrips cause serious damage to tea during dry period. With the onset of rains the populations reduce drastically.

Figure VI :3
An Adult *Scirtothrips Kenyensis*

Symptoms of attack
The young leaves are stunned and cupped, and margins of affected leaves are cracked and brown, changing to purple (Plate VI:11). A pair of brown lines is often seen on

the leaf blade, one on each side of and parallel to the main vein; similar lines may be caused by yellow tea mite (see page 175).

Control

The intensity of the attacks can be reduced by introducing finer plucking for a few rounds so that immature shoots are removed. The insects are mostly found within the folded terminal buds and if these are plucked as soon as they appear above the plucking table the Scirtothrips population will be reduced.

In severe attacks spray the foliage with malathion 50% EC at the rate of 2.4 ml per litre of water. Apply twice, at an interval of ten days, or spray with Karate 1.75% EC at the rate of 4 ml per litre of water or Fenitrothion 50% EC at 2 ml per litre of water, allowing at least one week between spraying and plucking.

(b) Black Thrips –(*Heliothrips haemorrboidalis)*

Symptoms of attack

Silver patches covered with black spots appear on the underside of mature leaves (Plate VI:12) In severe infestation both sides of the leaf are attacked and immature leaves may be damaged. The insect is dark brown or black, l.5 mm long, with whitish legs, antennae and wings.(Figure VI:4). Eggs are laid on the leaves.

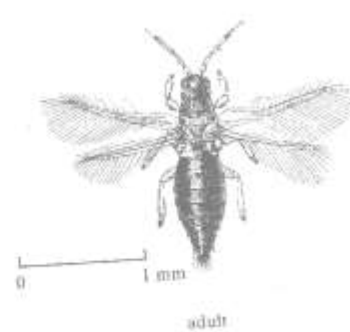


Figure VI: 4
An Adult *Heliothrips haemorrhoidalis*

Control

Attacks often die away naturally in wet weather. In Meru district of Kenya where severe infestations of black thrips are prevalent, excellent control is reported from a single application of Fenitrothion. Spray the foliage with Fenitrothion 50% EC at the rate of 2 ml per litre of water. Or spray with Karate 1.75% EC at the rte of 4 ml per litre of water. Allow a minimum of one week between spraying and plucking.

Thrips become noticeable again about three months after spraying, but if satisfactory rains occur they may not build up in sufficient numbers to justify a further spray for several months.

(xiii) Helopeltis – *(Helopeltis schoutedeni)* (Reuter)

Mosquito bug belongs to a group of insects in the order Hemiptera commonly known as bugs. They feed on young tender shoots causing serious damage to tea.

Symptoms of attack
Dark brown spots, up to 4 mm diameter, appear on the youngest leaves and shoots (Plate VI :13). These spots exude moisture from a central puncture when fresh. As the growing tissue expand, the spots turn black and produce leaf and stem distortions. If the infestation is severe, green shoots are attacked; this can lead later to branch canker.

The pest is a sucking insect up to l.25 cm long and is red in colour with black wings.

Control
Spray the foliage with Karate 1.75% EC at the rate of 4 ml/litre of water. Allow at least one week between spraying and plucking.

(xiv) Ants
Gramatogaster dohrni
They do not damage tea directly but are a nuisance to workers. Some species construct nests on tea bushes using the leaves and ends up defoliating the tea.

Control
To control the ants, destroy the nest and spray the nest and affected bushes with Karate 1.75% EC at the rate of 3 ml/litre of water.

(xv) Termites
Microtermes natalensis - Live wood termites
Pseudocanthotermes militaris
Termites are generally known as "white ants" because of their general resemblance in form and habits to the true ants, but these insects belongs to another order. Termites are highly organised social insects, living in colonies. They attack both living and dead wood.

Termites occur most frequently on recently established plantings. Plants wilt and die; the stem beneath the soil surface is ring-barked or the entire root system may be destroyed. Older plants may be stripped of leaves. Earthen tubes are generally present on the main stem and sometimes also on branches (Plate VI :14).

Pre-treatment attention: Dead wood and snags, and hollowed-out branches should be removed and the cut surface covered with protective paint (copper in raw linseed oil).

Control
Termites attack young plants through the soil. To control them effectively the soil around the plants should be sprayed with Dursban 48% EC at the rate of 10 ml per litre of water. Where possible destruction of termite nests and removal of the queen should be carried out. For scavenging termites, in addition to spraying, the mounds should be located and after removing the top treat with Dursban at the rate of l0 ml/litre of water.
Note: All chemical rates have been given in small quantities per litre of water because in most cases a few bushes are affected by disease or pest.

vi:1

vi.2

vi.3

vi.4

vi.5

vi.6

vi.7

Plate vi.1. Red crevice mite *Brevipalpus phoenicis* damage.
Plate vi.2. Red Spider mite (*Oligonychus coffeae)* damage.
Plate vi.3. Purple mite (*Calacarus carinatus*) damage.
Palte vi.4 Citrus aphid (*Toxoptera aurantii*) damage.
Plate vi.5 Fried egg scales (*Aspidiotus* spp.) damage.
Plate vi.6 Inset. Chaffer Grub (*Schizonycha* sp.) and damage.
Plate vi.7. Inset. Tea root weevil (*Aperitmetus brunneus) and* damage.

Plate vi.8. Kangaita weevil (*Entypotrachelus meyeri*) damage.

Plate vi.9. Stinging caterpillars (*Parasa vivida*)

Plate vi.10. Tobacco cricket (*Brachytrypes membranaceus*)

Palte vi.11 Yellow tea thrips (*Scirtothrips Kenyensis*) damage.

Plate vi.12.Black tea thrips (*Heliothrips haemorrboidalis*).

Plate vi.13. Mosquito bug (*Helopetis schoutedeni*) damage.

Plate vii.14. Termite damage on tea.

WEED CONTROL

(a) Weed control in young tea

The large area of soil exposed to full sunlight together with the fragility of young plants makes the control of weeds in young tea more difficult than in mature tea. Complete weed control is particularly desirable in young tea as the check of growth by diversion of water and nutrients to weeds can delay appreciably the time to start harvesting the crop. As the conditions are favourable for weed growth weed control in young tea is an essential mandatory operation compared to that in mature tea. Removing weeds by implements of any type (cheel hoe, jembe, fork jembe etc) inevitably results in heavy damage to roots and loss of both tea plants and nurse crops, so the use of any implement should be discouraged.

A circle around each young tea plant of at least 40 cm diameter must be kept completely clear of weeds. The only safe way to do this is for weeds within this area to be pulled out individually by hand. As weeds are pulled out, they should be put into a sack and carried off the field. If left in the field some will strike roots and grow again.

The ground outside the circle around each plant should be covered with a nurse crop such as oats. This crop, when cut and laid down, will act as mulch and also reduce weed growth but some weeds will inevitably appear. These can be removed by hand along with oats too close to the tea plants or it may be convenient to control them with paraquat (gramoxone), at the rate of 310 ml of the product in 124 litres of water per hectare. Paraquat will check the growth of oats but will not kill them unless applied very frequently in heavy doses.

Herbicide damage to tea plants can be prevented by shielding the plants when spraying. This can be done successfully in a number of ways. A piece of polythene sheet can be held around each plant by one man while another man is spraying the weeds. A four-gallon (20 litre) tin (debe) cut into halves or a cone made from any stiff material, which is easily dropped to cover individual plants, can be used by one man who does the spraying as well. The cones, if made from material of sufficient gauge and rigidity, have proved to be simple and effective.

When spraying any herbicide, it is important to minimise drift to the young plants which are not protected. A flood jet at reduced pressure gives a coarser spray which is less easily carried by wind. Alternatively, a Dribble-bar attached to a pressure sprayer produces coarse drops and has been used successfully. Always avoid spraying under very windy conditions.

It is essential to repeat weeding rounds, whatever method of control is employed, after a short interval so that weeds which have regrown are removed before they have a chance to seed or grow extensive root systems. The interval of rounds will vary; it may be as short as one week or as long as eight weeks and will depend on soil conditions, weed flora and climatic conditions. This must remain flexible and local management will need to exercise judgement continuously on this point. An inadequate number of weeding rounds at long intervals, whatever method is employed, is a complete waste of money.

A persistent herbicide sprayed over fields of young tea will prevent seedlings of many weeds from growing. Simazine is the only herbicide that can be considered in this respect, but it must be used with caution as young tea plants have on occasions been damaged by simazine. Dalapon must not be used on tea under two years old. Where perennial weeds such as sedges, couch or Kikuyu grass are the problem, glyphosate (roundup) can be used effectively. The other herbicides which can be considered for young tea under two years old are fluozifop-butyl (fusilade), oxyfluorfen (goal 2E), kamata, and basta. Again in all cases precautions should be taken to protect the young plants when spraying herbicides.

(b) Weed control in mature tea

Weed control must be planned as a complete programme. Only by making use of all suitable methods and using these at the correct time will a continuous reduction in weeds be obtained at a cost which will fall as time goes on.

It is now established in many areas that there is considerable benefit from an annual application of a persistent herbicide. This largely prevents growth of weeds from seed. However, there is no herbicide at present available which will control all weed species. Also, regrowth from larger roots or other soil borne propagules is not easily controlled. The use of a persistent herbicide, therefore, will not give complete absence of weeds until the next application. Weeds will reappear and these must be dealt with in other ways. If this regrowth of weeds is not kept under control, the weed species which are unaffected by the persistent herbicide will take advantage of the lack of competition and cover the ground.

Weeds which appear after the application of a persistent herbicide must be killed when they are small. This can be done in either of two ways; by hand weeding or by killing them with a contact or translocated herbicide. Presently, the persistent herbicides are less used in tea as new and more effective translocated herbicides come on the market.

When control measures are due, the choice of method will depend upon the conditions prevailing at the time. The interval between the occasions of clearing will vary widely and will depend upon size of tea plants, soil, weed population and weather conditions. Soil disturbance during weeding should be kept to a minimum as soil brought up from deeper horizons brings up fresh supply of weed seeds. Tea roots will be damaged, reducing the nutrient uptake of the bushes and making points where *Armillaria* or any other soil borne pathogens can enter.

The key to effective control is to deal with the weeds before they seed.

Perennial grasses

The effect of deep-rooted perennial grasses, such as *Digitaria scalarum* (couch or lumbugu), is very severe on crops. They have such an adverse effect on the growth of tea plants that only satisfactory control is complete eradication. They must be treated as a problem largely independent of the normal control of weeds. If the softer annual weeds are kept to a minimum, patches of couch are more easily seen and dealt with.

Removal of perennial weeds by hand is not satisfactory. It is limited, as small pieces of roots not removed will grow. Chemical treatments are generally very effective and a number of herbicides are available for this purpose.

(c) Translocated herbicides

1. Dalapon (Dowpon)

For a long time, dalapon was the only herbicide of greatest value for perennial weed control in tea and is readily available in several proprietary forms.

Rate

The normal application rate of dalapon is 5½kg per hectare in 250 litres of water. The chemical is largely taken up by the leaves of the plants so that it should be sprayed only on to growing weeds. It is most effective when the weeds are growing vigorously; slashing of the weeds to promote regrowth before spraying is often worthwhile.

As the herbicide is taken up relatively slowly by the plant, dry weather is required otherwise rain will wash the dalapon away before it has time to be completely absorbed. Preferably, there should be 48 hours without rain after application. If the foliage is damp, the application rate should be increased to 8½kg per hectare.

Any regrowth six to eight weeks after application should be treated again. Severe infestations of couch may need several treatments for complete eradication.

Dalapon should be kept away from tea leaves as far as possible since it will scorch them. Applied to couch on the ground at the rates recommended, dalapon will not affect mature tea. Local over-dosing must be avoided as this will affect tea severely. Dalapon does not persist in the soil for more than six to eight weeks.

2. Glyphosate (Roundup)

Glyphosate, a translocated herbicide which is more effective than dalapon, is now widely used for weed control in tea.

Rates

Glyphosate kills a wide variety of annual and perennial grasses and broad-leaf plants. It is rapidly translocated from aerial parts to underground roots, rhizomes or stolons of perennial weeds. Leaf symptoms appear within 7 to 14 days after spraying and complete desiccation usually occurs within 30 days. Visible effects are a gradual wilting and yellowing of the plants which advances to complete browning and deterioration of plant tissues.

The recommended rate of glyphosate in controlling weeds in tea is 2-4 litres of product per hectare. The water volume should be between 200 and 600 litres per hectare. The optimum environmental conditions for glyphosate are high relative humidity, temperature and light intensity, at the time of application; no rainfall within 6 hours, low temperature plus high relative humidity and light intensity, after spraying, for long-lasting weed control. Vegetative development at application time is very important to get optimum translocation to the underground parts of plants. Hence, a good coverage of leaves is essential for realisation of full efficacy of the chemical. Slashing before application without allowing regrowth decreases glyphosate performance because the area of spray reception is reduced. Cultivation prior to spray will also reduce glyphosate activity since some of underground propagules will not have aerial parts. Tillage will also prevent adequate translocation by breaking the underground vegetative system. Glyphosate should be kept away from growing tea shoots. Other formulations of glyphosate marketed as Kamata and Touchdown as well as Basta (Ammonium-DL-homoalanin-4-yl (Methyl) phosphinate) are useable as substitutes for round-up. Touchdown, a plyphoste based herbicide can be used as a substitute to round up.

3. Fluazifop-butyl (Fusilade)

Another highly active, selective herbicide for control of grass weeds, except sedges, in broad-leaved crops including tea is fluazifop-butyl. This herbicide is most affective as a post-weed emergence application normally in 100 - 800 litres of water per hectare. It is essential to obtain good cover of weeds and the spray volume should be selected accordingly to achieve this.

Rate

The recommended rate for annual grasses is 1 to 3 litres of the product per hectare, according to when the rhizomes have been fragmented by cultivation apply 2 to 4 litres of the product per hectare and for established perennial grasses apply 4 to 6 litres per hectare. Fluazifop-butyl can be applied at any time provided that most weeds have emerged and present sufficient leaf surface for good uptake of the herbicide.

Fluazifop-butyl is quickly absorbed through the leaf surface and translocated to growing points in the plant. First symptoms are often not evident until a week after application although growth usually ceases within 48 hours. Nodes and growing points become necrotic; young leaves show chlorosis followed by necrosis; there is a general loss of vigour and often pigment changes that are normally associated with senescence appear. Death is usually complete after 3 to 5 weeks.

Fluazifop-butyl remains active in the soil, up to 4 months after the application of high rates. This product has so far proved chemically and biologically compatible with a number of established herbicides although field data are, at present, limited.

As in the case of other herbicides, precautions should be taken to protect tea bushes when applying fluazifop-butyl.

(d) Persistent herbicides

Only two persistent herbicides are recommended for use in tea. These are simazine and diuron.

1. Simazine (Gesatop, Primatols)

Simazine controls most broad-leaved weeds and some grasses. It acts on very small seedlings by uptake from the ground only. It has no effect at all on larger plants. It does not affect mature tea, even at large over-dose rates. Simazine requires rain to wash it into the soil after application, preferably at 10 mm within 48 hours. Without rain, simazine is lost very quickly.

Rate

The normal application rate of simazine is 4.4 kg of the product per hectare.

2. Diuron (Reglone)

Diuron controls more species of weeds than simazine. It acts on very small seedlings but does also have limited effect on larger plants. Preferably rain should follow application but this is not as vital as with simazine. If Diuron comes in contact with tea leaves it causes them to lose colour and scorch. No noticeable visual effects have been seen on tea from ground applications at the recommended rates. Heavy over-dosing will affect tea severely.

Karmex, another form of diuron is applied at the rate of 2.75 kg of the product per hectare.

3. Oxyfluorfen (Goal 2E)

A persistent herbicide, oxyfluorfen, is also useable for weed control in tea. It controls a very wide variety of weeds. Oxyfluorfen is usually applied pre- or post - emergence of weeds. It kills by contact of the emerging weeds with the thin layer of the herbicide on the soil surface. Foliar or root uptake is negligible.

Rate

The herbicide is applied at rates ranging from 0.28 to 2.25 kg of product per hectare.

Before applying the herbicide, the soil must be clean weeded and clear of excessive trash and organic matter. The herbicide is more effective if sprayed on moist soil. After application of the herbicide, the soil must not be disturbed or cultivated; doing so greatly reduces or eliminates the herbicidal activity of oxyfluorfen. If weed patches emerge after treatment, a post-emergence application of oxyfluorfen at rates ranging from 0.16 to 0.28 kg of product/ha along with paraquat at the normal rate may be carried out. Oxyfluorfen has very desirable synergistic effects with many other herbicides such as paraquat and dalapon.

Persistent herbicides must be applied evenly. In order to ensure this throughout a field each container of spray solution must be applied to the same number of bushes (see Table VI.1). The amount of water needed to distribute a persistent herbicide depends on the equipment used; 280-560 litres per hectare are usual.

As these persistent herbicides generally have no useful effect on standing weeds, field must be cleaned by hand before application. Alternatively, a contact herbicide such as paraquat can be added to the spray mixture.

Contact herbicides

Two chemicals of this type are now recommended: Paraquat and diquat.

1. Paraquat (Gramoxone)

Paraquat is absorbed by all green parts of a growing plant. When light reaches the green parts they are scorched. Paraquat is not absorbed by bark and is completely inactivated when it reaches the soil; so uptake by roots does not occur. It is absorbed by the plants very quickly so it can be used effectively in wet weather unless the rain is extremely heavy. As the rate of action by paraquat depends on light, effects show more quickly in bright sunlight. The ultimate effect is the same whatever the light intensity. If the chemical falls on tea leaves they will burn in the same way as on other green parts of the plant. If a large proportion of the leaves of a bush are scorched in this way, its growth will be severely retarded.

Rate

Paraquat is normally dissolved in water at a dilution of 1 part in 400 parts of water, i.e. 310 ml of paraquat to 124 litres of water per hectare. The effect of paraquat is enhanced by the addition of a wetting agent, e.g. Agral 90, NAS or Teepol, in order of preference. The normal rate of wetting agent is 1 part in 4000 parts of water, i.e. 31 ml to 124 litres of water. Paraquat (Gramoxone W) includes a wetting agent so there is no need to add a wetting agent when using this material.

TABLE VI.1: *Number of bushes sprayed by 9.1 litres of solution at the rate of 280 litres per hectare*

Planting distance(cm)	Square, rectangular or contour planting		Triangular planting	
	Bushes/ hectare	Bushes/9.1 litres mixture	Bushes/ hectare	Bushes/ 9.1 litres mixture
121.9 x 61.0	13,448	437		
106.7 x 76.2	12,299	400	10,142	330
91.4 x 91.4	11,970	389	13,822	449
106.7 x 82.8	11,184	363		
100.0 x 100.0	10,000	325	11,626	378
121.9 x 76.2	10,766	350		
106.7 x 91.4	10,254	333		
121.9 x 91.4	8,975	292	12,044	391
106.7 x 106.7	8,784	285		
152.4 x 61.0	10,757	350		
152.4 x 76.2	8,611	280		
121.9 x 121.9	6,730	219	7,771	253
137.2 x 137.2	5,312	173	6,134	199
152.4 x 121.9	5,383	175		
152.4 x 152.4	4,306	140	4,972	162
182.9 x 182.9	2,989	97	3,452	112

2*. Diquat (Reglone)*

Diquat is very similar to paraquat but may be a useful alternative if there are broad-leaved weed species which are not affected by paraquat. It is sold as Reglone which contains 20% of the active chemical and is used at the same rates as paraquat.

When using these chemicals, they should only be applied to growing weeds. Do not broadcast on tea leaves. Likewise do not allow the chemicals to get in contact with the lower branches of the bushes. Since these chemicals kill growing points, they will also kill the dormant buds on the branches which might result in poor recovery from subsequent pruning. Leakage from spraying equipment must be repaired immediately. Either of these chemicals can be added to the water solution of a persistent herbicide at the rates already quoted.

When using chemicals for killing regrowth weeds, occasional plants will be found which are not affected. These are best removed by hand; if they are not too many the person doing the spraying can remove them as he passes.

(e) Hand-weeding

The essence of this operation is the removal of young weeds before they seed. Should this not be possible, the next weeding ought to be done whilst those seedlings which have germinated since the last weeding are still young. Weeds which have been removed must have soil shaken off their roots, particularly in wet weather. In no circumstances should weeds be buried in the soil. Where weed growth is limited, it is sufficient to rake the vegetation into a bund. Where weed growth is heavy, it is better to carry the material out of the field.

Conversion of manual weed control to weed control with herbicides

Where it is decided to introduce herbicides into a weed control regime which has hitherto been completely manual, results will not be satisfactory unless this introduction is carefully programmed to include manual operations.

Where the weed infestation is very dense, the first operation should be to cut the weeds down as close to the ground as possible. If this causes a lot of vegetation to fall on the ground this vegetation should be carried off the field.

Follow cutting-down as soon as possible (within a day or two) with a spray of paraquat.

When the effect of the paraquat reaches its maximum and before any weeds which are unaffected can seed, clean the weeds manually using a cheel hoe. This should take place between one and two weeks after the paraquat application. If there is a large amount of vegetation removed, it is best to carry off the field.

This cleaning must be followed by the application of a persistent herbicide, simazine, diuron or oxyfluorfen. If the application can be made immediately before weed seedlings appear, the persistent herbicide may be applied on its own. If weed seedlings have appeared before the spraying is done, combine paraquat with the persistent herbicide.

The persistent herbicide will now prevent growth of seedlings of soft annual weeds. Resistant rhizomatous and woody plants will continue to grow. These must be removed before they are able to become strongly established or seed. Couch, if present, can only be dealt with by the use of dalapon or glyphosate. The absence of soft weeds at this stage makes it easy to see and treat it. Other species can be removed by hand or using a contact herbicide. If a contact herbicide is used, large and tap-rooted plants should be pulled out of the ground and laid down before spraying. Whether manual or chemical treatments is used, ensure that weeds are dealt with before they seed.

Where initial weed density is not very high, the early stages of this programme can be omitted. In this case start with the application of the persistent herbicide at the time of pruning only.

If a large number of fields have to be brought into a new system, it is better to start on a limited number, and do these properly, than to attempt a large number and fail, because it is impossible to carry out the next stage quickly enough. It is inevitable that when changing to an improved system of weed control, cost will rise initially. However, as the standard of cleanliness of the field improves, costs should fall to well below the level prior to the introduction of herbicide.

Weeds resistant to paraquat

When paraquat has been sprayed on a field regularly, weeds which are comparatively unharmed by paraquat may begin to be noticeable.

These weeds may be resistant to paraquat for one or more of the following reasons:-

1. They have a waxy surface
2. They have hairy surface
3. They have thin stems
4. They regenerate from the roots or base of the stem

In this group are weeds such as *Borreria* spp, *Polygonum* spp, etc. To counter these paraquat resistant weeds, the following actions may be tried:-

1. Use diquat in the same concentration as paraquat
2. Increase the concentration of wetting agent when using Gramoxone W, add Agrol 90, NAS or Teepol at the rate of 31 ml to 124 litres of water.
3. Remove resistant weeds by hand and carry them away from the field.

4. Cheel (not in young tea) and restart the paraquat spraying soon after germination. Make sure that paraquat spraying interval is not extended until the weeds have grown too large.

Spot spraying

The herbicides, which are taken up by leaves must be sprayed on leaves only so that the process is one of spot-spraying the weed where it exists. This makes it difficult to control the application rate. It is important to remember that the application rates quoted for these herbicides apply only to the area actually sprayed and not the whole field.

When spot-spraying is being carried out it is very easy for the operator to give an unnecessary large amount of spray solution to individual weeds or patches of weeds. Apart from being wasteful this local over-dosing of herbicides can damage tea bushes. Use of the finest spray jet reduces the risk of over-dosing, but the operation needs careful supervision to avoid herbicide drift to tea bushes. Where the weeds are small, up to 5 cm tall, spraying until the foliage is thoroughly wet and no more, should give sufficient herbicide to kill the weeds without great risk of damage to tea. If the weeds are larger, it is better to cut them down and allow regeneration before spraying.

(f) **General precautions when using pesticides**

Pesticides can be very dangerous if basic precautions are neglected

These are:-

1. Read the label on the container carefully and follow the instructions.
2. Protective clothing such as goggles, gloves, apron, and boots should be used when handling and spraying pesticides.
3. The sprayer should wear a label with the name of the pesticide being used so that in case of accident where the victim is unconscious one would know the chemical being handled. This will facilitate proper treatment.
4. Smoking or eating should be avoided while handling pesticides.
5. Soap, water and a towel should be kept when mixing and using pesticides.
6. Avoid windy conditions and subsequent spray drifts where possible. Stand up-wind so that spray drifts or splashes blow away.
7. Maintain application equipment in good condition so that leakage are minimised. Do not blow clogged nozzles with mouth but clean them with water.
8. After spraying, the contaminated clothing should be removed at once.
9. Wash contaminated clothes and body after work.
10. The remaining chemicals must be marked properly, kept in original containers, and locked in a secure store.
11. Empty containers must be destroyed away from water sources.

In case of an accident

If a pesticide is ingested accidentally, vomiting should be induced at once if not already occurring and the patient be sent to the nearest hospital immediately. Vomiting can be induced by drinking a concentrated mixture of common salt in warm water. In case of skin contact with pesticides wash off with soap and water immediately and in case of eye contact, flush out with water for at least 15 minutes then consult a doctor at once.

(g) Herbicide damage

(i) *2,4-D*

Mature leaves curl backwards and may twist into a spiral. Young leaves and buds twist into spirals. There is normally no change of colour of the leaves except some lightening of the petiole. Young leaves may fall off in cases of extremely concentrated application levels.

Remedy

None. Unless the application level is extremely high, the bushes will return to normal in several weeks as this chemical is not persistent.

(ii) Glyphosate

In several cases, young leaves become needle-like and curl when they get into contact with glyphosate. Even the new leaves which subsequently develop on the directly contacted shoots display these symptoms which can be visible up to three months after the contact. Each needle-like leaf persists for a short period and then drops off.

Remedy

None. The bushes recover after some time.

(iii) Dalapon

Chlorosis of interveinal areas of the leaves is followed by browning and scorching. In severe cases these symptoms spread fully over the leaves which then fall off; also the stem tips may die back.

Remedy

None. Bushes will recover unless they are completely defoliated as dalapon is not persistent. Heavy rain may speed recovery by washing excess dalapon away.

(iv) *Paraquat*

Bright brown scorched patches appear where the chemical has made contact with a leaf. The affected leaves will fall off if heavily scorched by a large amount of the chemical.

- *Remedy*
- None. Since no harm is done to the rest of the bush, it will recover by putting out new shoots and leaves as if it had been pruned. No harm is done apart from a check to growth, but starch reserves will be reduced so that repeated defoliation will cause a progressive weakening of the bush.

(v) Diuron

Orange-yellow chlorotic patches appear in the interveinal areas of the leaves turning brown and scorching. Leaves fall off if a large area is scorched. Younger leaves fall off first leaving bare stems above the maintenance layer. In extreme cases, the stems die back, maintenance leaves fall off and the plant dies.

Remedy

None. The bushes will recover if the chemical is not present in a large quantity to kill them. Recovery will be slow as diuron is persistent in the soil.

(vi) Fluazifop-butyl and oxyfluorfen

Information on the damage of tea bushes caused by these two herbicides is limited. However, under the recommended rates no visible symptoms have been reported.

(h) **Formulations**

Pesticides are not sold in pure form. They are mixed with various other materials to make them convenient and easy for the grower to use. These mixtures are called formulations.

Dusts

These are dry powders containing 10% or less of actual pesticide. They are ready for use and should be applied using a special dust pump or shaken from a small sack. DO NOT MIX THEM WITH WATER. Herbicides are not formulated as dusts because of their hazardous nature.

Wettable Powders (WP)

WP are also dry powders but they contain high concentrations of pesticides (up to 85%). They should be mixed with water and sprayed on the crop. DO NOT APPLY THEM DRY AND UNDILUTED AS IF THEY WERE DUSTS. They require continual agitation.

Emulsifiable Concentrates (EC)

EC are liquids which mix with water to form a white milky emulsion. They usually contain from 25% to 80% active ingredient. They are normally sprayed mixed with water.

Ultra-low-volume (ULV)

ULV formulations are usually solutions of pesticides in a non volatile (non-evaporative) oil. They do not mix with water and should be applied undiluted. THEY MUST BE APPLIED USING SPECIAL SPRAY MACHINES WHICH PRODUCE A MIST OF SMALL DROPS. If applied with ordinary pumps they will burn the plant.

Miscible Liquids (ML)

These are liquid formulations containing a fixed percentage of the active ingredient of the pesticide which when mixed with water will be completely miscible.

Baits (B)

The active ingredient is mixed with a pest food or attractant.

Fumigants (F)

These are volatile chemicals which liquefy when stored under pressure or inert under hermetic conditions and are used in confined spaces or in the soil. When applied they form a gas which will destroy the pest organism.

(i) **Chemical toxicity**

The toxicity of a pesticide is its ability to cause immediate and severe injury to man and is expressed as the LD^{50}. The LD^{50} is the lethal dose required, on average, to kill 50% of the test batches of animals, when the pesticide is given by mouth (orally).

This is expressed as the amount in milligrams of active ingredient of the nearly pure pesticide per kilogram of the body weight of the animal (usually the male rat).

Dermal Toxicity Tests is performed to determine how toxic a compound might be when it comes in contact with the skin. This includes sensitive areas such as the eyes as well as the skin.

The lower the LD^{50}, the higher the toxicity and the lesser the safety of the pesticide and hence, the greater the hazard to human beings.

The following table gives an idea of the toxicity and safety of a pesticide if the oral LD^{50} and dermal LD^{50} to rate is known.

ORAL LD^{50}

Value(mg/kg)	Toxicity	Safety
Less than 50	Extremely high	Extremely low
50 - 200	Very high	Very low
200 - 500	Slightly toxic	Slightly low
500 - 1000	Low	High
Greater than 1000	Very low	Very high

DERMAL LD^{50}

Value(mg/kg)	Toxicity	Safety
Less than 200	Very toxic	Extremely low
200 - 1000	Slightly toxic	Slightly low
1000 - 200	Low	High
Over 2000	Very low	Very high

The safe handling and use of pesticides require that you know how toxic the pesticide is (i.e. the LD^{50}), how the product should be handled and what safety measures should be taken so that the operators and other people concerned in the exercise are not exposed to it.

(k) **Safety period**

Many pesticides leave a residue in or on the crop which may be harmful to man. A safety period is always specified for each chemical. This is the minimum period that should elapse between spraying and plucking. It should be strictly observed.

(i) **To calibrate a sprayer**

(1) Mark out an area of the crop 10 m by 10 m (=1/100 ha).
(2) Fill sprayer with water
(3) Spray the marked area
(4) Refill the sprayer, noting how many litres of water are needed to restore the original level.
(5) Multiply the amount needed to refill (=the amount sprayed) by 100.

(6) Mix the recommended rate of EC or WP with the calculated volume of water and begin to spray.

(j)Recommended Pesticides

Pesticide	Dilution rate	Pest/disease/weeds	Safety period
(i)Insecticides /Acaricides			
1.Karate 1.75% EC)	4 ml per litre of water	Aphids, mites, Helopeltis, thrips	At least 7 days between spraying and plucking for manufacture.
2. Dursban 48% EC	10 ml/litre of water	Thrips, beetles, termites, scales, cutworm	At least 14 days
3. Malathion (Killpest) 50% EC	2.4 ml/litre of water	Thrips, Helopeltis, scale insects, Caterpillars	At least 7 days
4. Dicofol (Kelthane)	2.7 gm/litre of water	Red spider mite, yellow tea mite, purple mite (all stages except eggs).	At least 7 days
5. Tedion (Tetradifon)	2gm/10 litres of water	Purple mite, red spider, mite eggs	At least 14 days
6. Carbaryl 85% WP	2.4 g/litre of water	Soft scales, caterpillars	At least 7 days
7. Volaton 0.75%	Ready bait – bait broadcasted	Cutworms, crickets	Not applied on plants
8. Fenitrothion 50%	2 ml/litre of water	Aphids, grasshoppers, thrips, Helopeltis, scales, beetles, cutworms	At least 7 days
9. Decis	1ml/5 litres of water.	Aphids, grasshoppers, thrips, Helopeltis scale, cutworm	At least 7 days
10.Permethrin, Cymbush,Ripcord	1 ml/litre of water	Helopeltis, thips	At least 7 days
11. Omite	3 ml/l of water	Red crevice mites, Red spider mites, purple mites	14
12. Murphoil	20 ml/l	Scale insects	7
13. Gladiator	10 ml/l	Termites, Tobaco crickets	14
(ii) *Fungicides*			
12. Dithane M45	4-6 g/litre of water	Grey blight, stem canker	At least 7 days
14. Copper, Benomyl (Benlate)	5-7 g/litre of water 3-5 g/litre of water	Grey blight, brown blight, stem canker, Hypoxylong wood rot.	At least 7 days
15. Ridomil	5-10g/l of water	Damping off	N/A nurseries
(ii) *Herbicides*			
16. Roundup (Glyphosate)	12-25 ml/litre of water	Grasses, sedges and broad leaves weeds	Not sprayed on crop plants
17 Touchdown (Sulphate)	12-25ml/l of water	“ “ “	“ “
18. Gramoxone (Paraquat)	4-6 ml/litre of water	Annual grasses and broad leaved weeds	Not sprayed on crop plants
19. Diquat (Reglone)	7.6 ml/litre of water	Annual grasses and broad leaved weeds	Not sprayed on leaved weeds crop
20. Dalapon (Dow pon)	10-15 g/litre of water	Perennial and Annual grasses	Discard first harvest

21. Diuron (Karrmx)	2-3 g/litre of water	Annual grasses and broad leaved weeds	Discard the first harvest
22. Simazine (Gesatop)	5-7 litre of water	Annual grasses and broad leaved weeds	Discard the first harvest
23. Mamba (glyphosate)	12-25 ml/l	Grasses, sedges and broad leaves weeds	Not sprayed on crops
24. Kalach	12-25 ml/l	Grasses, sedges and broad leaves weeds	Not sprayed on crops
25. Wipeout	25 ml/l	Grasses, sedges and broad leaves weeds	Not sprayed on crops

Note: In most cases spot spraying is done on a few bushes in a field. Therefore dilution rate is preferred to rates/hectare.

(l) **Lightning damage**

When lightning strikes a field of tea, the lightning heats the soil and may even set fire to a few bushes at the point. Within a roughly circular area surrounding this point, the leaves of the tea bushes may wilt and turn brown and in the next few days, all these bushes will die. Any number ranging from about 10 to over 100 may be affected in this way depending on the severity of the lightening strike.

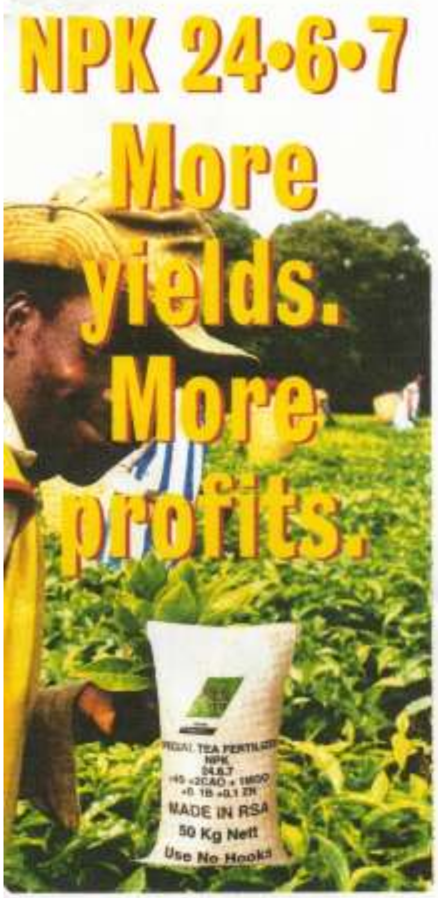
Around the perimeter of the affected area, there may be several bushes slightly affected; the leaves of such bushes may turn yellow but they recover quickly. There may also be some lines radiating out up to 50 metres or more from the central point of the strike, in which the leaves of the bushes also turn yellow; these bushes usually recover.

If there are shade tree in the planted area, one of them may be at the centre of the strike; this tree may be killed, or split open, or even set on fire, but sometimes a shade tree at the centre of a strike appears to be completely unaffected and continues to grow normally even though a large number of tea bushes are killed around it.

Within the area affected grasses and weeds which are growing in the tea usually get killed if the soil water boils. But sometimes the tea bushes may be killed and the surface-rooting grasses and weeds continue to grow.

Tea bushes which have been killed by lightning should be dug out and as much as possible their root systems should be removed, as soon as possible, so that they do not become centres of infection for Armillaria root disease.

It is said that when tea bushes have been killed by lightning, the ground in which they are growing becomes "sterile" and tea will no longer grow in it. There is no evidence that this is true, at least, in Kenya. Several cases are known in which bushes killed by lightning have been removed and the place replanted, and the new bushes are growing normally. It is thought that the belief may have arisen in places where the upper layers of the soil had become so depleted of potash that the amount remaining was inadequate for young plants, out in without fertilizer, to survive.



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Chapter VII

BLACK TEA MANUFACTURING TECHNOLOGY AND FUEL WOOD

(a) Black tea manufacture

(i) Introduction

The process of tea manufacture, converting plucked green tea leaves into the final saleable consumable product, is a vital step in the production of black tea. Good manufacturing practice can produce the best tea from the available good leaf, and hence realise the best market price. It is important to note, however, that the quality of tea produced depends on the leaf that is plucked, the type of tea bush, how the leaf is handled, the time of the day or of the year from prune, the standard of plucking, fertiliser rates and types.

In the estate sector of the tea industry in Kenya, the whole process of tea production, from planting to marketing, is in the hands of a single company, and thus the various stages can be integrated. This is much more difficult in the case of the small holder sector where a large number of individual farmers are responsible for all stages from planting to plucking, and then the giant smallholder organisation (KTDA) collects, transports and manufactures this (necessarily) very mixed leaf. This dichotomy must be borne in mind whenever considering tea manufacture in Kenya.

The type of tea produced in Kenya must also be considered. It is mostly plain to medium flavoury tea. This does not indicate that it is tasteless; the term "plain to medium flavoury" merely indicates that it does not have large amounts of the delicate "flavour" components found in certain other teas from some other parts of the world at various times of the year. It instead has the much sought after qualities of strength, brightness, colour and briskness and in some cases distinct flavour. For this reason, most of the tea produced in Kenya is by "unorthodox manufacture". This involves considerably greater maceration of the leaf than afforded by the "orthodox" methods, which is acceptable, as there is less need to try to maintain or produce the very delicate flavours associated with some other teas.

Finally, it must be repeated that high quality cannot be created in the factory. The original leaf determines the maximum quality of tea that can be produced. Poor leaf cannot be made into good tea, even by the best of factories. Similarly a badly organised factory may produce poor tea from the best quality leaf.

(ii). Black tea manufacture - the biochemical background

The leaves of a tea plant contain a group of chemical compounds called catechins. The leaves also contain an enzyme (biological catalyst) called polyphenol oxidase. In healthy leaves, these components are physically separated and therefore do not interact. When the tea leaf is processed, the maceration of the leaf disrupts its structure extensively. This causes the catechins and the enzyme to mix, and if oxygen is present (from the air) then a series of biochemical reactions commonly referred to as fermentation, take place.

These fermentation reactions lead to the production of mainly two new groups of compounds, the theaflavins and the thearubigins. The "brightness" and "briskness" of a tea liquor are thought to be due to theaflavins, and its "strength" (body) and "colour" due to thearubigins. These two groups of compounds give the characteristic taste of plain black tea. There are four major theaflavins in black tea with astringencies in the order theaflavin-3, 3'digallate > theaflavin-3-gallate = theaflavin-3'-gallate > theaflavin. The most astringent tea is produced when there is high level of total theaflavins and the correct theaflavin/thearubigins ratio, and/or high levels of the more astringent theaflavins.

Fresh tea leaves also contain protein complexes and free amino acids. The protein complexes breakdown into simple amino acids that are further oxidised via decarboxylation and deamination reaction to aldehydes during fermentation. The aldehydes can remain as final products in the black tea or are further reduced to alcohols or oxidised to carboxylic acids. The aldehydes, alcohols and carboxylic acids form part of the volatile flavour components (VFC) of tea. There are unsaturated fatty acids in the fresh tea shoots. Upon maceration, the fatty acids break down to aliphatic aldehydes through lipoxygenase-catalysed oxidation. The aldehydes are either reduced to primary aliphatic alcohols or oxidised to carboxylic acids to form part of the VFC. Most of the compounds imparting green grassy odour to black tea (Group I VFC) are products of fatty acids degradation.

There are terpene glycosides in fresh tea shoots, which are hydrolysed to terpene alcohols during withering and fermentation. Carotenoid compounds in green leaf break down during fermentation and firing to form volatile terpenoid compounds. Most of the terpene alcohols and terpenoid compounds impart pleasant aromatic flavour to black tea and form part of what is referred to as the Group II VFC. Some of these chemicals are retained during the drying of tea. Drying terminates all chemical reactions and removes moisture so that the tea can be stored in a stable form, which can be made available to the market.

The chemical reactions mentioned above are sensitive to a whole range of factors, some of which can be controlled in the factory or in the field. Several of these factors are discussed below.

iii) Factors influencing chemical quality characteristics of black tea

The amount of catechins

Generally, the more the amount of catechins present, the more theaflavins and thearubigins will be produced. The youngest shoots of the bush (two and a bud) contain the most catechins, the amount decreasing as the shoot part gets older. That is why the best tea is made from the youngest shoots. The amount of catechins varies with, for example, the time of day, the time of year, the prevailing and previous weather conditions, and the clones. There are six major catechins present in the green tea leaf. These are (+) catechin, (-) epicatechin, (-) epigallocatechin (+) gallocatechin, (-) epicatechin gallate and (-) epigallocatechin gallate.

The ratio of individual catechins

The proportions of each of the six major catechins in the leaf have important effects on the relative amounts of theaflavins and thearubigins produced and, hence on the quality of the made tea. Of vital importance is the composition of the individual catechins leading to formation of high amounts of gallated theaflavins. The same factors i.e. time/season and clonal variety which affect the amount of catechins can also affect the ratio of gallated to non-gallated theaflavins. These two factors are not under the control of the factory. However, the tea grower can influence these factors by using proven clones, practising the recommended husbandry practices and maintenance of good plucking standards. The growing conditions in Kenya are such that the leaf tends to have a reasonable balance of catechins all year round.

Aroma precursors

The production of aromatic black tea is more dependent on the amounts of precursors present for the relevant VFC. Generally, the total amount of VFC affects the aroma of black tea less than the ratio of the Group II VFC (sum of those volatiles imparting nice, flowery and fruity smell) to Group I VFC (sum of volatiles imparting green grassy aroma). This ratio is referred to as Flavour Index (FI). The amount of Group II VFC is affected by the amounts of terpene glycosides, amino acids, carotenes and enzymes involved in converting these precursors to the VFC. Also, some of the VFC from the precursors exist in fresh leaf as primary products and their levels also affect the sum of Group II VFC. The production of the Group I VFC is dependent on the amounts of unsaturated fatty acids and amino acids in the tea leaves, and the activities of the enzymes responsible for their degradation. Generally, the tea growing environment, agronomic and processing procedures, will affect the aroma of black tea.

Fermentation temperature

It has been shown that high fermentation temperatures (i.e. 25°C or over) produce black teas which have less theaflavins, more thearubigins and lower flavour index, and usually of a lower quality. It is therefore commercially advantageous to control fermentation temperature by installing cooling equipment. Since temperatures within tea growing areas of Kenya are usually not very high, use of water cooled, humidified air would suffice during hot seasons.

Fermentation duration

Several methods have been proposed to follow the progress of fermentation so as to stop it at the optimum duration. Rapid methods have been developed for the estimation of theaflavins in fermenting “dhool”, and it has been suggested that these can be used to determine when to terminate fermentation. It has been found that these techniques are not particularly useful in Kenya, due to the nature of the Kenyan leaf and Kenyan fermentation techniques.

Experiments at the Foundation have shown that sensory evaluation of tea at the dryer mouth is the most appropriate method of assessing optimum fermentation time, and indeed, this method enables the factory manager to make tea suitable for the intended market. The varied growing conditions and fermentation practices generate a very broad peak of optimum fermentation time, especially when “dhool” is fermented at low temperatures, and there is considerable leeway on how long the “dhool” can be fermented. As a general rule, shorter fermentation durations produce brisker, brighter and more aromatic black teas, while longer fermentation time produces thicker and more colour black teas. However, if fermentation duration is too long, the black teas become muddy in taste, whereas if fermentation duration is too short, then greenish black teas are produced.

Aeration during fermentation

Supply of oxygen from the atmosphere is essential for successful fermentation. Consequently, if leaf is fermented other than in very shallow layers, air must be forced through. This air should be cool and humid. This helps in keeping the temperature down and in preventing drying of the fermented leaf, which otherwise would inhibit the chemical processes that occur during fermentation.

Firing

This is the stage that halts most of the chemical processes of tea manufacture, and gives a stable, storable product. During the initial stages of drying, the chemical reactions of fermentation continue. They only stop once enough water has been removed or sufficiently high temperature has been attained to inactivate polyphenol oxidase and, thus, prevent further reactions. Prior to this point, there are some changes in the levels of the theaflavins and thearubigins, then finally a stable product is formed at 3.6% moisture. Very fast moisture loss during firing or incorrect temperature settings of the dryer can lead to case hardening, producing black tea which are wet inside the tea particles. Such teas deteriorate (lose quality) very fast upon storage. Because these reactions occur in the initial stage of drying, it is important at this stage to have the correct temperatures and airflow, and to minimise unwanted chemical changes. Excessive temperatures towards the end of firing produce “burnt” product. Even firing can only be maintained if inlet and outlet temperatures and leaf loading are kept constant.

(iv) Tea manufacturing stages

A plan of a “typical” Kenyan tea factory is shown in Figure VII.1. that gives an idea of actual factory layout. In most cases the withering section is placed as floor(s) of its own on top of the processing section, or is put up as a separate building. This is because withering requires large space to accommodate leaf in withering troughs. In more modern factories, part of the withering section having troughs instead of leaf holding tanks for achievement of chemical wither. In such factories at peak crop, withering is either done using the holding tanks only or through a two-stage process. This has been explained more fully under withering.

1. Leaf collection

The manufacturing process starts the moment tea leaves are plucked. The plucked leaves start to wither and at this point inadequate handling and transport will result in bruising of the leaf, heat development, initiation of uncontrolled fermentation leading to reduced quality. Care should be taken when transporting green leaf to avoid heat accumulation

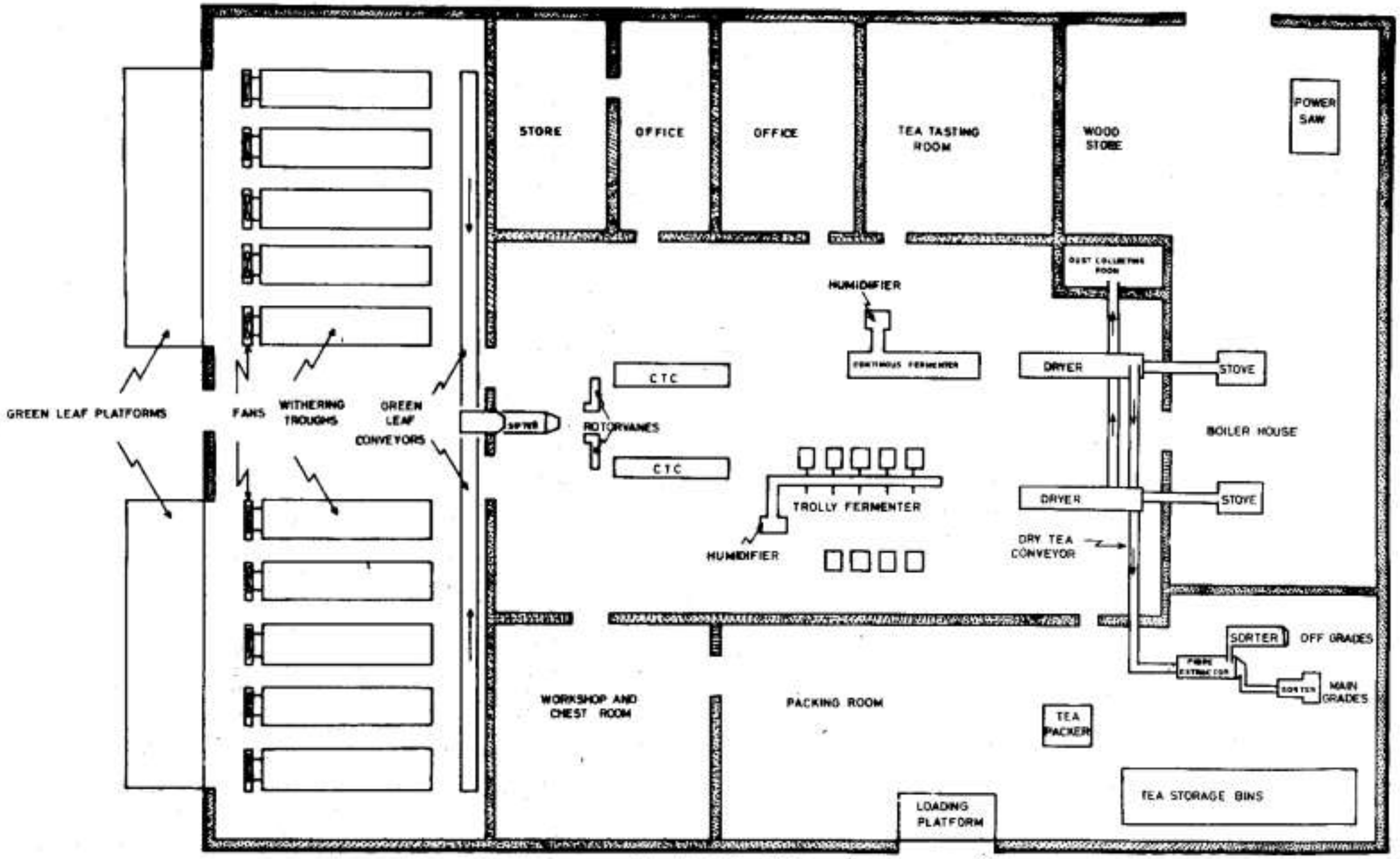


Fig. vii. 1: Model plan of a Kenyan tea factory.

and bruising. The use of suspended gunny sacks carrying about 10 kg of green leaf usually allows enough ventilation to avoid heat accumulation during transport from field to factory, provided the leaf does not over stay in the field or in the transport vessel. Where transportation to the factory can be done within an hour, leaf can be transported in any other convenient containers.The standard of plucking also affects the quality of made tea. A finer plucking, i.e. “two and a bud” standard will produce a higher quality tea that will fetch better price. It is important to have a constant supply of leaf with consistent plucking standard so that the factory does not have to keep changing the manufacturing conditions.

The estate sector is able to control the flow of leaf into a factory very effectively. However, in the smallholder sector leaf supply is erratic and this causes problems in maintaining consistent standards of manufacture. If the in coming leaf is “two leaves and a bud”, there is generally more leeway in manufacture. Withering times, fermentation times and drying times will not need to be so precise as in the manufacture of the coarser leaf.

2. Withering

This is an aspect of tea manufacture that is very expensive in terms of space, time, energy and labour utilisation. Unfortunately it is also one of the least understood processes in black tea processing. Withering is presumed to occur after the freshly plucked shoots are placed in the withering trough and air is blown through them for 14 - 18 hours. During this process, the most noticeable change is moisture loss which is accompanied by cell wall permeability changes which make subsequent maceration easy. This process of moisture loss and cell wall permeability changes is called physical wither.

However, less obvious is the chemical wither. This starts immediately the leaf is detached from the bush and chemical reactions involved in senescence start. The chemical wither reactions include the changes in the activity and nature of polyphenol oxidase (the enzyme responsible for turning green tea leaf to brown-black) hydrolysis of terpenoid glycosides to release terpenes, breakdown of proteins to amino acids, hydrolysis of lipids to free fatty acids, and breakdown of carotenes to simple terpenes. Although these changes mainly benefit black tea aroma, they also affect plain black tea quality parameters. Chemical withering is mandatory for production of high quality black teas. However, it is very difficult to control chemical wither duration in a commercial factory processing situation. Optimal chemical wither varies from 6 to 20 hours. Shorter chemical wither times produce green and harsh black teas, while longer withering durations result in dull black teas with low sensory evaluation.

In Kenya, plain teas are produced during the peak crop periods, while flavoury black teas are produced mainly from clonal leaf from some areas of the country during the slow growth (low crop) seasons. Plain teas were presumed to benefit only from physical withering. However, it is now known that both plain and flavoury black teas are affected by physical wither. Hard physical withers (high moisture loss i.e. below 72% moisture content) enhance the quality of the production of flavoury teas. However, for plain teas, hard physical wither reduces the levels of some plain tea quality parameters i.e. theaflavins, brightness and thearubigins. Thus, plain black teas benefit from controlled physical wither, the quality actually deteriorates when too much moisture is lost from the leaf.

Physical wither enhances factory throughput. The softly withered leaf is bulky and this slows down rotorvane output, and dryers may not cope with excess moisture in the leaf.

Consequently, withered leaf should have only up to 72% moisture content if the dryers are to give optimum throughput.

During periods of increased tea production, many factories usually face constraints in processing especially in the withering section. Studies have shown that the two-stage withering technique where chemical and physical withers are done at distinct stages make black teas with similar quality as black teas made through the conventional one-stage withering technique where physical and chemical withers are done concurrently. However, in a two-stage wither, chemical wither must be done before physical wither and during the process, black tea quality can be enhanced by using cold air to achieve physical wither. This knowledge has led to development of tanks which occupy less space but hold more leaf and use less electricity, as suitable vessels for chemical wither. Where tanks are not installed, factories can alternate over-loaded withering troughs with normal loads.

Upon achieving chemical wither, the normal-loaded troughs can be subjected to forced physical wither using high speed (velocity) air current. After physical wither has been achieved the leaf is removed for maceration, while the leaf in the over-loaded troughs is sub-divided into those emptied troughs, then subjected to forced physical wither. This process allows the factory to hold up to 35% more leaf in the factory than it could under traditional trough withering system.

The constraint in withering space is more acute during the peak crop seasons when the black teas produced are generally plain. Such teas can be manufactured without quality loss if chemical withering time is reduced to as short as six hours. The reduction of chemical withering time will permit factories to start processing early and, thus, create extra processing time. Additionally, the same enables the factory to use one withering trough more than once in a day, thus enabling the factory to hold more leaf.

Since leaf processed during peak crop periods produces plain black tea, and because for such teas softer withers make superior teas, factories which can cope with soft withers without suffering reduction in throughput at the rotorvanes or dryers as a result of some engineering modifications, can use tank wither only. In such manufacturing processes, all moisture is removed during drying. Due to the increased surface areas of macerated leaf, energy may be more efficiently utilised as moisture losses through evaporation are achieved faster. Economic survey has shown that it is more cost effective to install some withering tanks in factories than to build new factories or expand old factories with traditional withering techniques.

3. Leaf maceration

Almost all tea produced in Kenya is by unorthodox maceration, usually using one rotorvane and three Crush, Tear and Curl (CTC) machines in series or one rotorvane and a Lawrie Tea Processor (LTP). This is most suitable because the teas produced are mostly plain teas, and it is not necessary to preserve all delicate flavour components.

Teas made by unorthodox maceration are generally much smaller in particle size than those made by traditional (orthodox) maceration, and they give brighter, brisker and more coloured infusions. This is also of advantage to the tea market which has moved towards tea bags and “quick brew teas” over the last twenty years. It seems probable that more and more teas from Kenya will be processed using unorthodox techniques, with only a small percentage of specialist tea utilising orthodox methods of maceration.

The object of the maceration step is to mix up the catechins and the enzyme in the tea leaf tissues, and to allow free access of oxygen. This allows fermentation to proceed, producing theaflavins and thearubigins respectively. In delicate flavoury teas, other chemical reactions may be of equal importance, but this is not thought to be the case in Kenya plain teas. Thus it follows that rapid, severe maceration will cause maximum leaf disruption and lead to a finished product that has the characteristics desired of Kenya tea.

The first step in maceration is usually the use of a rotorvane. It consists of a cylinder containing a rotating central shaft. Spiral vanes on the shaft propel the leaf along the cylinder, and distortion and twisting of the tea leaf tissues occur by the rubbing and shearing action of the leaf against projections coming out of the cylinder casing. This whole process is designed to disrupt the cellular structure of the leaf.

After rotorvane maceration, leaf usually passes through a series of CTC machines. These machines consist of two rollers rotating at different speeds in opposite directions. Because the surface of the rollers is serrated, their rotation in opposite direction produces more leaf cellular disruption by crushing and stretching and cutting it into small particles.

The LTP is an alternative to CTC, and may be used in conjunction with a rotorvane. It is based on the principle of a hammer mill, with the rotating hammers disintegrating the leaf very quickly. In some factories this is considered sufficient for fermentation, but in others an extra cut with a CTC, usually in the middle of fermentation, is thought to be of advantage.

The net result of these maceration processes is to produce small particles of leaf and stalk that have had their internal structure broken down to allow air to easily reach the internal structure of the leaf, leading to even fermentation. The macerated leaf is known as “dhool”.

4 Fermentation

This is the stage of manufacture where the major chemical (rather than physical) changes occur. In essence, fermentation requires allowing oxygen to permeate the macerated leaf so that the endogenous catechins can be converted through enzyme-catalysed reactions to theaflavins and thearubigins. Some of the aroma compounds are also formed during fermentation.

Originally, the procedure was for leaf to be left in thin layers on slabs, so that air would penetrate naturally. However, oxygen requirement of leaf macerated by unorthodox means is much higher than at processed by orthodox means. This led to the use of air forced through the fermenting dhool to increase the oxygen level available for fermentation. The air also helps cool the dhool, as the chemical reactions of fermentation generate heat.

The commonest fermentation system in Kenya utilises George-Wiliamsons (G.W.) trolleys. These have a perforated metal base with a plenum chamber underneath. After loading with “dhool”, the G.W. trolley is then attached to a duct with humidified air forced through its plenum chambers and hence through dhool, thus aerating the fermenting leaf.

Because the air is humidified, the fermenting dhool does not dry out. It is possible that humidification could be dispensed with at the later stages of fermentation, causing a slight loss of moisture from the dhool, and reducing the load on the dryer. At these later stages there are less chemical reactions generating heat and oxygen demand is lower.

The second effect of humidification is that of temperature control. Use of the correct temperatures for fermentation is very important. The reason for this lies in the nature of the biochemical reactions producing theaflavins and thearubigins. Increasing the temperature does not produce the same result in a shorter time. Higher temperatures favour the production of thearubigins, thus producing a strong, coloured tea that can easily turn out flat and muddy. Lower fermentation temperature on the other hand, favour the production of theaflavins, higher flavour index and brighter coloured teas. Thus temperature control can change the type of tea produced. It is envisaged that, in the future when these reactions are better understood, it may be possible to change the temperature regime of fermentation to produce exactly the sort of tea that is required by the market.

The fermentation of dhool in deep fermenting beds can easily lead to the formation of "balls" of dhool, which in turn lead to an uneven fermentation. This has resulted in many factories using a mid-fermentation ball break, although doubt has been expressed at its usefulness. While there is often no detectable difference between teas that have or have not received such a ball break, it is still a useful precaution for those times when processing conditions are not ideal.

A more recent development is the use of continuous fermentation machines. There are a host of different designs, but at the moment there are three basic types:-

The Moving Belt Fermenter.

Dhool is fed onto the first of a series (usually 3 or 4) of variable speed moving belts, usually with humidified air blowing through. Transfer from one belt or from one part of the belt to the next can be accompanied by ball-breaking, and fermentation time controlled by the speed of the belt.

Trough fermenter. [Linsay Fermenter]

The dhool is fed into a trough and moved along by longitudinal or transverse rotating screws or vanes. The turning of the dhool allows aeration and also prevents ball formation.

Fixed Bed Fermenters.

The dhool is fed into a trough that has a perforated base plate through which air is blown. The dhool is then mechanically dragged along the length of the trough.

5 Drying

This is the process that stops fermentation and produces a stable product of low moisture content that can be shipped and endure storage. Changes do occur in black tea after drying, but they are small and have negligible effect on tea quality if drying is done well. In essence, the process of drying tea consists of exposing the tea to a flow of hot air. Traditionally (in a conventional dryer) the system is designed such that the driest tea is exposed to the air first, and wettest tea (straight from fermentation) last. This is usually achieved by having the tea pass on a belt through the same stream of air 4 to 6 times, with the wettest tea farthest away from the air inlet. This allows the maximum utilisation of the air, but recycling is not possible because of moisture pickup.

A recent development in drying technology is the advent of the fluid bed dryers. In this form of drying the tea enters a horizontal tunnel, the base of which is a perforated plate. Hot air is blown vertically through this plate, and the "dhool" forms a "fluid bed" i.e. it is suspended in the fluidising hot air. This not only gives rapid, even drying, but a combination of the air pressure and decline in leaf density forces the drying tea along the tunnel, thus removing the need for a moving tray. There are various advantages to this system. Moving parts are few leading to easier maintenance. The exhaust air from the end of the tunnel can re-cycled at the beginning of the tunnel, thus saving on fuel. Considerable fibre can be extracted during drying using a cyclone. Finally, the tea produced has a greater bulk density; therefore more mass can be packed in a standard container. As shipping costs depend on volume, not weight, shipping costs are reduced. Fluid bed dryers are slowly replacing conventional dryers in the Kenyan tea factories.

The source of fuel for dryers is a problem. Due to recent increases in the price of oil, wood is favoured by the estate sector. This is much more difficult to achieve in the smallholder sector as most factories in this sector have problems obtaining sufficient wood fuel. Consequently oil-fired boilers are mostly used, resulting in increased production costs.

Based on current estimates, about 10% of the production cost of tea is the cost of fuel wood. If this is replaced by oil, this figure can rise to 35%. The latter also results in a loss of valuable foreign exchange. It is possible that in the future, a considerable proportion of the energy required in tea production could be supplied by solar energy collectors built into factories. This would release land currently used for fuel wood for more productive purposes, and reduce the expenditure on oil imports.

6. Sorting

After drying, the fibre is removed from the tea before it is graded by size. This process is known as sorting. The main grades, which are also called primary grades and comprise between 85-95% of the tea are fibre free, are sold at much higher prices than the fibrous off grades. The grade distribution as ratio of primary to secondary grades, which affects the total income of the factory is heavily influenced by the original plucking standard, with coarser plucking leading to more secondary grades. The size distribution can also be manipulated by adjustments of CTC settings so that the factory maximises on the grades it sells best.

7. Shipping

Most tea is transported from the producing country to the consuming country which may be thousands of kilometres apart by road and sea. This means that the packaging must be designed to maintain the quality of the tea during transportation of about 3 months and beyond. The two major factors to be considered in designing the packaging material are the prevention of moisture uptake (to prevent mould growth and tea going off) and the prevention of taints.

Traditionally, this has been achieved by the use of wooden tea chests lined with aluminium foil. There are however, moves in various parts of the world to replace these chests. Not only are chests expensive and non-reusable containers, but they consume large amounts of wood in their production. This is a great disadvantage economically and a major environmental problem.

The replacement for the tea-chest is a polyethylene or aluminium foil lined, multi-wall paper sack. The sack is an effective barrier to moisture and taint, and lends itself to palletisation for transport in containers. The sack also costs less than half the price of a tea chest. It is also possible that sacks can be used with slip-sheets, thus allowing more tea to be shipped per container. Use of this system could result in a considerable saving in packaging costs, especially if tea is containerised at the factory.

b) Chemistry of tea quality

(i) Scientific analyses of made tea

As in other food and beverage industries, attempts are being made to develop scientific methods of analyses to determine the “quality” of tea. The idea is to discover objective, reproducible tests to support (but not replace) the more subjective estimates of the tea taster.

There is much international collaboration and discussion on this matter, and it is possible that, in the future, scientific analyses will be incorporated into some form of a Minimum Standards Agreement. However, much more work needs to be done before any international agreement is likely.

(ii) Details of reactions involving catechins during fermentation.

The six major catechins in fresh tea leaves can be divided into two groups. The simple catechins are catechin (C), epicatechin (EC), and epicatechin gallate (ECG). The gallocatechins are gallocatechin (GC), epigallocatechin (EGC), and epigallocatechin gallate (EGCG).

The reaction of a simple catechin and a gallocatechin, catalysed by the enzyme polyphenol oxidase (ppo) , leads to the production of a theaflavin. The four major theaflavins in tea, along with their precursors, are given below:-

EC + EGC $\xrightarrow{O_2,ppo}$ Theaflvain

EC + EGCg $\xrightarrow{O_2,ppo}$ Theaflavin-3-gallate

ECG + EGC $\xrightarrow{O_2,ppo}$ Theaflavin-3’-gallate

ECG + EGCg $\xrightarrow{O_2,ppo}$ Theaflavin-3,3’-digallate

The theaflavin products of some of the other possible combinations of catechins have been detected in tea, but only in very small amounts.

The chemical nature of the other major taste components in plain black tea, thearubigins, have not yet been elucidated. Thus the precursors and route of formation remain largely unknown.

(iii) Details of aroma formation during black tea manufacture

Black tea contains appreciable aroma compounds and over 600 such compounds have been identified. Biogenetic pathways for the formation of many of these compounds have not been fully established. Some of the aroma compounds are primary products in the tea leaf while others are secondary products formed during black tea processing via enzymatic, redox or pyrolytic reactions.

1. Primary products

Some aroma compounds existing in the fresh tea leaf have been identified in the aroma complex of black teas. These compounds are mainly alcohols and include *Z*-2-penten-1-ol, *n*-hexanol, *Z*-3-hexenol, *E*-2-hexenol, linalool plus its oxides, nerol, geraniol, benzyl alcohol, 2-phenyl ethanol, and nerolidol. The quantities of these compounds change during black tea processing. The levels of some of these alcohols increase during processing possibly due to various enzymatic reactions while levels of some alcohols reduce possibly due to volatilisation leading to losses or glycosidation rendering the alcohols non-volatile.

2. Secondary products

Many aroma compounds are formed during tea processing. These compounds are derived from carotenes, amino acids, lipids and terpene glycosides. Some of these aroma compounds are also formed naturally in the tea leaf i.e. are also primary products.

Carotene levels in the tea leaf decrease during withering, fermentation and firing with resultant production of various aroma compounds e.g. ß*eta*-ionone, *alpha*-ionone, 3-hydroxy- ß*eta*-Ionone, Epoxy- ß*eta*-Ionone etc. Such terpenoid aroma compounds produced form part of the Group II volatile flavour components and impart sweet flowery aroma to black tea. The formation of this group of compounds occur via enzymatic reactions during withering and fermentation or pyrolytic reactions during firing.

Proteins are hydrolysed to simple amino acids during withering. These amino acids are oxidised by quinones formed from catechins to form aldehydes. In this process valine, leucine, isoleucine, phenylalanine are converted to 2-methyl propanal, 2-methylbutanal, pentanal and phenyl acetaldehyde respectively. The aldehydes can remain as final aroma product, but some are reduced to alcohols while others are oxidised to carboxylic acids respectively.

Tea leaves contain free lipids and fatty acids. The lipids hydrolyse to free saturated or unsaturated fatty acids during black tea processing especially during withering. The unsaturated fatty acids break down to aliphatic aldehydes through a process catalysed by lipoxygenase enzyme. Thus linolenic acid forms *Z*-3-hexanal most of which isomerises to *E*-2-hexanal which is the major Group I VFC. Some formed aldehydes are further reduced to alcohols while little amount is oxidised to carboxylic acids. Most of the Group I VFC are products of lipid degradation during black tea processing.

Terpene glycosides also hydrolyse to simple volatile terpenes during black tea processing. For example, linalool glycoside releases linalool. The released terpenes form part of the Group II VFC.

(c) Impact of agronomic and cultural practices on black tea quality

Within the tea industry debates continue whether agronomic and cultural practices have impact on black tea quality.

Plucking is one agronomic practice known to have a contribution towards tea quality. Indeed, coarse plucking standard produces inferior quality tea. A plucking standard of two leaves and a bud compromises both quality and yields. However, in practice it is impractical to pluck exclusively two leaves and a bud. Thus for production of high quality black tea a plucking policy should be developed which not only ensures plucking mostly two leaves and a bud but also minimizes breaking back. Such a policy can be accomplished by plucking at short intervals of less than 10 days depending on the shoot growth. Indeed, such policy also results in yield increase.

However, if short plucking intervals like this may not be practical due to shortage of pluckers, selective plucking of two leaves and a bud accompanied by breaking back should be practised. Plucking by shears or motorised machines even if at short plucking intervals also lead to lowering of black tea quality. This may additionally affect the tea bush health in the long run. Thus, hand plucking leads to better tea quality and healthier bushes.

The environment also affects tea quality. Generally factors which tend to enhance tea productivity e.g. good growing weather conditions tend to reduce tea quality. Indeed, the black teas made during peak crop seasons are generally plain and of low quality even if manufacturing conditions are optimised. Teas which are grown at lower altitudes and hence warmer conditions tend to make inferior black teas compared to high grown teas. In Kenya however, such altitude effects tend to be minimal as teas are grown between 1500 - 2700 m above mean sea level. Shade environment which reduces tea growth rates and lowers yields tends to improve tea quality.

Although fertiliser application, especially nitrogenous fertiliser, is mandatory for increased productivity of black tea per given unit land area, excessive use of nitrogen lowers the quality of the produced black tea. Thus fertiliser regimes must also take quality implications into consideration. Nitrogen should therefore be applied at rates which compromise both yields and quality. Black tea quality improves as the tea nears next pruning time. Since pruning is a necessary agronomic practice that keeps the bushes at manageable heights, it is important that considerable mixing of leaf from different fields in different periods from previous prune is done to ensure consistent black tea quality.

The quality of produced black tea is also dependent on the genetic make up of the leaf material. In most cases farmers tend to look for high yielding cultivars without seeking to know their quality characteristics. It is important that farmers seek both high yielding and high quality planting materials. Such materials should however, be proven in areas of intended growth as different cultivars react differently to varying environmental conditions.

The effects of factory operations and procedures on quality of black tea are discussed in sections dealing with the particular processing stages and techniques.

d) Fuel wood

The use of fuel wood for energy purposes is a very old and important practice. Energy is an essential and scarce commodity and features strongly in modern economy. So long as fuel wood and charcoal can provide energy in Kenya, wood will continue to be an invaluable commodity. Kenya does not have the major traditional sources of energy, i.e. petroleum, oil, natural gas, coal and uranium. Furthermore, Kenya being basically an agricultural country has the comfort that while oil, natural gas, coal and uranium become depleted, wood fuel is a renewable resource and in theory can be available indefinitely. If enough land to plant fuel wood is available and the fuel wood is managed well, the much needed energy will be available in perpetuity.

However, in Kenya the production of wood fuel is in direct competition with production of food and other uses of agricultural land. To keep its price down, the wood fuel should be produced within reasonable distances because it is a bulky commodity and hence its price is sensitive to distances.

The tea industry in Kenya has been affected by prevailing world energy crisis because of the high oil prices. As a result, in some factories the oil fired dryers have been converted to wood fuel dryers. For that reason, it has become necessary to establish wood fuel plantations with tree species which grow fast and produce high yields of wood fuel (firewood) with high calorific values.

In rural areas smallholders require wood fuel for cooking and heating. Due to the small sizes of the small-holdings, the smallholders require fuel wood species which can be grown in tea fields, along the hedges, boundaries or road sides without adversely affecting the tea plants and other crops.

The TRFK has not experimented with fuel wood. Therefore the information given in this handbook is from the literature and communications from the personnel in the tea estates in Kericho and forestry officers. For further details on any aspect of growing wood fuel species, readers are referred to forest officers or rural afforestation officers near their farms.

(i) Fuel wood species

Eucalyptus (gum trees) species have been found to be the most productive in fuel wood plantations. In Kenya there are two species of Eucalyptus, *E. saligna* and *E. grandis* preferred by large estate tea producers . The two species are preferred because they coppice easily and are fast growers. To a lesser extent black wattle (*Acacia mearnsii*) is grown in fuel wood plantations. In addition to providing wood fuel, the black wattle produces bark which is sold for tannin extraction.

In small-holdings *Eucalyptus* (various species) are also grown, but being both heavy water feeders and very tall, *Eucalyptus* trees affect other crops grown around them. Other fuel wood species also grown are black wattle, *Cypress* and *Grevillea*. The *Grevillea* species may be grown in the tea fields so long as the trees are planted widely apart and the branches lopped regularly.

(ii) Production

The calorific value of fuel wood is important in considering which species to grow. Generally, the denser the timber the higher the calorific value. However, the rate of growth is also important because a species may have less dense timber but the rate of growth may be so high that the resulting volume has higher calorific value than timber from dense but slow growing species.

For drying tea using wood fuel, it has been found that in Kenya every 3.3 to 4 ha of tea require 1 ha of fuel wood.

(iii) Field management

The first cycle of *eucalyptus* takes 8 - 10 years. Once the trees are felled the stumps will coppice, each stump producing many shoots which should be thinned to 2 or 3 per stump after 6 to 8 months. In the second and subsequent cycles the trees will grow faster than in the first cycle, therefore these cycles should take about 6 or 7 years when the stems are 14 cm or more in diameter. The production of wood in plantations is 40-120 m^3/ha/year. A few trees will fail to coppice at each cycle and it is suggested that at every cycle there should be infilling of the trees which fail to coppice.

The black wattle trees are harvested after 7 - 10 years and do not coppice. Felling is done either by axe, bow-saw or power saw. There is a tendency for the stump height to rise when an axe is used in felling trees and therefore a bow-saw or power saw is preferred. When *Eucalyptus* are felled by bow-saw or power saw they coppice better than when felled by an axe.

After felling eucalyptus and black wattle, the logs are cut to convenient lengths, say 1 m or 2 m long, and left to dry for some time to reduce the transport cost. At the time of use the moisture content of the fuel wood should be below 20%.

(iv) Air-drying of fuel wood

The calorific value of fuel wood is affected by the moisture content. The amount of water in the wood not only reduces the heat value of a fuel by so much inert material but that some more energy is lost evaporating the water from the wood before it can burn. Therefore the fuel wood should be air-dried before use. On the other hand completely dry wood would burn extremely quickly making control of heater temperature difficult. Splitting thick logs of wood hastens the air-drying of the wood.

(v) Establishment

1. Eucalyptus

The seeds are planted in germination beds first and when the seedlings have 4-6 leaves they are transplanted to either boxes with soil which is 10 cm deep and at spacing of 5 x 5 cm square or into polythene sleeves of various sizes, e.g. 10 cm long and 6.25 cm diameter (10 cm lay-flat). Where the seedlings are transplanted into boxes, frequent root pruning is necessary to prevent the roots from growing into the soil below the boxes. The root pruning is accomplished by moving the boxes frequently or by passing a wire below the boxes. The sleeves with seedlings should also be moved once in a while to root prune as in boxes.

The seedlings are transplanted to the field when they are about 20 cm tall. The roots of the seedlings in boxes are side pruned so that each seedling's roots are covered by a soil cube 5 cm x 5 cm x 10 cm. Where the seedlings are in sleeves, the polythene must be removed at planting. Fertiliser is applied in planting holes at the rate of 30 g of triple super phosphate in each hole.

The site to be planted should be cleared prior to planting. The transplanting is done at the onset of the long rains. The young Eucalyptus are intolerant of competition with weeds and therefore should be kept weed free, especially immediately round the plants until the canopy covers the ground. The normal spacing is 2.5 m x 2.5 m square.

2 Black wattle

The land is prepared before the rains, making sure that all the couch and Kikuyu grasses are removed. The black wattle is easily established by direct seeding although seedlings may be raised in the nursery and later transplanted to the field. The seed should be treated before use to ensure rapid germination and an even stand. The seed is treated by immersing it in boiling water and then leaving the seed to cool and soak in the water for 24 hours. After this the seed is dried in the shade and planted directly. The treated seed should not be kept for planting in the following planting season.

Planting is done during the period of heavy rain. Sowing is carried out in lines and the seed is covered with about 2.5 cm of soil. The seedlings are thinned later to give a spacing of about 2.5 m x 2.5 m square. Plantations may be established in pure stands or under sown in cereals such as wheat and maize.

After felling the trees, re-establishment may be done by either re-planting or the brush is piled in rows and burned, burning being done in the cool of the evening to ensure that too fierce a burn does not take place. Later when the seed germinates and the seedlings are growing vigorously they are thinned to the required spacing leaving only the most vigorous seedlings.

Young plantations must be kept free from couch and excessive weed growth. Clearing a strip of 45 cm in breadth on either side of the line of growing wattle will normally suffice, but all other wattle regrowth should be removed.

(vi) Protection of the plantations

Both *Eucalyptus* and black wattle plantations should be protected from fire. For this purpose, adequate external firebreaks should be maintained at all times. As a further precaution, plantations are split into blocks interspersed by wide roads. Some of the roads may be planted with grass which is used for grazing.

Sometimes the young plants of Eucalyptus are attacked by termites. Where an attack by termites occurs, the termites can be controlled by application of Diazinon, Furadan and other insecticides

Appendix I

AGENTS FOR CHEMICALS

Fertilizers	***Herbicides***

Sulphate of Ammonia, Phosphate,
Potash NPKS 25:5:5s, NPK 20:10:10
UREA, Lime, DAP fertilizer etc.

Agents

MEA Ltd.
P.O. Box 1018
NAKURU.

MEA Ltd.
P.O. Box 1914
KITALE.

KTDA
P.O. Box 30213
NAIROBI.

HOMA Lime Co. Ltd.
P.O. Box 1
KORU.

Orbit Chemical Industries Ltd.
P.O. Box 48870
NAIROBI.

Pakson Enterprise
P.O. Box 174
KERICHO.

Kipsigis Farmer Store
P.O. Box 1219
KERICHO.

Brand Name	**Agents**
Gramoxone	Twiga Chemicals P.O. Box 30172 NAIROBI.
	KFA P.O. Box 35 NAKURI.
	MEA Ltd. P.O. Box 1018 NAKURU.
	Pakson Enterprise P.O. Box 174 KERICHO.
Round up	Twiga Chemicals P.O. Box 30172 NAIROBI.
	MEA Ltd. P.O. Box 1018 NAKURU.
	Pakson Enterprise P.O. Box 174 KERICHO.
Touch Down	Tealand Chemists P.O. Box 222 KERICHO
	Pakson Enterprises P.O. Box 174 KERICHO.
Marshalls 250 EC Gladiator Vapolia Termidor 25 EC Rogo Thiodan	MEA Ltd. P.O. Box 1018 NAKURU.
	Twiga Chemicals P.O. Box 30172 NAIROBI.
	Pakson Enterprise P.O. Box 174 KERICHO.
	Kipsigis Farmers Store P.O. Box 1219 KERICHO.

Herbicides	**Manufacturer**	**Distributor**
Touchdown	Zeneca Agrochemicals UK	Twiga Chemicals Industries Ltd. P.O. Box 30172 NAIROBI.

Erases(Mamba)	Dow Elanco Ltd., UK	Twiga Chemicals Industries Ltd. P.O. Box 30172 NAIROBI.
Kalach	Calliope S.A	Orion East Africa Ltd. P.O. Box 8422, NAIROBI.
Wipeout	Almandine Corporations, SA	Alpha Lima Ltd. P.O. Box 20529 NAIROBI.
Gramoxone	Seneca	Syngenta
Touch Down	Seneca	Syngenta
Round-up 360SL	Monsanto	Bayer E.A. Ltd.
Sebcor 480SL	Bayer E.A. Ltd.	Bayer E.A. Ltd.

Insecticides	**Manufacturer**	**Distributor**
Karate	Zeneca Agrochemicals, UK	Twiga Chemicals Industries Ltd. P.O. Box 30172 NAIROBI.
Omite	Uniroyal Chemicals, USA	Twiga Chemicals Industries Ltd. P.O. Box 30172 NAIROBI. Murphy Chemicals Ltd. P.O. Box 20495 NAIROBI.
Murphoil	Bazehem Ltd., Israel	FarmChem Ltd. P.O. Box 18407 NAIROBI.
Gladiator	DowElanco Ltd., UK	DowElanco Export, SA P.O. Box 4947 NAIROBI.

Insecticides	***Distributor***
Thiodan	Twiga Chemicals P.O. Box 30172 NAIROBI.
Kilpest	Crop Protection Chemicals
Sevin	KFA
Volation	KFA
Fenitrothion	“
Ambush	“
Rogor	“
Roxion	“

Insecticides	**Manufacturer**	**Distributor**
Marshalls 250EC	FMC	Farmchem
Gladiator	BASF	BASF
Confidor 200SL	Buyer EA	Bayer EA Ltd.
Termidor 25EC	Aventis	Aventis
*Fenitrothion		
Fenithion (Lebaycid)	Bayer EA	Bayer EA

Karate (Ambush)	Seneca	Syngenta
Bulldock EC	Bayer	Bayer EA Ltd.
Sevin	Aventis	Aventis

Fungicides	***Distributor***
Benlate	Hoechst
Ripcord 5% EC	Afro producers & Distributors
Carbonate	Crop Protection Chemicals
Dithane M45	KFA

Fungicides	**Manufacturer**	**Distributor**
Kocide 101 Kocide DF Kocide 2000 Copper Oxychloride	Griffin Corporation, USA	Twiga Chemicals Industries Ltd. P.O. Box 30172 NAIROBI.
Ridomil	Novartis, Switzerland	Novartis East Africa Ltd. P.O. Box 30393 NAIROBI.

Fungicides	**Manufacturer**	**Distributor**
Benlate	Dupont	Farmchem
*Ripcord		
Dithane M45	Aventis/Murphy	- do -
Antracol	Bayer E.A.	Bayer EA Ltd.
Bavistin	BASF	BASF
Kocide	Seneca	Syngenta

ADDRESSES OF AGENTS FOR AGRO-CHEMICALS

Kenya Farmers Association
P.O. Box 35
NAKURU.

Orbit Chemicals Industries Ltd.
P.O. Box 48870
NAIROBI.

SDS Biotech Europe Co-op.
P.O. Box 56325
NAIROBI.

Rentokil Ltd.
P.O. Box 44360
NAIROBI.

Homaline Company Ltd.
P.O. Box 1
KORU.

Crop Protection Chemicals Ltd.
P.O. Box 47480
NAIROBI.

Reg. Davidson & Company
P.O. Box 41895
NAIROBI.

Aventis Pasteur SA (EA)
P.O. Box 30104
NAIROBI.

Twiga Chemical Industries Ltd.
P.O. Box 30172
NAIROBI.

Bayer EA. Ltd.
P.O. Box 30321
Code 00100
NAIROBI
Tel. 02 860667-74

Syngenta (EA) Ltd
P.O. Box 30393
NAIROBI

Farmchem (Dupont Products)
P.O. Box 18407
NAIROBI.

Murphy Chemicals (EA) Ltd.
(Distributor)
P.O. Box 20495
NAIROBI.

Aventis Crop Science
P.O. Box 30438
NAIROBI.

BASF

P.O. Box 30466
NAIROBI.

Twiga Chemicals
P.O. Box 30172
NAIROBI.

Appendix II

CONVERSION TABLES

Table A: Metric units

Length	10 millimetres	(mm)	=	1 centimetre (cm)
		100 cm	=	1 metre (m)
		100 m	=	1 hectometre (hm)
		1,000 m	=	1 kilometre (km)
Area	100 square millimetres	(mm^2)	=	1 square centimetre (cm^2)
		10,000 cm^2	=	1 square metre (m2)
		10,000 m^2	=	1 hectare (ha)
Volume	1,000 cubic millimetres (mm^3)		=	1 millilitre (ml)
			=	1 cubic centimetre (cc)
		1,000 ml	=	1 litre (1)
		1,000 cc	=	1 litre
Weight	1,000 milligrams	(mg)	=	1 gram (g)
		1,000 g	=	1 kilogram (kg)
		100 kg	=	1 quintal (q)
		1,000 kg or 10q	=	1 tonne (t)

Table B: English/metric equipment

Length	1 inch (in)	= 2.540 cm	1 cm	= 0.394 in
		= 25.40 mm	1m	= 39.37 in
	1 foot (ft)	= 0.305 m		= 3.281 ft
		= 304.80 cm		= 1.094 yd
	1 yard (yd)	= 0.914m	1 km	= 0.621 miles
		= 914.40 cm		
	1 mile	= 1.609 km		
Area	1 square inch (in^2)	= 6.452 cm^2	1 cm^2	= 0.155 in^2
	1 square foot (ft^2)	= 0.093 m^2	1 m^2	= 1.196 yd^2
	1 square yard (yd^2)	= 0.836 m^2		
	1 acre	= 0.405 ha	1 ha	= 2.471 acres
Volume	1 fluid ounce (fl oz)	= 6.452 cm^2	1 cm^2	= 0.155 in^2
	1 pint (pt)	= 568.25 ml		= 1.759 pt
	1 gallon (gal)	= 4.546 litres		= 0.220 gal
	1 cubic inch (in^2)	= 16.39 cc	1 ml	= 0.061 in^3
	1 cubic foot (ft^3)	= 0.028 m^3	1m^3	= 35.31 ft^3
		= 28.32 litres	1 litre	= 61.02 in^3
Weight	1 ounce (oz)	= 28.35	1 kg	= 35.27 0z
	1 pound (lb)	= 453.59 g		= 2.205 lb

		= 0.454 kg		
	1 hundredweight (cwt)	= 50.80 kg	l ton	= 2,204.6 lb
	1 ton	= 1,016.0 kg		= 0.984 ton
		= 1,016 t		
Others	1 oz/yd^2 =	33.91 g/m^2	1 kg/m^2	= 1.843 lb/yd^2
	1 oz/yd^3 =	37.08 g/m^3	1 kg/m^3	= 1.686 lb/yd^3
	1 oz/gal	= 6.236 g/litre	1 g/litre	= 0.160 0z/gal
	1 lb/in^2	= 0.070 kg/ml		
	1 horse power (h.p)	= 0.746 kilowatt (kw)	1 kw	= 1.340 h.p
	1 B. T. U.	= 251.88 gram-calories (gcal)		

Temperature

^{0}F	^{0}C	^{0}F	^{0}C
32.0	0	125.6	52
35.6	2	125.6	54
39.2	4	129.2	56
42.8	6	132.8	58
46.4	8	136.4	60
50.0	10	140.0	63
53.6	12	143.6	64
57.2	14	147.2	66
60.8	16	150.8	68
64.4	18	154.4	70
68.0	20	158.0	72
71.6	22	161.6	74
75.2	24	165.2	76
78.8	26	168.8	78
82.4	28	172.4	80
86.0	30	179.6	82
89.6	32	183.2	84
93.2	34	186.8	86
96.8	36	190.4	88
100.4	38	194.0	90
104.0	40	197.6	92
107.6	42	201.2	94
111.2	44	204.8	96
114.8	46	208.4	98
118.4	48	212.0	100
122.0	50		

The formula for conversion from Celsius (Centigrade) to Fahrenheit is:

$$^0F = \frac{^0C \times 9}{5} + 32$$

Similarly, the formula for conversion from Fahrenheit to Celsius is:

$$^{0}C = (^{0}F - 32) \times \frac{5}{9}$$

Table C: Double conversion Tables for Weights and Measures

The central figures represent either of the two columns beside them. Example 1 metre 1.094 yds, 1 yard = 0.914 metres

Centimetres		*Inches*	*Metres*		*Yards*
2.540	1	0.394	0.914	1	1.094
5.080	2	0.787	1.829	2	2.187
7.620	3	1.181	2.743	3	3.281
10.160	4	1.575	3.658	4	4.374
12.700	5	1.969	4.572	5	5.468
15.240	6	2.362	5.486	6	6.562
17.780	7	2.756	6.401	7	7.655
20.320	8	3.150	7.315	8	8.749
22.860	9	3.543	8.230	9	9.843
25.400	10	3.937	9.144	10	10.936
50.800	20	8.874	18.288	20	21.872
76.200	30	11.811	27.432	30	32.808
101.600	40	15.748	36.576	40	43.745
127.000	50	19.685	45.720	50	54.681
152.400	60	23.622	54.863	60	65.617
177.800	70	27.559	64.007	70	76.553
203.200	80	31.496	73.151	80	87.489
228.600	90	35.433	82.296	90	98.425
254.000	100	39.370	91.439	100	109.361

Square		*Square*	*Hectares*		*Acres*
metres		*yards*	0.405		
0.836	1	1.196	0.809	1	2.471
1.672	2	2.392	1.214	2	4.942
2.508	3	3.588	1.619	3	7.413
3.345	4	4.784	2.023	4	9.884
4.181	5	5.980	2.023	5	12.335
5.017	6	7.176	2.428	6	14.826
5.853	7	8.372	2.833	7	17.298
6.682	8	9.568	3.237	8	19.769
7.525	9	10.764	3.642	9	22.240
8.361	10	11.960	4.047	10	24.711
16.723	20	23.920	8.094	20	49.422
25.084	30	35.880	12.140	30	74.132
33.445	40	47.840	16.187	40	98.843
41.806	50	59.799	20.234	50	123.554
50.168	60	71.759	24.281	60	148.265
58.529	70	83.719	28.328	70	172.976
66.890	80	95.679	32.374	80	197.686
75.251	90	107.639	36.421	90	222.397
83.613	100	119.599	40.468	100	247.108

Litres		*Gallons*	*U.S, Gallons*		*Imperial Gallons*
4.546	1	0.220	1.200	1	0.833
9.092	2	0.440	2.401	2	1.666
13.638	3	0.660	3.601	3	2.499
18.184	4	0.880	4.802	4	3.322
22.730	5	1.100	6.002	5	4.165
27.276	6	1.320	7.203	6	4.998
31.822	7	1.540	8.403	7	5.831
36.368	8	1.760	9.603	8	6.664
40.914	9	1.980	10.804	9	7.497
45.460	10	2.200	12.004	10	8.330
90.919	20	4.399	24.009	20	16.661
136.379	30	6.599	36.013	30	24.991
181.838	40	8.799	48.017	40	33.321
227.298	50	10.999	60.022	50	41.652
272.758	60	13.198	72.026	60	49.982
318.217	70	15.398	84.030	70	58.312
363.677	80	17.598	96.034	80	66.642
409.136	90	19.797	108.039	90	74.973
454.596	100	21.997	120.043	100	83.303

Grams		*Ounces*	*Kilograms*		*Pounds*
28.35	1	0.035	0.454	1	2.205

56.70	2	0.071	0.907	2	4.409
85.05	3	0.106	1.361	3	6.614
113.40	4	0.141	1.814	4	8.818
141.75	5	0.176	2.268	5	11.023
170.10	6	0.212	2.722	6	13.228
198.45	7	0.247	3.175	7	15.432
226.80	8	0.282	3.629	8	17.637
255.15	9	0.317	4.082	9	19.842
283.50	10	0.353	4.536	10	22.046
566.99	20	0.705	9.072	20	44.092
850.48	30	1.058	13.608	30	66.139
1133.98	40	1.411	18.144	40	88.185
1417.47	50	1.764	22.680	50	110.231
1700.97	60	2.116	27.215	60	132.277
1984.47	70	2.469	31.751	70	154.323
2267.96	80	2.822	36.287	80	176.370
2551.46	90	3.175	40.823	90	198.416
2834.95	100	3.527	45.359	100	220.462

Tonnes		*Tons*	*Millilitres per 100 litres*		*Fluid ounces per 100 gallons*
1.016	1	0.984	6.236	1	0.160
2.032	2	1.968	12.472	2	0.321
3.048	3	2.953	18.709	3	0.481
4.064	4	3.937	24.945	4	0.641
5.080	5	4.921	31.181	5	0.802
6.096	6	5.905	37.417	6	0.962
7.112	7	6.889	43.653	7	1.122
8.128	8	7.874	49.890	8	1.283
9.144	9	8.858	56.126	90	1.443
10.161	10	9.842	62.362	10	1.604
20.321	20	19.684	124.724	20	3.207
30.482	30	29.526	187.086	30	4.811
40.642	40	39.368	249.448	40	6.414
50.803	50	49.211	311.810	50	8.018
60.963	60	59.053	374.172	60	9.621
71.124	70	68.894	436.534	70	11.225
81.284	80	78.737	498.896	80	12.828
91.444	90	88.579	561.258	90	14.432
101.605	100	98.421	623.620	100	16.035

Litres per hectare		*Gallons per acre*	*Grams per 100 litres*		*Ounces per 100 gallons*
11.233	1	0.089	6.236	1	0.160

22.467	2	0.178	12.472	2	0.321
33.700	3	0.267	18.709	3	0.481
44.933	4	0.356	24.945	4	0.641
56.167	5	0.445	31.181	5	0.802
67.400	6	0.534	37.417	6	0.962
78.633	7	0.623	43.653	7	1.122
89.867	8	0.712	49.890	8	1.283
101.100	9	0.801	56.126	9	1.443
112.333	10	0.890	62.362	10	1.604
224.667	20	1.780	124.724	20	3.217
337.000	30	2.671	187.086	30	4.811
449.334	40	3.561	249.448	40	6.414
561.667	50	4.451	311.810	50	8.018
674.000	60	5.341	374.172	60	9.621
786.334	70	6.231	436.534	70	11.225
898.667	80	7.122	498.896	80	12.828
1011.001	90	8.012	561.258	90	14.432
1123.334	100	8.902	623.620	100	16.035

Kilograms per hectare		*Pounds per acre*
11.121	1	0.892
2.242	2	1.784
3.363	3	2.677
4.483	4	3.569
5.604	5	4.461
6.725	6	5.353
7.846	7	6.245
8.967	8	7.137
10.088	9	8.030
11.209	10	8.922
22.414	20	17.844
33.626	30	26.765
44.834	40	35.687
56.043	50	44.609
67.251	60	53.531
78.460	70	62.453
89.668	80	71.374
100.877	90	80.296
112.085	100	89.128

Table D.......: Plant spacing and population

Triangular planting

Spacing (ft)	*No. of plants per acre*	*Spacing (cm)*	*No. of plants per hectare*

4 x 2	5,624	121.9 x 61.0	13,896
3 x 3	5,589	91.4 x 91.4	13,810
3¼ x 3¼	4,762	100.0 x 100.0	11,767
4 x 2½	4,586	121.9 x 76.2	11,331
3½ x 3½	4,106	106.7 x 106.7	10,146
4 x 3	3,916	121.9 x 91.4	9,676
4 x 4	3,144	121.9 x 121.9	7,768
4½ x 4½	2,484	137.2 x 137.2	6,139
5 x 5	2,012	152.4 x 152.4	4,972
6 x 6	1,397	182.9 x 182.9	3,453

Double hedgerow planting

Spacing	N0. of plants per acre	Spacing (cm)	N0. of plants per hectare
4 x 2 x 2	7,345	121.9 x 61 X 61	18,150
4 x 2 x 2½	6,780	121.9 x 61 x 76.2	16,754
4 x 2½ x 2½	6,027	121.9 x 76.2 x 76.2	14,892

Rectangular and contour planting

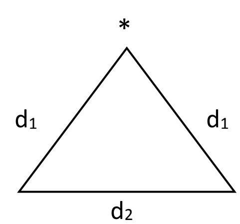
Spacing (ft)	*No. of plants per acre*	*Spacing (cm)*	*No. of plants per hectare*
4 x 2	5,624	121.9 x 61.0	13,896
3 x 3	5,589	91.4 x 91.4	13,810
3¼ x 3¼	4,762	100.0 x 100.0	11,767
4 x 2½	4,586	121.9 x 76.2	11,331
3½ x 3½	4,106	106.7 x 106.7	10,146
4 x 3	3,916	121.9 x 91.4	9,676
4 x 4	3,144	121.9 x 121.9	7,768
4½ x 4½	2,484	137.2 x 137.3	6,139
5 x 5	2,012	152.4 x 152.4	4,972
6 x 6	1,397	182.9 x 182.9	3,453

No. of plants per hectare

(1) Square planting: $\frac{10,000}{d^2}$

(2) Rectangular planting $\frac{10,000}{d^1 \times d^2}$

(3) Triangular (equilateral) planting: $\frac{11,547}{d^2}$



In each case, "d" is the distance or one of the distances between the plants in metres.

Conversion of green leaf into made tea

Average % out-turn of green leaf into made tea is 22.5% or 4.5 kg green leaf give 1kg made tea.

Appendix III

DEFINITIONS

Acaricide A chemical used for controlling mite pests.

Accumulator: A plant which accumulates in its tissues far more of a chemical element than it needs for normal growth and development. The tea plant is an aluminium accumulator, for example.

Active ingredient (a.i): That part of a pesticide that is actually responsible for the toxic effect.

Advection: The transference of heat by horizontal motion of the air in the atmosphere.

Adventitious root: A root which develops from leaf or stem (vegetative) tissue. All stem cuttings develop adventitious roots.

Agronomy: The study of management of land and the scientific cultivation of crops.

Albedo: The reflection coefficient for short-wave radiation of a given surface.

Apical bud: The bud at the top (apex) of a shoot.

Aboricide: An herbicide specifically used against trees and woody shrubs.

Ascospore: A-sexually produced fungal spore borne in an ascus (q.v).

Ascus: A sack-like hypha of a fungus containing ascospores (q.v)

Available water content: The quantity of soil water that can be taken up by the plant. It is that quantity between field capacity and permanent wilting point (q.q.v.), and it varies from one soil type to another.

Axil: The angle between a leaf and the stem.

Axillary bud: The bud found in an axil.

Axillary shoot: A shoot which develops from an axillary bud.

Baghjan pruning: Pruning repeatedly at the same level. This results in the formation of large callus knobs known as knots on the ends of the branches; these must eventually be pruned off.

Banjhi: Dormant: Usually applied to the condition of the apical bud; such a bud is very small. A bhanji shoot is a shoot with a dormant apical bud. The term is also applied to a bush or even to a whole field when the majority of shoots on that bush or in that field are banjhi.

Barie: An orchard. Confined to "seed barie:, an orchard containing plants allowed to grow up for seed

production. A clonal seed barie is one in which the seed bearers have been raised by vegetative propagation from selected parent plants; such baries are "biclonal", "triclonal", "polyclonal" etc., depending upon whether there are two, three or many clones included.
"Biclonal seed" is seed produced from two clonal parents. "Polyclonal seed" is from more than 2 clonal parents.

Bending See pegging.

Bheti plants: Plants dug out from the nursery with a cylinder of soil surrounding the roots.

Boma-site See Hutsite.

Breaking back: Plucking shoots down to the plucking table after the standard plucking has been completed. Necessary only when the plucking round is too long.

Bringing into bearing: A pruning, tipping or pegging operation designed to form the permanent branch system of the plant.

Bullate: Puckered, with raised areas between the leaf veins.

Bund: A ridge of soil to direct or restrict the movement of water on a slope. The term may also be applied to ridges formed from uprooted weeds, etc.

Calcicole: A plant species which grows best on soils containing a high level of calcium.

Calcifuge: A plant species which grows poorly on soils with high levels of calcium, and prefers acid soils.

Callus: A disorganised tissue, usually creamy white or brown, which develops on wounded bark. Associated with the basal cut of a cutting, with pruned branches, with recovery from insect and mechanical damage to roots and shoots, and with recovery from branch canker.

Callused cutting: Any cutting which has developed callus tissue on its basal cut. Particularly used for such cuttings which are then transplanted to sleeves or to other nursery beds.

Catchment: An area of land, typically basin-shaped, in which all drainage flows to a common point; this may be a stream or an aquifer. If the catchment has an impervious stratum beneath it, it is possible by measuring the stream flow at its exit from the catchment, to build up a drainage, run-off and plan water use.

Catechins: A group of carbon compounds found in tea leaves. They are the precursors of theaflavins and thearubigins (q.q.v.), major flavour components of black tea.

Centering: (Also de-centering). Pruning the central stem or stems of a plant to encourage the growth of lateral shoots. An essential operation on young sleeved plants. Not always effective on older plants, especially if they are suffering from potassium deficiency.

Cheel hoe: A hoe with a blade about 35cm across, which cuts weed roots within the top 2cm of soil.

Chloroform test: See page 38.

Chlorosis: The abnormal yellowing of leaves, due to inhibition of chlorophyll synthesis. In tea this is usually caused by mineral imbalance.

Cleaning out: Removing shoots which are thin, dead, cross over each other or are too close to other shoots at the time of cut-across pruning. Also used in the form "clean pruning".

Clonal seed: Seed from a clonal plant or from a clonal barie (see Barie).

Clone: Any population of plants raised by vegetative propagation to form a single parent plant. Members of the same clone may be growing in several different places at the same time or at different times and may be several generations removed from the original parent. Genetically, all plants of the same clone are identical.

Coarse plucking: Plucking shoots of three or more leaves and the bud.

Collar: The part of the plant which is at soil level.

Contact herbicide: An herbicide which kills plants only if it comes into contact with the above-ground parts of the plant.

Cotyledons: The "first leaves" of a seedling. In the tea plant the two cotyledons are fleshy and fill the seed. They remain below the soil surface after germination and supply food to the developing seedling.

Couch: A general term applied to any grass with long rhizomes (q.v). The most common example in East Africa is *Digitaria scalarum.*

CTC (crush, tear and curl): Type of tea manufacture in which withered leaf is passed between serrated cylindrical rollers revolving in different directions and at different speeds to efficiently mince leaf into fine pieces. The resulting cell and cell membrane destruction is more extensive than in orthodox manufacture (q.v.).

Cut-across prune: Pruning at a set level without any cleaning out.

De-centering: See centering.

Deficiency: The presence of a nutrient in quantities below that required for optimum plant growth.

Dormancy:	A rest period when a whole plant or a plant tissue shows no growth.
Endemic:	A situation where a host and its parasite have co-evolved for a long time, and as a result the disease presence is permanent.
Epinasty:	The greater growth of the upper surface of an organ, compared with the lower, causing the organ to bend downwards. (This may be caused by nutrient deficiency).
Epiphyte:	A fungus or bacterium existing on the surface of a plant or plant organ without causing infection.
Evaporation:	The loss of vapour to the atmosphere from the surface of a liquid; used most commonly in respect of water.
Evapotranspiration:	The loss of water from land (and vegetation), including both evaporation and transpiration (q.q.v.)
Experiment:	An investigation from which the data can be subjected to statistical treatment. In most work this presupposes adequate replication and randomisation (q.q.v.) so that the effects of irrelevant factors, such as soil variation, can be eliminated. A clonal field trial is formally an experiment.
Feeder roots:	Mat-like rootlets present on, or close to, the soil surface near the tea bush. Mulching enhances formation of feeder roots.
Fermentation:	The term used in tea processing for the biochemical processes during which the leaf turns brown. This is the oxidation of certain cell constituents (catechins, q.v.) in the presence of an enzyme (polyphenol oxidase, q.v.) by air.
Fertilizers:	Manufactured chemical compounds or mixtures of chemical compounds, which contain controlled amounts of plant nutrients. They generally contain a higher concentration of nutrients than organic manures.
Field capacity:	The moisture content in freely draining soil two days after heavy rainfall or irrigation.
Fine plucking:	Plucking shoots of one or two leaves and the bud.
Firing:	Removal of moisture and termination of enzyme activity by heating at the end of fermentation to achieve 2.5 - 5% moisture to be stored over a period of time.
Fish leaf:	Usually taken to be the topmost scale leaf (q.v.). It is usually serrated only along the leaf margin furthest from the stalk.
Fixation of nutrients:	A process by which a soil nutrient is made unavailable to the plant temporarily or permanently.

Floater: A seed which floats in water (does not sink), especially one which still floats after 24 hours.

Flushing: Applied to an actively-growing apical or axillary bud. Also applied to a bush or even to a whole field when the majority of shoots on that bush or in that field are flushing.

Food reserves: See Starch reserves.

Fordham effect: A special type of flush in which a large number of shoots on each stem grow at the same time, including shoots which would normally be dormant. This usually occurs when a long period of adverse weather condition is suddenly terminated.

Fork jembe: A digging tool having three or four prongs at right angles to the shaft. Sometimes used for removing deep-rooted weeds, but causes damage to tea roots.

Formative pruning: See Bringing into bearing.

Fructification: A product of spores by a fungus.

Fruiting body: A complex fungal structure containing spores.

Fungicide: A chemical used for controlling fungal diseases.

Growth regulator: A natural or artificial compound which induces easily detectable growth modification or change in the plant.

Hard banjhi: Applied to a shoot when its apical bud has been banjhi (q.v.) for a long time and the upper stem and leaves have become hard. Such shoots are unsuitable for manufacture.

Hard plucking: A plucking system which restricts the addition of young leaves to the maintenance foliage. Cropping then becomes over dependent upon the old maintenance foliage. Most usually affected by plucking right down to the plucking table.

Hardening off: The process of acclimatising a nursery plant to the conditions to which it will be exposed after transplanting in the field.

Hardpans: Soil layers of variable texture which may, in extreme cases, exhibit rocklike properties (also termed fragipans, or Orstein) and become almost totally impenetrable to plant roots, water and air.

Height-reduction prune: Low pruning carried out after several pruning cycles to rejuvenate the bushes that otherwise have become too tall to produce green leaf efficiently.

Herbicide: A chemical used for killing plants, especially weeds.

Hermetic sealing: The sealing of a container in such a manner that it is airtight, thus lengthening the storage life of the contents.

Hidden (latent) nutrient deficiency: Deficiency which occurs but does not cause any symptoms. It can only be detected by tissues analysis.

Humus: Decaying organic matter in the soil.

Hutsite: A restricted area of land in which tea grows poorly because of an accumulation of basic material which usually causes an increase in the soil pH (q.v.). Often the sites of huts or manyattas where organic refuse and lime from buildings has collected, or of livestock pounds (cattle bomas, etc) where there has been a concentration of manure. Similar effects can be caused locally by burning large trees or heaps of brushwood; in these cases the heat can destroy the surface soil structure.

Hypha (plural Hyphae): A fine thread-like fungal growth.

Infill: Any plant used to replace a dead or weak plant in the field.

Infiltration: The process of water entry into the soil, generally by downward flow through all or part of the soil surface.

Infiltration capacity: The amount of water that has infiltrated a soil during, a specific period of time and is expressed in volume units per surface area (units: $cm^3/cm^2/min$ or cm/min).

Insecticide: A chemical used for controlling insects.

Internode: The length between two leaves of a shoots.

Janum: The topmost and largest unserrated scale-leaf on a shoot, immediately below the fish leaf (q.v). A common term in India, but only infrequently used in Kenya.

Jat: A seedling population raised from seeds produced by a particular group of parent trees. Any seedling seed barie will produce a jat more or less distinct from all other jats. A clonal seed barie will produce a jat similar to those from the same clonal baries established elsewhere.

LD_{50}: Lethal Dose. The concentration of a chemical which would kill 50% of the target organism within a specified period.

Leaching: The removal of nutrients from the soil by dissolving in the soil water which then drains away.

Lenticel: A breathing pore on the bark. Often enlarged in the absence of oxygen (e.g. water logging, clay soils) and when certain fungi infect the plant.

Light plucking: A plucking system which permits an unnecessary number of young leaves to be added to the maintenance foliage. Most usually effected by leaving a leaf on the shoots above the plucking table at each plucking round so that the table rises rapidly. Used to add new foliage after adverse phenomenon like hail or drought.

LTP (Laurie Tea Processor): A type of tea manufacture in which the withered leaf is chopped into narrow strips. The machinery used is similar to a tobacco cutter or hammer mill. Fineness of the chopped leaf is controlled to be close to that of CTC (q.v.) manufacture.

Luxury consumption: The presence of nutrient levels in the plant which are above normal but not toxic. This can only be diagnosed by tissue analysis.

Maintenance foliage: The layer of leaves below the plucking table. These leaves produce the food to permit the development of new shoots and the accumulation of starch reserves in the roots and stems. The leaves become less efficient as they grow older, and gets thinner as pruning cycle progresses.

Manure: A natural organic material such as farmyard manure, compost, bone-meal etc., which contains plant nutrients. They are often variable in composition and the proportion of nutrients tends to be low.

Mature leaf: For leaf analysis purposes, a hard and dark leaf which has stopped expanding.

Mature tea: An arbitrary age of tea plants used for accounting purposes. Logically, mature tea is tea which is being plucked after having completed its formative pruning; the term is used in this sense throughout this handbook.

Meniscus: The name given to the curved surface of a liquid when it is enclosed, and which is especially evident when water is in a narrow cylinder.

Moribund tea: An old tea plantation whose productivity has stagnated or is declining, despite optimal cultural practices being applied to it.

Mother bush: Any bush from which cuttings are taken, especially when the bush is used solely for this purpose as in a multiplication plot.

Mother leaf: The original leaf of a standard cutting.

Mulch: Any material used to cover the soil surface to prevent soil loss during wet weather, to reduce evaporation from the soil, and to increase the humus content of the soil.

Multiplication plot: A clonal plot which is used solely as source of supply of cuttings.

Mutation: A sudden and permanent change in the genetic make-up of a plant. Such changes can be passed on to the plant's offsprings. Spontaneous mutation is rare, but induced mutation is used in plant breeding.

Mycelium: Mass of hyphae (q.v) of a fungus. Exemplified by the white growth beneath the bark of plants infected by *Armillaria*, root rot disease.

Necrosis: The death of a group of cells while still part of an organ of the living plant.

Nematicide: A chemical used for controlling nematodes (eelworms).

Net radiation: The difference between the total radiation energy incident on a surface and the radiation energy reflected and emitted by the surface.

Node: The point of attachment of a leaf to the stem.

NPK: Symbols for nitrogen (N), phosphorus (P) and potassium (K).

Nurse crop: A temporary crop grown to protect the main crop while the latter is young.

Nutrient toxicity: Abnormality (symptoms) or death caused by the excess of an essential nutrient in the plant organ.

Orthodox manufacture: Tea manufacture where the mixing of enzymes and polyphenols is achieved by rolling (q.v.). This is achieved by compressing and turning the leaf over, while keeping it in continual motion. Leaf disruption is less drastic than in unorthodox manufacture.

Parasite: An organism which obtains its food from the tissues of another living organism.

Pegging: Increasing the spread of a bush by bending the branches away and sloping from the vertical and pegging them down, using wooden or metal pegs.

Permanent wilting point: The water content of the soil at which plants permanently wilt even when the air is humid. This is the lower limit of available soil water.

Permanent frame: The part of the branch system which lies below the lowest level at which the bush will be pruned after reaching maturity.

Penman's equation: Used to estimate the potential rate of transpiration (q.v) of a crop using meteorological data (e.g. sunshine, air, temperature, humidity and wind).

Persistent herbicide: An herbicide which retains its herbicidal properties for a prolonged period after its application.

Pesticide: A chemical used for controlling pests. Acaricides, fungicides, herbicides, insecticides, rodenticides and nematicides (q.q.v.) are all categories of pesticides.

Petiole: The stalk of a leaf.

pH: An index of acidity, formally "the negative logarithm of the hydrogen ion concentration expressed in moles per litre". Neutrality is pH 7.0. Most suitable tea soils lie within the range 4.0 to 5.6 though higher pH may be found in hutsites and certain rich soils. The scale is logarithmic, so that a soil of pH 4.0 is ten times more acid than one of pH 5.0 and one hundred times more acid than one of pH 6.0.

Photosynthesis: The process by which the plant uses the energy of sunlight to convert carbon dioxide gas from the air into food.

Photosynthetically Active Radiation(PAR): That radiation energy within the 400-700mm waveband of the total sun's radiation, which is useful for green plant photosynthesis.

Plasmolysis: The shrinking of the cell contents away from the cell wall due to loss of water. At early stages this is reversible, but further loss causes permanent damage.

Ploidy: The constant number of chromosomes in all the nuclei of the cells of a plant. A reproductive cell is usually haploid (half the diploid) and a normal cell diploid (two basic sets). Genetic diversification can produce triploid (3), tetraploid (4) and polyploid (>two basic sets) plant nuclei.

Plucking: The routine removal of young (harvesting) shoots for manufacture.

Plucking round: The interval between successive pluckings of the same bush or field.

Plucking table: The upper surface of a bush at which level the shoots are plucked.

Polyphenol oxidase: The naturally occurring enzyme (biological catalyst) that converts catechins (q.v.) into other flavour components during black tea manufacture.

Potential evapotranspiration: The possible combined loss of water from a given area of land and vegetation during a specified period of time by evaporation from the soil surface and by transpiration from plants.

Pre-emergence herbicide: A herbicide used for preventing the germination of seeds.

Pruning: The use of a special knife, saw or secateurs to cut out, or reduce the length of branches or shoots.

Pruning cycle: The interval between successive prunings of mature bush.

Randomisation: The random allocation of treatments to plots in an experiment.

Replication: The allocation of several plots to each treatment in an experiment.

Rhizome: An underground creeping stem, exemplified by those of couch grass.

Rhizomorph: Melanised strand arising from an aggregation of fungal hyphae.

Rich soil: A soil which contains a large proportion of mineral bases.

Rodenticide: A chemical used for controlling rodents, e.g. moles, rats, etc.

Rogue: A sport or variation from the standard type of a variety. Also commonly used of a clonal plant which is planted in a plot of another clone.

Rolling The twisting and breaking up of the leaf to allow the juices to mix and fermentation to begin. The stage of manufacture after withering.

Rotorvane: An elaborate disintegrator in the fashion of a domestic mincing machine. In the manufacture, a rotor shaft, armed with projecting vanes, propels the leaf along the enclosing barrel against the resistance of counter vanes projecting from the casing, thus causing cell disruption.

Saprophyte: An organism, usually microscopic, that uses dead organic matter for food.

Scale-leaf: A minute unserrated leaf found at the base of a seedling or young clonal plant or shoot. They often fall off as the shoot matures.

Scheme plucking: Estate management plucking design whereby experienced pluckers are confined to individualised plucking units in each field in order to optimise productivity under minimum supervision.

Seed at stake: Planting seeds directly in the field near marking stake so that the seedling is never transplanted.

Serrations: The small tooth-like edgings to the leaf-margin.

Shelterbelt: A belt of trees and/or shrubs arranged as s protection against strong winds; a type of windbreak. The trees may be specially planted or left standing when the original forest is cut.

Single-stemmer: A young plant which produces a single main vertical branch after being pruned.

Sinker: A seed which sinks in water, especially one which sinks within 24 hours.

Skiffing: A very light prune to level-off a plucking table and sometimes used in place of a harder prune to extend the pruning cycle in mature tea.

Sleeve: A soil container, generally of thin polythene, used for growing cuttings or seedlings. Either in the form of bags, sealed to some extent at the base, or of cylinders, completely open at the base.

Slope pruning Pruning parallel to the ground, irrespective of the slope of the ground.

Soft banjhi: Applied to a shoot when its apical bud has only recently gone banjhi and upper stem and leaves are still soft. Such shoots are suitable for manufacture.

Soil compaction: Dynamic soil behaviour as a result of applied loads or pressure causing the density of the soil to increase. Soil drying and shrinkage may also cause soil compaction.

Soil sterilant: A chemical applied to the soil to provide control of soil borne pests, pathogens and weed propagules.

Starch reserves: The food reserves found mainly in the roots, stem and to some extent in large shoots and derived from the carbohydrates formed in the leaves. They are used when new roots or shoots develop.

Starch test: A simple qualitative test for the presence of starch. The test is carried out as follows: *Solution:* One litre of water; 3g iodine crystals; 6g potassium iodine. Keep well stoppered in a dark cupboard and preferably in a dark bottle.

Test: Cut across the root to be tested; smooth the cut if necessary. Apply the solution evenly over the cut. The solution turns the starch grains dark blue. The cut surface will turn nearly black if the reserves are at their maximum. If there are no reserves there will be no colour change.

Stomata: Pores found in large numbers on the surface of leaves through which gaseous exchange takes place.

Stump: The bare root of a nursery plant about two years old. A seedling stump consists of the tap-root, cut back if necessary to a length of about 45cm. The stems are normally cut 10cm above the nursery soil level.

Sub-soil: The lower humus-free layers of soil, largely mineral in character, containing the disintegration products of rock. Its composition depends mainly upon the type of parent rock. In tea areas subsoils are usually deficient in available nutrients because these have been leached out of the soil.

Surface run-off: This occurs when rainfall intensity exceeds the rate at which water can be absorbed by the soil. Soil particles are detached from their positions in the soil mass and they may then be transported by the run-off flowing on the ground surface, causing soil erosion.

Surfactant: A substance introduced into a liquid in order to affect (usually to increase) its spreading, wetting, and similar properties (i.e. properties which depend upon its surface tension).

Systemic compound: A chemical that when applied to a plant is absorbed by the roots or the leaves, and is translocated to different parts of the plant.

Systemic herbicide: An herbicide which is absorbed into the plant and moves within the plant, finally killing it.

Systemic pesticide: A pesticide that is absorbed by the roots or leaves of a plant and carried through the whole of the plant. It is thus able to kill pests at parts of the plant away from sites of application.

Tap-root: The single root possessed by a young seedling but rare on mature plants. Cuttings do not develop tap-roots.

Theaflavins: Products of enzyme initiated oxidative decarboxylation and condensation between a simple catechin and a gallocatechin in the presence of oxygen. Briskness and brightness of black tea are due to these compounds.

Thearubigins: Condensation and polymerisation products formed during fermentation of tea. Their structures are unknown. The thickness, body and colour of black tea are due to this group of compounds.

Tipping: Increasing the spread of a bush by removal of the shoots at gradually increasing heights.

Tipping-in: Removing the tops of shoots of a recently pruned or pegged bush so as to form a flat plucking table at specified height above pruning level.

Topsoil: The upper humus-rich layers of soil. Topsoil forms under mature tea from the leaf litter and prunings especially if there is no cultivation or disturbance of that soil; this layer is biologically highly active and contains a high proportion of available nutrients which can be exploited by the tea roots providing the roots are not killed by hoeing.

Translocated herbicide: A herbicide which when absorbed into the plant via the leaves or roots moves within it, finally killing it.

Translocation: The movement of soluble material through the plant.

Transpiration: The loss of water as a vapour from plants through (mainly) pores in the leaves known as stomata (q.v.).

Trial: A simple investigation, the data from which are at times unsuitable for statistical treatment. Trials are usually simple comparisons between treatments or varieties and may precede a formal experiment.

Tubercles: Wart-like processes on a fungal mycelium.

Unorthodox manufacture: Manufacture by CTC, LTP or Rotorvane. The leaf is cut into fine pieces ensuring more membrane break-up and allowing more mixing of enzymes, polyphenols and oxygen. Leaf disruption is more drastic than orthodox manufacture (q.v.).

Wetting agent: A chemical or mixture of chemicals added to sprays of insecticide, fungicides, herbicides and mineral sprays to improve wetting and thereby cover of leaf surface better.

Windbreak:	Any device normally in form of trees designed to obstruct wind flow and intended for protection against any ill effects of wind, such as soil erosion or evaporation.
Withering:	The removal of moisture from plucked leaf during processing accompanied by an increase of the permeability of the cell membranes that enables considerable mingling of enzyme, polyphenols and oxygen during fermentation. An increase of soluble amino acids and caffeine contents of plucked tea shoots also occurs.
Young tea:	Plants on which the formation of permanent frames has not yet been completed.
Vegetative propagation:	A method of multiplying plants without the use of seed. In tea taking cuttings of the parent plant usually does it. These develop into plants that are genetically identical to the mother bush.

Appendix IV

SERVICES PROVIDED BY THE TEA RESEARCH FOUNDATION OF KENYA

(a) Publications

(i) *Annual Report*

The Annual Report contains the full results of all experiments, investigations and progress reports on long-term experiments on which the Foundation has been engaged during the year.

It is circulated from the Foundation to recipients who are included on the official circulation list prepared by the Director of Tea Research Foundation of Kenya. Licensed producers with 8 ha or more of tea receive one copy free and larger producers receive one free copy for each 200 ha of their tea. The sale price for extra copies and for others who require the report will be quoted on application to the Director, TRFK, from whom copies of the report may be obtained.

(ii) *Tea Growers Handbook*

"Tea Growers Handbook" is distributed on the same basis as the Foundation's Annual Report. The sale price will be provided on request.

(iii) *"Tea"*

"*Tea"* is the official journal of the Tea Board of Kenya and is published twice a year. In addition to its content of general information of interest to the tea industry, it includes technical papers and reviews prepared by the staff of the Foundation and external authors.

(iv) *Quarterly Bulletin*

The *Quarterly Bulletin* is a new addition to a list of publications produced by the Foundation. For the time being it will be circulated to the tea industry and whoever requests free of charge. It is intended to reach a wider audience than the above publications, the use of which are restricted by virtue of their contents.

(b) *Visiting days at the Foundation*

Tuesday of each week is normally set aside as a visitors' day at the Foundation. Intending visitors should make their appointments in advance, by application to the Foundation.

Appendix V

SERVICES PROVIDED BY THE TEA RESEARCH FOUNDATION OF KENYA FOR THE KENYA TEA INDUSTRY ONLY

(a) Research Programme

Kenyan tea producers are directly concerned with the assignment of priorities in the research programme of the Tea Research Foundation through its Tea Research Advisory Committee, in which the interests of small and large producers are represented.

The research programme is reviewed twice annually. The first is in March/April when the results of the previous year's investigations are discussed. The second is in September and concentrates on research projects to be undertaken the following year. These are then forwarded to the Foundation's Board of Directors in the November meeting for final approval.

The research programme, having relevance to the general problems that confront Kenyan producers, has priority over specific technical demands from individual producers.

Most of the research projects embrace field trials, some of which are carried out with active and generous assistance from the estates and small-scale growers on which the trials are located.

(b) Technical visits from Foundation staff

Visits to tea producing areas are planned so that most producers are visited as frequently as possible. These visits are then followed by detailed reports from the Foundation.

Request for special visits at other times are complied with at the discretion of the Director, having regard to the time and staff available. The costs of such visits are borne by the Foundation.

(c) Soil analysis

Soil samples will be tested for pH when requested. The Foundation also has the equipment to do complete analysis of major elements in soil and this can be done on request. Samples should be taken as described on page 5 and sent to: -

Director,
Tea Research Foundation of Kenya,
P. O. BOX 820,
KERICHO.

Soil samples should be packed in polythene bags. Put in each bag a label that will not disintegrate when wet, and fix a similar label on the outside of the bag. Each label, together with a fully completed form which can be provided to all producers by the Foundation on request, must carry full details including the name of the estate/grower, the date, field number, identification number within the field and depth from which the sample is taken. Very many soil samples are received and they can be confused unless these details are given in full.

Where samples are despatched by parcel post, bus or other carriers a letter should be sent separately giving details of the samples, method of transport and a copy of the consignment note if possible. The Foundation can then ensure then that the samples are received. A copy of the letter should be put in the parcel with the samples.

A small fee (see page 162) is charged for the pH tests per sample and also for complete soil analysis. A remittance for the appropriate amount should be sent with the samples or covering letter.

(d) Leaf analysis

The Foundation operates a service on the tea plant nutritional and fertilizer use problems based on analysis of mature leaves. The method for taking samples is described on page 5.

In addition to the use of the leaf analysis to diagnose the cause of a low yielding area, it is advisable to have all fields tested once in a pruning cycle, preferably just before pruning. This will enable trends towards incorrect nutrition to be detected and corrected before yields fall.

The best time to sample is towards the end of the cycle (between 4 and 5 months before pruning). This will enable the results to be available and remedial applications, if necessary, to be assessed in time for these to be given to the tea immediately before or after pruning.

One sample should be taken from an area of roughly one hectare. Each sample should have at least 100 mature leaves. Detailed instructions are given below. Where the tea is fairly even, samples should be taken as above. Where the tea is very variable samples should represent a well defined area in which the tea is uniform.

(e) Instructions for taking leaf samples for technical analysis

The most recent research at the Foundation has shown that the uppermost mature leaf in the plucking table is a better indicator of fertilizer induced nutrient trends than any of the younger leaves. All growers who are interested in sending leaf samples for analysis are therefore requested to send the uppermost mature leaf only unless otherwise suggested.

The uppermost leaf is hard, dark and full in size. It is comparable to the lower maintenance foliage. It is the uppermost such leaf on a twig that bears or had previously borne, one or more growing shoots that is sampled and not on the edge of the plucking table or from inside the bush.

For each plot, sample at least 100 bushes, taking one leaf from each bush. The bushes must be uniformly scattered over the whole area, but avoid rows which adjoin roads, paths or large vacant patches. Sampling should be done on the same day. 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. Preferably dry the leaf as far as possible on very clean surface, but do not crush it.

Send the samples to TRFK, as described in soil analysis section with details of any problem and past history of the area. For this analysis a small fee per sample is charged (see page 162).

(f) Testing and calibrating instruments

The Foundation will test and calibrate simple instruments such as pH meters and tea moisture meters which are used by the tea industry. Advice will also be given on the purchase of instruments and associated apparatus, and the method of use will be demonstrated to suitable employees. The Foundation does not repair instruments.

(g) Analysis of fertilizers

The Foundation will analyse purchased fertilizers for growers wishing to verify their nutrient contents with that given by manufacturers. A small fee per sample is charged (see page 162).

(h) Miniature manufacture of clonal leaf

The TRFK will manufacture samples of green leaf by a standardised procedure and obtain tasters' reports on the made tea. At present, the only method of manufacture is CTC. Producers wishing to avail themselves of this service should carefully follow the following instructions. This should only be done with prior arrangement with the TRFK.

1. Samples must contain at least 600g of green leaf. If a grower wishes to have more than one sample from the same source manufactured, this can be done by submitting another sample separately.
2. The detailed origin of each sample must be disclosed. The TRFK will not divulge this information to other producers or the tasters or any other person without permission from the sender. The TRFK reserves the right to use the information and tasters' reports for research investigation. If this is done and results are published, the source of the leaf will be divulged without permission from the sender.
3. Leaf delivered a long distance from Kericho must be transported in such a way that natural withering takes place in transit without over-withering. The final degree of withering can be adjusted in the factory for under-withered leaf but over-withered leaf will not be accepted.
4. Leaf must be plucked to a good standard of "two leaves and bud" only. Badly plucked leaf is not acceptable.
5. Growers wishing to send leaf for manufacture must write well in advance stating when they wish to send samples. They must not send the leaf unless they receive acknowledgement that their leaf can be accepted. This is essential so that a programme for manufacture of TRFK and leaf from out growers can be drawn up well in advance.
6. The maximum number of samples which can be processed at present in one day is 12. Control sample (see page 44) should be included in each batch of samples. If the number of samples exceed one day's work, the same control should be repeated on each day to serve as a standard for comparison of each day's manufacture.
7. The manufacture of 600g of green leaf normally produces sufficient unsorted made tea for at least one standard tasting. The unsorted tea is normally sent for professional tasting and some is retained at TRFK. If the grower wishes to receive some or all of the manufactured leaf he should inform the TRFK when submitting the samples.
8. A small fee is charged for processing each sample.

(i) Release of TRFK clones

The Foundation clones are released as soon as they have shown, in trial plots, to be superior to commercially available seedlings in both yield and cup quality characters.

These clones can be tested at the TRFK substations, when established, and sometimes in the growers' farms. These places do not represent all the various soils and climatic conditions in which the clones are likely to be grown. It is therefore quite impossible for TRFK to guarantee the performance of its clones under various conditions and it is the responsibility of the buyers of these clones to verify them for their local conditions.

Clones being tried in a locality for the first time should always be included in a rooting and field trial as described on pages 39-41. As at 1st January 1999, the TRFK released clones were: -

6/8	7/9	12/12	31/8	100/5
7/3	11/4	12/19	31/11	108/82
303/156	303/577	337/3	337/138	303/348
303/199	303/999	303/186	303/156	303/388
7/14	303/366	347/314	347/366	31/27
347/326	347/573	303/1199	31/29	303/791
303/179	31/28	303/745	303/13	303/231
303/259	55/56	100/5	303/35	100/8
55/55	303/978	56/89		

This list may change from time to time as new clones become available for release or as demand for any of the clones ceases.

(j) Instructions to applicants

The release of the above clones will normally be restricted to 200 cuttings/clone/buyer/year, but large scale release may be considered on special occasions and if the material for cuttings is available. Clonal plants can be sold if available. The applications are sent to the Director of the Foundation.

The TRFK cannot always supply cuttings or plants at the time requested by the applicant and some correspondence is usually necessary. Applications should be in writing and not by telephone. Applicants for cuttings are advised to send their applications at least six months in advance to give the Foundation enough time to prepare the mother bushes. Orders will not be entered into the Order Book until full payment has been made.

If a new clone is released, following an announcement in the "Tea" Journal, or any other publication, the number of cuttings or plants which can be sold to each applicant will only be decided after an accurate assessment of demand has been made. Applicants should in this case, indicate the maximum number of plants or cuttings which they wish to purchase.

(k) Fresh cuttings

These will normally be released to purchasers who can plant the cuttings within 24 hours of removal from the mother bushes.

1. If 200 cuttings or fewer per clone are purchased the cuttings will be prepared individually and packed in polythene bags and cardboard boxes by the TRFK. For larger orders see (I) above.
2. For larger orders the TRFK will provide the purchaser with either prepared cuttings or the prunings from mother bushes. The purchaser will be responsible for transporting these prunings and for preparing the cuttings from them.

Fresh cuttings are sold on a graduated scale depending on the number required and the availability of any particular clone. A quotation of the price will be given on request.

(l) Other services

The Foundation also provides other services on plant protection, which include routine single identification and diagnosis of nematodes, fungi, bacteria and pests in the lab. Pesticides for registration and used in the field is also done.

m) ***Callused cuttings***

For a very long time now there has not been a request for callused cuttings. However, these will normally be released to purchasers who will plant the cuttings more than 24 hours after their removal from mother bushes. They will be ready four to six weeks after being planted in the TRFK callusing beds. For small orders (200 cuttings per clone or fewer) the cuttings will be packed in polythene bags and cardboards boxes by the TRFK. For larger orders the purchaser must provide suitable containers for the cuttings. The cost of callused cuttings will be given on request.

In addition, plants of miscellaneous clones, all of which are as good as or better than seedlings plants in all respects, but are not up to the standard of release clones and also those not fully tested, will be sold to the growers at a price which will be given on request.

The grower is responsible for ensuring that he is satisfied with the standard of the plants when they are removed from the nursery.

Notes to the buyers

Your requirements should be stated clearly and the application should include the following information: -

1. Your name and address.
2. The clones and number of cuttings or plants of each you require.
3. If you are ordering cuttings, state whether you want fresh cuttings or callused cuttings.
4. When you want cuttings or plants, it helps if you specify the exact date and time of collection.
5. If the order is small and you wish TRFK to dispatch the cuttings to you, please let the Foundation know how you want them sent, giving full details as the Foundation staff are not always conversant with your local facilities.
6. Do not forget to pay in advance. Your order does not exist until full payment has been made.
7. You are reminded that you must comply with local regulations concerning the movement and planting of tea.

(n) ***Plain Tea Quality Parameter***

This involves analysis of chemical parameters such as theaflavins and thearubigins and other parameters like total colour and brightness.

(o) ***Aroma analysis***

For a long time there was a belief that Kenyan tea is of plain quality only. It has now been established that some of our teas are flavoury as well. The Foundation is now capable of analysing compounds responsible for aroma in our teas.

(p) ***ISO 3720/Kenya Bureau of Standards specification for tea***

Most of our processed tea is exported (about 90%). There are strict minimum quality standards that the majority of buyers now require. In case you would like to ensure that your tea meet these minimum standards TRFK can do the analysis for you.

Appendix VI

EQUIPMENT FOR CHEMICAL APPLICATION

(a) Spraying equipment

The equipment available for application of chemicals range from such simple device as puff dusters and syringes to complex machines such as mist blowers, drift sprayers and ultra low volume (ULV) sprayers. For the purpose of this handbook those that are relevant to tea are discussed.

Spraying equipment is used in tea for a number of purposes:

(i) for application of insecticides to control insects on tea

(ii) application of acaricides for the control of mites on tea

(iii) application of fungicides and bacteriocides for control of tea diseases

(iv) application of herbicides to kill weeds

(v) Application of plant nutrients of foliar sprays such as zinc on tea.

The main function of sprayers is to atomise the spray fluid, which may be a solution, an emulsion or a suspension, into small droplets and eject the same with some force for distributing it properly. Another function is to regulate the amount of pesticide to avoid excessive application that might prove harmful or wasteful. They are designed for applying three types of pesticidal sprays: (i) space sprays (ii) residual or surface sprays and (iii) dual purpose sprays.

The atomization of a liquid in a sprayer is accomplished by one of the following mechanisms: (i) forcing a liquid through the nozzle by either hydraulic pressure or air pressure as in compressed air sprayer, (ii) by the use of high velocity air streams into which flows a jet of liquid of coarsely atomized liquid or coarsely atomised liquid as a motorised knapsack sprayer and (iii) by centrifugal force in which the liquid is fed under low pressure to the centre of a high speed rotating device such as disc or cup and is atomized by centrifugal force as it leaves the periphery.

Parts of sprayer

The important parts of a sprayer are tank, pump, agitator, power source, pressure gauze, valves, filters, air chamber, hose, spray lance and cut-off valve, booms and nozzles.

(i) *Tank*

The spray fluid has to be held in some kind of container while it is being sprayed. The capacity of the tanks coupled with the sprayer varies from less than one litre to over 2,700 litres. For tea there is a trend towards smaller tanks, unless aerial spraying is carried out. Tanks ranging from 5 to 20 litres capacity are commonly used. Material used for the construction of the tank is usually non-corrosive, being steel, brass or plastic.

(*ii) Pump*

Pumps are necessary for atomization of the spray fluid. The sprayer may be equipped with one of the following types of pumps: air pumps (pneumatic pumps), positive displacement pumps (plunger, rotary and diaphragm types).

1. *Air pumps.*
   They are used in compressed air sprayers. They force air into the air-tight spray tank and do not pump liquid directly.
2. *Positive displacement pumps.*
   The pumps take in a definite volume of liquid from the inlet and transfer it without possibility of escape, to the outlet.
3. *Centrifugal or impeller type pumps.*
   These pumps are fitted to many spray blowers used for spraying crops. A centrifugal pump consists of a cylinder, inside which a multiblade impeller rotates at high speed around a control axis.

(iii) Agitator

The pesticidal materials in spray-fluids are not always in solution. Therefore, most of the sprayers are provided with agitators for keeping the pesticidal material uniformly dispersed. For different spray-fluids, agitation requirements are different.

There are two methods of agitating the spray liquids, namely, hydraulic agitation where it is provided by return of excess spray material from the pump, or mechanical agitation provided by paddles or propellers.

(iv) Power source

Source of power for power-operated equipment is gasoline engines and the trend has been towards air cooled engines because they weigh less. However, most of the sprayers are manually operated.

(*i) Pressure gauge*

It is sometimes provided in discharge line as a quick means of assessing whether the components of the machine are functioning correctly and for guiding the operator in properly adjusting the pressure for each spray job.

(*vi) Valves*

The valves constitute an important part of any spraying apparatus, because they govern the direction of the flow of the spray material. They are fitted into the pipe system so that they allow the liquid to pass in the direction of the nozzles. They are of two types; Ball valves and Spring loaded valves.

(vii) Filters

The liquid must well-filtered to protect the pump from abrasion, to avoid interference with the function of valves and prevent blocking of the nozzles. There may be several filters in the spray assembly.

(viii) Nozzle

Field, high pressure and most aircraft sprayers rely upon the principle of hydraulic atomization. The nozzle in these sprayers is a vital part as it breaks the stream of the liquid and spreads it out into spry droplets.

Nozzles are designed for either high or low pressure, for producing a fan-shaped, solid-cone or hollow-cone spray patters (Fig A).

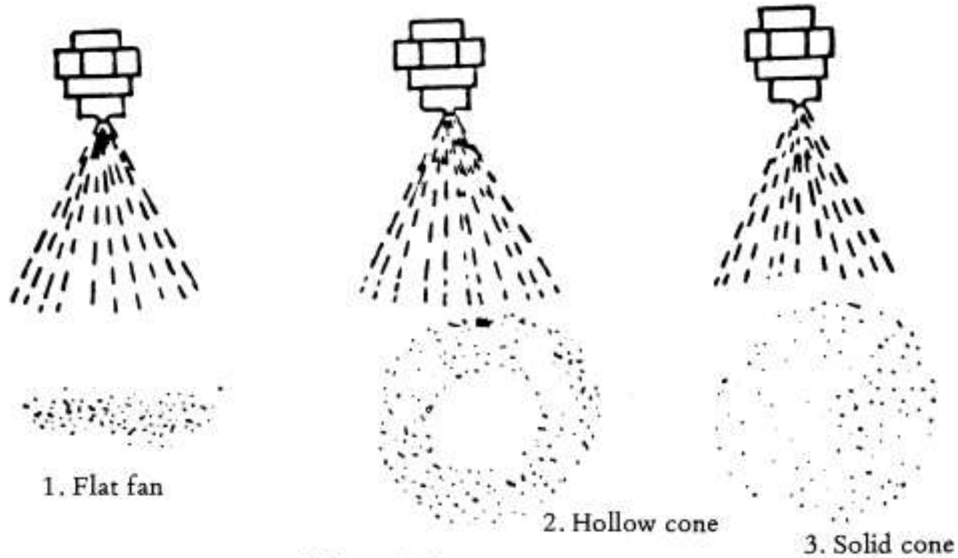


Figure A: Spray patterns

Factors influencing operation of nozzles

Factors such as increase in pump pressure, diameter of disc orifice and depth of the eddy chamber influence the operation of nozzles (Table A). Increase in pump pressure results in smaller spray droplets (Table A) and increased carry of droplets, spray cone and discharge. The output from the hydraulic nozzles varies approximately as the square root of the applied pressure. It is, therefore, necessary to change the nozzle (or the disc, where such a provision is made) to make gross changes in the output. However, their finer adjustments can be made by regulation of the pressure. Increase in the diameter of the orifice results in increase in the size of droplets, carry of the droplets, discharge of the spray fluid and the spray cone.

Manually-operated sprayers

According to the source of motive power the available spraying machines can be classified as (a) manually operated and (b) power operated.

Many simple yet efficient manually operated pesticide application machines are available. They are equally useful for both small and large scale tea growers. The manually operated sprayers either work on a pump, as in a Knapsack sprayer or on a compression system.

Table A: Factors affecting performance of nozzles

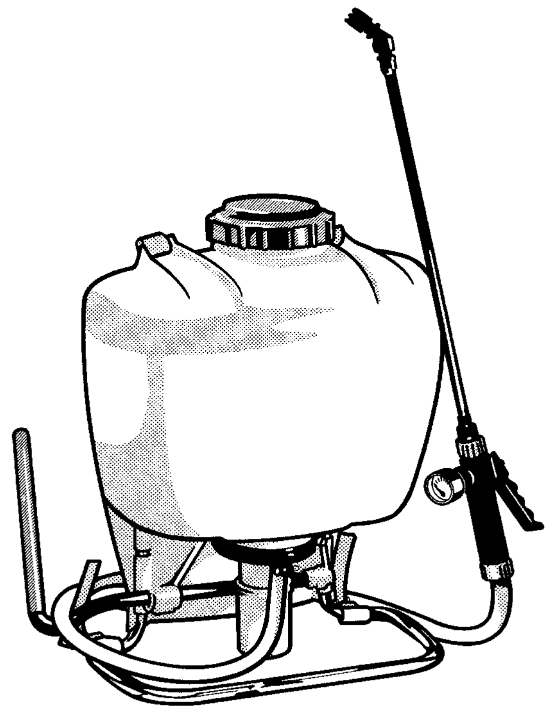
Effect desired	Adjustment required in			
	Pump pressure	Eddy-chamber depth	Disc thickness	Disc-orifice diameter
Faster output	Increase	Increase	Increase	Increase
Finer droplets	Increase	Decrease	Decrease	Decrease
Longer carry	Increase	Increase	Nil	Increase
Wider cone	Increase	Decrease	Decrease	Decrease

Knapsack sprayers

It has a flat or bean-shaped tank designed to fit comfortably on the back of the operator. The capacity of the tank is 15-20 litres, It is generally made of plastic.

In a Knapsack sprayer, the tank is provided with either a single pump and pressure barrel having a piston pump and mechanical agitator or with a diaphragm type with a lever for operating. Higher outputs are provided by the plunger type pumps than by the diaphragm pumps. However, the latter type of pumps require comparatively less energy for operating and also less maintenance. In addition, these pumps stand wear very much better than the plunger type pumps, especially with abrasive materials such as water dispersible powders. Provision is sometimes made for changing the operating lever from one side of the sprayer to the other so that it may be used in either the right or the left hand. Some models are equipped with a double-acting externally-mounted pump. A pressure chamber is provided to eliminate pulsations and to give a uniform spray. However, the pump has to be operated continuously while spraying for maintaining the necessary pressure. The spray line consists of a short rubber pipe, a lance and a nozzle. Settling of wettable powders in the tank of the sprayer is prevented in many cases by provision of a mechanical agitator consisting of a plate which is moved up and down inside the container by the pump lever.

Some models employ hydraulic or jet agitation from a small jet of the fluid issuing from the bottom of the pump. The pressure developed in these sprayers depends on the pump and varies from 3 to 12kg/cm^2 which is more than that developed in a compressed air sprayer. However, a pressure of 3-4 kg/cm^2 can be maintained in most cases without much effort. The sprayer can be used for spraying low crops, and nursery plants. It is also useful for spot treatment. These pumps are very commonly used in the tea growing areas. With these sprayers, the job of the operator is tiring, especially over a long period. The operator has to bear the weight of the sprayer containing the fluid and simultaneously required to operate the pump lever with one hand and the spray lance with the other hand. Under this situation, the lighter the equipment and lesser the effort needed for operation, the better.



Knapsack sprayer

Pneumatic hand sprayer

This machine has a container of 0.5 to 5.0 litre capacity. The container has in some cases a built-in pump (Fig B) while, in other cases, the air pump is mounted externally. In both cases, an outlet pipe is suspended in the container. The outer end of the pipe terminates in a nozzle. The container is filled to approximately three-fourths of its capacity and air is compressed in the remaining space by means of the pump.

Before use, the plunger type pump is worked to develop an air pressure of 0.15 - 3.00 kg/cm^2. The spray comes out from the nozzle usually via a suitable trigger-control valve. On opening the release by depressing the valve lever, the liquid rushes through the nozzle under the pressure of the air above the spray liquid to emerge in the form of continuous fine spray. These machines, when fully charged with compressed air, normally run for about 5 minutes before they require recharging.

Since they are charged prior to each operation, all the attention of the operator can be devoted to directing the spray and ensuring a good coverage. The application rate ranges from 45 to 112 litres per hectare. In some cases however, continuous pumping is needed to maintain the necessary air pressure in the container. These sprayers are used extensively for spraying in the nursery. They are valuable for use in glass houses. They are less tiring to operate than most atomizers. However if plants are low (below 60 cm in height), the operator is likely to get tired quickly due to bending unless an extension rods to permit directing the spray at any desired angle is fitted.

Power operated sprayers

Use of mechanically-operated sprayers powered by means of gasoline engines for the application of the spray fluid is recommended in place of the manually-operated type wherever the nature of the past problem permits this change and economic considerations justify it. Such sprayers result in saving cost of treatment. The treatments are more rapidly completed and may result in additional savings because of prompt control of the pests.

In some cases, mechanically-operated sprayers may prove to be superior in performance. Hydraulic pressure atomizes the liquid and carries it to the plant surface in some sprayers, while in others this function is performed by current of air or gas, or by other non-hydraulic means.

Ultra low volume applicators (rarely used in tea fields).

Efforts directed to reduce the amount of pesticidal carriers without affecting the uniform distribution of the toxicants led to the development of ultra low volume applicators. Development of special nozzles that were capable of producing fine droplets led to reduction in pesticidal carriers. Ultra low volume spraying, commonly referred to as ULV spraying, is a new concept in pest control It enables treatment of large areas quickly. With this technique, the pesticides are applied in small quantities (usually 0.5 to 2.0 1/ha for field crops) in a highly concentrated from. The pesticide is not diluted with water before spraying. ULV spray rates require the use of small droplets of 30 to 150 microns. Such small droplets cannot be forcibly propelled over a distance and their distribution, therefore, depends on gravity and air movement. The basic requirements of ULV spraying are (i) narrow and controllable droplet spectrum, (2) an accurately controllable emission rate and (3) non-volatile pesticide formulations of suitable viscosity and density.

Use of aircraft in pest control and fertilizer application (Fertilizer application only).

Use of aircraft enables coverage of large areas rapidly, timely and economically. Fixed-wing aeroplanes have been used for nutrient (zinc) application in tea in Kenya. They are hardly used for pesticide application.

Advantages of aerial application

For controlling pest and disease outbreaks, quick action is necessary to cover large areas within the shortest possible time. An ordinary aircraft flying at 130-160 km/hr can dust or spray 4 to 16 ha per minute depending upon the effective swath width which varies from 15 to 60 metres. Thus, in a day of 6 hours, over 400 ha can be dusted depending upon the weather, the terrain and other factors. Normally, however, dusting may be possible only for a few hours in a day as dusts are very prone to drift. Fertilizer can be applied by aircraft at the same rate as dusting.

In aerial spray applications, the volume of the spray fluid used per unit area is appreciably reduced because of the limitation of the load. With conventional spray nozzles delivering 15-20 litres of spray fluid per ha from a height of 2-4 metres above the crop, about 320-400 ha can be sprayed in one day. However, with ULV nozzles, spraying from a height of about 10m, over 1200 ha can be treated in a day.

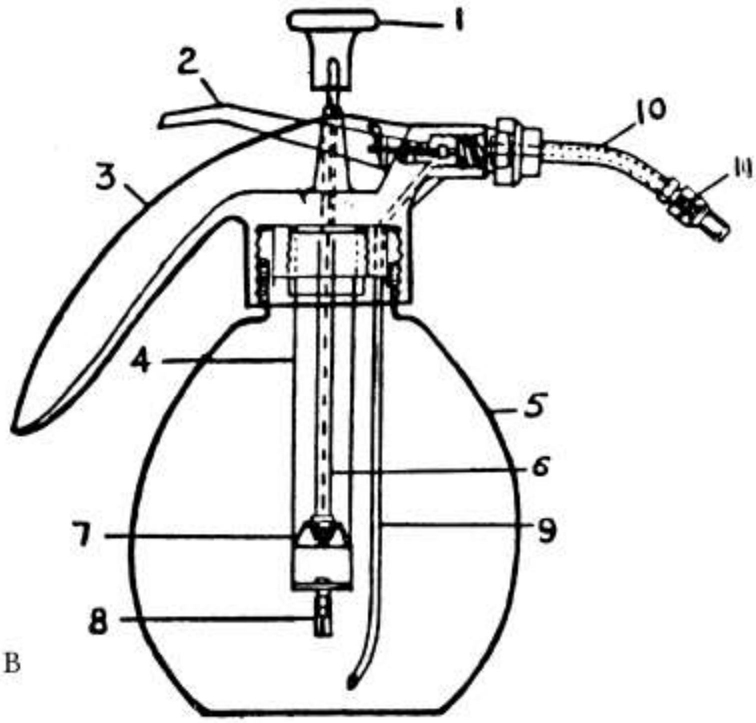


Fig. B

1. Knob 2. Cut-off lever 3. Handle 4. Pump barrel 5. Tank 6. Plunger rod 7. Bucket assembly 8. Air-check valve assembly 9. Discharge tube 10. Spray lance 11. Nozzle.

Limitations of aerial application

Aircraft application has, however, certain limitations. In aerial application, most of the spray/dust is primarily airborne. The droplets/particles lose their kinetic energy derived from emission within about one metre form the point of discharge and thereafter, their trajectories are determined by gravity and wind. Thus, drift is a serious problem. It is calculated that droplet of 100 microns emitted 3 m from the ground will drift 15 m in a 4.8 km/hr wind and 48 m in a 16 km/hr wind, while a 10 micron droplet will drift approximately 100 times more. The usual recovery of the pesticide sprayed from the air, on plants, is 85 per cent in conventional spraying and 70 per cent in ULV spraying. However, the effects of droplet displacement due to turbulence can be very serious. Under high turbulence conditions, recoveries of droplets less than 200 microns may be as low as 40 per cent of the recovery achieved under low turbulence conditions.

The degree of thoroughness of application that can be attained with ground equipment is usually not attainable with airborne equipment. In the control of certain pests, a good deposit of the pesticide on the under side of leaves have, however, been obtained by flying at lower height and slower speeds.

Dependency of aerial application on optimum weather conditions is also a great drawback. Weather conditions may not permit the aircraft to take off from the base or the operating site. Air currents affect the performance of aircraft appreciably in both dusting and spraying operations. Favorable conditions usually occur during early morning/late evening when the air is relatively cool and humid. It is often less expensive to treat small acreage with ground equipment than with aircraft.

(b) Soil injecting guns

Most soil fumigants are formulated as liquids. They can be applied by various kinds of soil injectors in required amounts at regular intervals and at the desired depth in the soil. The hand-carried applicators (Fig. C) are impracticable for large areas, but are useful for small ones. Small hand-operated soil injectors with a capacity of about 2.25-3.5 1itres of soil fumigant are commonly used for fumigating soil to a depth of 15-22 cm for controlling soil pests, particularly nematodes. They are quite light, weighing only 3.6-5.75 kilograms.

Using this equipment, one can treat about 0.4 ha in a day. All fillings should be done in the open air using a funnel, preferably fitted with an air vent. It is most important to check by removing the filter cap that the filter is in place, because it is essential to prevent dirt from entering the tank in order to get a long trouble-free service. It is necessary to ensure that the filter is clean. If necessary, the dirt from the filter can be removed with kerosene. Furthermore, on first filling or at any time after the tank has been emptied and refilled, it is essential to ensure that all air is removed from the valves and pipes. This is done by pushing down the injection handle. Gumming ad corrosion may occur if soil fumigant is allowed to remain in the injector for long periods. It is, therefore, advisable that on completing fumigation the tank be emptied by lifting the filter. By depressing the injection handle several times, the fumigant remaining in the lance can also be ejected. Further, for proper storage of the soil fumigant injector for long periods, recharge the tank with approximately 1 litre of a mixture containing equal amounts of a lubricating oil and kerosene. Thoroughly agitate the mixture and depress the injection handle a number of times until the soil injector is empty. Outside of the injector should also be cleaned with a similar mixture and, finally, it can be wiped with an oily rag before storage.

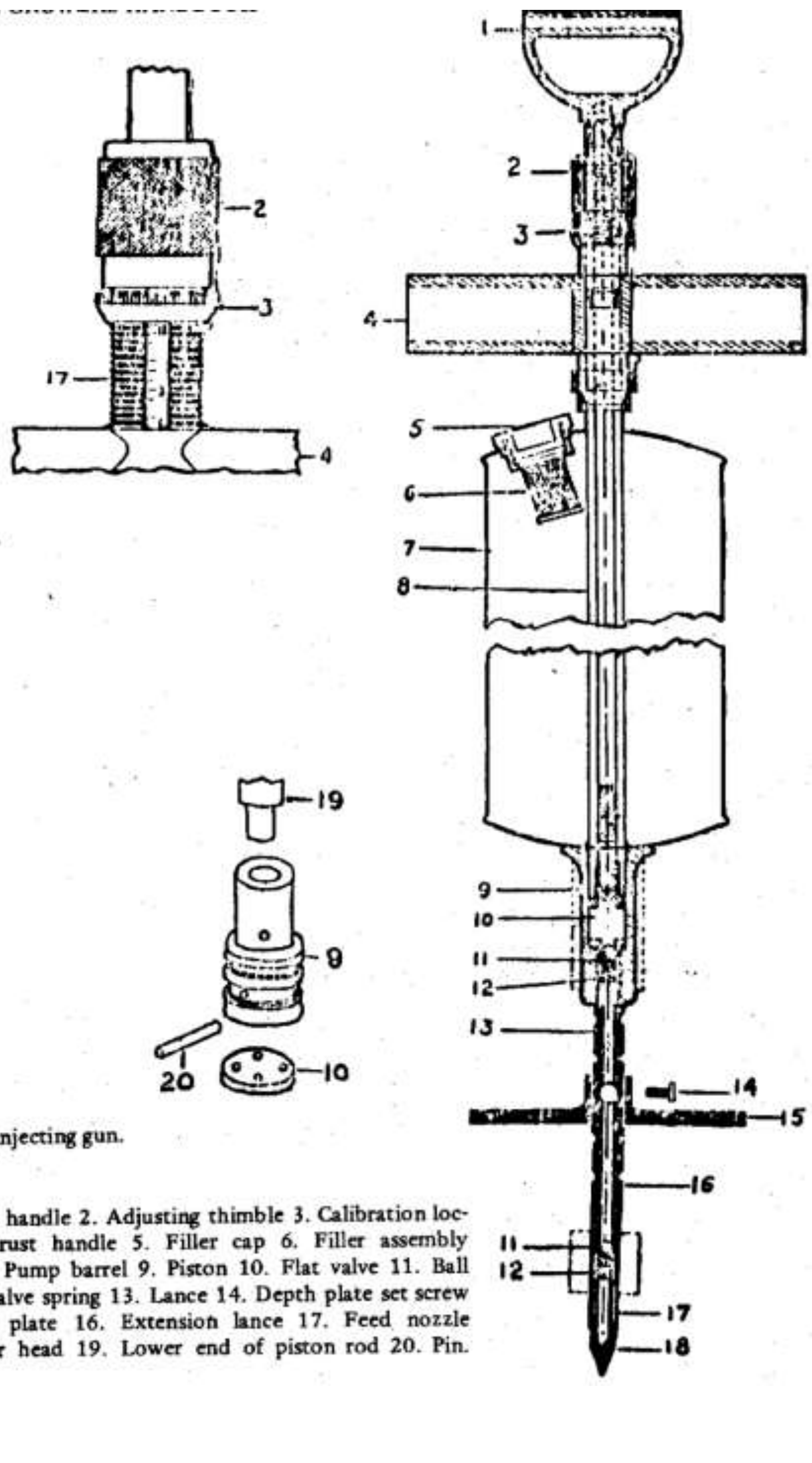


Fig. C. Soil injecting gun.

1. Injection handle 2. Adjusting thimble 3. Calibration locking 4. Thrust handle 5. Filler cap 6. Filler assembly 7. Tank 8. Pump barrel 9. Piston 10. Flat valve 11. Ball valve 12. Valve spring 13. Lance 14. Depth plate set screw 15. Depth plate 16. Extension lance 17. Feed nozzle 18. Injector head 19. Lower end of piston rod 20. Pin.

Index

KENYA TEA DEVELOPMENT AGENCY LTD.

A new beginning from a successful past

THE CHAIRMAN, BOARD OF DIRECTORS,
MANAGING DIRECTOR AND THE STAFF OF
KENYA TEA DEVELOPMENT AGENCY LTD.
congratulate

The Tea Research Foundation of Kenya for the production of the revised edition of the TEA GROWERS HANDBOOK

- KENYA TEA DEVELOPMENT AGENCY LTD. was incorporated on 5th May, 2000 and took over the assets and liabilities of its predecessor Kenya Tea Development Authority as from 1st July, 2000.
- KTDA Ltd. is one of the largest Tea Management Agencies in the world.
- K.T.D.A. Ltd's mission statement is "To provide effective management services to the small-scale tea sub-sector for efficient production processing and marketing of high quality tea for the benefit of farmers and other stakeholders.
- K.T.D.A. Ltd's vision is "To aim at being the best tea management agent in the production, processing and marketing of high quality tea in the world.
- K.T.D.A. Ltd produces 59% of tea output in Kenya
- It manages 45 tea factories in the smallholder tea sub-sector with nine additional factories under construction.
- K.T.D.A. Ltd. sells most of her teas through the Mombasa Auction, about 75-80%. It also sells tea directly to overseas buyers, about 15%.
- It also sells tea to local packers and direct ex-factory customers
- K.T.D.A. Ltd. teas are most sought after in the world because of their superior quality. The policy of two-leaves-and-a-bud is maintained.
- Approximately 360,000 small-scale tea growers participate in the scheme with an average of 0.25 ha. of tea per grower.
- K.T.D.A. Ltd authors the policy, articulates governance process, organizational strategy and company development. The Agency sets the corporate goals, objectives and priorities.
- Smallholder tea subsector makes a sizeable contribution to the national economic development and the improvement of the societal living standards.
- Smallholder teas are used basically to improve the quality of value added teas when blended with teas from other origins
- K.T.D.A. Ltd contributes approximately 60% of fundings to the Tea Board of Kenya which in turn provides financial support for tea research programmes conducted by Tea Research Foundation of Kenya.

TEA BRINGS PEOPLE TOGETHER

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MAKERS OF QUALITY TEA FOR PEOPLE WITH GREAT TASTE

KENYA TEA DEVELOPMENT AGENCY LIMITED
Farmers Building, Moi Avenue,
P.O. Box 30213, NAIROBI
Tel.: 331053 221441-4
Fax: 210636 245773 211240
E-Mail: ktda @ ktda. co. ke