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Tea Growers Guide



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**Kenya Agricultural & Livestock
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Tea (*Camellia sinensis* (L.) O. Kuntze) Production and Utilization in Kenya

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The major tea varieties grown in Kenya are:

 	<ol style="list-style-type: none">1. <i>Camellia sinensis</i> var. <i>sinensis</i>2. <i>Camellia sinensis</i> var. <i>assamica</i>3. <i>Camellia sinensis</i> var. <i>cambodiensis</i>	<i>Chinary</i> <i>Assamic</i> <i>a</i> <i>Cambod</i>
     		

Introduction

Tea was introduced to Kenya in 1903 at Limuru by Right Brothers. In 1924 commercial large estates started tea farming. The Tea Board of Kenya was formed in 1950 to regulate the tea industry. In 1954 smallholder tea cultivation commenced under the Swynnerton Plan with the first small holder tea factory established in Ragati, Nyeri County in 1957. In 1960 Special Crop Development Authority (SCDA) was established and two years later, Kenya Tea Development Authority was established under the Agriculture act (cap 318) section 191 (legal Notice No.42). In 1999 KTDA order was revoked through the legal notice No.44 as a result of recommendation of sessional paper No.2 of 1999 hence Kenya Tea Development Authority was privatized giving rise to Kenya Tea Development Agency to serve the interest of smallholder tea farmers in Kenya. Tea therefore contributes immensely to socio-economic development of the country. It is the leading foreign exchange earner amounting to 20% of the total foreign exchange earnings and contributing 4% of the Gross Development Product (GDP). It provides livelihood and supports 0.64 million Kenyans and contributes to rural development (Ref). This has been realized through active role played by all the actors in the tea industry in Kenya. Research and development in the tea industry through KALRO-Tea Research Institute plays a key role in improving productivity per unit area by availing cost

effective and sustainable tea technologies such as proving novel tea cultivars to the stakeholders in Kenya.

Research in tea was initiated by Brook Bond Liebig Co. Ltd within the African Tea Holdings Ltd in Kericho County in 1949. This served the whole of Kenyan tea industry and later the East African region. In 1951 the department was taken over by East Africa Tea Growers and renamed Tea Research Institute East Africa (TRIEA) which registered in Tanzania in 1959 and Uganda in 1977. The TRIEA collapsed with the breakup of East Africa community (EAC) in 1977 and in 1980, the Government of Kenya through Tea Board of Kenya took over the institute and established Tea Research Foundation of Kenya (TRFK). In July 2014, the institute was renamed Tea Research Institute (TRI) under the Kenya Agricultural and livestock Research organization (KALRO) following the state corporation reform process (Ref). Tea is one of the crops selected for realization Kenya's **The Big 4 Agenda** since the year 2017.



Fig 1: Mature tea field ready for plucking

Botany of tea

Tea is a heterogeneous evergreen plant with many overlapping morphological biochemical and physiological characteristics. It falls under the *Theacea* family in the *Camellia* genus and is named *Camellia sinensis*, consisting of two main varieties; var. *sinensis* and var. *assamica* known generally as China and Assam varieties, respectively. A third variety considered to be a subspecies of *Camellia assamica* named *Camellia sinensis* var. *assamica* spp *lasiocalyx* has semi erect leaves and is classified as ologophite (leaf angle 50°- 70°). The China varieties have small erect leaves and are classed as erectophiles (leaf angle < 50°), while the Assam varieties (considered small trees thought originally to have grown in the forest) have horizontal and broad leaves and are classified as planophile (leaf angle > 70°). Tea can grow into a tree attaining a height of 20-30m if unpruned and can have very long life span of more than 1,500 years (Ref). The tea plant is extensively commercially exploited. On average a tea bush under optimum Good Agricultural Practices (GAP) can produce up to 3.5kg green leaf/bush/year.

Propagation

Tea is commercially propagated by vegetative material. Tea plants can be raised from seed, cuttings and tissue culture (micro propagation). Propagation from seed is less common nowadays following development of operationally easy, rapid and cheap techniques of vegetative propagation (VP), which facilitate easy production of cultivars. However, if required, open pollinated seeds can be supplied from tea breeding seed barriers. Tissue culture is rapid and economical on space. However, it is costly for use in micro-propagation and is appropriate mainly for breeding purposes.



Tea seeds



Fig 3: Tea tissue culture



Fig 4: Tea plant from cutting

Fig 2:

Nursery: Sleeve nurseries are recommended for raising vegetatively propagated materials. The factors to be considered in site selection include: The closeness of the nursery to a permanent source of water and the availability of shelter from prevailing wind. Availability of deep free draining soil, friable and with pH range of 5.0- 5.6 which is considered ideal for nursery propagation. Avoidance of low lying area which becomes very wet during the rain or which get frost during dry months. Sleeves of 250 gauge with a width of 10cm or diameter of lay flat 5.25 cm and 25cm long. Mix 8 wheelbarrows of sub soil/top soil mixture with $\frac{1}{4}$ kg of DAP for 1200 sleeves. The sleeves are filled to depth of 17-17.5 cm (bottom $\frac{3}{4}$ of sleeve) with sub soil/ top soil + fertilizer mixture. The remaining $\frac{1}{4}$ of sleeve is topped up with sub soil only. Packing of the soil should be fairly firm; it should not be loose nor should it be packed hard and should be dap always. Care should be taken into consideration in selecting healthy and vigorous cuttings from mother bushes for nursery propagation that have been left to grow freely for 5 to 6 months after pruning. The propagated materials are ready for transplanting for a period of 8 to 12 months. Sleeved plants are ready for transplanting when the roots have reached the bottom of the sleeves and also have at least 20cm (8in) of top growth.

Selection of cuttings: Care should be taken into consideration in selecting healthy and vigorous cuttings from mother bushes for nursery propagation that have been left to grow freely for 5 to 6 months after pruning. The mother bush selected ought to be of a predetermined cultivar for mother bushes. Prune mother bushes twice a year even if the cuttings are needed only once. Prune by a straight normal cut-across method, about 2.5cm above the previous pruning level or 40cm if the bushes have not been pruned before. Clean out (remove weak and crossed branches) only once a year, during one of the prunes. New shoots are ready for cuttings between five and seven months after pruning. Never allow new

stems to remain on the mother bush for more than seven months as the material becomes hard and the resulting cutting grow poorly. Do not cover mother bushes after pruning. Apply twice as much fertilizer to mother bushes as would be applied to plucked bushes of the same age (i.e. rate 300kg N/Ha/yr). Apply the fertilizer in at least two doses each year. If they are pruned every five to seven months, apply two or three months after each pruning. Take back branches and shoot material left over after the cuttings have prepared, to the mother bushes as mulch.

Preparation of cuttings: Wrap cut branches or cuttings (whips) for cuttings in wet sacking, take to shelter near the nursery water immediately. Make cutting under shade and shaded at every stage. Use only vigorous young shoots between five to seven months old when making the cuttings. Discard the very soft tips and the very hard lower parts of the branches where bark is forming. Each cutting should consist of a single leaf with 3 to 4 cm of stem below the leaf. Prepare cuttings using very sharp knives. Soak cuttings, immediately they are prepared, in a container full of fungicide mancozeb (e.g. Dithane, Emthane) for about 30 minutes, before planting. Cuttings with damaged leaves should not be used.

Planting cuttings: The leaf or the bud must never touch the soil (plant cuttings in the sleeves so that bud is just above the soil level). In cases where the cuttings leaves are natural deflexed (bending backwards instead of upwards), the stems should be inserted into the soil at an angle so that 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 cutting should be kept moist during planting by frequent watering. Watering should be done gently as strong jets may displace cuttings. Stretch the clear polythene sheeting (250-500 gauge) taut over the hoops and bury 1ft deep into the soil, to exclude any exchange of air.

Nursery maintenance: Inspect all beds at least once a week, check for weed growth, insect pests' diseases and treat as necessary. Always weed by hand pulling. During dry weather, keep the soil around the polythene damp. Water the beds 21 days after planting or when the sheet is noted dry. Regulate shade depending on the prevailing weather. Shade should allow 50% of the incoming sunlight. Alternatively, UV nets are recommended for efficiency and can be reused for long hence very economical.

Hardening off process: About 3 to 4 months after propagation (new shoots are about 20cmcc), loosen the polythene sheeting at both ends of the bed and leaving the polythene sheeting loose on the ground. One week later, roll the polythene up at both ends and leave it that way so that air may circulate freely. After another one week roll the polythene sheeting up to 30 cm at each end and a week later roll it up 120 cm at each end. Increase this weekly opening by 1.2 m per week until the whole bed is uncovered. Do not allow the soil to dry up during the hardening off process. Start fertilizer application after complete removal of the polythene sheet by making weekly application of NPK(S) fertilizer in solution form of 1g/m² of nitrogen in 1.3 lL of water (10g NPK(S) in 10L i.e. 1tablespoon of NPK(S) in 10L watering can. Follow with an immediate application of water to wash the fertilizer solution off the leaves of young plants to avoid scorching. Plants are ready for transplanting to the main field when they are 8 to 12 months.



Fig 5: Tea nursery soil



Fig 6: sleeve being filling with soil



Fig 7: Sleeves filled with soil ready to plant



Fig 8: Planting tea cutting in sleeves



Fig 9: Cuttings being covered with polythene for field transplanting



Fig 10: VP materials ready for field

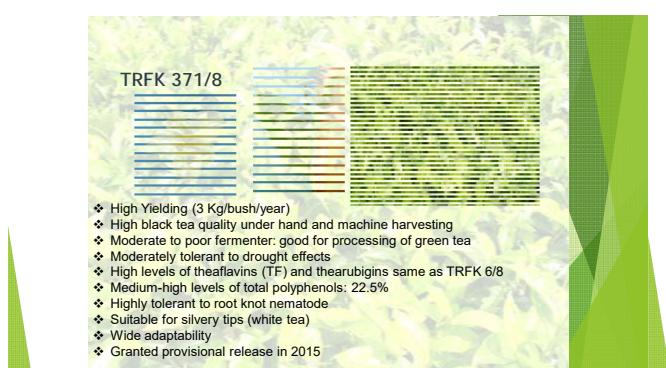
Access to tea planting material (Sites): The Vegetatively propagated material or cutting for own nursery propagation can be sourced from KALRO- Tea Research Institute, Kericho Centre for the stakeholders in the West of Rift Valley region and KALRO- Tea Research Institute, Kangaita Centre for the East of Rift Valley region as indicated in the table below:

Table 2: Location of Nurseries Propagating tea

Region	Location	Contacts
1 Western	KALRO-Tea Research Institute, Kericho	P. O. Box 820 – 20200, Kericho
2 Eastern	KALRO-Tea Research Institute, Kangaita	P. O. Box 987 – 10300, Kerugoya

KALRO - Kenya Agricultural & Livestock Research Organization

Some of the latest released tea cultivars by KALRO -Tea Research Institute available for stakeholders for commercial utilization with their special attributes.



Crop Management

Site selection and other basic considerations

Among the tropical crops there is none that demands such precise requirement as tea does if optimum yield is to be obtained. Tea requires a climate with specific limits of certain attribute; 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. Tea requires rainfall of 1200mm to 2200mm that is well distributed throughout the year and temperatures ranging from 13°C to 30°C with optimum of 30°C. An altitude of 1500 to 2250 meters above sea level is ideal for tea cultivation. Wind breaks reduce the speed of wind thereby decreasing loss of moisture from soil by evaporation and from the plants by evapotranspiration. The effective height of trees should be 10m tall and belts of trees should be 85m apart. Trees recommended for windbreaks are *Hakea saligna*, *Grevillea robusta* using trees and tea hedges can also be used to shelter the tea bushes. Tea does well in well in deep well-drained red volcanic (minimum of 2 metre or 6 feet deep) with soil pH range of 4-5.6. Tea is soil specific, and requires acid soil, humid environment and does not tolerate long droughts with the best quality tea being produced at high altitudes that remain free from frost. Crop Care should be taken during land preparation to remove all forest trees by ring barking to avoid armillaria root rot disease.

Field Planting

Sleeved plants are ready for transplanting when roots have reached the bottom of sleeves and also have at least 20cm (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 careful to avoid cracking the cylinder of soil and perhaps the roots and they should be stacked carefully and tightly on any vehicle taking them to the field. 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 the roots. The holes should be 15cm to 20 cm deeper than the sleeves and double their diameter, though the minimum should be 25. For standard 25cm long x 6.25cm diameter the sleeves the holes will be 40cm x 25cm. Use 15gm Diammonium Phosphate (DAP)/Triple super phosphate per planting hole or 30gm of single super phosphate. Mix fertilizers thoroughly with soil from planting holes.

FERTILIZERS FOR YOUNG AND MATURE TEA

Fertilizers for mother bushes

These are tea bushes, which are used as regular sources of cuttings. Removal of nutrients from mother bushes is at a much greater rate than from plucked tea. Bushes weakened by lack of nutrients (or because of pests, diseases, hail, drought, cold) produce less cuttings, which strike less easily and grow more slowly in the nursery than those from bushes

producing vigorous shoot growth after pruning. Mother bushes should be given twice as much fertilizer, of the same kind, per year as applied to plucked bushes of the same age. Apply the fertilizers in at least two doses each year. These can be made two or three months after each pruning. When a few bushes are pruned each day fertilizer can be applied to each bush immediately it is pruned. If it is anticipated that two or three months after pruning there will be no rain, then the fertilizer should be applied immediately after pruning.

Fertilizer placement in planting holes

Transplants establish and grow faster if super phosphate is mixed with the soil in the planting holes. Single super phosphate (SSP) is preferable to double super phosphate (DSP) because it contains sulphur, and should be mixed with the soil at rates which vary according to the size of the holes, as follows:

Planting hole (Depth x Width)	<i>Use either:</i>		
	<i>SSP</i>	<i>TSP</i>	<i>DAP</i>
45cm x 22.5cm	30g	15g	15g
50cm x 25cm	40g	20g	20g
60cm x 30cm	54g	27g	27g

Mix fertilizers thoroughly with soil from planting holes, on all soils except on very rich and hut site soils (pH 5.7 and above). Soils previously under grass or unfertilized arable crops require nitrogen and phosphate, hence diammonium phosphate (DAP) should be used instead of single or double/triple super phosphate (TSP). Do not use NPKS 25:5:5:5 on its own in the planting holes.

Fertilizer for infills

For quick infill establishment, nitrogen, phosphate and potash fertilizers must be used in the planting hole in proportion to the size of the hole. For a hole 60cm diameter by 60cm deep, use 115g DAP and 115g sulphate of potash (SOP). Three months after planting apply NPKS 25:5:5 to each plant to each at the rate of 50g per plant and thereafter as applied to the rest of the field.

Fertilizers for young tea

Young tea is tea of any age from the time of transplanting to the time of pruning at the end of its first cycle, after about three years' plucking (total of five years). In these five years, the plants need nutrients to maintain their health and extra fertilizer to encourage the development of strong root and branch systems, which will support vigorous cropping at maturity. 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. Young tea must be kept clear of weeds and other crops 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.

1st year application

Sleeved clonal plants have leaf shoots and active roots, and can respond to fertilizers applied as early as six weeks after transplanting. Delay beyond this time can reduce the growth potential of the plants, but the growth of plants of this age can also be checked by 'over applications' of even as little as 36g of NPK fertilizer applied as a single dose. The plants should therefore be given small but frequent applications of 1.5g nitrogen (6g NPK(S) – 1 soda bottle top) per plant starting at six weeks after planting. Repeat at about eight week (two month) intervals.

Do not apply during periods of drought. Spread the fertilizer round each plant in a broad ring, never less than 10cm wide. Fertilizer must not 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. Dribble the fertilizer 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.

2nd year application

In the second year after transplanting sleeved plants will benefit from having several small applications rather than a single large application. This should be applied in four doses (every 3 months) as per the rates shown below.

spacing	kgs/ha	kgs/acre	gms/plant
4"X 2"	160 (3bags)	65 (1.3bags)	12
4"x 2.5"	160 (3bags)	65 (1.3bags)	15
5"x 2.5"	160 (3bags)	65 (1.3bags)	19

Do not apply the fertilizer during periods of drought, and do not have less than eight weeks between two successive applications.

3rd year application

Apply in a single dose by broadcasting in the inter-row spaces as per the following rates:

spacing	kgs/ha	kgs/acre	gms/plant
4"X 2"	720 (14bags)	292 (6bags)	54
4"X 2.5"	720 (14bags)	292 (6bags)	67
5"X 2.5"	720 (14bags)	292 (6bags)	84

4th year application

Apply in a single dose by broadcasting evenly over the surface in the inter-row spaces as per the rates below.

spacing	kgs/ha	kgs/acre	gms/plant

4"X 2"	920 (18bags)	373 (8bags)	68
4"X 2.5"	920 (18bags)	373 (8bags)	86
5"X 2.5"	920 (18bags)	373 (8bags)	107

In the fourth and fifth years areas with a single rainy season the fertilizer can be given in a single application, preferably at the start of the rains. In areas with two distinct rainy seasons it is preferable to give two half-applications, one at the start of each rain season. **Do not apply fertilizer 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.**

Mature tea

Tea becomes mature after 1st initial pruning and application is given in a single dose by broadcasting evenly over the soil surface in the inter-row spaces at the rate of 150kg N/Ha/yr as shown below:

spacing	kgs/ha	kgs/acre	gms/plant
4"X 2"	600 (12bags)	243 (5bags)	45
4"X 2.5"	600 (12bags)	243 (5bags)	56
5"X 2.5"	600 (12bags)	243 (5bags)	70

CAUTION: Do not apply fertilizer during drought. Apply only when there is rain or where irrigation is available.

In the third, fourth and fifth years if the plants are growing very vigorously, the applications can be increased according to the observed vigour of the tea, to 800 kg/ha (16 bags), 1000 kg/ha (20 bags) and 1200 kg/ha (24 bags) respectively. Larger applications than these can be made if the tea plants are growing very vigorously or 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 can be increased by about 25 per cent in the second and subsequent years.

NOTE: 10kg Nitrogen = 4/5 bags of NPK(S)

Type of fertilizer

The Institute recommends 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 by:

- (1) Use of a compound fertilizer
- (2) Mixtures of straight fertilizers
- (3) Alternating compounds with straight fertilizers. This may be done either within an annual programme, or in certain cases on a cycle basis. 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.

Time of application of fertilizers

Tea under severe nutritional stress should receive a curative fertilizer application as soon as practicable. If nitrogen is the deficient nutrient, fertilizer application should wait until the grower can be sure that rain will follow within a few days. Phosphate and potassium fertilizers run little 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 at 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 twigs will return nutrients to the soil, making it unnecessary to add to this before tipping. There is also risk of the nitrogenous fertilizer components reacting with fresh mulch resulting in lowered efficiency of this nutrient. The more highly weathered mulch at tipping time could be considered to be safer in this respect. 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. 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 be delayed until there is evidence of improved growth. There is no evidence to show that heavy application of a fertilizer nutrient can improve recovery from pruning on a bush in reasonably balanced nutrition.

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.

Split applications: Split applications do not significantly improve yield in mature tea. However, 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. If it can be conveniently arranged, the same fertilizer should be allocated to the last application in 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.



Different types of blended NPK fertilizers



Different types of compounded NPK fertilizers



Bio-fertilizer application



Organic and inorganic fertilizers



Fertilizer application

Recommended Plant Spacing and population:

The recommended methods of planting are Triangular, Rectangular and Contour planting.

Table 3: Plant Spacing and population

Spacing(ft)	No. of plants per acre	No of plants per Ha
4 x 2	5,379	13,448
3 x3	4,788	11,970
31/4 x 31/4	4,762	10,000
4 x 21/2	4,000	10,776
31/2 x 31/2	3,510	8,784
4 x 3	3,590	8,975

4 x 4	2,692	6,730
5x3	2,871	7,179

Bringing young tea into bearing

Any operation designed to shape the plant into a permanent frame which is low, broad, heavily branched and capable of producing a large number of shoots (*tea table*), culminating in a high leaf yield. The reasons for bringing young tea into bearing are: To have a quick, efficient tea plants with good canopy establishment to support yields. Good system encourages (Benefits).Leads to faster financial returns on investment as it enables plucking to be started early. Healthy tea bushes that give high yields as soon as possible and sustainably maintaining this yields. Enable the frame to be low, strong, and have a good spread.

Systems of bringing into bearing: These systems have been developed to obtain a formation of good permanent frames.

i). Formative pruning

Is not injurious to root development. Decenter the plant at 6" (15cm) when the plants are 12" (30cm) but only when there are at least three leaves below 6".Prune all the shoots at 11" (28cm) when they are pencil thick. Prune all the shoots at 16" (40cm) when they are pencil thick. Tip in for three rounds at 20" (50cm).Tip-in for three rounds at 50 cm by removing shoots as soon as they develop three leaves and a bud

NB. The best system depends on clone, vigor (Vigorous clones establish faster)



Fig 11: Formative pruning

ii). Pegging

No longer recommended unless old clonal material and wide spacing are used. New clones; growth habit is erect; pegging not suitable for rapid ground cover. Pegging is injurious to plant branches, predisposing them to stem and branch cankers (*phomopsis*).Is tedious and labour intensive, Materials not readily available. Is an avoidable management expense. Pegged field reduces plucker productivity (manual and mechanized, due to intertwining branches impeding uninterrupted movement).The shoots that develop after the first light prune are bent downwards when are 60cm tall and have developed reddish bark. They are pegged so that they radiate outwards and upwards from the main stem. Pegged branches form the basis of permanent frame which is added to the vertical shoots from auxiliary

branches. Auxiliary buds are encouraged if the two terminal leaves and a bud are removed from the pegged branch (removes apical dominance). Tipping-in should be done at low level so that auxiliary buds develop and contribute to frame formation.



Fig 12: Pegging method

iii). Continuous Tipping

The procedure of continuous tipping is tip at 20cm and again at 30cm, and 40cm for two rounds by removing shoots that have developed three leaves and a bud. Tip-in at 50cm for at least 5 rounds by removing shoots that have developed three leaves and a bud. Regular plucking follows

NB: tipped shoots may be processed if the third leaf is broken off and discarded. And if tipping is delayed at 20cm, or if a few shoots have developed, then the shoots should be snapped at that height and not broken off.



Fig 13: Continuous Tipping being exhibited

Tipping has been shown to be disadvantageous for root development and dry matter accumulation since it entails removing shoots (three leaves and a bud) of tea plants at gradually increased heights. Root growth is reduced and such plants become drought susceptible in dry (marginal) areas

iv). Free growth

Has been demonstrated to be no less superior to pegging or formative pruning in terms of plant growth, cropping will start later as result. Decenter the plant at 6" (15cm) when the plants are 12" (30cm) but only when there are at least three leaves below 6". Allow to grow

freely for 18 months. Prune at 16 inches (41cm).Allow to grow to 20 inches (50 cm).Tip in for three rounds at inches (45 cm) the commence plucking
The advantages of free growth are; Quick ground cover, deep root establishment (Root growth proportional to shoot growth), high yields and is drought tolerance and Cheap.

Tea plucking Management



Fig 14: Mature tea field ready for plucking



Fig 15: Mature purple tea field ready for plucking

Tea plucking is the removal of the top most bud and tender shoots of tea for processing. This may be done by hand, hand wielded implements or motorised mechanical plucking machine.

Selective plucking: The act of removing only mature pluck able tender shoots of tea from the plucking table.

Non selective plucking: The removal of all shoots protruding from the canopy. These shoots comprise tender, dormant, immature, and mature and over mature shoots.

Fine Plucking: Removal of two or less leaves and the bud. This is done for the production of very high quality teas.

Coarse plucking: This involves removal of more than two leaves + a bud and may go up to 4 leaves + bud depending on factory or estate requirements. It is done when gross yield is more important than quality.

Light Plucking: The harvesting of only 2 leaves + bud from shoots protruding above the table, leaving 1 leaf above the plucking table. This encourages faster table rise and gives high quality tea with reasonable yields while allowing development of the maintenance foliage. Frequent light plucking results in rapid table rise and crop going out of reach before pruning is due.

Hard plucking: The removal of all mature and immature shoots protruding above the table. It restricts the table rise and does not allow development of new leaves to the maintenance layer. It gives poorer quality tea but high yields. Continuous hard plucking causes deterioration of maintenance foliage due to ageing of leaves which are not replaced

Bhanji shoot- A shoot with bud that does not develop into an active terminal bud but remains dormant. *No apical growth occurs.*

Bhanji formation: When terminal buds of shoots fail to develop into active buds. This could be due to adverse weather to growth (too hot or too cold), secondary branches developing alongside the primary branch produce shoots whose terminal buds do not develop.

Soft bhanji: Young bhanji shoots that are just protruding above the plucking table. These are newly formed and are soft as the term suggests.

Hard bhanji: These are old mature bhanji shoots. They are hard as the name suggests.

Reasons for plucking: To provide the factory with leaf that is suitable for processing. The grower makes money when he/she sells leaf to the factory .The factory, after processing the leaf, makes money by selling the made tea to consumers and tea traders

Plucking standard

Depend on factory requirement (KTDA-2leaves+bud) factory requirement. Therefore grower/estate has to provide the type (standard) of leaf required. In normal practice there are five types of shoots that can be plucked. These are:-One soft leaf and a bud, One soft leaf and a banjhi bud (soft banjhi),Two soft leaves and a bud (rolled leaf),Two soft leaves and a banjhi bud, Three soft leaves and a rolled leaf (*not to exceed 25% by weight of the harvest*)

Plucking is restricted to above leaf standards only in order to maintain good quality made tea. Restricting the numbers of pluck able leaves on a shoot, is to maintain high shoot grade composition and quality tea



Fig 16: Field ready for plucking



Fig 17: Two leaves and a bud ready for plucking

Plucking Interval

Plucking Interval is the time between two successive plucking. It will depend upon the rate of re-growth after the last plucking. The great majority of growers make a flexible plucking interval as they find that a strict timetable is not practicable. However, a grower may successfully have a fixed plucking interval of say 9-10 days and achieve this by varying the size of shoots plucked each time. A field should be picked when there is sufficient leaf to pick. During peak flush periods the picking interval will be shorter than during periods of little flush

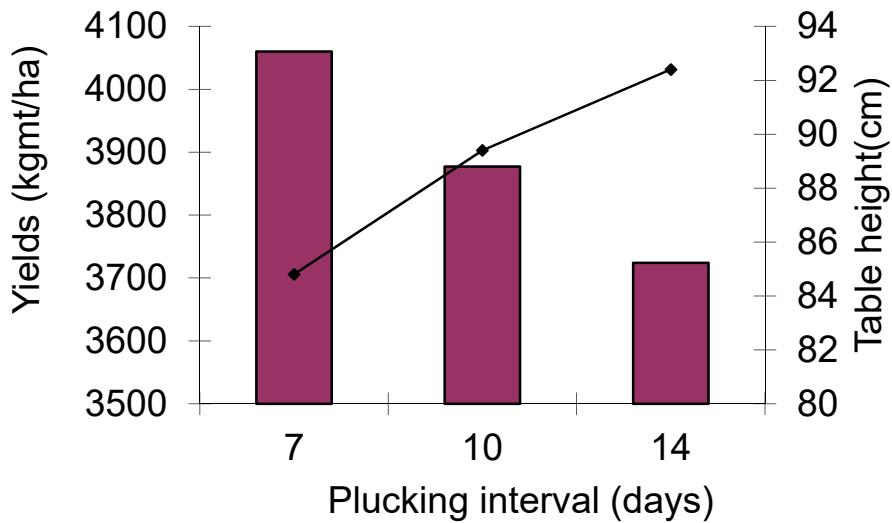


Fig 18: Graph depicting the effect of plucking interval on yield

Methods of plucking

Plucking can be done manually or mechanically (shears, handheld machine, Bobard)



Fig19: Mechanical tea harvester

Socio-economics of tea plucking

Mechanical Versus Hand Plucking

There is no significant differences ($P<0.05$) between different plucking methods and yields. Plucking speed differed significantly with methods of plucking Bobard being 3 times higher than hand-held and more than 10 times higher than manual Hand plucking had most leaf containing H2+.Mechanical plucking had low 4+.Bobard plucking had the highest of all the various grades. There is no significant differences ($P<0.05$) between plucking methods and shoot grades

Objectives of Mechanical Plucking: To maximize on the labour force and reduce on the cost of operations.Tea plucking is a major operation that accounts for up to 70% of the Estate overheads.Machine plucking can be cheaper provided the leaf standards are maintained



Fig 20: Machine plucked tea field



Fig 21: Tea harvester (Mitsubishi -Model T320

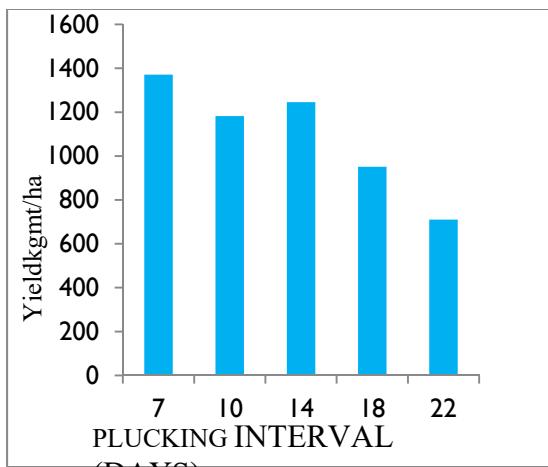


Fig 23: Effects of Plucking Intervals on Yields

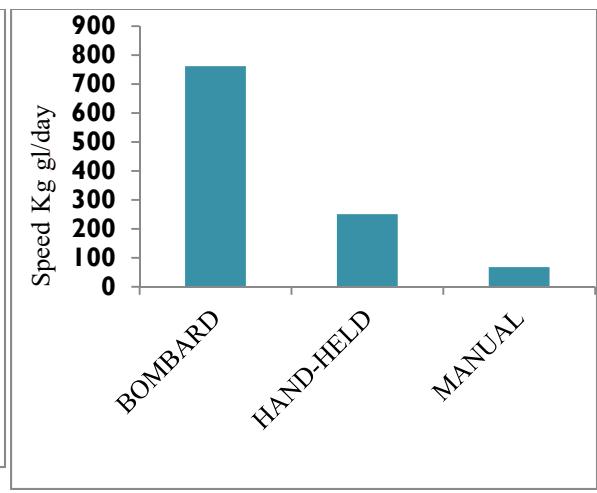


Fig 24: Effects of methods of plucking Speed

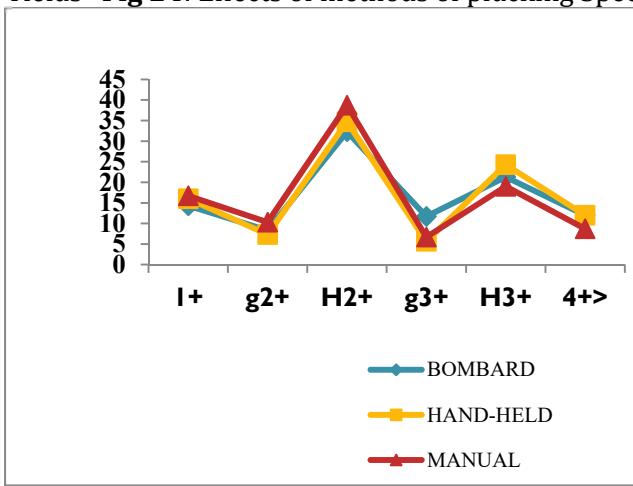
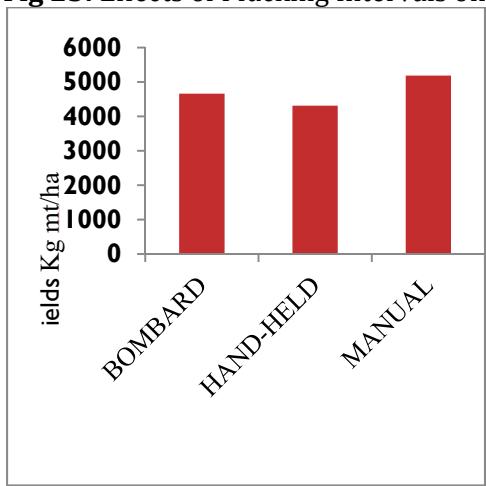


Fig 25: Effects of methods of plucking on yield **Fig26:** Effects of methods of plucking on shoot grades

Tea pruning

The reasons for pruning of tea are: To maintain size and form, stimulate vegetative growth, keep bush frames healthy & prevent reproductive growth phase (flowering-seeding) and accessibility for plucking.

Requirements for pruning: Done when the plucking tables reach 120 to 150 cm, within 3-4 years but may be shorter or longer depending on plucking regime

When Pruning should be done: Pruning should be done when there is adequate reserve carbohydrates, soil moisture not limiting and when temperature is cool

Types of pruning

- i) **Cut-across pruning:** This involves the removal of all the leaves and stems above the desired pruning height. It results to slower regrowth especially in high yielding clone which have lower carbohydrates reserves. Low pruning (less than 45 cm) leads to *Hypoxylon* wood rot infestation.
- ii) **Lung pruning:** There are three types of lung-pruning: **Rim-lung** (*lungs in periphery*), **Centre rim lung** (*lungs in center*), **Savani** (*1/3 of bush unpruned*). Alleviate poor recovery due to carbohydrates deficiency (*esp. high yielders*), lungs assist pruned tea in faster regrowth and improve growth and yield of tipping. Lungs continue photosynthesizing, thus replenishing starch reserves and yields increase with the number of lungs



Fig 27: Lung pruning

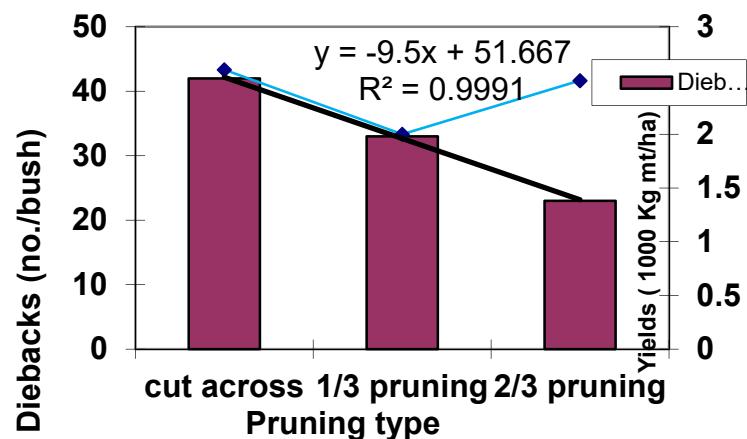


Fig 28: Effect of lung pruning on dieback and yields

- iii) **Down (Reduction) pruning:** Down pruning is done when maximum pruning height of 28 inches (70 cm) is reached. Done to rehabilitate moribund bushes. Depending on the plucking frequency, this type of pruning can be done once in 12 to 30 years

(depending on pruning cycle, 3-6 years). However, most farmers practice it due to inadequate plucking & pruning management. (ignorance/culture). Down-pruning stimulates new shoots, and renews maintenance foliage from lower levels, low yields due to down-pruning tea can last long (8-10 years) and low yields associated with down-pruning are due to poor, late, or totally failed regrowth

Prunings

Should be left *in situ* to enrich soil with organic matter, provide micronutrients (*factored in fertilizer formulation and rate recommendations*), reduce water loss (mulch reduce evaporation) and suppress weeds

Problem associated with pruning

Poor pruning results to large cuts, splits, diebacks, bark injuries *phomopsis*. Low pruning heights results to *hypoxylon infestation*. Wrong pruning implements (Knives, Panga), wrong pruning times (any time of year), failure to cover with pruning's immediately after pruning, removal of pruning's and subsequent use as firewood leads to yield reduction (up to 30% reported).



Fig 29: Plant section hypoxylon infestation



Fig 30: Hypoxylon wood rot



Fig 31: Infected on sun-scotched

Mechanized and Hand pruning predetermine heights

To solve the problem of low pruning heights, one has to adopt predetermine height as follows: 22", 24", 26" and 28". 28" is the maximum height and after down pruning is done and normal cycle starts again from 22'. Each and every cycle is an increase of 2".

Economics of mechanized pruning

Cost calculations - one acre (0.4ha) containing (4306 tea plants)

Hand

- Labour = 29 people each earning Ksh. 269.00
- **Total operation cost=Ksh. 7801**

Machine

- Time: 11 hrs

- Fuel= 11 Litres and 440mls of 2T oil
- Labour= 2 people
- **Total operation cost=Ksh. 1893**
- **Savings 75.73%**

Advantage of mechanized over hand pruning

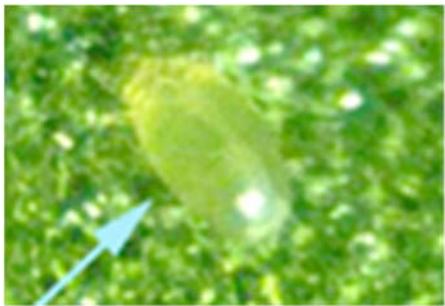
Mechanical pruning is more efficient & cost effective than to hand pruning, safe guards against the issues related to low pruning such incidences of *Hypoxyllon Serpens*. There is Uniform rejuvenation, reduced number of die-backs, faster and time saving. No effects on yields and no operator injuries

Tipping-in after prune

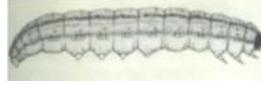
The objectives of tipping after prune are: To produce level plucking surface that facilitates efficient plucking and develop an adequate depth of maintenance foliage. Tipping-in should start before shoots go banjhi at a height of 25-30cm. The best tipping-in height is 10cm above the pruning level (usually 3 months after prune- *depends on weather & clone*). During tipping-in, shoots that have developed to three leaves and a bud above the tipping-in level should be plucked off at the tipping-in level, tipping-in aids may be used. Tipping-in should not be delayed so that buds just below the tipping level does not become mature and take longer to develop into new shoots **Caution**-Never tip-in with a knife.

Table 3: Pests, Diseases and Weeds of tea and their control

	Name of Pest/Disease	Symptom	Management Recommendation
	Pests		
1	Crevice/Scarlet Mite <i>(Brevipalpusphoenicis)</i> 	Affected leaves turn corky brown on the underside of leaves, premature leaf fall occurs, during severe drought young leaves are attacked. 	Mainly adequate tea nutrition (Not above recommended rates or below or none at all) <ul style="list-style-type: none"> -Use of resistant clones e.g. clone 31/8 is classified as resistant to red crevice mites -Pruning is one of the main cultural practice Pruning can be done if due -when severe, spray with Omite (Propargite) at 3ml/litre of water • Note Allow 14 days interval before plucking
2	Red spider mite <i>(Olygonychuscoffeae)</i> 	The upper surface of mature leaves darkens, turns brown and appears scorched leading to defoliation. 	>Mainly adequate tea nutrition (Not above recommended rates or below /none at all) <ul style="list-style-type: none"> -Use of resistant clones e.g.-BBLK 152, TRFK 6/8 and TRFK 7/9 are classified as resistant or tolerant to <i>O. coffeae</i> - Pruning is one of the main cultural practices. Pruning can be done if due -when severe, spray with Omite (Propargite) at 3ml/litre of water

	Name of Pest/Disease	Symptom	Management Recommendation
3	Yellow Tea Mite <i>(Polyphagotarsonemuslatus)</i>	Young leaves curl inwards, become distorted and brown corky. 	-Mainly adequate tea nutrition (Not above recommended rates or below /none at all) -Use of resistant clones -Pruning is one of the main cultural practice. Pruning can be done if due -when severe, spray with Omite (Propargite) at 3ml/litre of water
4	Purple Mite (<i>Calacaruscarinatus</i>)	Affected leaves turn purple and bronze in colour.  	Mainly adequate tea nutrition (Not above recommended rates or below /none at all) -Use of resistant clones e.g.-BBLK 152, TRFK 6/8 and TRFK 7/9 are classified as resistant or tolerant to <i>O. coffeae</i> - Pruning is one of the main cultural practice. Pruning can be done if due -when severe, spray with Omite (Propargite) at 3ml/litre of water
5	Soft Scales (<i>Coccus spp.</i>)	-Leaves sometimes turn black with sooty mounds ad ants 	Pruning can be done if due -Use resistant clones -Use of petroleum oil sprays (it is not regarded as insecticide) and is safe on their natural enemies (parasitic wasp) -In the natural environment, the natural enemies contribute up to about 10% control. -Control ants by spraying Karate 2.5WG at 1g per

	Name of Pest/Disease	Symptom	Management Recommendation
			litre of water around base of attacked bushes.
6	Citrus Aphid (<i>Toxopteraaurantii</i>) 	Brown aphids are found in large numbers on the youngest shoots and on the underside of leaves. The affected leaves curl backwards. 	Increasing the frequency of plucking and or hard plucking till their population goes down. With on-set of rains, the population will also go down -Spray of pyrethrum based pyrethroid pesticides such as pygro, which have very low pre-harvest period (less than 48 hours) and are effective -Syrphid flies occurring naturally in tea fields also play a large role in their control. - In severe cases, Spray affected parts with Karate 2.5WG at 1g/ litre.
8	Helopelits (<i>Helopeltisschoutedeni</i>) 	Dark brown spots appear on the youngest shoots when fresh which turns black and produce leaf and stem distortion as the growing tissue expands.  	-Use of resistant clones -Clearing of bushy areas adjacent to the affected site -Spray foliage with Karate 2.5WG at 1g per litre of water.
9	Common cutworm (<i>Agrotissegetum</i>) 	Stem damage in new seedlings failure 	-Karate 2.5WG at 1g per litre of water.
10	Tobako crikets (<i>Gryltalpaaficana</i>) 	Young plants are cut off from the ground and the plant dies 	-chemical bait formulation

	Name of Pest/Disease	Symptom	Management Recommendation
11	Beetle chafer grub (<i>Schizonycha spp.</i>) 	Leaves wilt and surface of root is damaged just below the soil surface -Extensive callus growth (swelling) around and below the collar 	Spray holes before planting and the soil around the bushes with Karate 2.5WG at 1g per litre of water.
12	Black thrips (<i>Heliothripshaemorrhoidalis</i>) 	Young leaves stunted and cupped, margins get cracked and turn brown then purple. 	- Spray with Karate 2.5WG at 1g per litre of water. -Practice fine plucking
9	Termites <i>Microtermesnatalensis</i> <i>Pseudoacanthotermes</i> 	Plants wilt and die -Stem beneath soil is ring-barked -Entire root destruction 	Destroy termite nest and remove the top and treat with Cyren (Jawabu) at 10 ml per litre of water or tricel 480 EC at 10ml per litre of water. Spray around the plants with above chemicals
10	Common cutworm (<i>Agrotissegetum</i>) 	seedlings failure 	-Karate 2.5WG at 1g per litre of water.
13	Mole rats and porcupines 	Damage tea by feeding on roots resulting in completely destruction of plants. 	-Trapping -Good cultural practices - Controlling weed particularly grass along the edges of farm

	Name of Pest/Disease	Symptom	Management Recommendation
			-in an epidemic fumigation with Detia/Phostoxin can be conducted by The TRFK staff(Licensed to handle Restricted Class chemicals)
	Diseases		
1	Armillaria rot rot (<i>Armillaria mellea</i>) 	Reduction in growth, yellowing, premature flowering, defoliation and eventually death. At the collar region longitudinal cracking of the stem can be observed.	<p>Killing trees by ring barking, prior to felling. This is best done during primary land preparation.</p> <p>-Removal of roots and stumps of tree that may harbor the pathogen. Done as exhaustively as possible.</p> <p>-Within a field of tea, infected bushes should be removed by thoroughly digging them out as soon as they are recognized.</p> <p>NB: The use of a bio-control agent (<i>Trichoderma sp.</i>), as integrated strategy or a substitute can be done--conduct TRFK for more information).</p>
2	Branch and collar canker of tea (<i>Phomopsis theae</i>) 	Decline of the bush occurs due to sectorial death of the primary branches which may result in the ultimate death of the whole bush. Canker lesions develop at the base of affected plant or on the branches or both. Upper edges of the lesions are usually heavily callused Leaves on branches/whole bush girdled by the lesions turn yellow and ultimately die. Where the lesions girdle the main stem the whole plant ultimately dies.-Stem cankers and lesions at base of the	<p>Minimize injuries on the bark of tea by mulching to avoid stress due to soil moisture deficit.</p> <p>-Pruning off badly affected branches of infected plants at least 10 cm below the lesions. Pruned bushes should be treated with a protectant fungicide such as the</p>

	Name of Pest/Disease	Symptom	Management Recommendation
		branches which finally turn yellow and die.	dithiocarbamates or copper oxychloride. -Sanitation-the pruned off branches should be destroyed by burning -Use of resistant clones -Prompt uprooting of affected young and infilling with resistant clones
3	Hypoxylon wood rot of tea <i>(Hypoxylon serpens)</i>  	<p>Decline of the bush due to sectorial rottin and death of the primary branches result in the ultimate death of the whole bush. The rotten wood bears superficial irregular dark-grey to black raised patches of fructifications (stomata) of various sizes.-Dead branches carry small black patches</p>	<ul style="list-style-type: none"> - Prevent sun-scorch by shading exposed branches with prunings immediately after pruning -use sloping cuts so that rainwater runs off. -Paint wounds with fungicides -Avoid low pruning down pruning is the key predisposing factor. -Through adherence to correct pruning heights -Ensure adequate tea nutrition (Not above / below recommended N rates) -NB: Use of Potassic fertilizer in already affected fields makes the bushes withstands the disease stress (Technical advice is required prior to it being adopted) -Once the disease is diagnosed the dead and dying branches must be selectively pruned off right down approx. 10cm into the healthy wood. After the large cuts should be painted over with a

	Name of Pest/Disease	Symptom	Management Recommendation
			wound dressing fungicide such as copper oxychloride 50% WP in raw linseed oil. -Carry out field sanitation during every prune by surgically pruning-off the affected branches, removal from field and destruction of the same by burning.
4	Leaf spot of tea (a) Brown Blight (<i>Colletotrichumcamelliaeemassee</i>) 	Attacks nursery plants	Outbreaks can cause severe damage only in the nursery -In nursery, use fungicides such as dithiocarbamates -Treat or attend to the pre-disposing causes.
3	(b) Grey Bright (<i>Pestalotiathaeae</i>) 	The fungus infects mature and senescent (old) leaves of tea, which then forms 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. Under certain circumstances, cause twig die-back of plucked shoots in the field. -Light to dark circular to oval brown patches with greyish centre on upper leaf surface. -Black postules in concentric lines on upper surface.	Easily accomplished by optimizing shading and watering. -Control only necessary if it affects plants in the nursery. -Casting of shade by adjacent tall trees on susceptible mature tea has been noted to predispose the bushes. -Use of healthy and disease free mother bushes. Cuttings may be dipped in a fungicide suspension before planting or sprayed just after planting. -Predisposing factors:- mainly too much shade and over watering should be identified and corrected.

	Name of Pest/Disease	Symptom	Management Recommendation	
	Weeds			
1	Dodder (<i>Cuscutajaponica</i>)	 	<p>Can be controlled or eradicated by pruning of infected branches and complete removal and disposal of infected host plants.</p> <p>Burying or burning reduces a dodder infestation</p> <p>Public education is necessary as a strong early detection program and a way to limit dispersal activity</p>	
2	Ragworts. (<i>Scenecio</i> spp.)		<p>Plants with Pyrrolizidine Alkaloids which are of toxicological concern and can lead to rejection of shipments</p>	<p>Integrated weed management methods can be employed to manage weeds in tea. Use of herbicides is done when a field is heavily invaded by weeds which are difficult to manage. Preference is given to manual weed management, to include uprooting, slashing and jembe weeding.</p>
3	Wondering Jew (<i>Commelinacryptostachys</i>)		<p>Hard to kill perennial weed with succulent stems and leaves. Increases cost of tea production</p> 	<p>Integrated weed management methods as above.</p>

	Name of Pest/Disease	Symptom	Management Recommendation
4	Button weed <i>Borreria princeae</i> . 	Very hard to kill perennial common in tea fields 	Integrated weed management methods as above.
5	Couch grass 	They are Perennial which propagate themselves by underground rhizomes and stolons	Integrated weed management methods as above.
6	Kikuyu grass (<i>pennisetum clandestinum</i>)	Perennial which propagate themselves by underground rhizomes and stolons 	

Bearing

In Kenya tea is grown in the east and west of rift valley where favorable tea growing condition prevails. Tea begin bearing 3 to 4 years after transplanting and continue bearing for over 100 years (Fig 32). This crop has large return on investment and is sold at the factory door sales, produce markets, grocery shops, Kenya tea packers (KETEPA), supermarkets and at the Mombasa auction market.

Yield

The success of Kenyan tea industry has among other factors, been ascribed to deployment and leveraging of appropriate research and development outputs in the production value chain. Tea is adapted to wide agro-ecological zones in Kenya. The yields are influenced by agro-ecological zones, variety, soil-type, soil nutrition management and crop management practices. The average yield of 1,500 kg to 3,300kg of made tea per hectare per year (mt/ha/yr) has been realized on the large estates and an average of 600kg to 2,300 kg mt /ha/yr under the smallholder production system has been achieved.



Fig 32: Mature tea field ready for plucking

Marketing

Tea is sold at factory door sales, village markets and grocery shops. Tea is also packaged and marketed by several small agribusinesses enterprises in Kenya grocery shops, Kenya tea packers (KETEPA), supermarkets. Most of the tea (95%) is exported at Mombasa Auction market making Kenya the leading exporter of tea in the world.

Gross Margin Analysis

Smallholder tea growers' gross margin analysis and enterprise profitability in Kenya. The yield difference in tea productivity between large estates and stallholder tea growers could be attributed to low technology adoption rate, deployment of technologies and socio-economic constraints (Table 4).

Table 4: Gross Margin Analysis and enterprise profitability

Item	Unit Cost	Total Cost	% Cost
population per hectare (1.2 x 0.60m)		13448	
Average yield per bush per year (Kg)		1.2	
Total yield per hectare/yr-1 (Kg)		16137.6	
Tea income		Unit price (Ksh)	Amount (Ksh)
1st payment	14.50	233,995.20	
2nd payment	35.00	564,816.00	
Tea Output Value (TOV) (Kshs)		<u>798,811.20</u>	
Variable costs (Kshs)		Unit price (Ksh)	Amount (Ksh)
Fertilizer (NPK 26:5:5) - 12 bags/ha	1800.00	21,600.00	8.8
fertilizer application 4 bags/ Manday	250.00	750.00	0.3
weed control (glyphosate) 3ltrs/ha x 2 times	1200.00	7,200.00	2.9
Herbicide application labour cost 3ltrs/manday	250.00	500.00	0.2
Plucking cost	12.00	193,651.20	79.0

Pruning cost	2.00	21,532.00	8.8
Variable Costs (VC)(Kshs)		245,233.20	
Interest (13.5%VC)		33,106.48	
Total Variable Cost (TVC)(Kshs)		523,572.88	
Gross margin/year (Kshs)			
GM= TOV-TVC		275,238.32	
Gross margin per bush/year (Ksh)		20.6	

Strategies to minimize production cost

To minimize plucking cost which account 79% of the total cost, pluckers should be paid basing on the amount of kg plucked instead of daily rate. Use cost effective technologies like pruning and plucking machines which saves more than 70%, they are also efficient and faster. To minimize on fertilizer cost, apply fertilizer once per year instead of split application which entails extra cost in terms of storage and there no significance difference in terms of yield. To minimize on weeding cost, maximize on plant population capacity per unit area, gaps ought to be filled up, once the tea matures its canopy covers the ground hence zero weeding cost. Ensure that all prunings are left to rot in situ as it helps in smothering/suppressing the weeds and releases some nutrients once it rots.

TEA PROCESSING AND VALUE ADDITION

Introduction

Green and Purple leaf from the field are normally harvested for tea processing aerated, non-aerated, semi-aerated teas and Puerh (fermented) teas. Value added tea include food and non-food products. Food products include flavoured or spices teas, tea biscuits, cookies, cakes bread, alcoholic beverages, non-alcoholic beverages, ice cream, and yoghurts among others. Non Food products include, soaps, hand washes, detergents, shampoos, hair conditioners, lotions, creams, mouth washes e.t.c. Tea extracts can also be made from the various teas processed from green and purple leafed teas. Thus several areas of value addition options on tea are available for adoption by various manufacturing sectors (Ochanda, 2010; Ochanda *et al.*, 2011). They can be broadly categorized into the following groups;

Tea types based on processing steps

Tea Processing

Although each type of tea has a different taste, smell, and visual appearance, tea processing for all tea types consists of similar set of methods with only minor variations. Tea processing operations include;

Plucking

Tea leaves and flushes, preferably a terminal bud and two young leaves, are picked from *Camellia sinensis* bushes. Plucking is by hand (Fig. 33) or machine. The plucking frequency and season depends on the region where the tea is grown and on the type of plucking (Li, 2007; Luo *et al.*, 2008; Sen *et al.*, 1983).



Fig 33: Harvesting of green leaf tea from a tea field by hand puckers

Withering/ Wilting

The tea leaves begin to wilt soon after picking and enzymatic oxidation gradually sets in. Withering is important in removing excess water from leaves, initiation of oxidation, breakdown of leaf proteins into free amino acids and increasing the availability of freed caffeine which changes the taste of the tea (Chan, 2006; Chen and Lin, 2008). The leaves can be withered under the sun or in a cool breezy room (Fig 34).

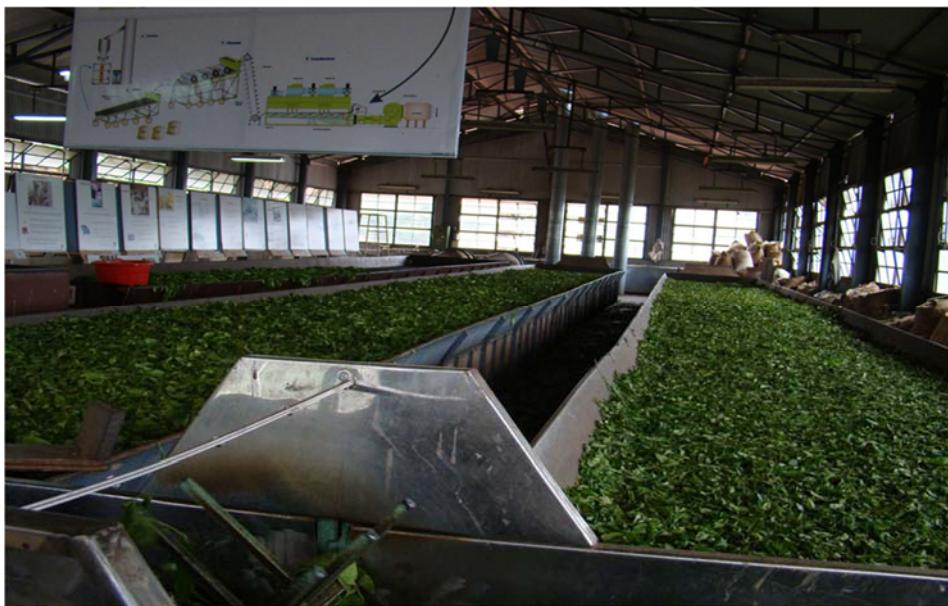


Fig 34: Withering of green leaf under in a factory on withering units with fans

Maceration

Maceration which is also known as disruption causes bruising, tearing or shredding of the leaves in order to promote and quicken oxidation. Leaf disruption can be done by shaking and tossing in a bamboo tray, kneading or tumbling in baskets, rolling, tearing, using an orthodox machine and crushing by machinery (Fig 35). Maceration can also be done

manually by hand. The leaf cells structures are broken down allowing the co-mingling of oxidative enzymes with leaf sap and atmospheric oxygen setting off oxidation (Varnam and Sutherland, 1994).



Fig 35: Maceration process using orthodox machine

Oxidation

Oxidation is also referred to as aeration and "fermentation". Tea leaves are left in an atmosphere-controlled room or chamber where they progressively turn darker through enzymatic activity which transforms chlorophyll and tannins (Fig 36). The tea producer decides when the oxidation should be stopped, depending on the desired qualities in the final tea as well as the atmospheric conditions (heat and humidity). In light oolong (semi-aerated) teas oxidation may be 5-40%, darker oolong (semi-aerated) teas 60-70%, and aerated black teas 100%. Oxidation is important in the formation of taste and aroma compounds, which gives aerated tea liquor colour, strength, and briskness. Under-oxidation/fermentation results in grassy flavours while over-oxidation results in overly thick winey flavours (Nabarun et al., 2007).



Fig 36: Oxidation process during the manufacture of black tea

Fixation/Kill-green

Fixation also known as kill-green or shāqīng is done to stop the tea leaf oxidation at a desired level. It is accomplished by moderately heating tea leaves, thus deactivating their oxidative enzymes and removing unwanted scents in the leaves, without damaging the flavour of the tea (Fig 37). This is accomplished through panning, steaming, baking or drum rolling. In some white teas and black CTC teas, kill-green is done simultaneously with drying (Willson and Clifford, 1992).



Fig 37: Heat fixation of green tea using a pan fryer

Sweltering

Sweltering or yellowing is unique to yellow teas in which warm and damp tea leaves from after kill-green are lightly heated in a closed container, causing the previously green leaves to turn yellow. The resulting leaves produce a beverage that has a distinctive yellowish-green hue due to transformation of the leaf chlorophyll. Sweltering for 6–8h at close to human body temperatures causes chemical changes of the amino acids and polyphenols in the processed tea leaves giving it distinct briskness and mellow taste (Varman and Sutherland, 1994; Chen and Lin, 2008).

Shaping

In shaping also known as rolling, the damp tea leaves are rolled and formed into wrinkled strips, by hand or using a rolling machine which causes the tea to wrap around itself (Fig 38). The rolling action also causes some of the sap, essential oils, and juices inside the leaves to ooze out, which further enhances the taste of the tea. The strips of tea can then be formed into other shapes, such as spirals, pellets, balls, cones and others. In many types of oolong teas, the rolled strips of tea leaf are formed into spheres or half spheres by placing the damp leaves in large cloth bags, which are kneaded by hand or machine in a specific manner (Luo et al., 2008).



Fig 38: Shaping of teas by hand rolling

Drying

Drying is done to "finish" the tea for sale by reducing the tea's moisture content to safe levels of between 3-4%. This can be done in a myriad of ways including panning, sunning, air drying, solar drying, microwaving or baking (Fig 39). Great care is taken to not over-cook the leaves. The drying of the processed tea is responsible for many new flavour compounds particularly important in green teas (Nabarun et al., 2007; Luo et al., 2008).



Fig 39: Drying of teas in electrically heated baskets

Aging

While aging or curing is not always required, some teas require additional aging, secondary fermentation (involving bacteria and fungi), or baking to reach their drinking potential. For instance, a green puerh tea, prior to curing into a post-fermented tea, is often bitter and harsh in taste, but becomes sweet and mellow through fermentation by age or dampness (Fig 40). Additionally, oolong can benefit from aging if fired over charcoal. Flavoured teas are manufactured in this stage by spraying the tea with aromas and flavours or by storing them with their flavorants (Gong et al., 2000; Zhou et al., 2005; Hial and Engelhardt, 2007).



Fig 40: Aging of Post fermented -Puerh tea

Types of teas

White tea

This type is processed from new growth buds which have undergone minimal oxidation through slight withering before drying by baking (Fig 41). White tea is produced in lesser

quantities than most other teas, and is correspondingly more expensive (Hial and Engelhardt, 2007).



Fig 41: White tea

Green tea

This tea has undergone the least amount of oxidation by halting the process by the quick application of heat after tea picking, either with steam or dry heat (Fig 42). Tea may be dried as separate leaves or shaped into pellets to make gunpowder tea. Variation in fixation, rolling and drying alters the flavour of green teas (Graham, 1992).



Fig 42: Green orthodox tea

Yellow tea

This tea is processed like green tea, but instead of immediate drying after fixation, stacking, covering and heating of the leaves in a humid environment is done (Fig 43). This oxidizes chlorophyll resulting into a yellowish or greenish-yellow tea (Zhou *et al.*, 2005).



Fig 43: Yellow orthodox tea

Oolong tea

Tea's oxidation is stopped somewhere between the standards for green and black tea. The processing involves withering, maceration, aeration, drying and grading (Fig 44). Oolong teas differ in degree of oxidation and shape (Chen and Lin, 2008).



Fig 44: Oolong tea product

Black tea

Tea leaves are allowed to completely oxidize (Fig 45). Green leaf is withered, macerated, aerated, shaped, dried and graded (Varnam and Sutherland, 1994).



Fig 45: Black CTC tea

Post-fermented tea

These are teas that are allowed to undergo a second oxidation after fixation and which also undergo microbial fermentation (Fig 46). The group includes teas like puerh, liu'an, and liubao which are collectively referred to as secondary or post-fermented teas (Wen *et al.*, 2010).



Fig 46: Puerh (brick) tea

Flavoured and consumer packaged teas

Flavouring of teas with herbs and spices like ginger, lemongrass, rosemary, cinnamon, tea masala; jasmine and packaging into consumer packages is a form of tea value addition. The addition of flavours to tea increases consumer acceptability thus packers and retail vendors like KETEPA

Ltd, Lipton tea, Unilever tea, Ceylon tea, Melvins tea, Everton tea among others have effectively sustained their businesses in this way (*Ochanda et al., 2011; Ochanda et al., 2015*).

Table 6: Kericho Gold tea brands

SNo.	Product	Description	Type
1.		Tea bags	Black CTC tea
2.		lemon Flavoured tea	Green tea
3		Jasmine and Passion flavoured tea	Green tea
4.		Mint flavoured tea	Green tea

Table 7: KETEPA Products showing tea value addition

SNo.	Product Name	Description	Type
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1.		Enveloped tea bags	Black tea
2.		Enveloped tea bags	Green tea
3.		Non-enveloped tea bags	Black CTC tea
4.		Loose tea bags	Black CTC tea
5.		Iced Tea	Black iced tea ready to drink product

Tea extracts

Extracts from aerated, semi-aerated and non-aerated teas can be made. Extraction plants for processing tea extracts for use in food, non-food, pharmaceutical and industrial applications are available.

In the food industry the extracts are used as colorants, flavorings and fortifiers. In the pharmaceutical industry the extracts are used as antioxidants and recent research has shown their potential for use as medicines in treatment of cancer, diabetes, inflammation and microbial infections.

Non-food and industrial applications include the use of extracts in the production of polyphenol standards, creams, shampoos and beauty products. Companies like Damin foods International, Finlays Limited and Everton tea among others are in the business of producing such extracts (Wachira and Kamunya, 2005; Lelgo *et al.*, 2011; Koech *et al.*, 2013; Kerio *et al.*, 2013).

Table : Cocacola tea products from various countries of the world

S/No.	Product	Description	Type
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1.		Iced product	Black tea concentrate
2.		Coke flavoured with tea	Black tea extracts
3.		Assorted ready to drink tea beverage products	Black tea extracts
4.		Ready to drink Cocacola products	Green and black tea extracts
5.		Ready to drink fruit flavoured tea drinks	Organic food tea drinks

Tea fortified products

In developed countries like Japan, China, USA, Canada and in some developing countries like India and Malaysia, have developed ready to drink and eat tea fortified food products. These

include iced teas, tea sodas, tea alcoholic beverages, tea candies, tea biscuits, tea seed oil, to mention a few. These products contribute immensely to the revenue from tea value addition as is evident from the operations of companies like Ketepa tea limited (table 1), Marinet food, Tenfu tea foods, Kericho Gold Damin foods among others. (Ochanda, 2010; Omondi *et al.*, 2013; Kilel *et al.*, 2013). These companies have also developed non-food products including soaps, shampoos, paper towels, lotions, mouth washes, sanitizers, drugs, fertilizers among others with tea extracts (Koech *et al.*, 2013; Njuguna *et al.*, 2013).

Table: Assorted Non-Food Tea Products

S/No.	Product	Description	Type
1.		Shampoo	Green tea
2.		Hand wash	Green tea
3.		Shower gel	Green tea
4.		Bar soap	Black tea
5.		Lotion and gel	White tea

References

- Chan, K.P. (2006). *First-step to Chinese puerh tea*. Taipei, Taiwan: WuShing Books Publications Co. Ltd. ISBN 978-957-8964-33-4.
- Chen, H. and Lin, S. (2008). *The first lesson in Taiwanese tea*. ISBN 978-986-6702-21-1.
- Gong, Y.X; Cai, L.W., Cai, S.W and Jin, H.J. (2000). "Study on the effect of stack cover process on the taste of yellow tea". *Journal of tea science*.
- Graham, H.N. (1992). Green Tea Composition, Consumption, and Polyphenol Chemistry". *Preventive Medicine*. **21**: 334-350. doi:10.1016/0091-7435(92)90041-f
- Hilal, Y. and Engelhardt, U. (2007). "Characterisation of white tea-Comparison to green and black tea" *Journa fur Verbraucherschutz und Lebensmittelsicherheit* **(2)**: 414-421.
- Kilel, E.C., Wanyoko, J.K., Faraj, A.K., Wachira, F.N. and Mwingirwa, V. (2013). Green tea from purple leaf coloured tea clones in Kenya-their quality characteristics. *Food Chemistry*. **141**:769-775.
- Koech, K.R., Wachira, F.N., Ngure, R.M., Orina, I.A., Wanyoko, J.K., Bii, C. and Karori S.M. (2013). Antifungal activity of crude tea extracts. *African Journal of Agricultural Research*. Vol. **8 (19)**: 2086-2089.
- Lelgo, S.K., Kamunya, S.M., Ochanda, S.O. and Wanyoko, J.K. (2011). The effect of processing technique on biochemical composition of adapted Kenyan and introduced Japanese and Chinese Tea germplasm. *Tea*. **32(1)**: 22-33.
- Li, G. (2007). The Traditional Processing of Wuyi Rock Teas: An interview with Master Ling Ping Xang, in Ling Chun Chin. *The Art of Tea* (Wushing Book Publisher) **(2)**: 76-83.
- Luo, Y., Tang, M; Cai, W., Wen, D.; Wen, Z. (2008). Study on the Optimum Machine-plucking Period for High Quality Tea. *Journal of Tea Science*. En.cnki.com.cn Published online.
- Nabarun, B., Sohan, S., Bipan, T., Pradip, T., Arun, J., Devdulal, G., Rajib, B., Manabendra, B. and Santanu, S. (2007). Detection of optimum fermentation time for black tea manufacturing using electronic nose. *Sensors and Actuators B: Chemical*. **122**: 627-634.
- Njuguna, D.G., Wanyoko, J.K., Kinyanjui, T. and Wachira, F.N. (2013). Polyphenols and free radical Scavenging Properties of Kenyan Tea Seed Oil Cake. *International Journal of Research in Chemistry and Environment*. Vol. **3**: 86-92.
- Ochanda, S.O. (2010). A review on tea manufacture, tea types and tea products in the Kenyan tea industry. *Tea*. **31(1)**: 38-48.
- Ochanda, S.O., Wanyoko, J.K. and Henrik, K.R. (2015). Effect of Spices on consumer acceptability of purple tea (*Camellia sinensis*). *Food and Nutrition Sciences*. **6**:703-711.
- Ochanda, S.O., Wanyoko, J.K., Kamau, D.M., Kamunya, S.M., Faraj, A.K. and Onyango C.A. (2011). The effect of selected spices on un-aerated tea product from clone TRFK303/577. *Tea*. **32(2)**: 88-99.
- Omondi, K.G., Kinyanjui, T., Wanyoko, J.K., Okong'o, K.M., and Wachira, F.N. (2013). Extraction and analysis of tea (*Camellia sinensis*) seed oil from different clones in Kenya. *African Journal of Biotechnology* Vol. **12(8)**: 841-845.

- Sen, R.N., Gangulgi, A.K., Ray, G.G., De, A. and Chakrabarti, D. (1983), "Tea-leaf plucking-workloads and environmental studies". *Ergonomics*. **26**: 887–893.
- Varnam, A.H. and Sutherland, J.M. (1994). *Beverages: Technology, Chemistry and Microbiology*. Springer.
- Wachira, F.N. and Kamunya, S.M. (2005). Kenyan teas are rich in antioxidants. *Tea*. **26**: 81-89.
- Wen, Z., Zhang, L.Y., Wu, P. and He, Y.Q. (2010). Research on the action on microbes on post-fermented tea processing. *Tea Communication*. **37(2)**.
- Willson, K.C. and Clifford, M.N. (1992). *Tea cultivation to consumption*. London: Chapman and Hall. Pp769.
- Zhou, J., Chen, Y., Sun, Y. and Ni, D. (2005). Studies on the Piling Technological Effects on Luyuan Yellow Tea. *Food Science*.
- Zhou, J., Chen, Y., Sun, Y. and Ni, D. (2005). Studies on the Piling Technological Effects on Luyuan Yellow Tea. *Food Science*.