TVET CERTIFICATE V in Crop production

INDUSTRIAL CROPS GROWING

CRPIC501

Grow industrial crops

Competence

Credits: 9

Learning hours:90

Sector: Agriculture and food processing

Sub-sector: Crop production

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Purpose statement

This module describes the skills and knowledge required to apply cropping and harvesting techniques applied to industrial crops (Coffee, Tea, Pyrethrum and Sugar cane) mainly grown in Rwanda.

The module will allow the learner to install the nurseries, establish, maintain and harvest industrial crops

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Learning Unit 1 –Prepare the field, tools, materials and equipment

LO 1.1 – Identify the site according to crop requirements

- **Content/Topic 1: Criteria for site selection on industrial crops**

The criteria for site selection on industrial crops are:

a. Back ground of the field:

- Previous crop(respect of crop rotation plan) with advantages of crop rotation which are to control pest and disease ,maintenance of soil fertility ,soil erosion control ,control of weeds ,proper utilization of nutrients
- Identified pests and diseases
- Applied fertilizers and pesticides

b. Field accessibility:

- The site desired for industrial crops growing should be: (near the road for facilitating the transport,
- Near the market (processing unit, city) to facilitate the commercialization

c. Ecological requirements:

Crop/Ecological factor	**Coffee**		**Tea**	**Sugar cane**	**Pyrethrum**
	Coffea arabica	**Coffea robusta(canephora)**			
Soil	Acidic soil pH range of 4.2-6.2 Deep well drained and fertile soil Volcanic soils	Slightly acidic soils Deep-well drained fertile soils	The crop requires deep drained soils because the tap root extends to about 2metres Acidic soils pH 5.5 to 6.0	Fertile, well-drained soil. The soil pH range from 6.0 to 7.7. The optimum soil pH is about 6.5	Well drained light and medium loamy soils are suitable. pH of >5.6 Soils with good texture and structure It does not

					tolerate
Temperature	Low temperature of 10-15^{o}c High humidity	High Temperatures (2 0 to 25^{o}c) High humidity	Minimum temperature:12.8^{o}c ,maximum temperature:23.9^{o}c	High temperature(32 ^{o}c to 38^{o}c) stimulates sprouting of buds(germination)	Temperature for germination;20-22^{o}c Less than 17^{o}c for at least 6weeks.
Rainfall	Rainfall of 1500 to 2250mm per year and well distributed. Bimodal if 300mm/year, monomodal of about 350mm per year. Dry spell of 34months for flowering and ripening	Rainfall of about 900mm per year and well distributed. Dry spell of 34months for flowering and ripening	It requires about 1000 to 1400mm per year It can tolerate dry spell This makes it suitable for areas close to Equator where rainfall distribution is favorably more uniform.	Rainfall of 1500mm per year	Rainfall of 750mm up to 1100mm

Altitude	Altitude of 2000-2100m/high altitude	Altitude of 1100-1400m above sea level/low altitude	Altitude of 1200-1900m	Altitude of 1000m	It grows well at altitude of between 1700 to 2300 M.S. L Volcanic region

LO 1.2 – Prepare tools and equipment referring on agricultural practices for industrial crops

- **Content/Topic 1:Criteria for selection of tools, materials and equipment.**

Criteria for selection of tools, materials and equipment are the following:

Soil: The soil is one important criterion for tools and equipment selection.

Field topography: steep land is not accessible and is very exposed to soil erosion

Climate: In dry season the selection of tools and equipment will focus on strength of them basing on soil hardness while rainy season will require soft tools and equipment as the soil is not too hard for working.

Crop: Industrial crops need special tools and equipment according to their special agricultural operations.

LO 1.3: Prepare planting materials respecting the standards

- **Content/Topic 1 : Propagation ways of industrial crops**

Plant propagation is the process of plant reproduction of a species or cultivar, and it can be sexual or asexual. It can happen through the use of vegetative parts of the plants, such as leaves, stems, and roots to produce new plants or through growth from specialized vegetative plant parts.

The most common forms of **vegetative propagation** are grafting, cutting, layering, tuber, bulb or stolon formation, suckering and tissue culture.

Sexual (Generative) propagation involves the union of the pollen (male) with the egg (female) to produce a seed.

The following table summarizes the ways of planting materials preparation basing on type of crop (coffee, tea, sugar cane and pyrethrum).

Planting materials involved in industrial crops

Crop	Scientific name	Family	Seed	Variety/cultivar	Fertilizer	Pesticides

Coffee	*Coffea arabica/robusta*	Rubiaceae	Grain (bean), cutting	Jackson2, bourbon Mayaguez 71, bourbon Mayaguez 139	Organic matter, NPK 17-17-17+ UREA, NPK 22-6-12+S, NPK 20-10-10	SUMITHION, CABRIO, Fungicide (coper oxychloride, dimenthoate)
Tea	*Camelia sinensis*	Theaceae	Grain , cutting	C. sinensis assamica	Organic matter, SSP, TSP, NPK 25-5-5, NPK 20-10-10+ S,	PYRETRINOIDS, DITHAN M 45
Pyrethrum	*Chrysanthemum cinoreraefolium*	Asteraceae.	Grain, splits	Clon 1353 (ruwawa), HT1, HT8(Musimali)	Organic matter,TSP	Tuzet (fungicide)
sugar cane	*Saccharum officinarum*	poaceae	Cutting, suckers, tips	Pindar (fidji), No Co 310 (India), F 146 (Taiwan)	Organic matter, NPK 100-60-15, NPK 130-70-150	Aldrine

Content/Topic 2 : Procedures for planting materials preparation

a) Procedures for planting materials preparation for Pyrethrum

Pyrethrum varieties:

- Nyiragahini,
- Capita chef,
- Capita moke,
- HT1+8,RW218,
- RW203

✓ **Preparation of planting material / split**

- Take good size split (about 2cm bush diameter)
- Cut roots to a length of 8-10cm with a sharp knife
- Remove the old thick woody roots ,leaving only young root system on the split
- Cut off the top of the split leaving about 15cm of vegetative top

Seedling characteristics:

- Seedlings should be of pencil size.
- The seed bed should be sufficiently wet before uprooting to minimize injury to the roots
- Seedlings are ready for transplanting in 3-4months.

b) Procedures for planting materials preparation for sugarcane

✓ **Characteristics of seed pieces**:

- Sett has 2 to 3 nod**es**
- Setts with three well developed and viable buds
- Setts come from healthy plants
- ±30cm long
- If taken from nursery, not more than six months age.
- Seed pieces are taken from vigorous cane plants and free from pests and diseases
- The canes are topped a week before planting which stimulates the dormant buds to sprout and swell quickly(germination)

Note: Topping removes apical dominance and encourages mobilization of sucrose to younger parts of the cane causing germination

✓ **Seed cane treatment**

- To protect the crop from soil borne diseases causing pathogens, which usually gain entry into the setts through the cut ends following planting and cause sett rotting and damage to buds, thus affecting germination.

Treat the setts soon after cutting in 0.1% (at 1g/liter) Carbendazim solution for 15 minutes.

- Three important diseases viz., grassy shoot disease, smut and ratoon stunting disease are carried forward through seed cane material. These diseases lead to progressive decline in yields and degenerate sugarcane varieties.

For control of these diseases treat the seed material (setts) with moist hot air at 52°c for 30 minutes.

- To control termites early shoot borer and scale insects treat the setts in a systematic insecticide viz.

Malathion 50EC (at 2 ml/liter) or Dimethoate 30EC (at 3 ml/liter) for 15 minutes.

✓ **Seed pieces preparation**

- soaking seed pieces for **48hours** to hasten germination
- Soaking in fungicides (ex: Mercuric chloride for 1minute)

✓ **Sugar cane varieties**:

- **Rwandan varieties**: pindar, nyiragasheke

- **Other varieties:**

- co.419,
- co.740,
- co7219(sanjeevani)

c) Procedures for planting materials preparation for tea

✓ **Propagation by seeds**

- Selected daily from clean plots
- Cracking seeds to speed germination
- Protect site against wind, cold and near water
- Soil is mixed with insecticides(dieldrin(40kg/ha))

✓ **Propagation by single leaf cutting**

- Cut a single leaf internode from the middle of each branch
- Care must be taken not to damage the leaf
- Keep the cuttings **(3-4cm long**) floating in water to prevent wilting up to when they are planted
- Plant each cutting in its own sleeve by pushing it at a slanting angle. Take care for the leaf petiole not to touch the soil.
- Filling bags:1/3 non fertile soil (upper side) ,2/3 fertile soil(lower side)
- Cuttings are ready for transplanting when they are about ±**20cm**
- Time of transplanting: **10-12months** (the roots have reached the bottom of the sleeve).

d) Procedures for planting materials preparation for coffee

✓ **Propagation by seeds**

- Identify healthy plants
- Select good mature seeds basing on weight and size
- Immerse chosen seeds in water
- Retain and pulp those that sink and dry them to a moisture content of **15 to 17%**
- The seeds are planted with the flat side down in individual polypots/sleeves or seedbeds at a spacing of 15cm between seeds.
- **Germination time**:4-8weeks(±12weeks) and are ready to be transplanted after 6months
- **Germination type**: hypogeal germination
- Transplanting at 6 leaf stage(6-10months)

✓ **Propagation by cuttings**

- Identify healthy and high yielding plants

- Remove the green to semi-ripened branches which have developed six to eight nodes, using grafting knife.
- The suckers should have their tips removed fifteen days before the cuttings are taken.
- The segment is **7-10cm** in length, consisting of **one node** and **two leaves** which are cut half or a third of the way along their length so as to limit evapotranspiration.
- The cuttings may be cleaved that is they are cut into two longitudinal segments, each having one leaf.
- Deep each cutting in rooting hormone powder like **seradex** or **welgrow** and plant in a polypot.
- Care the emerging seedlings in a nursery by regular watering, disease control, pest control, humidity control and providing a shade.
- The seedlings are ready for transplanting after 8 to 12weeks.
- Acclimatise (hardening off) the seedlings before transplanting.
- The seedlings are ready for transplanting when reaching ±**30cm** tall.
- Hardening off is achieved by:
  - Reducing the amount of watering gradually
  - Reducing the amount of shade provided
  - Cutting the tap root (growing through the polypot).

- **Content /Topic3: Nursery establishment for industrial crops.**

a. Nursery site selection criteria

✓ **Nursery site selection criteria for pyrethrum**

In the selection of the nurseries „site the following factors are important:

- The soil must be fertile, well drained and of good structure and texture. Water logged fields must be avoided.
- Sites near water sources are preferred in case supplementary watering is required or when timing of the seedling propagation coincides with a prolonged dry spell
- Nursery sites should be selected as close to the intended planting fields as possible to reduce on transport requirements during transplanting
- Termites infested fields should be avoided.

✓ **Nursery site selection criteria for tea**

- **Location of the nursery**

Choose a location that is:

- Close to a permanent source of water
- Sheltered from strong winds but exposed to sun
- Close enough to your house so you can protect the nursery from thieves and animals.

In addition, it is convenient if you can choose a location close to the source of the soil. Avoid low-lying areas where the soil becomes water-logged.

In and around the nursery, dig shallow ditches to permit excess water to drain.

To produce1.000 seedlings, a nursery area of about 150 square meters is needed.

- **Shade for the nursery**

The nursery should be protected from the sun by a shade trellis made of bamboo or wood.

To support the trellis, firmly drive vertical posts of bamboo or wood into the ground at intervals of 2-3 meters. The tops of the poles should be 150-160 cm above the ground (or whatever height is convenient for working in the nursery). Then, make a frame of horizontal bamboo cross-pieces on top of the poles. Finally, the shade is provided by thinly spread grasses, palm leaves, or ferns tied between thin strips of bamboo that are firmly tied on the top of the bamboo cross-pieces. The shade trellis should be strong enough to withstand heavy winds.

- **Use of net houses**

An alternative way to protect nurseries of young tea plants is to build a frame or cage made from wood or bamboo over the young plants. Then, this bamboo frame is covered with fine net cloth. The net cloth allows light and fresh air in, but prevents insects from entering the crop from outside. Of course, net houses do not prevent insects that are already on the cuttings when they are brought from the mother plants.

Although initial investment for preparing the net houses is high, savings from reduced sprayings can make it interesting. When properly prepared and maintained, net houses can be used more than once. Inside a net house, the temperature may be a bit lower due to shading effect of the net and the humidity may be a bit higher than outside. This may result in a quicker growth of the crop but it may also result in some more disease problems.

- **Collecting soil for the nursery**

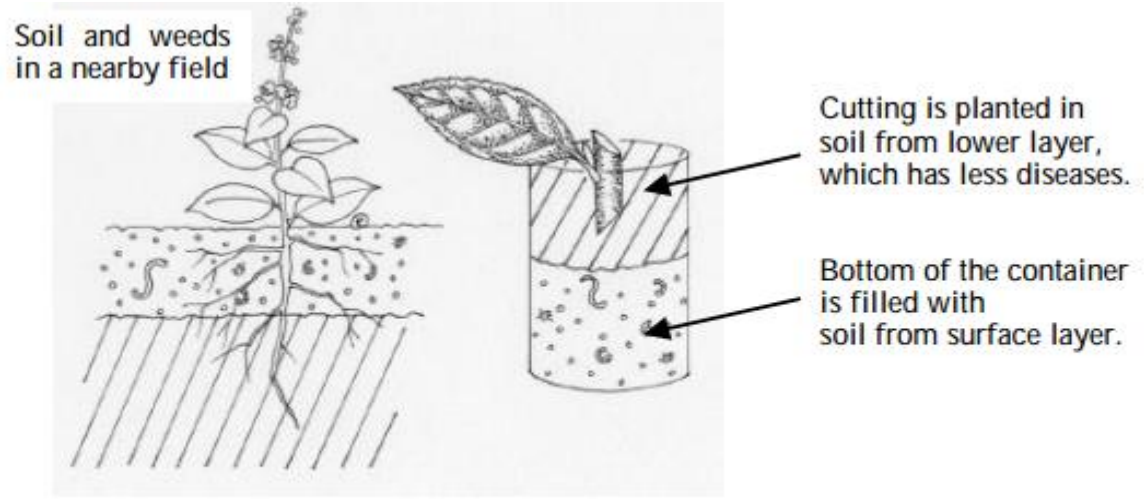
Soil for the nursery should be red-brown in color, slightly to medium clay, with little organic

Matter and a crumbly texture. If the soil contains too much clay, it can be improved by adding sand. Soil pH should be between 4.5 and 5.0 (never above 5.5). Do not use soil in which tea was planted recently, because it may contain tea diseases.

There are 3 things that farmers can do to reduce problems caused by soil diseases (such as fungi or nematodes).

- **Remove the surface layer of soil**

The surface layer of soil, where the roots of weeds and other plants live, may contain root diseases. Therefore, farmers should always remove the surface soil before collecting soil to use in the nursery. Normally, the surface layer is discarded and only the lower layer is used. If it is necessary to use the surface layer of soil, it should be removed and set aside so that it can be used to fill the bottoms of the planting containers (see drawing below).



Surface soil should be put only in the bottoms of planting containers, to avoid infecting seedlings or cuttings with soil-borne diseases.

- **Mix some compost with the soil.**

Farmers should experiment with mixing some compost with the nursery soil. In many crops, using compost in nurseries helps control root diseases. If you sterilize the soil , then add the compost after you finish sterilizing.

- **Sterilize the soil using heat from the sun.**

If you are worried that the soil might contain diseases, and you cannot choose another source of soil, then you can sterilize the soil before using it. To do this, use a shovel or hoe to form the soil into a low smooth bed (like a seedbed for vegetables). Wet the soil thoroughly. Then, cover the bed of wet soil tightly with a sheet of clear plastic (polythene).

The plastic sheet should rest on the surface of the soil. Bury the edges of the plastic sheet under the edges of the soil bed, to avoid losing heat. The sun heats up the soil through the plastic, and the plastic keeps the

heat inside the soil. The sheet should be left on the soil for about 4 weeks, and then the soil will be ready to use.

- **Filling the containers**

It is very convenient to plant the seeds in plastic bags (size 8 x 12 cm). However, seeds can be planted in any available containers, or even in the ground of the nursery. If you are using the surface layer of soil, put it in the bottoms of the containers.

Several weeks before you plant the seeds, fill the bags or containers with soil and arrange in rows in the nursery. Let the filled containers stand in the rain (or water them). This will allow the soil to settle in the bags or containers. After the soil has settled, add more soil as needed.

b. Establishment of industrial crops nursery

✓ **Nursery establishment for pyrethrum**

Pyrethrum seedlings take 3-4months in the nursery before attaining the suitable size for transplanting and thus timing of preparation and sowing of pyrethrum nurseries must ensure that this is done about 4months to the expected planting season.

The following are the steps for establishment of a good pyrethrum nursery:

- The land is ploughed to remove all existing vegetation
- The field is then harrowed and raked to attain a fine soil tilth. This is critical due to the small size of the pyrethrum seed as emerging from large clods of soil would be difficult
- Prepare raised beds of about 1-1.5metres wide and of any convenient length, leaving paths of about one foot for working
- Make furrows of 2cm deep and 15cm apart
- Apply fertilizer at a rate of 20gm per meter length to accelerate root development and thus rapid development of the seedlings
- Apply **5gm** per meter length of a recommended **nematicide** where nematodes are a problem. This also helps in control of termites.
- Cut grass to be used for mulching early to allow it dries before the day of sowing the seed. Use of wet grass may transfer insect pests which will attack the emerging delicate seedlings to the nursery

- **Sow** the seeds in such a way that approximately **10seeds** fall on a **2.5cm furrow length** (about **400seeds per meter length**) .This will usually come with experience. Note that over seeding will result in fusing of adjacent seedlings as they develop, reducing the seedlings count output per unit length of seedbed. Attempts to separate the fused seedlings will injure roots of the young plants making them more vulnerable to soil born diseases
- After sowing, **mulch** seedbed with the dry grass and water the bed
- Regularly water the beds preferably on alternate days during dry weather to avoid water logging the beds
- Germination occurs in **10-18 days** gradually
- After germination mulch should be reduced in stages to allow hardening of seedlings by exposure to natural environmental conditions. A raised shade made using the mulching to protect the young seedlings from strong sun and heavy rain storms
- Remove weeds by hand thinning to minimize competition from weeds. Use of hoes will uproot the young seedlings.
- The seedlings will be ready for transplanting in the fields in **3-4months**, with seedlings maturing faster in warmer areas compared to those in cold areas.

✓ **Nursery establishment for Tea crops**

Collecting seeds

Tea bushes will flower and produce fruits if they are more than 5-10 years old and have not been pruned for a year or more.

In July-August, select strong high-yielding bushes as sources of seed. Stop plucking these bushes and start giving them balanced fertilizer. This will allow the bushes to make more seeds and better-quality seeds. Tea bushes flower in October-December. The tea fruits open, and tea seeds fall onto the ground, about one year later (September-October). When the tea fruits are matured and starting to open, collect the fruits to obtain the seeds

Planting the seeds

Seeds should be planted at a depth of 1.5-2.5 cm, with the “eye” of the seed pointing downward. Some tea seeds may sprout within a month of planting, while others may take several months to germinate. Some seeds will fail to sprout. To avoid wasting containers, the farmer can plant some extra seeds in the ground in the nursery. Then, these seedlings can be transplanted into any containers in which the seed failed to sprout. Or, pre-sprout the seeds before planting them in containers. To pre-sprout seeds, place

them on a bed of clean moist sand, then lightly cover them with more sand. Keep the sand moist and protect it from direct sun. Check the seeds every 1-2 days. In seeds that have begun to sprout, the tough seed coat will crack. These cracked seeds should be planted. The root will emerge a few days after cracking, but it is best not to keep seeds in the sand until the roots appear, because the young roots can be damaged when the seed is planted. Any seeds that have not cracked should again be covered with sand and examined every 1-2 days.

- **How to produce new tea plants from cuttings**

Preparing mother bushes

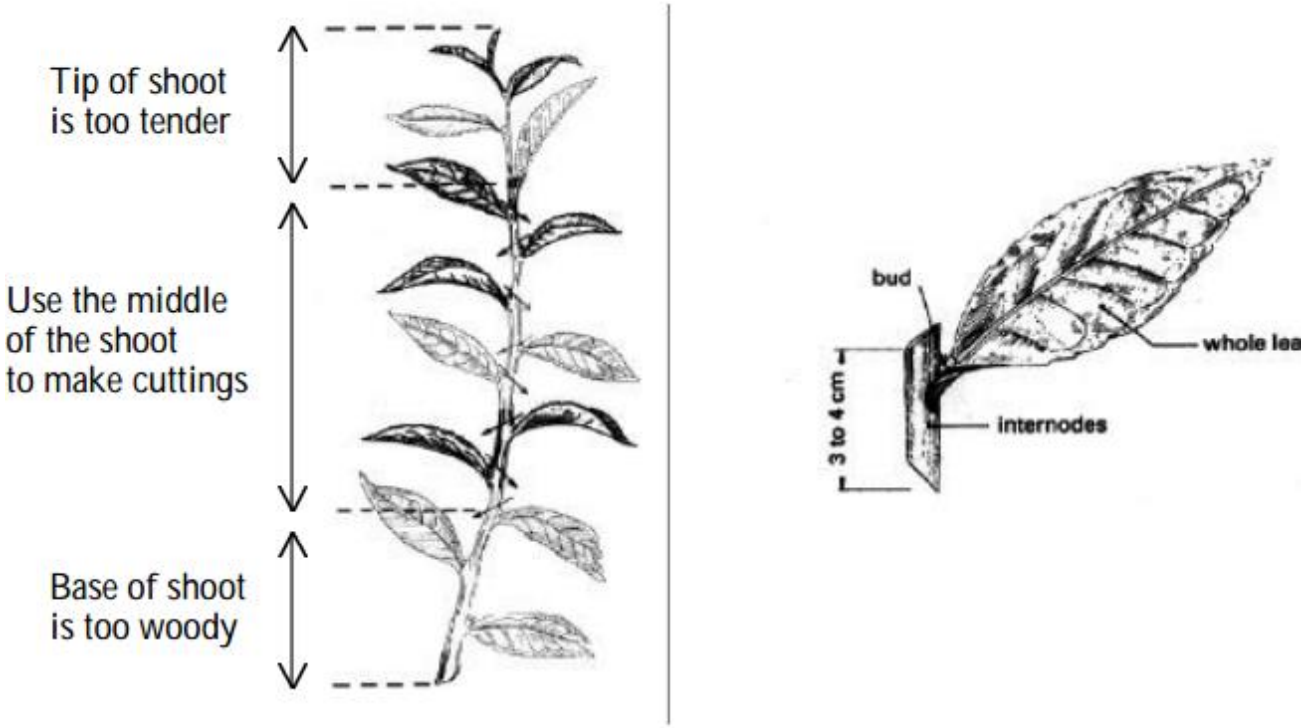
Make mother bushes from a tea variety that is suitable for your farm. In August-September, choose healthy, vigorous bushes to use as mother bushes. These bushes should not have been pruned in the past 4-9 months. Stop plucking these bushes, and start applying extra fertilizer

Calculate how many mother bushes to prepare based on:

- Each mother bush can produce 100-150 cuttings per year,
- To plant 1 hectare of new tea will require about 22.000-28.000 cuttings (approximately twice as many cuttings as the number of plants required, to allow for some cuttings that will fail to root).

Making cuttings

Cuttings should be taken in November-December (2-3 months after plucking stopped). Take cuttings on a cool cloudy day. Take the cuttings from the primary shoots (the shoots that you would usually pluck). The middle portion of the shoot, which is neither too soft nor too hard, makes the best cuttings (see drawing). The topmost 2-3 tender leaves are too soft to make good cuttings. Also, the bottom leaves on the hard and rough reddish-brown portion of the stem are too hard.



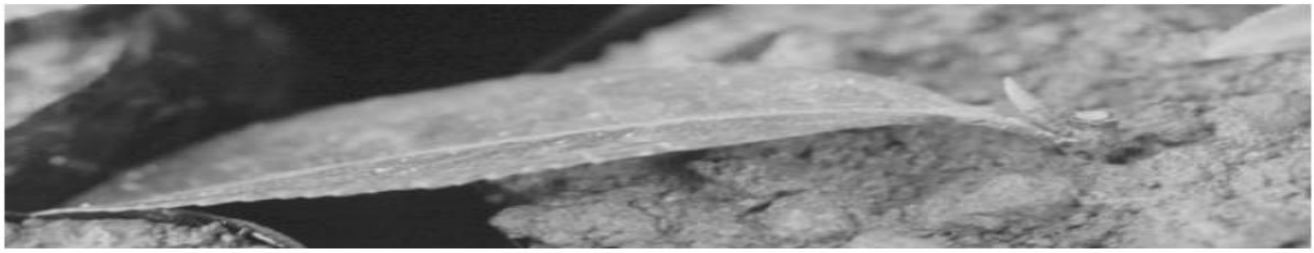
Left: Portion of the shoot from which cuttings should be made.
Right: A tea cutting.

Each cutting should be a 3-5 cm length of stem with one healthy leaf (free of insects and diseases). Using scissors or a sharp knife, cut the stem diagonally about 0.5 cm above and 2.5 cm below the leaf. Both cuts should be parallel to the leaf (see drawing above). If cuttings are made with scissors, be careful not to pinch or bruise the stem. Cutting with more leaves lose too much water and dry out.

- **Planting cuttings in a nursery**

The nursery and containers (plastic bags) should be prepared as described for seeds (above).

Before putting the cuttings in the containers, water the soil until saturated. Plant the cutting with the stem straight or slightly slanted so that the leaf does not touch the soil (if it does, it may become infected with diseases). Once the cutting is planted, align the container so that the leaf is parallel with the wind (the most common wind direction).



Close-up of a single cutting. Can you see any mistake that the farmer made?

Cuttings planted in plastic bags and aligned with the direction of the prevailing wind.

✓ **Nursery establishment for coffee crops**

Coffee may be grown from seed or from cloned plants in the form of cuttings, grafts or tissue cultured plants. Arabica coffee is most commonly grown from selected seed unless there are special reasons for using clones. A number of steps are necessary for production of good seedlings.

- Select the seed.
- Keep records.
- When to start the nursery.
- Calculate the amount of seed needed and the area required.
- Build nursery shelter and seedbeds.
- Plant the seed.

- **Select the seed**

Arabica coffee should be grown from fresh seed of the recommended varieties. Seed loses viability within three months and should not be used after that period unless properly stored at low temperature and high humidity.

Select ripe healthy fruit from the required variety and from plants that have good productivity, low or no incidence of rust and good cup quality. Pulp cherries, ferment for one night, wash clean, and dry the parchment slowly in shade on raised platforms or trays with good air movement for two to three days. The moisture content of the seeds should not fall below 10%, otherwise the viability will be seriously affected.

The seeds should be sorted to eliminate those that are small or abnormally shaped or are infested with pests.

NOTE: Coffee seed that is used for planting is actually parchment with the parchment hull still in place. It is not green bean from which parchment hull has been removed.

- **Keep records:** It is very important to keep good records of nursery operations. Good records will help avoid confusion and problems. The sample record on the next page can be photocopied for practical use.
- **Nursery record book**

Crop	
Cultivar	
Scientific name	
Origin of material	
Date sown	
Treatments (if any)	
Date of seed emergence	
Date of transplanting	
Growth stage at transplanting	
Other information / comments	

- **When to start the nursery**

New seed should be planted as soon as possible after harvest. The longer it is stored, the lower the percentage of germination and the smaller the plants will be at the time of transplanting.

- **Build the nursery shelter & beds**

Select a frost and flood free area with access to a suitable water supply. Completely fence the area to keep out domestic livestock.

- **Shade house and plastic tunnels**

Coffee seed is very slow to germinate in December and January (the coldest months) and clear plastic/polyethylene should be used to accelerate germination and plant growth. (Coffee seed that is used for planting is actually parchment with the parchment hull still in place. It is not green bean from which parchment hull has been removed).

c. Maintenance of industrial crops seedlings in nursery

The following table summarizes the maintenance activities carried out on industrial crops seedlings.

✓ **Maintenance of coffee crops seedlings in nursery**

- **Watering**: The quantity of water required per day being in the order of five liters per square meter. During the dry season the plants should be watered every five days
- **Chemical weeding**: is carried out by spraying with Diuron at a rate of 17g of commercial product per $100m^2$ of beds. A thin layer of mulch also helps to limit weed growth
- **Disease control** methods should, if necessary, be carried out against „"damping off"" disease using copper-based treatment or against cercospora spp (leaf spots) by increasing the shade. The main pests such as crickets, larvae and grubs, stem borers and termites are controlled by dusting the soil with insecticides such as Aldrin and organophosphates
- **Fertilizer** can be administrated by spraying the leaves with urea (**30-50g** dissolved in **10liters** of water), applying three treatments at ten-day intervals.
- **Hardening off** the plants and prepare them for transplanting.

✓ **Maintenance of tea crops seedlings in nursery**

- Put the polythene sleeves under a shade preferably polythene to ensure high humidity in the shade
- Water regularly
- harden off at 3months
- Weed the seedlings regularly due to the appearance of weeds
- Apply pesticide

✓ **Maintenance of pyrethrum crops seedlings in nursery**

- Apply 5gm per meter length of nematicide where nematode are problem
- After sowing, mulch seed bed with dry grass
- Water regularly the beds preferably on alternate days during dry weather to avoid water logging the beds
- After germination, reduce mulch to allow hardening off seedlings by exposure to natural environment conditions.

- Weed by hands thinning to minimize competition from weeds
- Fertilizer recommendations:
  - **Organic fertilizer**:10-12kg/are
  - **T.S.P** fertilizer at a rate of 20gm per metre length to accelerate root development and thus rapid development of the seedlings
  - **Top dressing** with CAN (26% N) at the rate of 20g/metre length 2 months after sowing to boost vegetative development(Calcium, Ammonium, Nitrate)

LEARNING UNIT 2 – Conduct industrial crops plantation

LO 2.1 – Plough the field according to crop requirements

- **Content/Topic 1 : Land clearing for coffee, tea, pyrethrum and sugarcane**

✓ **Land preparation**

Tillage includes all operations of seedbed preparation that optimize soil and environmental conditions for seed germination, seedling establishment and crop growth.

Tillage is defined as the soil-related actions necessary for crop production.

Tillage is any physical loosening of the soil as carried out in a range of cultivation operations, either by hand or mechanized.

The overall goal of tillage is to increase crop production while conserving resources (soil and water) and protecting the environment.

✓ **The benefits of tillage**

The benefits of tillage are:

i. field preparation,
ii. weed control,
iii. evaporation suppression,
iv. water infiltration enhancement, and
v. erosion control.

These benefits together result in increased and sustained crop yields. The definitions of tillage, as given above, embrace the concepts and features of both conservation and conventional tillage systems.

✓ **Factors affecting the choice of tillage practices**

For any given location, the choice of a tillage practice will depend on one or more of the following factors :

Soil factors Relief (slope) Erodibility Erosivity Rooting depth| Texture and structure Organic-matter content Mineralogy	**Climatic factors** Rainfall amount and distribution Water balance Length of growing season Temperature (ambient and soil) Length of rainless period
Crop factors Growing duration Rooting characteristics Water requirements Seed	**Socio-economic factors** Farm size Availability of a power source Family structure and composition Labour situation Access to cash and credit facilities

✓ **The Objectives of tillage for crop production**

- To facilitate adequate soil aeration for gaseous exchange in the seed and root zone
- Adequate seed-soil contact to permit water flow to seed and seedling roots
- A non-crusted soil to permit seedling emergence
- A low density soil that permits root elongation and proliferation
- To create an environment that provides adequate light to the seedling (weed free environment).
- To create pest and pathogen free environment
- To mix the applied manures and fertilizers with the soil
- To remove the hardpan, if any to increase the soil depth for water absorption

✓ **Field preparation for coffee**

The area where a mother garden is to be established must be well prepared and existing trees should be ring-barked at least one year before planting in order to prevent infestation by the root rot disease. The roots of old tree stumps are a source of infection to the young Coffee by the above fungus.

It is recommended to take the following steps:

● Clear the land and remove all tree stumps with their roots

● Plough and level the land during the dry season

● Plant windbreakers

● Mark out rows following the contours

● Plant shade trees

● Set up a water delivery system from the water source to the plants.

The above implies that:

- ❖ Arable land must be cleared of all un-wanted vegetation in preparation for planting the mother garden.
- ❖ Land must be free from obnoxious weeds.
- ❖ Leave some mature trees for shade cover, at a spacing of 20 m x 20 m. This gives a good shade cover while avoiding competition for water and nutrients.
- ❖ Avoid trees that are alternate hosts to the Black Coffee Twig Borer (BCTB). Example : Avocado.
- ❖ Carry out deep ploughing. It is a good way of rejuvenating the soil.
- ❖ Plant bananas for extra shade if required.
- ❖ Cover crops should be planted at early stages of mother garden establishment to avoid soil erosion.
- ❖ For sloped terrain, apply soil and water conservation measures such as contour trenches, contour terraces, vegetative barriers, soil bands, grass strips and cut-off drains to avoid soil, water and nutrient loss.

Permanently planted windbreaks are only recommended in sites exposed to strong winds, and even then, only where they are needed to supplement inadequate natural forest if required

✓ **Field preparation for tea**

There are at least three steps in preparing a new field:

- Ringing and cutting down any trees,
- Planting green-manure bushes or grass, and
- Improve the soil

i. Ringing and cutting down trees

If the field has some shade trees, you may want to leave them alive to provide shade for the tea crop.

But if you need to cut down any trees, the trees should be “ringed” one year before cutting. “Ringing” means that a ring of bark should be stripped off all the way around the base of the trunk. This will slowly kill the tree, causing the tree to use up the store of starch in its roots. If the tree is simply cut down while it is alive, its roots will be full of starch and will provide food for many root-rot fungi to grow. These root diseases will later spread to the tea roots.

Ringing is a delicate operation.

If it is not deep enough, the tree will continue to store starch in its roots. If it is too deep, the tree will die quickly with the supply of starch still intact in the roots. After ringing, allow at least one year to pass before

cutting down the tree. After cutting down the part above the ground, farmers need to dig out all of the root system to a depth of about 50 cm. The purpose is to make the soil softer, so that when you plant the new tea, its roots will be able to penetrate deeper into the soil and get nutrition more easily.

ii. Planting green-manure bushes or grass

If the farmer is planning to plant tea cuttings or seedlings from a nursery, it is best to plant green-manure bushes one year before planting tea. The developing green-manure bushes will:

- Protect the soil against erosion,
- Help control weeds,
- Produce abundant leaves for green manure, and
- Provide temporary shade for young tea plants.

If the field you are planting was previously planted to tea bushes, and those tea bushes had problems with root-rots or nematodes , then do not plant green-manure bushes. The reason is, many green-manure bushes are susceptible to root-rots and nematodes.

Instead, plant grass for 18 months or more. Grass is not susceptible to tea root-rots or nematodes, and also produces lots of organic matter (from periodic cuttings) that stimulates beneficial micro-organisms.

iii. Improving the soil

The third task before planting tea is to improve the soil. Soil preparation should be done 1-2 months before planting tea. To provide organic matter for the soil, cut the branches of the green-manure trees and bury them in ditches as green manure. Ditches should be about the same size as the holes for planting tea: about **30 cm wide and 60 cm deep**.

If the soil is poor, it is also good to apply compost (up to 20 tons per hectare).

- **Content/Topic 2: Primary and secondary ploughing for coffee, tea, pyrethrum and sugarcane**

The objectives of primary tillage are:

- To attain a reasonable depth (10-15 cm) of soft soil with varying clod sizes;
- Kill weeds by burying or cutting and exposing the roots
- Soil aeration and water accumulation; depending on the soil type and the plough the soil will normally be inverted aerating the deep layers and trapping water during a rainfall event
- Chop and incorporate crop residues.

Secondary tillage

Secondary tillage is any working completed after primary tillage and is undertaken for

- Reducing clod size,
- Weed control,
- Incorporation of fertilizers,
- Leveling soil surface.

Kinds of Tillage Operations

1. On Season Tillage: Tillage operations performed at the start of or during the cropping seasons. (June–July or Sept.–Oct.).

They are of two main types;
1. Preparatory Tillage
2. Intercultivation (or Inter tillage)

2. Off Season Tillage: Tillage operations carried out during fallow or non-cropped periods (summer).

3. Special Types of Tillage: As the name refers, these tillage operations are carried out with some special objective.

1. On Season Tillage

The tillage operations performed during the onset of cropping season to preparation of seedbed for better crop growth and later during the crop stand, are called on-season tillage operations.

A. Preparatory Tillage

The tillage carried for preparing a piece of land for cropping.

a) Primary tillage

Primary tillage operations constitute initial cutting and inverting of soil after previous crop or fallow tillage. The depth of primary tillage operations range from 10-30 cm. The soil loosens and opens as a result of plowing and planking, providing good tilth.

The main **objective** is to control weeds to incorporate crop stubbles and to restore soil structure.

b) Secondary tillage

Primary tillage operation do not leave fine soil and leaves cracks and crevices. To get fine tilth, shallow tillage operations are carried out to cover the crevices and break the clods left after primary tillage. The soil is stirred and clods are broken. In addition, mixing of fertilizers and mulching, harrowing, pulverizing and ridges and furrows are also made during secondary tillage operations.

c) Seed bed preparation

Shallow operations carried out for fine seedbed preparation are carried out as final steps for cultivation of crops. The main purpose is weed control and structural development of the soil.

B. Inter Tillage/Inter Cultivation

The tillage operations carried after sowing of the crops and before the harvest are called inter-tillage operations. These include hoeing, harrowing, inter-cultivation of other crops etc.

The main **purposes** are to root-out weeds and incorporation of fertilizers or manures.

2. Off Season Tillage

Tillage operations for improvement and conditioning of the soil during off-season (uncropped season) are carried out with the objective of leaching to remove salts for reclamation, water conservation, control of pest population and disease vectors in the soil.

a) Post harvest tillage

Tillage operations carried out after the harvest of crops to root-out the stubbles of the previous crop and weeds with the objectives of water conservation and conserving soil structure are called post-harvest or

stubble tillage operations.

b) Summer tillage

Tillage operations carried out during summer with the objectives to control pests and disease pathogens, reducing soil erosion and conservation of soil moisture as well as retaining the rain water through summer showers. It affects the soil aggregates, organic matter but it may favor wind erosion.

c) Winter tillage

Winter tillage refers to the tillage operations carried out in during winter season in the temperate areas with low temperatures. The fields are plowed and harrowing is done to root out weeds and improve physical conditions of the soil.

d) Fallow tillage

Fallow tillage refers to the tillage practices carried over an arable land in uncropped land. The objectives are to root out all the weeds and destruction of the pathogens or eggs of insect pests in the soil. Soil is vulnerable to wind and other types of erosion when tilled in fallow condition.

3. Special Types

Special type tillage includes

a) Sub-Soiling

Sub-soiling is unlike other tillage operations which involves breaking of hardpan formed in the field. The hardpan is cut open with subsoiler or chisel plow. The soil is not inverted in this operation. It is done once in 4–5 years where there is a colossal loss of topsoil due to carelessness.

b) Land Leveling

Land leveling is major requirement for better crop stand and fair distribution of irrigation water. Hence, levelers and scrapers are used for land leveling. Leveling has its own advantages of resistance to soil erosion and help in other operations.

c) Puddling

Tillage operations doing in standing water for preparation of field for rice cultivation. The conditions are anaerobic.

Other types include;

Strip tillage – tillage in strips

e) Strip tillage - Ploughing is done as a narrow strip by mixing and tilling the soil leaving the remaining soil surface undisturbed.

f) Clean tillage refers to cleaning the entire field of the plants with the objective to control soil borne pathogens and eggs of pests. All the plants are uprooted and soil is turned.

g) Ridge tillage refers to forming ridges by ridge former or ridge plough with the objective of sowing the seeds.

h) Conservation tillage refers to tillage practices implemented for purpose of conservation of soil moisture. In these practices, mulch is retained on the surface of soil.

The important criteria of a conservation tillage system are:

i) Contour tillage refers the preparation of contours for cultivation. This reduces soil erosion.

i) Blind tillage refers to tillage done after sowing the crop and either at the pre-emergence stage or during the early stages of crop growth so that crop plants are damaged, the purpose is to uproot the weeds.

LO 2.2 – Establish the plantation for industrial crop considering the type of crops

- **Content/Topic 1 : Planting material handling**

Crops	Planting material handling
Coffee	• when coffee is planted on virgin soils after forests, direct seeding is done in the field • Seedlings are planted in the coffee fields when they reach 20-40 cm i.e at 6 leaf stage, 6-10 months old. • The roots have to be trimmed to prevent the tap roots from becoming twisted, by cutting the plastic bags with a knife 1cm from the bottom • Holes 60cm wide and 80 cm deep are then lined out, the spaced with 1mX 2m depending on type and fertility of soils and cultivars • Dug the holes two to four weeks before transplanting and filled in again a few days beforehand, thoroughly mixing the soil. • Planting is done at the start of the rainy season to ensure quick and faster start of the sucker • Approximate months are: - March, (season B) -October or November(Season A) • The young leaves may temporary shaded with palm leaves or other vegetation
Sugarcane	• The direction of setts differs according to the slope and shape of field • They are buried in furrows in moist soils, horizontally or at **45º** side by side. • Depth of ploughing: **-45-90cm** for deeper surface soil **-15-20cm** where hard pan layer
Tea	• Plough level and put roads and paths picketing to determine the contours for soil erosion measures • **Planting hole or trenches of 30 cm diameter and 60 cm depth**. Or pits of 30cm x 30cm x 45cm (depth) and if land is not good 45cm x 45cm x 45cm (depth) or 60cm x 60cm x 60cm (depth) • Remove bags

	• Transplant when its roots reach bottom of the bag **Date of planting**: **On hills**: November/ December/ January **Marshy areas**: February to march
Pyrethrum	**Land preparation**: Fields for pyrethrum establishment should be well tilled to: • Allow easy penetration of the plant roots • Enhance percolation of water when rainfalls, thus reducing chances of water logging and soil erosion. • Enhance aeration of the soil. • Fields should be ploughed early before onset of rains beginning February/March. **Planting holes** are dug at a depth of **10-15cm** **Planting procedure**: • Apply a teaspoonful**(5-8gm**) of T.S.P fertilizer or **200gm** of manure in the hole and mix with soil • Place the planting material in the hole ensuring that the roots are not bent sideways or upwards. • The base of the plant(where the roots meet the stem) should be at the ground level ,with all roots below the ground and all leaves/stem above the ground • Fill **1/3** of the hole with soil and firm the soil with hands, and then fill the hole and firm the soil again. **Planting material**: Establishment should be from selected splits or seedlings. March-May(**season B)**

- Content/Topic 2 : **Spacing**

Crops	**Spacing**		
Coffee	**Robusta**: 4*2.5m 3*3m 3*2.5m	**Arabica**: 4*2.5m 3*3m 2*2m	**Dwarf varieties** **(Caturra, catuai):** 2*2m 2*1m

	3*2m 2.5*2m		1*1m
Tea	Tea seedlings are usually ready to be transplanted into the field about 12 months after planting cuttings (can range from 10-20 months). Spacing varies from region to region and variety to variety. In general is 120cmx60cm It is difficult to prescribe a definite plant spacing but there are specific factors influencing the spacing such as: - To allow for sufficient sunlight when palms are tall; - To allow for sufficient working space within the plantation; and - To provide sufficient space for root development.		
Sugarcane	Transplant in the main field at a spacing of 90 cm x 50 cm		
Pyrethrum	Spacing is **60cm** between the rows (inter-row) and **30cm** from plant to another within a row (Intrarow).Also 60cm*80cm The plant population of **55.000plants.**		

- **Content /Topic3 : Fertilizer application**

Crops	Fertilization
Coffee	• Use 20kg basket of organic manure per plant at the beginning of each rainy season (March and September) • **Mineral fertilizer**: Apply one of the following formula: ✓ NPK20.10.10:**400g/tree** splitted in two times;**200g** during March and **200g** during November ✓ NPK17.17.17+Urea46% splitted in two times;**120gNPK+50g urea** during March and the same quantity during November ✓ **Urea 46%+mulch**:**75g** of urea during March and 75g urea 46%during November, with mulch • On too acid soils, coffee growers will add 1kg of lime per plant every three years

Tea	• **Mineral fertilizer**:**60g** of NPK 20.10.10 per plant when pricking out
Sugarcane	• **Basal fertilizer**: 3kg urea/are • **Top dressing fertilizer**: ✓ NPK:100-60-150 per ha for first harvesting sugar cane ✓ NPK:130-70-150 per ha for ratoon crop either after harvesting or 2 to three weeks after planting or at the beginning of growth phase
Pyrethrum	• The fertilizer should be mixed thoroughly with soil in the hole to avoid scorching the plants roots. • Farm yard manure: **40tons/hectare** especially in poor soils. The manure should be applied **3months before planting** to allow decomposition • Decomposed manure can be applied at planting time: **200gm** / hole and mixed with the soil. • Top dressing with nitrogenous fertilizer on pyrethrum has not proved to be beneficial and is thus not recommended

LO 2.3 – Maintain plantation according to the standards

- Content/Topic 1 (From Curriculum)

i. Coffee

When the coffee trees are planted the work is not finished.

The grower still has a lot of work to do to look after his crop.

A grower who does not look after his plantation properly cannot get a good harvest of berries and will not earn much money.

Crop	Maintenance activities
Coffee	**(1) Weed management:** Weeds compete with plants for water and nutrients and eventually lead to reduced vegetative growth of the mother bush and thus low sucker yields in a mother garden. Weeds should, therefore, be properly managed and adequately suppressed to achieve maximum bush productivity. **(2) Soil and water conservation practices:** Soil and water conservation practices are important for conserving soil moisture for use in the dry period and for

minimizing loss of soil fertility through erosion.

(3) Cultural practices: Cultural management practices are crop production and management techniques utilized by the farmers to maximize their crop productivity.

Example :

- ✓ **Planting of cover crops(**Mucuna spp, Phaseolus spp, Lablab and groundnuts)
- ✓ **Planting of grass (**Grasses such as Vetiver grass, leguminous plants such as Tithonia diversifolia (wild sunflower) or Napier grass)
- ✓ Planting of trees
- ✓ Mulching

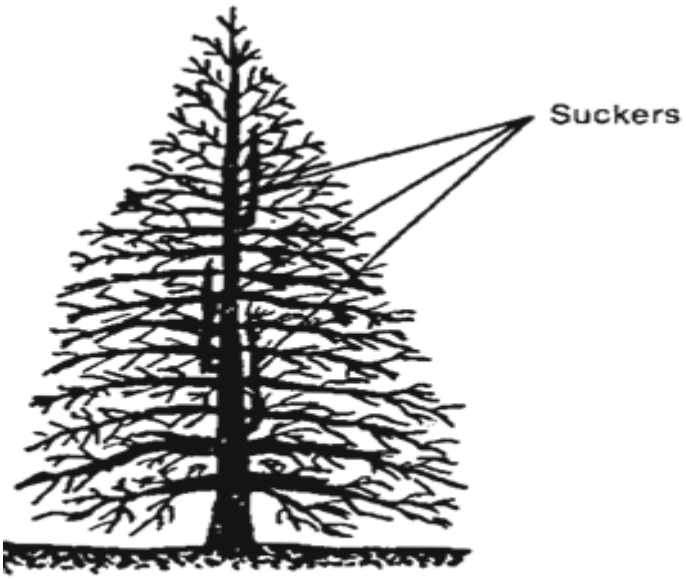
(4) Training: is the bending of the young Coffee plants in an East to West direction and pegging them down at about 45 degrees to enable the orthotropic stem to produce suckers, from which harvesting of cuttings is done. Bending leads to the breaking of dormancy resulting in multiple buds emerging at the base hence growth of numerous suckers. Bending is done when the Coffee seedlings are about 5-6 months after planting or when the Coffee plant reaches a "knee-high"height of 60 cm.

(5) Nutrition and fertilizer management of a mother garden: Continuous harvesting of suckers leads to nutrient depletion. It is therefore, recommended that manure or fertilizers be applied to replenish the nutrients.

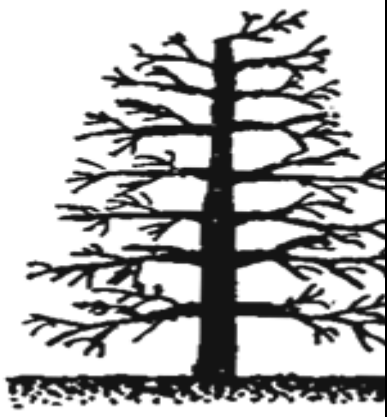
(6) Pruning

- ❖ **Pruning these coffee trees is simple:**

- Cut off the top of the tree so that the coffee tree is not taller than 1.5 to 2 metres.
- Remove the branches at the bottom of the trunk.
- Leave only the thickest and best branches on the trunk.
- Cut away all the small branches that grow on the trunk.
- Cut away all the dead and dry branches, and all diseased branches.
- Cut away suckers; they are not needed.



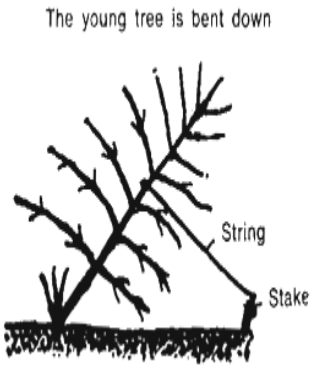
Arabica coffee tree before pruning

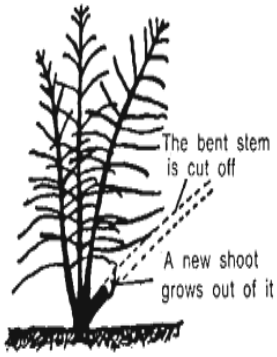


Arabica coffee tre after pruning

Pruning these coffee trees is difficult

- Bend down the first stem and tie it to a stake

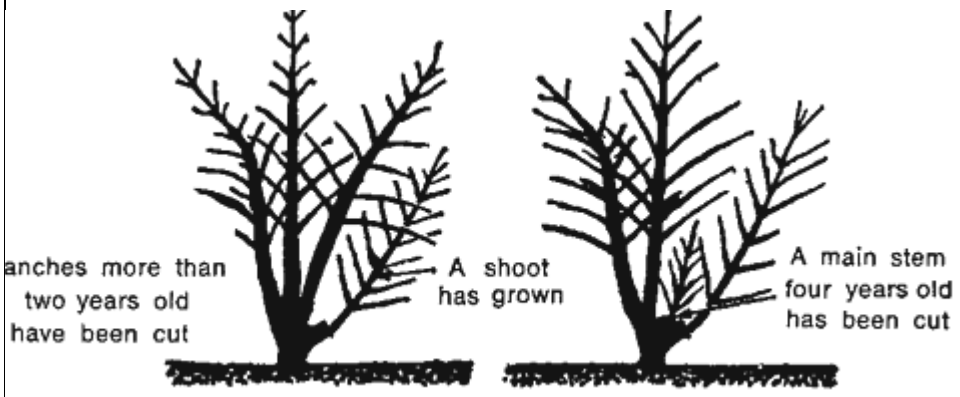




- Let three to five main stems develop: they will bear fruit.
- Cut off the bent stem: a new stem will grow in its place.
- On the main stems, branches will grow and bear fruit.

  After two years of harvests, fruit will grow only on the tips of the branches: cut down these branches.

- When a main stem has borne fruit for three to five years, cut it off.
  In the place of the stem you cut off, a new stem or shoot will grow and bear fruit.
- Every year cut off one of the main stems.



- Cut away suckers: A sucker is a twig that grows upward out of a main stem. A sucker never bears fruit.
- Cut away also all dry or dead branches.

Pruning is periodically carried out by:

1. Removing suckers
2. Removing unproductive branches
3. Removing branches and leaves growing close to the ground
4. Removing old stems that are too high for picking berries
5. Removing dead and awkwardly growing branches

❖ **Purpose of pruning**

- Restore the effective area of branches and leaf-bearing nodes as much as possible. The new branches will then be capable of producing additional inflorescence and are likely to ensure the continued development of the plant without any pHysiological problems such as „‟Die-back‟‟.
- Provide the trees with a robust and well-balanced framework which will support the fruitbearing branches and will be at a convenient height for handling and harvesting.

Advantages of pruning

- Free air circulation which controls attack by pests and diseases
- Uniform production of berries
- Branches do not overbear berries

- It is easy to weed, spray and apply fertilizers
- Plant remain vigorous and healthy
- Encourages good quality products to be produced
- Keeps the crop in a good shape for harvesting

❖ **Demerits (disadvantages) of pruning**

Pruning is generally not necessary in coffee plantation due to the following reasons:

- We do not have well trained labourers.
- The period of pruning of the plants is uncertain due to irregular rainfall.
- The worldwide research tells us that evergreen plants do not need pruning.
- The cost of pruning is very high.
- The yield and plant condition serve as the best index to manipulate the shade management.
- Our rainfall is irregular with higher rainy days.
- Frequent pruning will shorten life span of the plant.
- Only minimal saving on manures.
- Give a very high yield.
- More leaves lead to more photosynthesis.
- Running blossoms extends harvesting period.
- Nutrient management can regulate our quality crops.
- In root pruning, plants waste its resources and time.
- Conservative tillage and no tillage are gaining popularity world over

• **The pruning systems in coffee growing**

Two main methods can be used: single-stem pruning and multiple-stem pruning.

A. Single-stem pruning system

Topping of growing main-stem

Capping: Cutting of terminal bud of the stem, sometimes carried out in several successive stages at 0.60m,1.2m and 1.8m to enable a solid frame to be created. It starts towards the end of the **third year** lasts until the height of the bush is approximately **2m**.

❖ **Purpose of topping/capping**

1) To restrict vertical growth and facilitating lateral branching giving increased fruiting area.

2) Thickening of main stem: It also helps in diversion of food material to thicken the main stem and primary branches.

As soon as the plant reaches a desirable height (first topping height) the growth of bush is restricted by topping/capping.

Advantages of single-stem pruning

- Regular production can be permanently achieved at an optimum economic level on all the plots in the plantation
- Permits the use of automatic harvesters which are currently in use in some production areas.
- The production of secondary branches makes it appropriate for use with many commonly grown species and varieties which naturally produce fruits on secondary growths.

Disadvantage of single-stem pruning

- Requires careful planning and a skilled workforce
- It is estimated to be the most labor-intensive task; an average worker being able to prune between 50 and 60 trees a day.

B. Multiple-stem pruning system (Agobiada)

The multiple-stem system of pruning is used on coffee plants from which the fruit is to be harvested mainly from the primary branches.

In Africa, for both Arabica and robusta, the young seedlings are capped at the nursery or in the first three to four months after field planting, to raise two stems in the first cycle, followed by two to three stems in subsequent cycles depending on plant population.

- Capping can be done when seedlings are at about 38cm or after transplanting when they are about 50cm high.
- Two or more stems are allowed to grow
- Both suckers are allowed to develop up to 1.5m.
- Train the branches by bending them downwards for easy picking, stems are cut back and new shoots allowed growing.
- It is a common practice in the growing of robusta coffee because the lateral branches are shed so is „"self pruning"".

Agobiada: the stem is bent and pegged to the ground which creates many shoots

	to sprout. Multiple stem training system is practiced under certain circumstances viz., **1) Replanted fields:** When old blocks are to be replanted with a new material, the old plants are stumped and converted into multiple stem to yield crops until the new plants come to bearing. **2) High density** planting**:** Here coffee is planted very closely in the initial years and later thinned out to normal spacing. **Advantages of multiple-stem pruning** ➢ Simplicity of its implementation; no skilled labor is required and the operations can be carried out fairly rapidly. ➢ Having early spacers which will retard growth to some extent. **Disadvantages of multiple-stem pruning** ➢ An excessive number of stems per tree and the interlacing of their internal secondary branches may complicate plant protection treatment. ➢ The bushy habit of the stump branches and their height make them unsuitable for mechanical picking by the automatic harvesters which are currently available. **(7) Replacing missing seedlings** Sometimes certain coffee seedlings do not grow well. They remain small or die. During the months after planting, you must look often to see whether your coffee trees are growing well. If you see diseased or dead coffee trees, pull them out and burn them. In their place, plant other coffee seedlings from among those you have kept in the nursery.
Tea	**(1) Watering**: Watering seedlings and light shading after transplanting **(2) Mulching**: is done within the rows but as the crop grows, it is no longer necessary. The seedling is allowed to grow branches laterally but they are pruned **(3) Training young tea** **Centering:** To induce more laterals centering should be done 3 - 5 months after planting. The main leader stem should be cut, leaving 8 - 10 matured leaves.

Tipping: Tipping at a height of 35 cm from the second tipping at 60 cm from ground level.

(4) Pruning: To maintain convenient height and vegetative growth and to remove dead and diseased branches:

Types of pruning

Rejuvenation pruning: The whole bush should be cut near the ground level less than 30 cm with a view to rejuvenate the bushes.

Hard pruning: Formation pruning of young tea at 30 to 45 cm (12" to 18") for proper spread of bushes.

Medium pruning: To check the bush growing to an inconvenient height this type of pruning is done in order to stimulate new wood and to maintain the foliage at lower levels less than 60 cm.

Light pruning: Pruning depends on the previous history of the bush raising the height of medium pruning by an inch or less to manageable heights for plucking (less than 65 cm).

Skiffing: This is the lightest of all pruning methods. A removal of only the top 5 - 8 cm new growth is done so as to obtain a uniform level of pruning surface (more than 65 cm).

Shade regulation: Pollarding of shade trees should be done prior to heavy rains at a height of

8 - 10 m from the ground level.

Annual lopping: Cutting the erect type branches on the laterals in shade trees.

The methods used in pruning tea

There are two methods used in pruning tea both of which lead to the formation of plucking table. These methods are:

(a) Formative pruning

(b) Pegging

(a) Formative pruning (to form a frame)

- First shoot is decapitated at 15cm from the ground (when it is 30cm high and more than 3leaves)
- When less than 3leaves, decapitating later (when reach 20-30cm)
- Do two pruning after decapitation (1st at 28cm; 2nd at 40cm)
- First pruning: 18months-20months after planting; 2nd, 12-15months later

	➢ Never harvest after 1st and 2nd pruning to allow sufficient root development, enough reserves of carbohydrates into roots to ensure great performance ➢ After second pruning, the plucking table at 60cm-90cm from the ground. **(b) Pegging** ✓ Young plant is cut back at a height of about 15cm ✓ The new shoots that sprout from the cut end are allowed to grow up to about 60cm-70cm tall ✓ The branches are later pegged down using pieces of wood. Pegging stimulates sprouting along the length of branch. ✓ After pegging, the terminal bud is removed. The shoots which sprout along the branch continue growing for about 3months.
Sugarcane	**(1) Fertilisation** Fertiliser is applied to promote development of the plant. Fertiliser can be spread by hand by applying a standard container of fertiliser over a predetermined length of cane row. In general all the phosphorus should be applied before four months, nitrogen before six months and potassium before seven months period. **(2) Irrigation** The frequency of irrigation depends on the stage of development of the cane. Light, frequent irrigations are preferred when the seed is germinating and the young seedlings are getting established. As the root system extends into deeper and deeper soils, the irrigation intervals should be extended, and the amount of water applied with each irrigation increased. As the cane approaches maturity, extended irrigation intervals should be scheduled to reduce the rate of vegetative growth, dehydrate the cane, and force the conversation of reducing sugars to recoverable sucrose. **(3) Weed control** Weed control methods employed will be either hand weeding or by application of herbicides. It is necessary to spray herbicide (weed killer) in order to prevent weed competition and losses in sugarcane production. Sugarcane is most susceptible to

weed competition during the first eight to 10 weeks after cane begins to sprout.

Weeds can also be removed from the field manually by hand hoeing. Recommended herbicides and chemicals for weed control in sugarcane can be used.

(4) Earthing-up

Earthing-up operation is also known as "hilling-up". This operation is carried out in two or three stages.The first earthing-up operation is known partial earthing-up and the second/third operation is known as "full earthing-up".

The partial earthing-up is done at 45 days after planting. In partial earthing-up, little amount of soil from either side of the furrow is taken and placed around the base of the shoots. While doing partial earthing-up, the furrow in which the cane row is present gets partially filled-up.

Full earthing-up is done after 120 days after planting coinciding with the peak tiller population stage. During full earthing-up the soil from the ridge in between is fully removed and placed near the cane on either side. This operation converts the furrows into ridges and ridges into furrows.This operation could be done either manually or by using a bullock-drawn/tractor drawn furrower depending upon the spacing adopted.

Full earthing-up at the end of formative phase (i.e., 120 DAP) checks further tillering, provides sufficient soil volume for root proliferation, promotes better soil aeration and provides a sound anchorage or support to the crop and thus preventing lodging.

One more earthing-up after cane population is stabilized at 180 DAP may be helpful in preventing lodging and water shoots formation. It also improves aeration and helps to control weeds.

(5) Detrashing

Detrashing refers to removal of unwanted bottom dry and green leaves at regular intervals. Sugarcane stalk bears large number of leaves (30-35) equal to the number of inter-nodes under good management systems.

Detrashing should be taken up after the cane formation around 150 days after

planting. There after it could be done at bi-monthly interval depending up on the labour availability.

Detrashing helps in:

- Maintaining clean field
- Enhances air movement and enriches Co^2 with in the crop canopy providing an ideal micro-climate for unrestricted growth of cane
- More food material is made available for stalk growth
- Reduces the problem of infestation of several insect-pests like scales, mealy bug, white flies etc
- Reduces bud sprouting due to accumulation of water inside the sheath in some varieties.
- Bud sprouting is not desirable as it would reduce main stalk growth and affect sugar accumulation
- Facilitates easy entry and movement in the field, particularly to inspect the condition of the crop and drip laterals and thus accordingly plan the fertigation and plant protection schedules
- A clean field minimizes rodents, rats, squirrels in the field which may otherwise cause damage to the crop
- Facilitates easy and economy in harvesting besides clean canes for crushing
- Detrashed trash can be used as a mulch for moisture conservation
- Clean leaves can be used for composting

(6) Propping

The operation of tying the leaves together using the bottom dry and green leaves is known as propping. It is primarily done to check lodging of cane. Usually the trash without removing from the cane is twisted to form a sort of rope and cane stalks are tied together. This is known as trash-twist propping. Propping can be either done for each row or two rows can be brought together and tied.

In areas where cane top growth is heavy and wind velocities are high, propping is very much necessary to prevent lodging. This is because lodging leads to several problems:

- Cane breakage and thus loss of stalk number at harvest and thus loss of cane

	yield • Infestation of certain pests and diseases causing microbes through lodged and damaged canes • Damage by rats and rodents • Bud sprouting leading to reduced cane quality • Aerial root formation which also affects cane quality • Difficulty in inspection of driplines and harvesting **(7) Removal of Water Shoots** Water shoots are the late-formed tillers or side shoots, which are robust and fast growing. They originate mainly due to plentiful supply of water, inadequate earthing-up and late fertigation. These water shoots, as the name indicates, contain lot of water and less sucrose and more of reducing sugars. Water shoots affects the growth of adjacent stalks. They harbour insect-pests and when they are harvested and sent to mill for crushing, lead to reduced juice quality and affect sugar recoveries. Therefore it is advisable to remove water shoots as and when they arise. The water shoots can be used as cattle feed
Pyrethrum	**(1) Weed control**: -Weeds are a major pest in pyrethrum and can reduce yields by up to 50% -Weeds can be ordinary controlled every **4weeks** during the rainy season -Chemical weeding using pre-emergent soil applied herbicides (eg:Metrbuzin) has been shown to control weeds up to 4-5months. **Note**: the products are applied strictly between the plant rows and only on the soil of a cleaned field as the mode of action is to stop sprouting of new weeds. **(2) Flower harvesting**: Picking of all mature flowers should be done fortnightly (after every 2weeks) for optimum production **(3) Crop rotation**: -Pyrethrum plants should remain in the fields for **3-4 years,** after which they are uprooted and transplanted to new fields. -After the 4th year the flower yield declines to uneconomical level due to the accumulated effects of pathogens, pests and nutrients depletion. The flower yield is maximal in the **2nd -3rd years**.

	-To restore soil structure and reduce pests/diseases, the fields are rotated with a cereal crop. **(4) Cutting-back:** **-Pyrethrum** crop should be cut back after a full season of harvesting flowers. -Cut back is done just before the on-set of the following season‟s rains using a sickle to remove old unproductive flower stalks. -It is recommended to cut the plant at a level of **15cm above the crown.** A cut back crop regenerates on on-set of the rains and is back in production in about **6weeks**.

- **Content/Topic 2 : Pests and diseases control for industrial crops**

(a)Main pests of industrial crops

(i) Pests of coffee

Pests	**Scientific name and type**	**Symptoms**	**Control**
Antestia bug	**Antestiopsis orbitalis)** (Sucking pests)	• Short internodes and multiple shoots or fan branching in young plants • Flower buds become black and fall off. • Young green berries drop off • Mature berries develop longitudinal marks on the parchment which appear like zebra crossings	✓ Open pruning to increase air circulation and deter multiplication of the pest. ✓ Using pesticides like Parathion, Fenitrothion or Fenthion.
Aphids	***(Toxoptera aurantii)*** Sucking pests)	• Large numbers of small black aphids (2 to 3 mm long) concentrated on new growth. • Often associated with black sooty mould.	**Chemical:** Neem oil **10 to 20 ml/L**, plus soft, finely grated laundry soap at about **7 g/L water**.
Coffee berry borer	**(Hypothenemus hampei)**	• **I**t penetrates the berry of coffee grown at low altitude which is heavily shaded • Larvae bore tunnels in the beans and the beans become blue in color • The berries are completely destroyed. • Fruit drop of young, green cherries.	✓ Carry out field hygiene by destroying all dry berries ✓ Regular picking of coffee ✓ Pick all berries from the stem after the harvesting season ✓ Reduce on the shade as it discourages natural enemies of coffee

			berry borer.
Coffee leaf miner	***Leucoptera coffeina***	• They are small white moths whose larvae bore into leaves and feed on the palisade layer. • The tunnels created appear as brown blotches on the upper epidermis • PHotosynthetic surface is reduced and above all, the affected leaves fall off.	Spray with parathion or fenitrothion ✓
Stem borers	***Zeuzera coffeae(Red stem borer)***	• The adult has white and black spotted wings • Wilting of leaves and dead trees or branches. • Affected branches are easily broken off. • When trees are first infested there may be evidence of frass (sawdust- like residues) on the ground. • The trunk may be ring barked.	**Preventive:** ➢ Less damage occurs under conditions of good shade. Higher altitude (**above 800 m.a.s.l.)** seems to reduce the incidence of infestation. ➢ Burn affected trees or branches with borers inside. ➢ Do not plant trees with twisted taproots.
	White stem borer (***Xylotrechus quadripes).***	• Young larvae feed on the corky tissue just under the bark, which splits making the stem appear ridged. • Later, larvae enter the heartwood and tunnel in all directions, even into the roots.	**Chemical:** ➢ No effective chemical control known.

(ii) **Pests of tea**

Pests	**Type and scientific name**	**Damages**	**Control**
Caspids	**(*Heloptis bergrothi* and *H. schoutedeni*)** Sucking pests which damage the buds	Sucking pests which damage the buds	Spray with Fenithrothion
Red crevice mite	**(*Brevipalpus pHoenicis)***	• An eight legged arthropod with sucking mouth	Spray with chlorobenzilate, Dicofol or

		parts. • It pierces leaves from underneath creating patches. Leaves fall prematurely.	Dinocarp
Yellow tea mite	**(*Hemitarsonemus latus)***	• It sucks sap from young leaves making them disfigured and curling inwards. • The main veins have developing corky patches in between .This is seen on the lower epidermis.	Spray with chlorobenzi late,Dicofo l or Dinocarp
Black tea thrips	**(*Heliothrips haemorrhoidalis)***	• Sucking pests whose effect causes silver patches with black spots on the underside of mature leaves. • The attack is severe in dry conditions	Spray with pesticide e.g: Fenithrothion.

(iii) Pests of sugarcane

Pests	**Type and causal agent**	**Symptoms**	**Control**
Sugar cane stalk borer	**(Diatraea sacchari)**	• A large moth whose eggs hatch into larva that bores the cane. • The cane becomes hard, loses sweetness at the affected internodes, tillers die and stem becomes weak. • Pupation occurs inside the stem and leaves a very thin layer to make it easy for the moth to break and fly out.	Biological control has proved very effective using the Red fire ant (*Solenopsis invita*) and a wasp from India (*cotesia flavipes*).
Armyworm	**spodoptera exemptawalk.**	• Young plant may be completely defoliated	Use of recommended insecticides.
Eldana borer	**Eldana saccharina**	• It causes severe loss in cane quality	• The use of recommended insecticides. • Important natural control is achieved by predators such as ants, cockroaches, spiders

			and mites. • Plant varieties that have been proven less susceptible to Eldana, • Field hygiene is important. Remove whole stalks from the field and leave no stubble. • At harvest, burn heavily infested and drought stressed cane. • Reduce other stress factors such as poor drainage and weed competition, which can also induce an increase in Eldana.

(iii) Pests of pyrethrum

Pests	**Pathogen/ cause**	**Symptoms**	**Control measures**
Chrysanthemum aphids (*Macrosiphoniella sanborni*) and other aphid species are pests on chrysanthemums.	*Macrosiphoniella sanborni*	✓ Distorted growth, stunting and sometimes death of the entire plant. ✓ Unsightly, dark fungal growth.	✓ Applying a forceful spray of water to the plants every 2 days, especially to the undersides of leaves. Continue as needed, but at least 3 times. ✓ Several naturally occurring enemies feed on aphids. ✓ Spray with one of the following materials: insecticidal soap, horticultural oil, acephate, malathion, cyfluthrin,

			permethrin, or bifenthrin.
Two-Spotted Spider Mites (*Tetranychus urtica*) and other mite species are pests of chrysanthemums.	*Tetranychus urtica*	With a light infestation, leaves develop stipples (tiny yellow spots) and appear dusty. Early damage is often overlooked until damage is more severe. With heavier infestations, symptoms include distorted leaves, and withered and discolored blooms. In addition, fine webbing can be seen on flower buds, between stems and on the undersides of leaves.	Destroying severely infested plants or portions of plants. Spraying plants forcefully with water. Repeat as needed, but at least 3 times. Insecticidal soap, if started early in the infestation, is effective at controlling spider mites. Stronger miticides are tau-fluvalinate and bifenthrin.
Chrysanthemum Leafminer	*Phytomyza syngenesiae*	The larvae hatch and penetrate the surface to enter the leaf and live between the upper and lower surfaces of the leaves. As they move through the leaf feeding, they create winding trails that are pale green to brown in color. Dots of black waste products are visible in some of the trails. Severely infested leaves may dry up and droop downward along the stems.	Prune off and destroy infested leaves. Any leaves that fall to the ground should be picked up and destroyed. Remove and destroy any plant remains in the fall. If damage is severe, spray with a foliar systemic insecticide, such as acephate or spinosad.

Foliar Nematodes	*Aphelenchoides ritzema-bosi*	• Hardy chrysanthemums that develop yellow-brown spots starting on the lower leaves and gradually moving up the stems may be infested with foliar nematodes. • Yellow-brown spots on the leaves eventually run together and cover the entire leaf, which dies, turns brittle, and falls. Severe infestations can kill entire plants. Foliar nematodes are easily confused with leaf spot (see above), but fungal leaf spots are most often black, not brown. They additionally infest hosta and ferns.	Remove infested plant material, along with the surrounding soil. Mulch plants in the spring to discourage nematodes from climbing up from the soil, and avoid spraying water on the leaves when watering. Foliar sprays with insecticidal soap may help reduce nematode populations.

- **Content /Topic3 : Types of diseases of industrial crops**

(i) Diseases of coffee

Disease	Type and causal agent	Symptoms	Control

Coffee leaf rust	Fungal disease (*Hemileia vastatrix*)	✓ Yellow spots appeared on the leaves, enlarging rapidly into orange lesions occasionally the whole leaf becomes covered with rust spots. ✓ Orange fungal spores are formed on the underside of leaves ✓ Leaf drop occurs, which if severe, can lead to dieback and berry loss and a loss of both yield and quality. ✓ Berries tend to be very small, not fully ripe and turn black.	✓ Open pruning ✓ Spraying with copper fungicides, Dithane M_{45} or orthodifolatan ✓ Regular weeding ✓ Monthly copper sprays (May to October).
Coffee berry disease	Fungal disease (*Colletotrichum coffeanum.*)	✓ Twig dieback: yellowing and blight of affected leaves. Twigs wilt, defoliate and die at the tips. ✓ Dark brown blotches appear on the flowers ✓ Brown blight :Small dark sunken patches appear on green and ripe berries; turn black and hard	✓ Spray with copper fungicides such as, Benlate and Captafol ✓ Use resistant varieties
		Leaf necrosis: Leaves have brown patches circular in nature on the margins.	

Coffee wilt disease (Tracheomycosis)	Fungal disease(***Gibberella xylariodes)***	➢ It makes the plant die from top downwards by drying. ➢ It attacks the phloem tissues killing the plant systematically and is capable of wiping out the entire plantation.	✓ Uproot and burn affected plants. ✓ Disinfect pruning tools used ✓ Limit transportation of planting material from affected areas. ✓ Avoid using coffee husks as mulch in coffee gardens ✓ Plant varieties which are resistant.
Dieback.	➢ Insufficient nutrition. ➢ Insufficient shade. ➢ Insufficient irrigation.	➢ Cherries ripen prematurely and become hard and black. ➢ Dieback causes alternating bearing (heavy crop one year and poor crop the next). ➢ Plants decline and eventually die if the problem is not corrected in early stages. ➢ If there are too many cherries and not enough leaves, all the	➢ Maintain good plant health. ➢ Maintain good shade (50%). ➢ Use a wellbalanced fertilizer program and apply adequate nitrogen and potassium as recommended earlier.

		food goes from the leaf to the developing cherry. Leaves then drop off, causing dieback. - Plant health decline continues and if plants are not well cared for with adequate watering and nutrients; the plants will succumb and die.	

(ii) Diseases of tea

Pests/Disease	Type and scientific name	Damages	Control
Caspids	**(*Heloptis bergrothi* and *H. schoutedeni*)** Sucking pests which damage the buds	Sucking pests which damage the buds	Spray with Fenithrothion
Red crevice mite	**(*Brevipalpus pHoenicis)***	➢ An eight legged arthropod with sucking mouth parts. ➢ It pierces leaves from underneath creating patches. Leaves fall prematurely.	- Spray with chlorobenzilate, Dicofol or Dinocarp
Yellow tea mite	**(*Hemitarsonemus latus)***	➢ It sucks sap from young leaves making them disfigured and curling inwards. ➢ The main veins have developing corky patches in between .This is seen on the lower epidermis.	- Spray with chlorobenzilate,Dicofol or Dinocarp
Black tea thrips	**(*Heliothrips haemorrhoidalis)***	- Sucking pests whose effect causes silver patches with black spots	- Spray with Fenithrothion.

		on the underside of mature leaves. - The attack is severe in dry conditions	
Armillaria root rot	**Fungal disease(*Armillaria mellea)***	- It attacks roots and causes rotting and death of the tea bush.	✓ Remove all tree stumps ✓ Destroy affected bushes by uprooting and burning.

(iii) **Diseases of sugar cane**

Disease/Pest	**Type and causal agent**	**Symptoms**	**Control**
Gumming diseases	Bacterial diseases (Xanthomonas vasculorum)	✓ Yellow translucent stripe on leaf tips ✓ Vascular bundles in the stem become red and produce a yellow gum when cut.	Use resistant varieties
Leaf scald	Bacterial diseases (Xanthomonas albilineans)	✓ Thin, pale, yellow stripes appeared along the leaf blade, going up to the leaf sheath. ✓ Vascular bundles become red and numerous small tillers are produced.	Breeding resistant varieties
Pineapple disease	Fungal disease (Theilaviopsis paradoxa)	It attacks setts making them black at the centre giving them a smell of over-ripe pineapples.	Disinfect setts before planting.
Down mildew	Fungal disease	It attacks tillers.	
	(Sclerospora sacchari)		

Ratoon stunting disease	**Viral disease (RSD)**	✓ **It c**auses retarded growth of canes in the ratoon stage. ✓ Vascular bundles become orangered and growing points turn pink.	Hot water treatment of setts at 50^{o}c for 2hours and sterilizing knives for cutting setts.
Chlorotic streak	Viral disease	**Yellow** stripes on young leaves accompanied by necrosis (dead tissues).	Use „"clean „"setts or hot water treatment for 30minutes at 50^{o}c
Sugar cane stalk borer	**(Diatraea sacchari)**	✓ A large moth whose eggs hatch into larva that bores the cane. ✓ The cane becomes hard, loses sweetness at the affected internodes, tillers die and stem becomes weak. ✓ Pupation occurs inside the stem and leaves a very thin layer to make it easy for the moth to break and fly out.	Biological control has proved very effective using the Red fire ant (*Solenopsis invita*) and a wasp from India (*cotesia flavipes*).

(iv). Diseases of pyrethrum

Disease	**Symptoms**	**Pathogen/Cause**	**Management**

Disease	Symptoms	Pathogen/Cause	Management
Ascochyta Ray Blight	Flower development is retarded on one side of the bud. Petals exhibit a brown discoloration. Browning and blackening extends down the stem, causing the flower to droop. Brown to black irregularly shaped spots develop on leaves.	*Ascochyta (Mycosphaerella)*	Avoid overhead irrigation. Apply a fungicide to protect healthy plants.
Alternaria or Stemphylium Ray Speck	Pin-point dead spots develop on petals. These spots may not enlarge. If enough spots are present, the entire flower dies.	*Alternaria or Stemphylium*	Avoid overhead irrigation. Maintain greenhouse humidity below 98%. Apply a fungicide to protect healthy plants.
Bacterial Blight	Cuttings turn dark brown and collapse. Surviving cuttings may be infected but have no symptoms. Established plants wilt during the day when infected and recover at night.	*Erwinia chrysanthemi*	Purchase culture-indexed cuttings that are free of the pathogen. Disinfect propagation beds between crops. Destroy infected cuttings.
Bacterial Leaf Spot	Small dark brown to black spots on lower leaves enlarge and become irregular in shape. When infected leaves dry, the spots become brittle and crack. The disease often spreads up plants in one side of the pot, eventually to the flowers.	*Pseudomonas cichorii*	Do not plant infected cuttings. Avoid overhead irrigation. Water in a manner that keeps leaf surfaces dry at all times. Protect plants grown outdoors from splashing.

Disease	Symptoms	Pathogen/Cause	Management
Botrytis Blight	Light brown spots form on lower petals. Browning spreads to other petals. Infected tissues become covered with dusty gray spores.	*Botrytis cinerea*	Maintain greenhouse humidity below 98% at all times. Apply a fungicide to protect healthy plants.
Chlorotic Mottle	Leaves, at first mottled, become completely yellow. Infected plants grown under low light conditions and when temperatures average less than 20° C (69° F) exhibit no symptoms.	*Chrysanthemum chlorotic mottle viroid*	Purchase virus-indexed plants that are free of the pathogen. Destroy infected plants and disinfest tools used to handle them. Do not handle healthy chrysanthemums after handling infected plants.
Fusarium Wilt	Symptoms vary with the cultivar infected. Yellowing of leaves, wilting, and discoloration of the vascular tissue develops up one side of the plant.	*Fusarium oxysporum*	Management: Purchase culture-indexed cuttings free of the pathogen. Plant in pasteurized soil or soilless mix free of the pathogen. Maintain soil pH between 6.5 and 7.0. Use nitrate rather than ammonium forms of fertilizer. Apply a fungicide to protect healthy plants.
Powdery Mildew	Leaves have white, dry fungal growth on their surfaces.	*Golovinomyces cichoracearum (formerly Erysiphe)*	Apply a fungicide to protect healthy plants.
Pythium Root and Stem Rot	Stems turn dark brown to black at the soil line. Plants are stunted, wilt, and die.	*Pythium*	Plant in pasteurized soil or soilless mix free of the pathogen. Apply a fungicide to protect healthy plants.

Disease	Symptoms	Pathogen/Cause	Management
Rhizoctonia Stem Rot	Young infected plants wilt during the day and recover at night. Reddish-brown dead areas develop at the soil line and girdle the plant.	*Rhizoctonia solani*	Plant in pasteurized soil or a soilless mix free of the pathogen. Apply a fungicide to protect healthy plants.
Rust, Brown	Dark brown masses of spores form in pustules on both leaf surfaces.	*Puccinia chrysanthemi*	Remove and destroy infected leaves. Apply a fungicide.
Rust, White	Small, yellow to tan spots are observed on the upper surface of leaves. On the underside of the leaf below the spots, raised, pinkish to white to cream-tan areas develop in which spores of the fungus are produced.	*Puccinia horiana*	Contact your state plant inspector and comply with regulations requiring the destruction of infected plants and fungicide treatment of remaining chrysanthemums.
Stunt	Symptoms vary with the cultivar infected. Young leaves are light green and very upright. Plants are stunted to half their normal height at maturity. Infected plants flower prematurely and flower size is reduced. Some cultivars exhibit small dead spots or flecks on the leaves.	*Chrysanthemum stunt viroid*	Purchase virus-indexed plants that are free of the pathogen. Destroy infected plants and disinfest tools used to handle them. Do not handle healthy chrysanthemums after handling infected plants.
Verticillium Wilt	The margins of lower leaves wilt and die. Or, the entire leaf dies. Symptoms proceed up one side of the	*Verticillium*	Plant in pasteurized soil or soilless mix free of the pathogen.

Disease	Symptoms	Pathogen/Cause	Management
	plant.		

LEARNING UNIT 3 – Harvest industrial crops

LO 3.1 – Identify maturity signs according to the type of crop

- Content/Topic 1 : **Differentiation of base period for industrial crops.**

(i) **Maturity stage of pyrethrum crop**

Flower picking can be done every **two or three weeks**.

It is advisable that flowers are picked when **the ray florets have opened to horizontal position** and approximately **three rows of the disc florets are open**.

Flowers with all the disc florets open and those at the early overblown stage should also be picked as they still contain appreciable amounts of pyrethrins.

Young flowers contain little pyrethrins and if picked in large quantities will lower the pyrethrins content.

Flowers picked with excessive moisture are liable to ferment resulting in losses of pyrethrins. It is recommended, therefore, that growers allow dew and rain water to fall off before picking.

Avoid picking flowers with flower stalks because stalks have little pyrethrins and therefore cause reduction in pyrethrins content of the flowers.

The best picking is achieved by holding the flower between the first and the second finger and jerking the flower head with the thumb.

(ii) Maturity stage of Sugar cane crop

The maturity of sugarcane depends upon following factors:

- Temperature during the growth period
- Time of planting
- Variety
- Application of manures and fertilizers
- Irrigation

Criteria of harvesting of cane at right time

A) crop age

Harvesting is done based on maturity (age) group. Even most sugar factories give cutting orders to farmers based on crop age. This is not a scientific method since, planting time, crop management practices, and weather conditions etc influences maturity.

B) **Visual Symptoms**

Some of the visual indices of assessing maturity of cane:

- ✓ Yellowing and drying of leaves
- ✓ Metallic sound of mature canes when tapped
- ✓ Appearance of sugar crystal glistening when a mature cane is cut in a slanting way and held against the sun

C) Quality Parameters

Important sugarcane quality parameters for assessing cane maturity are the juice Brix, pol or sucrose percentage and purity.

(iii) maturity stage of tea crop

Plucking stage is attained when tea plant is of 3 to 4 years old. However, plucking stage under ideal management conditions is attained in 18 to 20 months stage.

Young leaves with more of tannins and polyphenols produces better quality tea than old leaves with less tannin content. Maximum yields (stable/economical stage of yield) are obtained in 6th or 7th year and there after the yields remains constant.

It is clear that, plucking of the terminal bud only or with terminal bud with I leaf gives excellent quality tea. Bud is usually plucked with I and II leaves.

(i.e., Best plucking is two leaves and a bud)

Type of shoot/ Leaves/Bud	Tannin (%)
Bud	25
I leaf	28
II leaf	21
III leaf	14

Stalk between II leaf and bud	12
Stalk between II and IV leaf	6

(iv) Maturity stage of coffee

On average it takes about 5 years for the **coffee** bush to reach **maturity**

- Content/Topic 1 : **Maturity signs for industrial crops (color, dimension/size, flowering)**

Crop	**Maturity signs**
Coffee	Red Color
Tea	Two and a bud
Sugarcane	Dimension/size
Pyrethrum	Flowering

Maturity signs of coffee

When a **coffee** tree reaches **maturity**, which can take from 4 - 7 years, it begins to bear fruit in clusters along its branches. Referred to as cherries, the fruit is initially green and turns red when it is ready for harvesting.

vi. Maturity signs of tea

Kinds of plucking depending on the extent of maturity of shoots

1. Young leaves with more tannin and polyphenol content produces superior quality tea. Two and a bud: plucking of terminal bud and two most recently opened/expanded leaves. Two leaves and a bud are considered as one plucking unit. Two and a bud are called fish leaf or Janam flucking
2. Fine tea: Anything less than two and a bud. It is also known as fish or janam plucking. Young leaves will produce superor quality tea.
3. Coarse tea: Anything more than two and a bud. Older leaves will produce coarse quality tea.
4. Light plucking or light pruning: Carried out during initial years to encourage side branches and to make the bush full with tender branches.
5. Too tender shoot/One leaf and a bud: Produces very good quality tea but yield goes down drastically.

- **Time of plucking**

Better quality tea is obtained from the shoots plucked in the morning than in the evening hours.

Morning: More soluble proteins are present and produce good quality tea.

Afternoon: Insoluble proteins will be increased

Night: Break down of amino acids and formation of amino acids

vii. **Maturity Signs of Sugarcane**

- ✓ General yellowish color of the whole crop.
- ✓ Cessation of growth and emergence of flowers in case of flowering varieties.
- ✓ Swelling of eye buds.
- ✓ Metallic sound of cane when tapped with finger nail.
- ✓ Breaking of cane at node region.
- ✓ Sweetness of juice.

viii. Maturity sign of pyrethrum

Flower picking could be done every 2-3 weeks under rainfed condition but might also be done every 3 days if the field is under irrigation. It is advisable that flowers are picked when the ray florets have opened to horizontal position and approximately 2-3 rows of the disc florets are open.

Flowers with all the disc florets open and those at early overblown stage should also be picked as they still contain appreciable amount of pyrethrins but in a separate container. Young flowers contain little pyrethrins and if picked in large quantities will lower the pyrethrins content to be obtained from the total dry flower yield.

Flowers picked with excessive moisture are liable to ferment resulting in losses of pyrethrins. It is recommended, therefore, that growers allow dew and rain water to fall off before picking. It is also important to avoid picking flowers with flower stalks, because stalks have little pyrethrins and therefore cause reduction in pyrethrins content of the flowers.

Holding the flower between the first and the second finger and jerking the flower head with the thumb so that no extra flower stalk included is found to be the best picking.

- **Content /Topic3 : Types of maturity for industrial crops**
  - **Physiological Maturity**

1. In a physiological sense, maturity refers to the attainment of final stage of biological function by a plant part of plant as a whole.

2. It is the stage of development of any plant organ at its maximum size and growth.

3. The physiological maturity is judged of measure by rate of respiration and sugar: acid ratio.

4. It always followed by senescence.

However, *physiological maturity* needs to be distinguished from *commercial maturity*. The former is reached when development is over. It may or may not be followed by the ripening process to achieve the commercial maturity required by the market. Every industrial shows one or more apparent signs when it reaches physiological maturity. Commercial maturity is reached well before the end of development.

- **Commercial maturity**

It is the state of plant organ required by a market. It commonly bears little relation to Physiological maturity and may occur at any stage during development stage.

LO 3.2 – Select harvesting methods and techniques according to the standards and crop types

- **Content/Topic 1 : Identification of different parts to be harvested on industrial crops.**

Crop	**Parts to be harvested**
Coffee	Fruits
Tea	Leaves
Sugarcane	Stem
Pyrethrum	Flower

- **Content/Topic 2 : Harvesting techniques on industrial crops.**

(i) Coffee harvesting

The two methods of harvesting coffee are selective harvesting and strip harvesting**.**

a. Selective harvesting:

✓ Selective harvesting is **the picking of only ripe coffee fruit by hand.**

✓ Unripe coffee is left on the tree for future harvesting.

✓ Overripe coffee can either be left on the tree (not recommended) or picked and kept separate from the ripe fruit (recommended).

✓ After several weeks the picker will go back and again pick only ripe fruit.

✓ This process is repeated until the producer determines that it is no longer worthwhile to harvest.

➢ **Advantages of Selective Harvesting**

Only ripe fruit are picked, resulting in a lower percentage of unripe in the harvested coffee and higher prices for producers.

Because the coffee is picked by hand, the trees can be planted on steep slopes that are common to the topography of many coffee regions, resulting in more efficient use of farm land.

- **Disadvantages of Selective Harvesting**

Hand picking requires a large rural labor force willing to work for minimal pay.

As wages increase, producers are less able to afford the labor cost of selective harvesting.

b. Strip Harvesting

The alternative to selective harvesting is strip harvesting.

Here all coffee fruit are mechanically "stripped" from the coffee tree at once, resulting in harvested lots of varying maturation levels.

There are three common ways that coffee is strip harvested:

- **Manual Stripping**

- In the first method, pickers place a canvas on the ground.
- They then grab the branch next to the trunk with their hands and pull outward, knocking all of the fruit onto the ground.
- After doing this with all branches and trees for the length of the canvas, the pickers then collect the coffee in bags and take it to be weighed.

- **Mechanical Stripping**

- The second strip harvesting method is similar to the first but with some mechanical assistance.
- Here pickers use mechanical strippers.
- As with the previous method, the pickers first put down a canvas.
- They then use the mechanical strippers to knock all of the coffee onto the canvas.
- The accumulated coffee is then put into bags

- **Mechanical Harvesters**

- The third way to strip harvest coffee is with a mechanical harvester.
- These machines, first introduced in the early 1970s, use vibrating and rotating mallets to knock the coffee fruit off the tree into collection units.

- They can be calibrated to minimize the yield of unripes by adjusting rotation and vibration rates as well as the speed at which the mechanical harvester moves through the rows.
- Another common technique is to remove the bottom mallets at the beginning of the harvest since the coffee on the top of the tree normally ripens more quickly.

- **Advantages of Strip Harvesting**

- Strip harvesting requires far less labor to complete.

- Harvesting can be completed more quickly.

- **Disadvantages of strip Harvesting**

Strip harvesting produces lots of various levels of maturation, which, if not separated, can lead to disuniform drying and lower quality product.

Note: To achieve optimal quality, coffee producers must have adequate post- harvest technologies such as pulpers and optical sorters. The heterogeneous lots produced by strip harvesting result in higher percentages of unripes, which reduce the quality and sale value of the final product, meaning less profit for producers.

(ii) **Pyrethrum harvesting**

Flowers picked with excessive moisture are liable to ferment resulting in losses of pyrethrins. It is recommended, therefore, that growers allow dew and rain water to fall off before picking.

Pick flowers once in **2-3weeks** when ray florets are horizontal and about rows of disc florets are open. Harvest once the daisies are in full bloom as this is when the concentration of pyrethrins is at its peak. The pyrethrum plant is cultivated for the production of pyrethrins.92% of all pyrethrins is found in the flowers. The amount of pyrethrins concentration in the flower is determined by genotype and the environment (altitude, temperature).The flowers develop through 8stages from the bud to the seed stage.

The right stage to pick pyrethrum is when the ray florets are horizontal and the disc florets are open.

Avoid picking flowers with flower stalks because stalks have little pyrethrins and therefore cause reduction in **pyrethrins** content of the flowers.

Do not pick flowers under rainy conditions to avoid fermentation that leads to low pyrethrin concentration.

The best picking is achieved by **holding the flower between the first and the second finger and jerking the flower head with the thumb.**

The picking interval is between 2-3weeks and will have attained maximum pyrethrins content. Young immature flowers contain low pyrethrins concentration, which increases from the bud stage up to when its disc florets are open, and then decline gradually. Flower harvesting is selectively done by hand, and flowers dried and delivered to the factory for processing.

(iii) **Tea harvesting**

Tea is harvested by plucking the tips of young shoots by hand (two leaves and a bud).This should be done carefully to maintain the plucking table. Traditionally, a stick always placed in front of the plucker to show the height of the table.

Harvested leaves should not be compressed as it initiates fermentation before time and reduces the quality. The harvest is weighed and kept in shade till they are taken for each tea bush is plucked once **every 5 to 7 days in the flush season** and once in **10days during the slower growth periods**. When a shoot has had five shoots harvested, it goes into a dormancy stage called „"**Banjhi**"". Plucking at this stage should include one leaf and a bud. The process of tea harvesting is continuous once the crop reaches maturity.

Yield: **1-2tones/ha**

Procedure

- ✓ Get big enough and suitable containers
- ✓ Pick the two fresh leaves that form a fork and put them in the containers. Do not compress
- ✓ When the container is full, take it for weighing, place the harvested leaves under a shade to avoid loss of moisture from them.
- ✓ Load into open and well aerated vehicles to keep the leaves fresh.

Precaution

- ✓ For good quality, harvest only the two fresh tender leaves.
- ✓ Harvest in the morning when it is cool to avoid heat from overhead sun
- ✓ Keep harvested leaves under a cool shade.
- ✓ Transport in a well aerated vehicles to the processing plant on the day of harvest.

(iv) Sugar cane harvesting

Harvesting of sugarcane at a proper time i.e. peak maturity, by adopting right technique is necessary to realize maximum weight of the mill able canes (thus sugar) produced with least possible field losses under the given growing environment.

Harvesting either **under-aged or over-aged cane** with improper method of harvesting leads to loss in cane yield, sugar recovery, poor juice quality and problems in milling due to extraneous matter.

Proper harvesting should ensure:

- To harvest the cane at peak maturity (i.e. avoiding cutting of either over-matured or under-matured cane)
- Cutting cane to ground level so that the bottom sugar rich internodes are harvested which add to yield and sugar
- De-topping at appropriate height so that the top immature internodes are eliminated
- Proper cleaning of the cane i.e., removing the extraneous matter such as leaves, trash, roots etc.
- Quick disposal of the harvested cane to factory

The planted crop matures after **14 to 18 months** while Rattoon crop matures after **12months**.

Manual Harvesting

Hand knives, cutting blade or hand axes are used for manual harvesting. It requires skilled laborers as improper harvest of cane leads to loss of cane and sugar yield, poor juice quality and problems in milling due to extraneous matter.

Improved harvesting techniques:

1. Cutting: Canes cut close to the base
2. Topping: Top or cut the upper portion of the stalk for planting material
3. Hauling: Are excluded because no sugar affect milling operations
4. Milling: Canes milled after harvesting or within 48hours.When delay, loss of sugar.

- **Content /Topic3 : Frequency of harvesting (Period)**

Crop	Harvesting period
Coffee	Harvesting coffee cherries from April to September
Tea	Once every 5 to 7 days in the flush season and once in 10days during the slower growth periods.
Sugarcane	December to March is the period of harvesting
Pyrethrum	The picking interval is between 2-3weeks

LO 3.3 – Perform pre-processing operations of raw materials according to requirements

- Content/Topic 1 : Techniques of industrial products handling

(I) Handling techniques of tea leaves

The rule of **two leaves and the bud"**is strictly followed.

1) **Reception of leaves**

Weigh and unload leaves on dry floor put into concaves netted bags.

The plucked leaves are examined on the collection point and weighed before the actual processing starts which are divided into five separate processes:

2) **Withering**

Here, the thick and still malleable leaf is rid of approximately 30% of its humidity. There are two methods:

a) The natural withering where the leaves are spread out on laths which are covered with jute, wire or nylon nets. The withering time takes depending on the weather and humidity content of the leaves, between 14-18 hours.

b) The modern withering in large troughs of a length of 25-30 meters which are covered with wire grids and are ventilated with large ventilators. These can also be used to warm the leaves, should it be necessary, to reduce the withering time to **8-12 hours.**

3) Rolling

With the help of press spindles or rollers where the still green leaves are cut open and the released cell fluid reacts with the oxygen in the air (= oxidation similar to that of a bitten into apple).

This process takes **30 minutes** each and is repeated **3 times**. The damp and lumpy, now dark green leaves are scattered with the help of a shaking or sieving machine.

CTC - Method (= Crushing – Tearing – Curling)

Once rolled for **30 minutes**, the entire leaves are torn in specially constructed thorn drums. The stems and leaf ribs are separated as far as possible and only the torn "meat" of the leaves is processed further. This simple processing gives much higher yields compared to the classical production method.

4) Fermentation

This oxidation and fermentation process already starts with the rolling. The leaves are spread out on large boards in 10-15 cm thick layers in a special room with a room temperature of **40°C** for 2/3 hours and additionally sprinkled with water. Thereby, the leaf takes up its copper-red to brown color and starts to unfold its unique aroma which can be found again, when the tea is infused. The correct fermentation is very important for the final quality of the tea.

5) Drying

On the high point of the fermentation, the leaves are transported through so-called tiered dryers on metal conveyor belts. The tea is dried for approximately **20 minutes** with hot air of **80-90°C** which makes the cell fluid stick to the leaves and gives it its dark brown to black color. The final humidity of the leaves is between **5-6%.**

6) Sieving/Sorting

The finished tea is then sorted into common grades via mechanical jarring sieves.

First line (Grades: PF1 (Pekoe Fanning1), PF (Pekoe Fanning), PD (Pekoe Dust) and BP (Broken Pekoe1))

Second line (BP (Broken Pekoe), F (Fanning), BMF (Broken Mixed Fannings))

7) **Packaging** (containers (45, 50, 55 and 60kg)

8) **Quality control** (by tea makers)

Handling techniques of tea leaves

Handling techniques of tea leaves are the following :

- ✓ Packaging
- ✓ Loading
- ✓ Weighing
- ✓ Quality analysis

Based on different types of processing techniques, tea can be classified into four:

a) Green Tea or Unfermented Tea

b) Oolong Tea ·or Semi fermented Tea ·

c) Instant Tea

d) Black Tea or Fermented Tea

a) Green Tea

A brew made from green tea is similar to the one prepared from dried tea leaves in taste and composition. The objective is to destroy the enzymes in the tea leaf as soon as it is plucked, thus preventing fermentation all together.

b) Oolong Tea

It is an intermediate type of made tea between green and black tea. While the latching process is the same as that of green, Oolongs are allowed to ferment while green are not. The oolong tea has the colours and appearances of black tea but it has flavour and taste of green tea.

c) Instant Tea

It is a ready-to-drink beverage just like instant coffee. The basic objective in the manufacture of instant tea is to extract the water soluble solids from a pure tea brew, and convert them into a powdery form.

d) Black Tea

The basic objective of black tea making is to condition green leaf for fermentation, and when that has been achieved, arrest the fermenting process through application of heat. Thus heat is to be applied at a much later stage than that of green tea manufacture.

The basic operations involved in black tea manufacturing are:

a) Withering,

b) Rolling,

c) Fermenting,

d) Drying

e) Sorting into leaf and broken grades, i.e. Sizes.

a. Withering

The withering reduces approximately 30% of the humidity content of the leaf within a time of 12 - 18 hours.

b. Rolling

Subsequently, the withering green leaves are rolled in large rolling machines. The leaves are moved across a slowly rotating screw conveyor through a cylinder into which oxygen is introduced in order to accelerate the fermentation.

c. Fermentation

During the fermentation - which takes 2 - 3 hours - the leaves change their colour, which gradually becomes a copper-red.

d. Drying

The fermentation is finished when the desired grade of fermentation is reached, i. e. as soon as the tea has developed its typical smell and the copper-red colour is dried.

e. Sorting

The black tea, which is released by the dryer, is the so-called raw tea, which is now sieved via a number of shaking, mechanical sieves with varying sieve sizes with which the common leaf grades are separated from each other.

(ii) Handling techniques of Sugarcane

- ✓ **Grinding**

The stems are crushed and shredded by rollers in a process called grinding. During grinding, hot water is sprayed over the shredded material to extract the remaining sugar.

- ✓ **Storage**

Raw sugar is stored at bulk sugar terminals before being sent to refineries. Blakes Loops is typical of a storage yard close to the mills. The mills have full and empty bin yards as well as holding yards for storage. Dome technology can be used for sugar bulk storage.

- ✓ **Transport**

Sugarcane is transported from the field to an open area or siding by a tractordrawn self-loading trailer. Most sugarcane are transported by road to the mills in specialised trailers hauled by tractors or heavy road lorries and trucks or by rail. Transport used should be thoroughly cleaned before use, in order to minimise the risk of re-infection with diseases. Bulk sugar is transported from the mills in containers by road or rail to the terminals, where it is carried by conveyor belts into the storage shed. When a ship arrives it is filled quickly via conveyors.

(iii) **Handling techniques of pyrethrum flowers**

The ideal method of drying flowers, where small scale production is concerned is by **sun drying**. It is less costly and entails no significant loss of pyrethrins. However, in cloudy weather or when large quantities of flowers need to be dried fast, artificial drying may be employed.

Artificial methods of flower drying however pose a higher risk of causing losses of pyrethrins and require close attention and great care.

Where it is necessary to use mechanical dryer, extreme care should be taken to keep the drying air temperature in the dryer at a maximum of 50 C to avoid excessive loss of pyrethrins through overheating.

Pyrethrum flowers should be dried immediately after picking to avoid any fermentation, a biological process that naturally breaks down pyrethrins. There are several methods of drying the flowers but sun drying is the most ideal where small scale production is concerned. However I predominant cloudy weather conditions or when large quantities of flowers need to be dried fast, artificial drying may be employed.

To ensure that pyrethrins in flowers do not deteriorate ensure that:

- Flowers are delivered immediately after drying.
- Prolonged flower storage leads to deterioration of pyrethrum
- Dry flowers are packed in well aerated gunny bags and delivered directly to the factory.
- Flowers are processed immediately it is received at the factory
- In case of temporary storage pack flowers in well aerated gunny bags and store them on wooden pallets and shielded from direct sun light and moisture.

Good quality dried flowers contain approximately 1.4% to 1.8% pyrethrins. Moisture content: 13% before transporting to the flower collection centers.

(iv) Handling techniques of coffee

There are two types of processing: dry processing and wet processing.

Dry processing

Berries are dried in the sun on cemented floor, mats, wire trays or tarpaulins. Berries should not come in contact with rain .When thoroughly dry, they are taken to a factory (hullery) to remove the skin and parchment.

Time: 15-25days.

The main limitation for dry processing is that, all stages of berries harvested be it green, ripe or dry look alike at the time of processing. This gives rise to poor quality beans or hard coffee when farmers include green berries. The quality of coffee however differs when at table. It is therefore best to use wet processing because all berries must be visibly ripe.

Wet processing

Berries are taken to a pulpery and ***pulped*** on the day of harvest to remove the red cover. This leaves the two beans covered in a parchment. The parchment has a mucilage coating which is slippery and insoluble in water.

The beans are **washed** with running water and any that float are removed .This helps to evade tainting the beans before fermentation .**Fermentation** is done in wooden boxes and it loosens the mucilage and the reaction is faster when temperatures are high. In Arabica growing areas, processing is done at lower altitudes where temperatures are higher.

After fermenting, beans are **washed**, dried on raised perforated trays, first under shade then in the sun after becoming skin dry. Rain should be avoided at this stage as it reduces the quality. When fully dry, they are taken to a **hullery** to remove the parchment. In both methods, **sorting** to remove broken, deformed, black beans should be done before putting the beans in bags.

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