



FEED THE FUTURE

The U.S. Government's Global Hunger & Food Security Initiative



AVOCADO PRODUCTION MANUAL

(PERSEA AMERICANA L.)

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Document developed and compiled by Feed the Future Mboga na Matunda (FTFT-MnM) project and its partners as a contribution to the avocado sector in Tanzania.

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I. INTRODUCTION

The Feed the Future Tanzania Mboga na Matunda Activity (FTFT-MnM) is a four-year initiative (January 2017-January 2021). The purpose of FTFT-MnM is to increase the productivity and profitability of horticulture value chains while integrating large numbers of women and youth, and improving the nutritional status of Tanzanians. The activity will achieve this by:

- Scaling improved technologies and practices that lead to increased productivity of women, men, and youth.
- Leveraging horticulture to improve family nutrition (e.g. expanding access to nutrient rich crops and utilization of profits for non-horticultural nutritious food items).
- Scaling market system models to empower value chain stakeholders and improve efficiencies and profitability.
- Strengthening the overall capacity of the horticulture subsector through investments along the value chain.

The geographic scope of FTFT-MnM encompasses 16 districts in the mainland, focusing on the Southern Agricultural Growth Corridor of Tanzania (SAGCOT) - Morogoro, Mbeya, Songwe, Iringa - and 10 districts in the Zanzibar Islands of Unguja and Pemba. The activity uses a value chain approach to ensure integrated development. Interventions encourage the development of business relations; efficient transactions; and adoption of innovations and good business practices throughout the value chain.

FTFT-MnM, in collaboration with other stakeholders in the avocado value chain in Tanzania, have prepared this Avocado Production manual, to help growers in Tanzania access the necessary information required for production, as well as for the export market. This manual contains several subject matters to consider, from land selection, seedling preparation and planting, site designing, harvest, and postharvest procedures required by the avocado market.

In Tanzania, avocado production is mainly found in the southern highland regions of Iringa, Mbeya and Songwe, as well as the northern regions of Kilimanjaro and Arusha. Smaller scale production is found in other regions like Kigoma, Rukwa and Ruvuma which target local regional markets. The purpose of this manual is to help all avocado farmers, input providers, and exporters of avocado throughout Tanzania.

2. BASIC CONCEPTS

In general, avocados require a high initial investment, technical assistance and the adoption of new technologies for planting, fertilization, phytosanitary control, pruning, harvest and postharvest handling.

2.1. ORIGIN AND DISTRIBUTION

An avocado is a tree fruit that originates in Mexico and Central America. Some archaeological research indicates that avocados were found in Mexico in 8000 B.C. and in Peru towards 3000-4000 B.C. The area of origin is not exactly known, given the existence of several wild populations. The Spanish name "aguacate" comes from the Aztec "ahuacatl" (FAO Production Yearbook).

2.2. AVOCADO RACES

2.2.1. Mexican avocado (*persea americana* var. *Drymifolia*)

The Mexican avocado originates in the valleys and high plateaus of central Mexico where the climate is subtropical and mild and the elevation is between 1,500 and 2,000 m.a.s.l. The Mexican avocado is resistant to cold weather, generally small, between 30 and 80 mm in length, weighs between 90 and 180 g, has a pyriform shape, thin skin, and a smooth exterior. Avocados are generally green, but can have purple or

black tonalities. Their flesh have a high fat content (10 to 25 percent) and a nutty taste when ripe. Their leaves are smaller than those of the other two types and have essential glands that smell like anise, which is noticeable when the leaves are squeezed. The seeds are small in size.

2.2.2. *Guatemalan avocado (Persea nubigena var. Guatemalis)*

The Guatemalan avocado originates in the western central region of Guatemala with an elevation of between 1,000 and 2,000 meters above sea level (MASL). It has thick skin and is resistant to transport. It is less resistant to cold weather than the Mexican avocado and its fruit is medium to large, 7.5 to 25 cm in length and weighs between 120 and 1500 g. The fruit is spherical, oval or pyriform in shape, the thickness of the epicarp is between 2 and 12 mm with a hard consistency, and its surface is brittle and sometimes grainy and its color ranges from opaque green to purple. The flesh is somewhat fibrous with a high fat content (18 to 20 percent). When ripe its taste varies from buttery to nutty. The seed is large and fills its cavity. The leaves are bigger than the Mexican avocado's leaves and they don't smell like anise.

2.2.3. *West Indian (Persea americana var. americana.)*

The West Indian avocado comes from the Pacific coast of Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama, from an elevation below 1,000 MASL. It is susceptible to cold weather, and resistant to salinity and chlorosis. The period it takes from flowering to the formation of fruit is fairly short. The peduncle is long and shaped like the top of a nail. The West Indian avocado is adapted to low elevation and high temperatures, its fruit is medium to large (7.5 to 25 cm in length), and can weigh between 110 gr. and 1,100 gr. The fruit can be oval or pyriform in shape, has thin skin, although stronger than the skin of the Mexican avocado. It is light green to reddish yellow, its flesh has a low fat content (5 to 15 %) and its flavor varies between watery/bland to buttery. The seed does not generally fill up its cavity.

The characteristics that set each race apart are the flowering stage, the harvesting period, the flowering-harvesting period, the weight and type of skin, the flesh's fat content and resistance to cold weather in both young and adult plants. Other characteristics to be taken into consideration are how the leaves smell (anise or no odor), shape of the peduncle, and type of flower group (A and B).

2.3. AVOCADO MORPHOLOGY

2.3.1. *Root system*

Roots are usually superficial. The main root is short and weak, like most tree species from environments with abundant water during the vegetative period (Calíbrese). The root system reaches depths of 1.0 – 1.5 meters, but in looser soils it can reach deeper. The root system has a horizontal growth pattern that is concentrated in the first 50 centimeters of soil. Since the roots do not have a lot of absorbent hairs, the water and nutrient absorption takes place in the primary tissues on the tips of the roots. This characteristic of avocados makes them susceptible to flooding because the plant can easily asphyxiate and become vulnerable to attacks by fungus. (Godínez et al.). For this reason, it should be planted in deep soils that do not have internal drainage problems or soil textures that contain too much clay.

2.3.2. *Trunk*

Avocados have woody, straight trunks that can grow as tall as 12 meters, although there are reports of trees that are 20 meters high with trunks that have a diameter of more than 1.5 meters (Godínez et al.). The bark has a cork like appearance, from smooth to cracked, and with a thickness of 30 millimeters. The woody tissue is a creamy color with wide vessels (Calíbrese). Trees that are under 5 meters in height make phytosanitary control, harvest and foliar fertilization practices easier.

Branches are abundant and thin, sensitive to sunburns and frost, fragile against the wind and an excess of production. For this reason, it is a recommended practice to plant dwarf varieties but also to select areas protected from the wind.

2.3.3. Leaves

Avocado leaves are simple, elliptical, alternate, whole, elliptic, elongated, peduncle, pinnately veined and petiolate. The epidermis is pubescent and when it reaches maturity, it becomes smooth with an intense green upper side. Some varieties have a short period of defoliation before flowering, which indicates adaptation to places that are not appropriate for this crop.



2.3.4. Flowers

The inflorescence is axillary and the flowers are hermaphrodites, symmetrical and are grouped by greenish yellow clusters. The flowers have both female and male organs, but they do not function at the same time, thus not allowing for self- pollination. For this reason, varieties are classified based on their behavior as either type A or B (Pérez Rivera). See figure 1. For both types they open first as female, close for a fixed period and open again as male. This characteristic of avocado leaves is a very important consideration when planting in order to obtain the desired production volume. Varieties that are adapted to the same altitude and that are type A and B in a proportion of 4:1 should be mixed, where the highest population planted is that of the desired variety. Each tree can produce up to a million flowers and only 0.1 percent of those will produce fruit due to flower abscission and abortion of small fruit.



Figure # 1. Classification of avocado varieties based on type of flower.

Variety	Type of flower
Booth 7	B
Booth 8	B
Choquette	A
Hall	B
Simmonds	A
Fuerte	B
Hass	A
Nabal	B
Guatemala	B
Ettinger	B

2.3.5. Fruit

The fruit is a fleshy pear-shaped drupe, ovoid, globular or elongated with smooth or rough skin. Fruit color varies from light to dark green and violet to black depending on the variety and ripeness, which takes place when the fruit is picked from the tree. The flowering and ripening periods are cultivar-specific. For the West Indian race, this period lasts 5-8 months, for the Guatemalan 10-15 months, and for the Mexican 6-8 months. These features and others, such as the structure and consistency of the skin and

flesh, are determined by the race and variety grown. Fruits with tough skin withstand transport and handling.

2.3.6. Seed

The seeds of the West Indian race have a medium to thick membranous cover. In other races, this layer is thin. The endocarp or seed is important in terms of the fruit/seed ratio, with larger flesh ratios and a medium to small seed being the ideal.

2.4. PHENOLOGICAL GROWTH STAGES OF AVOCADO

Avocados have characteristic phenological behavior where flowering, fruit ripening, vegetative sprouting, and dormancy overlap, shorten or lengthen due to climatic conditions, management, and high genetic variability (Téliz et al). An example of phenological phases, such as flowering and fruit ripening, are shown in Table 2 for avocado Hass in Tanzania.

Table 2. Flowering and fruiting season of avocado Hass

Variety	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan
Hass			Normal flowering									Brief flowering
		High harvest season										Short harvest season

Data provided are based on Mbeya Region production pattern.

2.5. NUTRITIONAL IMPORTANCE

Avocados have important nutritional and medicinal properties due to their high oil (12 – 30 %) and protein (1.5 - 2.5 %) content. They also contain carbohydrates, vitamins, and minerals (see Tables 3). For these reasons they have great potential for an increase in human consumption. Currently, avocados are starting to be grown at an industrial scale to produce food, oils and pharmacological products.

According to Rodríguez Suppo, a 100g avocado flesh sample contains on average 15.6 g fat, 1.6 g protein, 4.8 g carbohydrates, 24 mg calcium, 47 mg phosphorus, 0.53 mg iron, 0.09 mg thiamine, 0.14 mg riboflavin, 1.19 mg niacin, 14 mg ascorbic acid, and 152 calories. In addition, adding avocados to our diet helps reduce cholesterol levels.

Table 3. Analysis of the contents of 100 grams of Hass avocado flesh.

Element	Amount (mg)	Element	Amount (g)
Calcium	24	Fiber	0.4
Iron	0.5	Carbohydrates	5.9
Zinc	0.42	Protein	1.8
Magnesium	45	Total fat	18.4
Sodium	4.0		
Potassium	604		

Source: Téliz et al. and Calabrese.

3. AGRO-ECOLOGICAL REQUIREMENTS FOR AVOCADOS

3.1. CLIMATE

The interaction of climate factors makes growing avocados feasible. Climate requirements for growing commercial varieties of avocados are described below.

Despite its tropical origin, avocado plants and plantations can be found at a latitude of up to 43° (Gaillard, op. cit.). This wide adaptation can be explained mainly by their genetic diversity, broadly outlined in its three horticultural races. The West Indian race prefers equatorial areas and is useful in the sub-tropics only as stock in high-salinity conditions, the Mexican race withstands temperatures down to -7°C for a few hours, and the Guatemalan race is in between these two. Almost all the sub-tropical commercial varieties are Mexican, Guatemalan or hybrids of these two races. Hass avocados prefer areas with well-defined dry periods.

3.1.1. Temperature

For West Indian varieties, ideal conditions include temperatures around $25 - 30^{\circ}\text{C}$ during the day and night temperatures around $15 - 20^{\circ}\text{C}$. Temperatures above 36°C cause severe damage, particularly during pollination and fruit-setting. A cool period (around 10°C) in winter is necessary to encourage floral induction. Springs and summers that are not too hot may lengthen the fruiting phase in some late cultivars, extending the harvest.

In general, frost-free areas should be chosen to grow Hass avocados as this factor has a direct incidence on the length of the flower-to-fruit period, which increases as temperatures fall. In cool areas, this period lasts up to 10-14 months, while in warm areas it lasts 5-8 months. This variety is sensitive to severe frost and excessive heat, mainly during the flowering and fruiting seasons. Ideal conditions for this variety include mean annual temperatures of 14 to 24°C with day temperatures ranging from 20 to 30°C and night temperatures from 10 to 20°C , allowing the fruit to remain longer on the tree and extending the harvest.

In terms of temperature, the varieties behave according to the parent race; the West Indian race is not very resistant to cold weather, as opposed to the Guatemalan or Mexican races.

3.1.2. Sunlight

Avocado branches that are in shade are unproductive, making it very important to prune appropriately and control plant density. Full sun exposure is highly beneficial for the crop; however, the stem and primary branches are susceptible to sunscald (Bárcenas).

3.1.3. Relative Humidity

In terms of relative humidity, the requirements for avocados are around 75-80 percent in order to get better seedling take and flower setting. Excessive humidity may cause algae or lichens to grow on the stem, branches and leaves, or fungal diseases to affect the foliage, as well as flowering and fruit development. An excessively dry environment causes pollen death with detrimental effects on fecundation and thus decreased fruit formation.

3.1.4. Rainfall

Avocados need from 1,000 to 2,000 millimeters of rainfall throughout the year. The Hass variety requires an annual rainfall of 1,200 to 1,800 millimeters. However, supplementary irrigation should be provided during the dry season and any hot spells that occur during the first year of establishment.

During the production phase, localized irrigation lengthens production, increasing yields by 30 to 50 percent, and improving the organoleptic properties of the fruit as well as tree development. The most critical period, when the plant should have enough water, stretches from fruit setting to harvest. Avocado plants are susceptible to waterlogged soils that cause root drowning and favor the development of fungi such as Phytophthora Cinnamom, which produces root rot. Long dry spells cause leaves to fall and reduce yields, and excessive rainfall during flowering and fruit formation can decrease production.

3.1.5. Wind

Avocado crops are susceptible to strong winds, both hot and cold, that inhibit pollination and fruit formation and cause severe damage when branches, flowers and fruit fall. Winds also produce injuries due to fruit and branch abrasion. Dry winds injure the stigma and prevent pollinators from flying, as well as dehydrating the plants and causing the fruit to fall.

Plots intended for avocado production should have good natural protection against the wind or windbreak barriers should be established one year before planting the trees. Winds cause branches to break and fruit to fall (especially small fruit). In addition, dry winds during flowering reduce the number of pollinized flowers and, therefore, of fruit.

3.1.6. Altitude

Avocados can be grown from sea level to 2,500 MASL; however, altitudes ranging from 800 to 2,500 MASL, are recommended to avoid root diseases.

Table 4: Avocado varieties for different altitudes.

Altitude* 0-1,000	Altitude* 1,000-1,500	Altitude* 1,500-2,500
Simmonds	Choquete	Nabal, REED (X- Ikulu)
Booth 8	Hall	Fuerte, Zutano
Booth 7	Simpson	Hass
	Booth 8	Ettinger, Pinkerton
	Simmonds	Wurstz

* Meters above sea level

3.2. SOIL

3.2.1. Adaptation to Soil

Avocados can adapt to a wide variety of soils, ranging from almost completely sandy to clay soils, as long as good drainage is available. In this regard, it is advisable to have at least 0.8 – 1.0 meters of soil with a good structure over a porous sub-soil in order to ensure the trees have a long life.

Ideal soils for growing avocados are those with medium texture: loamy, sandy loamy, clay sandy loamy, and porous deep soils with good drainage, and with neutral or slightly acidic pH (5.5-7.0) to help with the uptake of the main nutrients and ensure root growth. Avocados can also be grown on clay or clay loamy soils as long as good drainage is provided.

It is important that the organic matter content ranges from 2.5 to 5 percent in order to have good structure with sufficient porosity to provide adequate air and water rations in the soil.

4. GROWING AREAS FOR TANZANIA AND PLANTING SEASON

Production Zones in Tanzania	Region	District	General situation
Southern Highland	Njombe	Ludewa, Makete, Njombe and Wanging'ombe	Commercial Production for local market. Some export initiatives have started for Avocado Hass but with some inconsistencies. The areas have potential and have all the agro ecological conditions to succeed. Soil acidity is one of the production limiting factors and a strong capacity-building program is required to capacitate farmers on how to deal with this condition. Pest and diseases pressure is still low and general inputs for avocado production are available in the main towns but specify inputs like fruit fly lures, Zinc fertilizers are not available.
	Songwe	Ileje and Mbozi	
	Mbeya	Rungwe and Mbeya	
	Iringa	Kilolo, Iringa and Mufindi	
	Ruvuma	Mbinga and Madaba	Commercial production for local Market
Nothern Zone	Kilimanjaro	Siha, Rombo, Moshi Hai, Mwanga	Commercial Production for Local Market and some Export Initiative
	Tanga	Lushoto,	Commercial production for local Market
	Arusha	Meru, Karatu, Monduli	Commercial Production for Local Market and some Export Initiative
	Manyara	Babati, Hanang, Mbulu	Commercial production for local Market
Lake Zone	Kagera	Misenyi, Muleba, Bukoba	Commercial production for local Market

5. VARIETIES

5.1. HASS AVOCADO

5.1.1. Origin

Hass avocados were obtained from the seed of a Guatemalan plant in La Habra Heights, California by Rudolph Hass and patented in 1935. Hass avocados are the main commercial variety worldwide (Teliz et al.). This variety is widely grown in the U.S. and has been introduced to Israel, the Canary Islands, southern Spain, and South America. It has 95 percent of the characteristics of the Guatemalan strain and just 5 percent of the Mexican.

Flowers of Hass avocados self-pollinate, but better results are obtained by crossing them with Fuerte and Ettinger varieties. The tree is relatively vigorous, and can produce good crops under appropriate ecological conditions. Fruits are of medium size and the shape ranges from pear to egg-shaped; the skin is thick and green, turning purple when mature. The fruit can remain on the tree without suffering alterations and production takes place in the months of March-June.



5.1.2. Characteristics

Initial growth is slow to moderate, depending on sunlight. The crown of the tree is somewhat flat and very productive in the lower and mid thirds. Leaves are lanceolate and long. The fruit is oval and pear-shaped, weighing 150-300 grams. The skin is thick, withstands transport well, and is easily removed, changing from green to deep purple when mature. The flavor of the flesh is excellent, with little to no fibers, and an oil content between 18-22%.

Hass avocados are widely used in cuisine and are easy to peel. The flesh is of excellent quality, without fibers, and the small and round seed adheres to the mesocarp. It is recommended the use of Hass and Fuerte varieties for high altitude areas (1,200-2,000 MASL) which can be planted together since they belong to different floral groups (Hass: A and Fuerte: B) in order for cross-pollination to occur. Also, there is the advantage of staggered production as Fuerte production season differ from Hass.

5.1.3. Production

Hass avocados are highly productive and, with localized irrigation and balanced fertilization applications, may yield around 16 tons per hectare. In Tanzania, plantations managed without irrigation and basic management produce from 6 to 7 tons per hectare.

The main flowering season in Tanzanian avocado production zones occur in March to April and the harvest is around the same period with a more prolonged time (March to May). Occasionally, some flowering is present around December and January. It is estimated that for the Hass variety the period from flower to fruit ranges from 9 to 14 months, increasing with altitude above sea level.

6. PROPAGATION

Avocados can be reproduced using seeds. Grafting is recommended in order to ensure early crops and fruit consistency, as well as better quality.

6.1. ROOTSTOCK

To obtain a good plantation, is very important to make a right selection of rootstocks. Attributes to look for include compatibility with the scions, short height, vigorousness and rusticity.

6.1.1. Seed Selection

Seeds used for stock must come from healthy fruit, be of good size, and be taken directly from the tree. Seeds remain viable for up to three weeks after the fruits have been extracted. There are some varieties known to be good to produce rootstock such as Duke and Fuerte, but in most cases it is not easy to obtain enough seeds from these varieties as some of those varieties such as Fuerte are also needed in the global market. As such, selection of local varieties with medium size seeds and free from diseases is a good option. A medium size is about the size of a chicken egg.



Seed selection by size and health.

6.1.2. Cutting the Seed

The narrow part of the seed should be sliced to encourage sprouting and carry out the first selection, as seeds that are not naturally yellowish-white due to rot or injury can be eliminated. When the germination capacity of the plant is in doubt, 1 to 2 cm of the tip of the seed is removed by a cross cut; this is used to encourage moisture to enter the seed.



Slight cut on the avocado seeds.

6.1.3. Seed Disinfection

The fleshless seeds should be exposed to sunlight for 20-30 minutes in order to facilitate peel removal. The next step is to put the seeds in water and fungicide solution such as Methyl Thiophanate Methyl (Megasin-M) for 10 minutes.

Powder fungicides such as Captan may be used to coat the seeds using a 10 gram per kilo of seed rate. Hot water at 45 – 50 °C can be used for 30 minutes to eliminate *Phytophthora cinnamomi*. One must be cautious of temperatures lower than 45 °C are not effective and those above 51 °C damage the seed embryo. The seeds are then cooled and air-dried to remove the peel. (Rodríguez Suppo and Samson).



Seed treatment.

6.1.4. Seedbed Disinfection

There are several techniques used to disinfect the seedbed including solarization, use of hot water or applying products such as, Metalaxil, Chlorothalonil among others, to clear the seedbeds from pathogens.

One method to disinfect the seedbed substrate is to mix 25 kilos of lime and 5 kilos of copper for each 6 cubic meters of soil or substrate. This mixture can be used as substrate for nursery bags.



Seedbed disinfection.

6.1.5. Stock Planting.

A. Primary Nursery

The sanitized seeds should be planted immediately in a 1 m wide by 30 cm high seedbed of the desired length with good drainage. The disinfected substrate for the raised beds will consist of loose soil, loam and sand. In a two square meter bed, rootstocks may be produced for one hectare. Planting distance is 10 cm between seeds and 20 cm between rows. The germination period ranges from 30 to 60 days, depending on climate and variety.

B. Secondary Nursery

Using the “germination bag technique” seeds are placed in 220 g. plastic bags filled with sandy loamy soil which is 65% sand. The seeds take 3 weeks to germinate and the seedlings are allowed to grow for one month in the bags. They are then transplanted to final bags.



Planting in treated seed beds.

Planting in both raised beds and bags should be done at a depth of 5 cm and the seeds should be placed with the wider part at the bottom and the tip facing up.

6.2. GRAFTING

Grafting can be done at the nursery or at the final planting site. However, it is advisable to do it at the nursery. Grafting is carried out when the stem of the stock plant is 1 cm wide (approximately 6 months after planting) and at 10 cm from the base of the plant. This operation must be performed in a cool and ventilated area in order to achieve good vascular joining of the stock and the scion.

Lateral grafting is a widely used method for avocados, although end wedge grafting provides good results as well. Budding and wedge grafting are also used but with lesser success.

Scions for grafting should come from selected trees representing the chosen variety. It is advisable for the scions to have different widths in order to fit the different diameters of the stocks.



Lateral grafting is done at approximately 20 cm on the stock. Once the graft has taken, after 22 to 30 days, the upper part of the stock needs to be eliminated gradually up to the graft itself, cutting at an angle and covering it with a copper-based fungicide paste.

When the graft is 20-25 cm high, it can be transplanted to the field, as long as the cut has been healed and covered by the grafted stem.

For more information on nursery establishment and management, see Annex I.

7. ESTABLISHING THE PLANTATION

Seedlings are ready for the field 2-6 months after grafting, depending on variety. The layout will depend on soil and terrain, variety (due to vigor, growth habit), and prevalent environmental conditions. With lower altitudes and more fertile soil, more space should be left between plants. When establishing a plantation, consider the layout of the trees on the plot and the following technical criteria:

7.1. MEASURING THE PLOT

A plot plan provides an overall picture including boundaries, angles, and potential plant layout.

7.2. PLOT CONTOUR STUDY

A topographical survey of the plot allows farmers to plan in advance the planting system, planting density, irrigation system design, orientation in terms of sunlight and wind, windbreak barriers, and soil conservation structures.

7.3. PLANTING SYSTEMS

The most commonly used planting systems for orchards are dictated by plot topography. These include:

- **Square pattern.** Consists of placing the trees in straight and parallel lines, in order to have the same distance between plants. This system is recommended for plots with slopes between 0 to 5 percent.
- **Hexagonal pattern.** Plants are placed equidistantly, forming equilateral triangles. This system allows 15 percent more plants per area compared to the square pattern. It is recommended for plots with slopes between 5 to 15 percent

- **Contour lines.** This system is used in plots with steep slopes in order to reduce potential soil erosion issues, help with orchard management tasks, and carry out soil conservation work. It should be used in plots with 15 to 45% slopes. This system may be used combined with other types of layout (square, hexagonal, and rectangular patterns) as long as contour lines are considered.

7.4. PLANTING DISTANCES

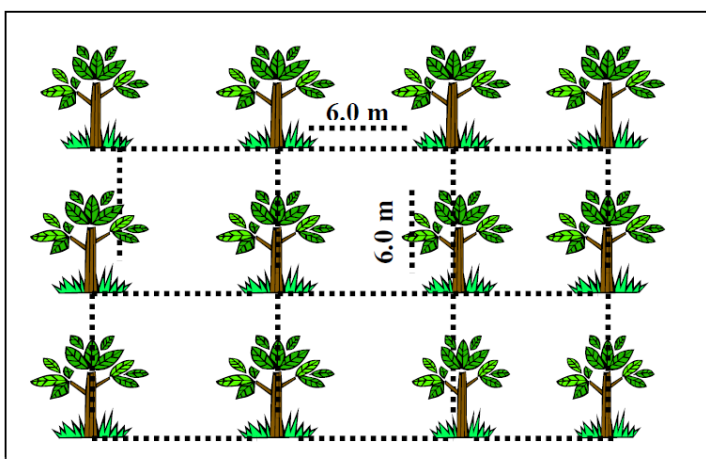
Planting distance should not be less than 7 x 8 m for Tanzanian farmers. However, some farmers prefer high density planting distance of 8x4 m, with 4 m in a north/south orientation for the best light penetration. The result is 312 trees/ha density. This provides higher early returns per unit area. Tree width and height must be controlled when crowding occurs, and be removed after some years to get 8x8 m. This system should not be used for the Fuerte variety.

However, in other planting systems for plots with slopes up to 5 percent, the square pattern should be used, with 6 m x 6 m distances between rows and lines, in order to obtain a density of 278 trees/Ha. In plots with 5-15 percent slopes, the hexagonal layout can be used with the same lines and rows distances or less, up to 10 m x 10 m to obtain a density of 100 trees/ha.

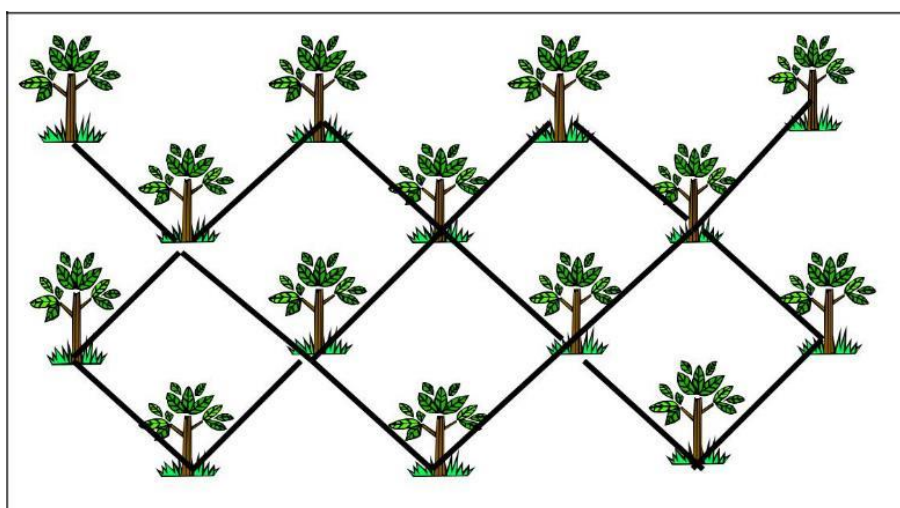
For slopes that are greater (15-45 percent), contour lines should be used every 6 m x 7 m between plants and rows in order to obtain a density of 238 plants/ha in a rectangle or a hexagonal layout.

Table 6 shows traditional avocado planting distances in different countries. These planting distances are suitable for the wide growth habit of the Fuerte cultivar, which was the most popular variety worldwide thirty years

ago. Since then, the Hass cultivar has become the main variety in the fruit trade at the international level. Due to its more erect growth pattern, most avocado producing countries have adopted closer planting distances in comparison to the old Fuerte orchards. Precocious cultivars with an even more erect growth pattern are now being planted at closer distances than the Hass variety (Whiley et al).



Planting distance: 6 x 6 m (278 plants/ha).



Planting distance: 10 x 10 m (100 plants/ha).

Table 6. Traditional avocado planting distances used in different countries (Gaillard).

Country	Planting distance (m)	Trees/ha
United States (Florida)	9 x 9	123
Mexico, Chile, Spain, South Africa	8 x 8	156
Australia	5 x 5	400
Israel	6 x 10	167
United States (California)	7 x 7	204

7.5. LAND PREPARATION AND MAKING PLANTING HOLES

The only chance to do proper soil preparation is prior to planting of trees therefore this activity that has to be done properly and cannot be overlooked otherwise our plans can be severely affected.

First, a soil analysis is highly advised, especially in high rainfall areas with acidic and leached soils. If pH is lower than 5.5, Lime (2- 3 Ton/Ha Calcitic or Dolomitic) and Phosphate (e.g. 2T/Ha) should be applied over the entire soil surface.

Thereafter, the soil needs to be deep ripped to an actual depth of at least 60 cm and then cross-ripped at a 60-degree angle to the first rip while the soil is dry i.e. not in the wet season. This will ensure that the Lime and Phosphate are well incorporated into a good depth.

In flat lands where there may be some sort of impeding subsoil layer which in wet times could result in the lifting of the water table and drowning of the roots, ridges may be needed to increase topsoil available for good root development as the trees grow. Topsoil is moved onto the ridge from the sides as shown in the photograph below.



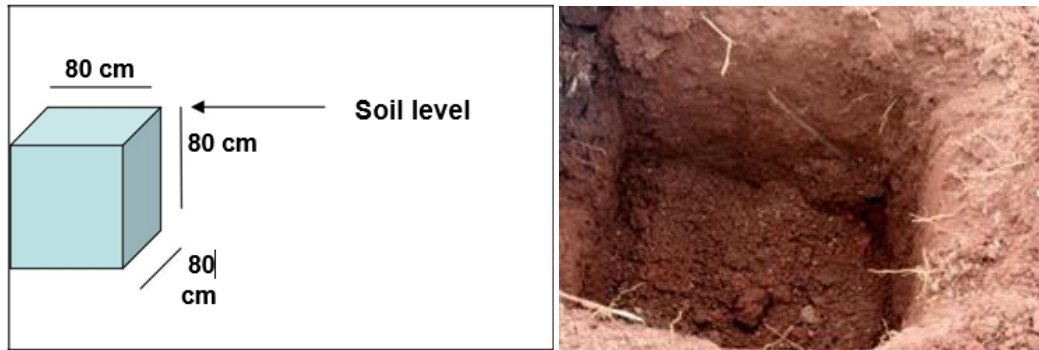
Land preparation and raised beds (ridges). If there are naturally homogenous, deep, well-drained soil there may be no need for preparation of planting ridges (direction North to



Since avocado trees are highly susceptible to both water logging and Phytophthora root rot disease, if ridging is not required, at least 10 cm of mound should be made to increase the soil depth for improved drainage.

The holes should be prepared during rainy season or immediately after. During the dry season, soils dry out making the task more difficult, which increases labor costs. The size of the hole will depend on the soil type:

- In loose loamy soils, the holes are 0.80 m (depth) x 0.80 m (width).



- In heavy clay soils, holes should at least measure 1.00 m x 1.00 m in order to ensure root growth and thus more vigorous trees.

Holes should first be marked using a center stake as reference. If the superficial soil is black, this should be set aside from the clay soil to be used to fill the hole later.

7.6. FILLING THE HOLES

If soil matches all avocado soil requirements (loam, deep, drained and organic matter), holes filling may not be required and the above described land preparation activities should be sufficient. If hole filling is needed, it should be done in advance, and at least one month should go by after the holes are dug before they are filled. The inputs needed to fill holes include:

- Black organic soil
- Dolomite lime
- Systemic insecticide-nematicide
- Compost

The holes should be filled as follows:

- Scrape the bottom of the hole;
- Apply half a pound of dolomite on the bottom and sides;
- Place the first layer of superficial soil on the bottom of the hole;
- Mix black soil and five spadeful of compost with 1Kg of Agriculture lime (dolomite) to fill the hole halfway;
- Gently tamp the dirt to get rid of air pockets;
- Apply 15 g of granulated insecticide;
- Mix black soil and five spadefuls of compost, plus 1 kg of Agriculture lime (dolomite) to fill the hole to the brim;
- Apply 15 g of granulated insecticide and nematicide (e.g. Imidacloprid,);
- Gently tamp the soil to get rid of air pockets;

- Place the stake again in the center of the hole;
- Finish filling the hole leaving a small mound of dirt above ground level;
- Water the holes on a weekly basis with 40 liters of water per month and then proceed to plant the trees.

7.7. TRANSPLANT

Producers should buy grafted avocado plants from reputable nurseries, in order to ensure that the planting material is of the best quality. Seedlings should be transplanted during the rainy season to ensure the proper plants rooting and growth. Transplant can be done during other seasons, but the growth of new branches will probably be delayed. When transplanting, the seedlings should have been grafted for at least six months. Steps to follow for the transplant are the following:

- Dig a hole the size of the avocado plant's root ball;
- Remove the polyethylene bag from the root ball;
- Cut coiled or malformed roots;
- Place the root ball in the hole and cover it with soil making sure it covers all the roots and is level;
- Gently tamp the soil to get rid of air pockets.

If it is not raining, plants should be irrigated using 30- 40 liters of water per week split into two weekly watering during the first dry season after planting.



To remove the plant from the bag cut the bag along the base and remove the base.

Position the tree in such a way that most of the branches and leaves face in the direction of the hottest sun in order to protect the tree against sunburn. Fill the hole with the topsoil and irrigate accordingly.

8. PLANTATION MANAGEMENT

8.1. FERTILIZATION

The fertilization plan should be based on a soil and foliar analysis; this practice will contribute to obtain the most in terms of agricultural and financial benefits without damaging the environment. In the case of

avocados, nitrogen (N) and potassium (K) are the most important macro-nutrients, as well as calcium (Ca) and magnesium (Mg). In soils with moderate to high phosphorus (P) content, without pH issues or other factors that may decrease its availability for the plants, phosphorus should be applied only based on crop removal standards every two to three years (see Table 8).

Table 8. Avocado plant nutrient extraction in gr/t of fruit in four countries

Element	United States (California)	Venezuela	France	Brazil
Nitrogen	1,380.00	3,152.00	2,800.00	2,848.00
Phosphorus	400.00	736.00	350.00	301.00
Potassium	2,700.00	3,530.00	4,530.00	2,027.00
Calcium	140.00	547.00	130.00	79.00
Magnesium	46.00	474.00	200.00	168.00
Sulphur	110.00			183.00
Boron				3.70
Copper	4.00			3.00
Iron	7.00			7.00
Manganese	0.90			2.00
Molybdenum				0.02
Zinc				4.50

Source: (Avilán 88).

To reference avocado nutrient deficiencies, see Annex 2.

Appropriate fertilization should start at the nursery. Starting a plantation with well-fed plants will help to avoid many management and production issues. The first field fertilization should take place 30-40 days after the transplant (see Table 9).

When response levels to nutrients are not available from field tests, using response levels based on the age of the avocado plants is a good initial guideline, but we should not forget that the prescriptions for fertilizing the cultivated field are specific. The following is a suggested fertilization plan:

Table 9. Fertilization plan according to cultivated field age.

Cultivated field age (years)	Nutrients (grams/tree/year)		
	N	P ₂ O ₅	K ₂ O
1-4	100-300	200-450	100-450
5-8	301-680*	451-900	451-900
> 8	681-1,400*	901-1,100	901-1,400

*Depending on expected productivity.

Table 10 shows an example of the commercial fertilizer amounts to be used based on the nutrients level used in table 9:

Table 10. Amount of commercial fertilizer needed to achieve desired levels.

Cultivated field age (years)	Nutrients (grams/tree/year)		
	Ammonium nitrate (33.5% N)	Triple superphosphate (46% P ₂ O ₅)	Potassium chloride (60% K ₂ O)
1-4	100-300	200-450	100-450
5-8	301-680*	451-900	451-900
> 8	681-1,400*	901-1,100	901-1,400

8.1.1. Fertilization Schedule for adult orchards

The times when plants demand more nutrients are during flowering, start of vegetative development, and fruit development. Therefore, fertilization is recommended during the following periods:

- 1st application: December to February
- 2nd Application: June
- 3rd application: August- September (if there is no irrigation this fertilization has to be postponed until rains get started)

8.1.2. Foliar Fertilization

Micro-nutrients can be applied if the soil and foliar analysis recommend it, preferably around June- July during early stages of fruit growth. The critical micronutrient required by Avocado are zinc (Zn) and boron (B).

8.1.3. Establishment Period.

Thirty to forty days after transplanting the avocado plants, 15 grams of nitrogen per plant (45 grams/plant of Ammonium Nitrate), and 30 grams of P₂ O₅ (65 grams/plant of Triple Superphosphate) should be applied. One hundred and eighty days after the transplant, apply 20 grams of nitrogen per plant (60 grams/plant of Ammonium Nitrate).

8.1.4. Fertilizing the Field- General recommendations

In general terms, the following suggestions may be used for avocado fertilization:

- At the time of transplant: apply 250 g of a phosphorus-rich fertilizer such as 10-30-10 or triple superphosphate to the bottom of the planting hole. Per every year of age of the plant we can add one kilo of a fertilizer rich in nitrogen and potassium such as 18-5-15-6-2, split in three applications, one at the onset of the rains and the other two every two months.
- The maximum amount of fertilizer is 12 kilos for trees that are 13-years old or more. This amount should be maintained if production is consistent and the soil analysis shows a low pH and a percentage of interchangeable aluminum.
- When trees enter production, nitrogen fertilization should increase during the period between flowering and fruit maturation because the trees demand more nitrogen. One kilogram of additional urea is recommended, 40 days after flowering if irrigation is available, otherwise it should be added at the onset of the rainy season.

- Apply micro-elements such as copper, zinc, manganese and boron twice a year. In Tanzania, Boron should be applied quarterly and preferably on a mulched surface to encourage the soil to bind the boron for longer retention. Foliar sprayed boron on avocados may show improvement in leaf analysis but boron does not move backward in the avocado, therefore it is essentially useless. Boron must be applied to the soil in order for the tree to truly benefit.
- Fertilizers provided as complete formulas should be applied through furrows or holes dug parallel to the plantation line at a depth of 30 cm and 20 cm away from the tree's dripping zone (canopy area).
- Nitrogen fertilizers are placed in more shallow holes or on the surface, in a circular shape around the tree's drip area.

8.2. IRRIGATION

Irrigation is key for commercial avocado farming. Producers should have enough water available to meet the needs of the cultivated field. Productivity, when irrigation is available, is definitely higher than that of plants grown without it, both in terms of fruit and tree vigor. However, if irrigation is not managed properly, it damages the crop and the soil, as well as reduces the economic benefits for the producer. Trees absorb different amounts of water based on size, canopy density, and environmental conditions. The same tree needs more water during dry and hot spells than in humid and cool periods, and thus watering should be tailored according to these needs.

Where, as seems to be the situation in Tanzania (southern highlands), annual total rainfall amounts to approximately 2000 mm per annum. The primary focus of any irrigation system would be to cater for peak water demand during the dry period from flowering and fruit set until the advent of the first rains i.e. from approximately late June/July up until the end of November. Any form of supplementary irrigation during this period will mitigate against stress and optimize fruit set/yield.

The watering needs of plants vary with age, size and canopy density, time of year and their physiological condition. As for reference, if we have the ETo of our zone we can calculate our water needs considering that Avocado Water Consumption Coefficient (Kc) is 0.6, 0.85 and 0.75 during the plant growth, flowering and fruiting stages respectively (FAO, 1,998)

The water used for irrigation should have some important characteristics for appropriate tree management:

- Total dissolved solids: less than 850 ppm.
- Sodium: less than 3 meq/l (milli-equivalents per liter)
- Chloride: less than 107 ppm.
- Boron: less than 0.7 ppm.

Implementing pressurized irrigation systems such as **drip irrigation** improve delivery efficiency up to 90% with water savings of up to 50% compared to sprinkler irrigation. Such systems also prevent the detrimental effects of wetting the trunk and branch interception.

In addition, drip irrigation has the following advantages:

- Significant savings in labor costs
- Adapts to several topographical condition in the plot
- Maximizes the use of water resources
- There is no contact of irrigation water between trees

It is important to consider that if one plant is attacked by bacteria, fungi, or nematodes, irrigation water should be prevented from reaching other plants, as pests and diseases are transported by it.

8.3. PRUNING

The general principles for pruning avocado plants include:

- For pruning, we should take into account the response of each variety, pruning goals, and climate and soil conditions. The least possible number of branches should be pruned, as a strong decrease in woody structure will diminish production, at least during the following year.
- The fruit-to-leaf rate should be balanced, as it determines tree yield.
- Branches with 1-2 year-old twigs are the ones that produce fruit and thus an adequate amount of these should be pruned to obtain good yields. If these are pruned improperly, only vegetative growth will be encouraged.
- Intense pruning encourages new wood formation and, in some cultivars, this is detrimental to fruit formation. Also, excessive radiation causes sunscald on the stem and branches, favoring the start of cankers and dieback.
- Pruning should be conducted before the onset of the rainy season, eliminating the branches damaged during harvest.
- In adult trees, pruning main purpose is to eliminate dry, weak or out of place branches, as well as cutting the tips of a specific number of branches (approximately 30%) to encourage fructiferous flowering
- Cuts should be made on the lateral branches, as pruning main branches will encourage vegetative growth of the plant.
- The cuts and stems exposed to the sun should be protected using covers such as white latex paint, paraffin, or Bordeaux paste. Cuts need to be clean, at an angle, and leaving no stumps in order to avoid rot. Beeswax helps healing of cuts.
- Tools used for pruning (saws, secateurs, chainsaws) should be disinfected before pruning the next tree using a 5% bleach or formaldehyde solution.

In terms of annual pruning, we should remember that, in the tropics, this encourages vegetative growth in detriment of fruit formation, and thus should be limited, in most cases, to eliminating dry, malformed and crooked branches.

8.3.1. Pruning Systems

Pruning is an important practice in Avocado and the pruning system to be used will be influenced by the age, production system and condition of the tree. In general, we can group pruning system in three types:

Shape Pruning

The first shape pruning can be performed after planting, especially in the case of Hass avocados. This task entails cutting 2 or 3 centimeters from the growing tip to promote re-sprouting. This apical pruning should be carried out only if trees need it, as some of them may already have bifurcations or future productive axils even in the nursery (F. Produce). Later, unwanted branches are eliminated, including those pointing to or near the ground, and those crisscrossing the central part of the tree. Also, malformations are pruned in order to correct growth defects.

The second shape pruning is performed during year three to prevent the development of multiple stems, eliminating suckers and branches emerging close to or under the graft, leaving three or four main branches

to make management easier and make the most of sunlight, as well as to ensure proper air flow around the center of the plant (F. Produce).

Adult Tree Pruning

Once production starts, severe pruning should be avoided, as it may cause nutrient imbalances, leading to poor flowering, and thus a decrease in production.

Bottom branches should be pruned up to a meter above ground level, taking care not to get rid of productive branches on the lower layer of the tree where harvesting is easier and more profitable. Very slanted or almost creeping branches should be pruned because they encourage pests and diseases to attack the fruit (Solares, s.f. and Godínez et al.).

Excessive pruning of the lower branches causes vertical growth, which is not conducive to plantation management. This type of pruning is conducted when the shape of trees needs adjustment to fit the irrigation system or weed control methods. It is worth noting that cultural techniques should adapt to the trees and not the other way round (Calabrese).

The central growing tip should also be eliminated together with the tips of lateral branches in order to facilitate plant protection management (F. Produce). This is recommended until the trees reach a height of 6 to 8 meters (Godínez et al.). Topping is used in fast-growing varieties that grow over the ideal height. Hedging is performed when planting patterns are tight, providing better lighting for the lower parts of the trees and easing the movement of laborers and equipment (Calabrese). Excessive pruning of the top branches delays production, as the plants enter a juvenile vegetative growth stage; if this type of pruning is carried out, it should be alternated, never cutting all the branches at the same time (Godínez et al. and Solares).

Unproductive inner branches that are in the shade can also be pruned. This task should be carried out after harvest (F. Produce).

Adult tree pruning can take place every one or two years, but continued fruit production may be affected. Some authors recommend pruning every four years to obtain gradual yield increases (Santacruz).

Tree Elimination, Row Spacing and Direction.

Some production systems aiming for achieving high yields, normally use high-density planting up to 400 trees per hectare. The canopies of the trees on these types of plantations often thicken excessively within a few years. The main drawback is that light will only penetrate to the top of the trees and very little of it will reach the interior and/or the bottom (Table 12).

In order to establish more intensive plantations but avoid thickening of the canopy, the following measures should be implemented:

- Plant trees in a rectangular pattern. This will provide an opening between rows that will allow light to penetrate and reach the bottom of the trees.
- Plant trees close to each other in a North-to-South direction. This will allow both sides of the tree to receive sunlight.
- Prevent widening of the top of the trees which stops sunlight from reaching the base.

Table 12. General guidelines for spacing (m) new plantations and potential tree elimination.

	Spacing (m) and plants		
	Varieties		
Plantation age (years)	Pinkerton-Ryan	Hass in areas of low vigor	Hass in areas of high vigor
1 to 7-10	5.5 x 3.0 (606)*	6.0 x 3.5 (476)	7.0 x 3.5 (408)
8-10 to 14	5.5 x 6.0 (303)	6.0 x 7.0 (238)	7.0 x 7.0 (204)
8-14 to 20	11.0 x 6.0 (151)	12.0 x 7.0 (119)	14.0 x 7.0 (102)

* The number in parenthesis shows the number of trees/ha.

8.4. WEED CONTROL

Weeds are a problem for plantations because they compete for nutrients, water, space, and light, as well as increase costs and reduce yields and crop quality. They do provide a beneficial ground cover that needs regular and careful management.

In young plantations, weeds compete for light and nutrients, while in developed plantations they create unfavorable micro-climates under the trees, providing alternative hosts to pests and diseases. Weeds are responsible for a decrease in yields of between 5 to 15% (Godínez et al.).

In areas with high rainfall and moderate to steep slopes, the weeds on the lower rows should be kept but trimmed as they protect the soil from erosion, but they should be eliminated on the tree's critical root zone.

8.4.1. Mechanical and Manual Control

Mowers can be used for weed control between rows and the dripline zone (critical root zone) can be weeded using a machete or weed cutter. It is important to check for weeds half way through the rainy season and at the end of it, as well as during the dry season

In places where machinery cannot be used, manual control can be used exclusively. Tools should be used with great care to avoid damaging the root system of avocado trees, as weeding with hoes, disc ploughs, and other tilling devices favor pathogen invasion (Samson).

8.4.2. Chemical Control

Chemical control during the first years can damage young plants. In places where labor is scarce, herbicides are used only on adult plantations. The dosage will depend on the types of weeds. These chemicals should not be applied close to water sources and all the environmental cares as well as safety measurements have to be taken.

8.4.3. Cultural Control

Several alternative measures may be implemented in order to control weeds, as well as to benefit the soil and plantation:

- **Mulch:** the use of mulch helps conserve soil moisture and prevent from pest attacks. Mulches are used at the end of the rainy season and during the dry season and not in the rainy season because they favor the proliferation of fungi and pathogens.
- **Stubble:** if there is a sufficient volume of stubble and weeds, these can be piled crosswise on the slope of the plot, covering as much area as possible.

- **Ground covers:** these should be fast-growing legumes planted on the ridges to control weeds and encourage organic matter formation; the weeds that remain should be removed manually.

9. INTEGRATED PEST MANAGEMENT

Avocados produced commercially under a monoculture system normally increase the risk for some biotic problems like insect pests and pathogens

The health of the crop is an important measure in avocado production, pest and diseases should be prevented and controlled timely as they can produce serious consequences in all stages of the crop; being the most obvious impact during fruiting stage. Therefore, this section contains information developed for Tanzania about pests, diseases and their management.

9.1. PESTS

The golden rule is to not spray any insecticide until one is certain which pest is involved and what levels of the pest at any particular time will lead to levels of commercial damage which will justify spraying interventions. If such pest thresholds are exceeded, only appropriate chemicals registered for use on avocados for that specific pest may be considered, and then only if such usage falls within the scope of accepted chemicals and residues allowed in the various markets.

Injudicious use of insecticides on a random basis will in the long term severely upset the natural pest: predator (beneficial insects) balance in the orchards, leading to increasingly severe pest repercussions, costly control, and ultimately lower profitability.

Integrated Pest Management is advocated, whereby 'softer' chemicals may be used depending on scouted observations by trained staff (scouts) at critical times when predator populations are not that susceptible.

Avocado crop is mainly affected by certain insects and arachnids that cause damage by reducing yields and quality. There are also a couple of quarantine pests which **MUST** be controlled in order for exported avocados to enter various markets. With the purpose of identifying and controlling them, this section presents the economic importance pest in Tanzania.

9.1.1. Thrips

There are several genus and species, but the most common ones found in Avocado are *Heliothrips haemorrhoidalis*, *Selenothrips rubrocinctus*, *Scirtothrips aurantii* and *Thrips tabaci*.



Heliothrips haemorrhoidalis: Adult. Picture from US Davis Dept. of Entomology.



Heliothrips haemorrhoidalis: nymphs and adult. Taken from www.entomology.umn.edu



Nymphs of *Selenothrips rubrocinctus* and black excrement. The red band can be seen only on nymphal stages (www.daff.qld.gov.au)

Damage caused by thrips

Damage is caused by both the adult and larval stages through feeding injury. This is caused by the piercing and sucking out of the contents of cells (chlorophyll), which results in the cell wall to collapse. Discolouration (bronzing) of the surface of the leaf and fruit takes place. Heavy infestations cause the pericarp to crack. Damage done by the two thrips species is similar. Damage is done during early fruit set and later on more maturing fruit. On mature fruit, damage appears as irregular-shaped bronze patches on the sides of the fruit. This is because the thrips are most prevalent where fruit touch each other, as they prefer to feed there.



Thrips damage on fruit, leaves, and small fruits.

Control

Although thrips is a minor pest in avocado orchards, it has the potential to become a major pest if control methods are not carefully executed. Therefore, it is very important to remember that there is a huge variety of thrips species that are involved in pollination, as well as predatory thrips. The crucial time for thrips control is during fruiting and early fruit development. To determine control, it is important to scout every week, some products like Imidacloprid, Thiamethoxam, Spinosad, etc can be sprayed if required.

9.1.2. Mites (several species: *Oligonychus punicae*, *O. perseae*, *Hemitarsonemus latus*, *Tetranychus* sp.)

The mites, sometimes called spider mites or red spiders, are not insects; they are more closely related to the spiders. The adults have eight legs rather than the six legs found on insects, and are very small. They feed by extracting the plant sap and chlorophyll by means of their piercing-sucking mouthparts. Despite their small size, they can cause great damage because of their large numbers and possibly also because of the ability of some species to inject a toxic substance into the plant tissue.

Damage

The mites are primarily on the upper surface of the leaf, first along the midrib and later along the veins and eventually entirely over the upper leaf surface. Their location on the leaf is evidenced by the brownish discoloration, which may eventually cover the entire upper surface of the leaf. Myriads of whitish hatched eggs and cast skins of the mites also characterize an infestation. The mites must be very abundant to cause defoliation, and control measures are usually not employed unless the infestation is extremely severe.

Control

Since mites are generalist pest most of species can be controlled with the same methods. Always the weekly scouting is an important activity to make spraying decisions. Mites have lot of natural predators however some products like Sulfur and Abamectin can be sprayed if required.



Oligonychus perseae.



Oligonychus punicae.

9.1.3. Fruit flies (Several species of *Ceratitis* and *Bactrocera*)

Fruit flies are quarantine pests; several species are known to attack different types of commercially grown crops. In avocados, the economically important genus are *Ceratitis* and *Bactrocera*, causing considerable damage. The female punctures the fruit with her ovipositor and deposits eggs within the host fruit. Larval development within the fruit causes direct damage, which as a result may become rotten. Larvae then drop to the soil to pupate. Losses are due to direct feeding damage and also to loss of export markets as a result of quarantine restrictions imposed by importing countries free of these pests.

Proper fruit fly monitoring system is very important to timely detect the problem. This is normally achieved with monitoring traps or stations:

For ***Ceratitis*** traps with Trimedlure catch males of *C. capitata*, traps with Enriched Ginger Oil catch several species (mostly males), traps with Questlure catch - *C. capitata*, *C. cosyra*, *C. rosa* (males and females), Biolure-fruit-fly catch also the three species (males and females).

For *Bactrocera invadens*, Monitor and control can be done with a highly species specific lure: Methyl Eugenol (ME) with attract males only.

The avocado is not a good host for the development of fruit flies and usually under good orchard practices no larval development takes place in fruit on the tree. If that happens, normally there is a main host around our avocado orchard (mango, papaya, watermelon, etc.). Ripe fruit that has fallen to the ground results in higher rates of fruit fly presence in the orchard. Therefore, it is advisable to clear the orchard floor of any fallen fruit to prevent fruit flies from breeding in the orchard

Control options

Cultural

Fruit flies are active after periods of rain or high humidity. Sprays for fruit fly control may not be necessary in dry seasons. Do not allow fallen fruit to accumulate under trees. Fallen fruits can be buried 50 cm underground as a cultural practice.

Biological

While there are a number of parasitoids that can help control fruit fly populations, these kill the insect in the pupal stage and are therefore of little use in preventing damage if populations are already high. However, they do help to reduce the next generation of flies, particularly in isolated or marginal fly areas. Application of *Metarhizium* to the soil and foliage during flowering stage is also a good biological option.



Fruit fly Larvae.



Invasive Fruit Fly (*Bactrocera invadens/dorsalis*).

Chemical

Some chemical options are available and can be sprayed as needed; A protein bait for the control of female fruit flies, the Male Annihilation Technique (MAT) cup that contains a male attractant, rapid kill insecticide to control male fruit fly populations, and other baited insecticides like Spinosad (sold combined with a fruit fly attractant) are also effective.

Adult fruit flies lay eggs on ripening fruit, which makes application of chemical pesticides a potential pesticide residue problem. Resistance to chemical active ingredients, compound the problem. There are many sophisticated and expensive technologies (SIT male annihilation, bait sprays, post-harvest treatments) which help to mitigate the problem, however to control fruit fly effectively it is necessary to integrate all monitoring and control options described in this manual.

9.1.4. False Codling Moth (FCM) - (*Cryptophlebia leucotreta* / *Thaumatotibia leucotreta*)

FCM adults live for two to three weeks during which time the female mates several times (Schwartz). The eggs are oviposited on the fruit. Cannibalism by the larvae ensures that most often only one larva develops on a fruit (Catling & Aschenborn). Larvae may gnaw through the skin but are unable to develop further (for *C. leucotreta*). Entrance holes on the fruit can be spotted by the white exudate and frass, which is often apparent. The larvae exits the fruit upon pupation. The larva drops to the ground and pupates in a cocoon of fine soil particles on the soil surface or beneath leaf litter.



Control:

The orchard sanitation measures have remained the single most important recommendation for suppressing the pest in avocado orchards. There are also some specific control methods that can be implemented like **Mating Disruptants**. This method relies on the prevention of mating as well as deposition of fewer viable eggs on the fruit. This is achieved by releasing high concentrations of female sex pheromones, which ensures that males get confused and cannot find females to mate. This should be applied early in the season when the population number of DCM is still low.

Some avocado approved **agrochemical** can also be applied. Bait traps containing pheromones (eg “Last Call”) and poisons are placed in the orchards to attract and control the moths. Broad based sprays of insecticides are only advocated in instances where baiting alone is not adequately controlling population levels and fruit damage is at significant levels.

Due to the complexity of its life cycle, more than one control measure should be used to control this pest. The life cycle of FCM is relatively synchronized early in the season; therefore, a significant benefit could be obtained with a well-timed spray. Due to the overlapping of generations later in the season, linked to environmental ephemerality of some products, spraying late in the season may not be as effective. Spray coverage is very important, as the insides of the trees should be adequately covered with active pesticides in order to manage neonate larvae.

Differences between fruit fly and FCM damage:

Lesions caused by fruit flies and FCM (*C. leucotreta*) are often confused. During the first few weeks of fruit damage, the fruit fly and FCM lesions are very similar in that they both display a small hole which is covered by fruit sap, which later dries and becomes a white powder (Du Toit et al.). Fruit damage by the fruit fly's ovipositor develops into a typical star shaped lesion in contrast with FCM, which raises a crater with an inconspicuous hole in the middle where the larva of FCM has entered (Du Toit et al., 1979). Granular excreta can also be seen in the case of FCM.

9.1.5. Aphids

Aphids are soft-bodied insects that use their piercing sucking mouthparts to feed on plant sap. They usually occur in colonies on the undersides of tender terminal growth. Heavily-infested leaves can wilt or turn yellow because of excessive sap removal. While the plant may look bad, aphid feeding generally will not seriously harm healthy, established trees and shrubs.

Aphids may become abundant on avocado trees where they are growing close to aphid-infested citrus trees. The species involved are those ordinarily found on citrus, mainly the spirea aphid, *Aphis spiraeicola*, and the melon aphid, *Aphis gossypii*. At considerable distances from citrus, the only species the writers have found on avocado trees is the dock aphid, *Aphis fabae*, and the melon aphid but only on an occasional succulent twig terminal. Nicotine sulfate, oil-rotenone, or tetraethylpyrophosphate (TEPP) preparations are currently being used for the control of aphids on citrus.



Aphids being controlled by a predator. Taken from www.pestkilled.com.



Different Aphid species affecting tree buds. Taken from www.agric.wa.gov.au.

Control:

Aphid insects have a lot of predators and normally low presence of them does not represent a threat to avocado farmers. They usually affect crops during the dry season, and due to the nature of their body,

low infestations can be controlled with natural products like agriculture oil, soap, garlic and neem extracts. If damage reaches economic levels that justify use of agrochemicals, some products like Imidacloprid and Thiamethoxam can be sprayed.

9.1.6. Scales:

There are different types of scales affecting avocados. The most common one is the heart shaped scale (*Protopulvinaria pyrifomis*)

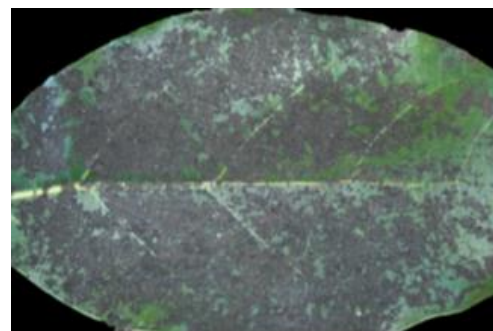
Scales feed mainly on the ventral side of avocado leaves, where they extract plant sap. Fruit and shoots can also be attacked. Scales excrete honeydew, which settles on the lower leaves and fruit. Females reproduce parthenogenetically, and lay about 200-300 eggs, protected by a white, woolly secretion beneath her body.



Adult female scale.



White woolly egg secretion.



Sooty mold develops on the honeydew, which causes a black coating on the fruit and leaves. This fungus normally disappears by itself after controlling scales.

Control:

Scales have several natural predators that normally keep them under control, but if the damage reaches economical levels, agrochemical sprays like Buprofezin can be scheduled. Biological products like Beauveria and Metarhizium have also demonstrated good control.

9.2. DISEASES:

The avocado, despite being a rustic crop, has several phytosanitary problems that farmers have to deal with. Due to this situation, avocado growers must know all strategies to identify, prevent, and control all pathogens causing diseases in their avocado plantations. Diseases should be kept at levels that do not produce economic damages and avoid the arrival of new ones. This manual contains the most important avocado diseases present in Tanzania.

9.2.1. Root rot (*Phytophthora cinnamomi*)

Phytophthora root rot is the most destructive and important disease of avocado. It can be extremely serious, killing most trees in an orchard. Nursery plants and young replants are particularly sensitive to root rot and often die soon after infection.

Symptoms

Phytophthora species can invade the roots and crowns of woody trees, but foliar symptoms may not become evident for months or even years. Leaves are pale green, wilted and fall readily. Shoots die back from the tips so that eventually the tree is reduced to a bare framework of dying branches. Death of the tree may take from a few months to several years. Declining trees commonly set large crops of small fruit (avocados). Lack of foliage and dieback of small branches exposes fruit and major limbs to sunburn. Feeder roots are black, decayed and few in number. As infected roots lose the ability to exclude salts, leaf margins in affected trees develop brown, necrotic symptoms typical of salt burn. Under severe waterlogging rapid decline of trees may occur. The leaves wilt and die, leaving a canopy of brown, dead leaves. A weeping stem canker may occur on the lower trunk. When the pathogen is present, the soil environment plays a very important role in the development of symptoms. Symptoms do not appear unless there is an upset in the balance between water requirements of the leaves and the capacity of roots to absorb water.



Avocado plants showing different level of root rot infestation. From mild infestation to a dead tree. Dead trees should be uprooted and burned in the same place.

Photo taken from presentation: "Foro Veracruzano de Fruticultura y Cultivos Tropicales"

Control options

- Use an integrated approach that relies on pathogen-free nursery trees, cultural and biological controls, resistant rootstocks, and chemicals.
- Plant on well-drained soils or improve drainage using mounds.
- Irrigate carefully, avoiding both over- and under-irrigation.
- Increase the organic matter content of the soil using ground covers and mulch. Keep mulch away from tree trunks.
- Apply Lime (or gypsum if pH is optimum) under the canopy of the trees to suppress the formation of spores. High pH favours development of the disease.
- Provide adequate nutrition.
- Use recommended systemic chemicals in addition to these cultural practices.

This fungus may be widespread, especially in previously cultivated non-virgin soils.

Control on young trees is a good nursery practice, and the use of Aliette (Fosetyl Aluminum) stem paint. At planting, a soil treatment of Metalaxyl may also be used to suppress the fungus. However, this treatment

is usually only effective for the first year, whereafter *Phytophthora* has been shown to develop resistance to the fungicide.

On older trees, there are options of doing foliar sprays using commercially registered formulations of Fosetyl AI, or of doing annual or bi-annual trunk injection with such registered commercial formulations e.g. “Avoguard”.

Timing of such injections is of cardinal importance to ensure good effect and that fruit, once harvested with the recommended safety interval post treatment, is compliant with the accepted market maximum residue threshold tolerances.

Much research is presently under way to enable a better understanding of this aspect. Growers wishing to inject their trees should seek expert advice in this regard before proceeding.

Another important measure that should be taken preventatively is the inoculation with beneficial microorganisms that suppress the presence of the pathogen in the soil. Products like *Trichoderma*, *Bacillus subtilis* and other effective microorganisms will help.



Injection of Potassium phosphite. Photo taken from presentation: “Foro Veracruzano de Fruticultura Y Cultivos Tropicales”.



Spraying Metalaxil. Photo taken from presentation: “Foro Veracruzano de Fruticultura Y Cultivos Tropicales”.

Unfortunately, root rot is not a problem that can be controlled with just a single method. As previously mentioned, integrated management with cultural practices (good land preparation, drainages, good nursery practices, irrigation, weeding on time, etc), biological inoculations and use of agrochemicals, will be required.

9.2.2. Anthracnose (*Colletotrichum* spp.)

For Hass, one can expect that a warm, humid subtropical microclimate can be very conducive to fungal proliferation. The most prominent post-harvest disease to be expected is Anthracnose, caused by the *Colletotrichum* fungus which manifests itself as rotting on ripening fruit.

Symptoms

These fungal diseases cause the development of dark, sunken spots or lesions, often with a raised rim, on affected foliage, stems, and fruit of a wide range of horticultural crops.

Pink spores are followed by black fruiting bodies. Immature fruit do not show infections until fruit ripens. Disease development after harvest is the result of infection of fruit on trees before harvest. The fungus may remain dormant in green fruit for many months. Leaf spots are large and tan-colored with dark brown margins. Pinkish spore masses may form on the spots under humid conditions. Leaf spots are extremely rare and generally form only after prolonged wet or humid weather. Large circular brown spots may form

around puncture marks to the skin of the fruit. The spots darken with age, centers become sunken and, in moist conditions, pinkish spore masses may form on the spots. Small spots less than 5 mm in diameter may develop around the breathing pores (lenticels). The fungus also causes a major post-harvest problem in ripe fruit. Internally, the rotting penetrates deep into the flesh in a hemispherical pattern. Pepper spots on avocados are seen as a myriad of small, dark, raised spots on the fruit's surface. It also affects twigs.



Avocado plants showing Anthracnose infection at different fruit stages. Photo taken from www.daf.qld.gov.au.

Control options

The critical phases for disease control are during flowering and fruit set, and after harvest. This disease is most severe during wet weather, when new growth flushes are particularly susceptible. The leaf spot symptom is generally not serious enough to warrant treatment or preventative measures. However, prevention against the fruit rot symptom requires regular spraying and orchard hygiene.

Follow a recommended fungicide spray program for your crop from flowering to fruit set. Control fruit-damaging pests such as FCM and fruit fly. Pay attention to orchard hygiene by pruning out dead wood before flowering, and regularly removing infected fruit and dead leaves entangled in the canopy. Keeping the canopy open by judiciously pruning and tree shaping helps to reduce the severity of infection. Use regular leaf and soil analyses to keep nutrient levels, particularly calcium and nitrogen, at adequate levels, as this increases the resistance of the fruit to infection. Avoid planting susceptible varieties.

Chemical control to this pathogen especially in dense orchards with little air movement can be difficult. Copper sprays on all fruit (sprayed from both inside and outside the tree) is important. E.g. Copper oxychloride or cuprous hydroxide can be used at a concentration of 75 to 80g/100 liters of water.



Pruning of dead and unproductive branches as well as thinning some lines for proper ventilation. Photo taken from presentation: "Foro Veracruzano de Fruticultura Y Cultivos Tropicales".

9.2.3. Leaf spot (*Cercospora* sp.)

Symptoms

Small, brown flecks develop with a reddish border, expanding to circular spots about 4 mm wide with an ashy-grey center. This tissue becomes thin and brittle, and often drops out, leaving a ragged hole.

Round water-soaked lesions develop on leaves, petioles, and stems. The lesions enlarge and have light brown centers, with dark brown-red margins. As lesions expand, an outer water-soaked area and dark ring may form beyond the original lesion margin, so that the lesion center becomes surrounded by concentric rings. With age, the lesion centers dry out and crack. In avocados, leaves and fruit develop dark brown lesions.

Control

The goal of any avocado grower should be to prevent fungal diseases like *Cercospora* spot from erupting in the first place, so before you consider treatment, let us talk about prevention. *Cercospora* is often transmitted from plant debris or weeds that are around the tree, so make sure that you clean up all fallen leaves, shed fruit, and keep the area free of unwanted plants. If there are any avocados that were not picked or did not fall last year, they should be removed.

The other important condition is airflow. Fungal infections love pockets of stagnant air because they allow humidity to build, creating a fungal nursery. Thinning the inside branches of your avocado, like with any fruit-bearing tree, will not only decrease the humidity in the canopy, but also improve the quality of the fruits you get. The actual treatment of *Cercospora* is pretty straightforward. Copper spray, applied three to four times a year, seems to keep the fungus under control. The first spray should be done at the beginning of your wet season, and then monthly.

10. HARVEST AND POST-HARVEST MANAGEMENT

10.1. HARVEST

Usually, the first commercial harvest takes place five years after planting, with grafted trees and the number of fruit produced depending on the variety and how the field was managed during the trees' development. At five years of age, generally fifty fruit are harvested; at six, one hundred and fifty; at seven, three hundred; and eight hundred at eight years old. Some varieties such as Hass, Fuerte, and others with small fruits may produce 1,000-1,500 fruits at ten years of age (Table 14).

In Tanzania, Hass production is collected in two seasons. The high production season goes from March to June and the low season from Nov- Jan. Optimal fruit maturity for harvest is difficult to determine due to the diversity of species and environments, the variations in the length of the flowering-to-harvest period, and the differences in oil content during fruit ripening. The prevalent yardstick for maturation is based on the fat content of the fruit.

Table 14. Yields expressed in terms of number of fruit and weight by metric ton per hectare (with irrigation).

Age (years)	Yield in number of fruits and tons/ha		
		Number of fruits/tree	Fruit (mt/ha)
5		50	2.0
6		150	6.0
7		300	12.0
8		800	16.0

The percentage of dry matter correlates to the oil content, and it is used as a maturation index in most avocado producing areas. The minimum dry matter content required ranges from 19 to 25%, depending on the variety (19% for Fuerte, 20.8% for Hass, and 24.2% for Gwen).

In general, avocados are characterized by their high fat and/or oil content, with Mexicana cultivars having the highest (10%-15%) oil content. In the Guatemalan cultivars, this ranges from 10 to 13%, with West Indian cultivars having the lowest percentages (from 4 to 7%). This percentage refers to the weight of the fruit excluding the skin and pit. As the fruit reaches its physiological maturity, the oil content increases. The sugar content of the fruit decreases as it reaches maturity.

Mature fruit do not ripen and soften on the tree. You must learn to judge when hard, green fruit is mature and ready for harvest. If an immature avocado is picked, it will not ripen to an acceptable eating quality and will often shrivel and develop fruit rots.

Mature avocado can be recognized by a dull appearance of the skin or shriveling and yellowing of the fruit's stalk. When the fruit is cut open and the seed removed, the seed coat is dark brown and dry, and does not adhere to the flesh. Large fruits are found on the northern and eastern side of the tree, and the fruits at the top and outside of the canopy usually mature first.

NB: Check maturity before starting picking by doing a ripening test and dry matter test this is very important before you decide to harvest.

For a ripening test, select 5 to 10 avocados from tree scattered throughout the block and representative of the fruit that may be ready for harvest. Sample sound fruits that show no sign of broken skins, insect stings, or disease. Allow the fruits to ripen at room temperature, examine, and test the fruits when ready to eat. Mature fruits usually ripen within seven to twenty days without shriveling and have good flavor.

Fruit collection is done manually using ladders; the peduncle is cut above the insertion point to the fruit. Since avocados have strong respiratory activity after harvest, storing them for long periods is difficult because they have intense microbial activity and a strong decrease of water content. The extent of fruit respiration depends on the variety, degree of ripening, and environmental conditions of the area and storage facility.

When harvesting, exposure of the fruit to the sun must be avoided, as an increase of the core temperature will trigger physiological and chemical processes that quicken fruit ripening and decay. The fruit should not be subjected to knocks or compression as these affect the firmness of the flesh, which upon softening develops spots and becomes watery and, therefore, unfit for consumption. Rubbing the fruit and other damage or skin lesions speed up water loss, respiration, and ethylene release, increasing maturation and fruit decay, as well as providing points of entry for pathogens.

The fruit should be handled carefully once it is picked and taking to the packing facility. Fruit should be picked when it has reached its physiological maturity and is at the stage, locally known as "seasoned", "three quarters", etc.

The following guidelines are recommended when harvesting fruit:

- Take a 4 m bamboo or other light material pole, place at the end an iron ring approximately 25 cm in diameter, with 5 cm projecting sharp edges on top. On the bottom part of the ring, a canvas bag should be placed to collect the fruit. The operator introduces the fruit in the ring, and shakes the pole up and down so that cutting edges break the peduncle which is caught in the canvas bag.
- From the pole bag, the fruit goes to the canvas bag on the shoulder of the laborer. When the bag is full, the fruit is transferred to plastic crates placed in shady areas where the contents of the bags are emptied carefully to avoid bruises. It is worth mentioning that harvested fruit should keep a section of the peduncle (1-3 mm) in order to avoid injuries and later rot caused by fungus. Usually, peduncle rot is caused by fungi such as *Colletotrichum gloesporioides* or *Fusarium* sp.
- The plastic crates should not be filled to more than 80% of their capacity to avoid crushing the fruit. Trailers or vehicles used to transport the fruit in the farm should not be overloaded and loads should not be carried loose.
- Avoid Picking during wet weather, as fruits are more susceptible to skin damage and fungal infection. If fruit are to be stored in cool conditions for more than two weeks, avoid picking during extremely hot conditions, above 35 °C, as fruits are more susceptible to breakdown.
- Avoid excessive delays between picking and delivering to the packing shed. The maximum delivery time recommended varies with the length of the market period and fruit temperature.

Maximum time between picking and delivery to packing shed

Marketing period	Fruits temperature less than 30 °C	Fruits Temperature more than 30 °C
Less than two weeks	36hrs	12hrs
Two to three weeks	12hrs	6hours
More than three weeks	3hrs	Do not Pick

- The fruit should be carried to the packing facility the same day it was collected. It should be covered, to not expose it to direct sunlight or to prevent it from getting wet if it rains. However, sufficient ventilation should be provided to avoid overheating. During transport, loads should not shift, and they must be properly secured. Loading and offloading should be done carefully, not hitting the crates or moving them excessively.

10.2. MANAGEMENT AT THE PACKING FACILITY

After the fruit is harvested, it should be taken to the packing facility as soon as possible to be cooled, slow the maturing process, and get it ready for cold storage.

Ideally, no more than six hours should elapse between the harvest and pre-cooling, but if this is not possible, the fruit should be prevented from reaching core temperatures above 26° C in the field or while being transported to the packing facility where it will be placed in cold storage. The pre-cooling temperature can be the same as that of cold storage, namely 4.5 to 5.5°C. The fruit should be stored for 8-12 hours at 90-95% relative humidity. Among the different refrigeration systems, forced air has shown to be more effective than cold chamber.

When the fruit arrives at the packing facility, the crates should be placed in a way that different batches are not mixed and due note should be taken of the origin, supplier, etc. In the period spanning from arrival to processing, relevant sampling should be conducted to detect quarantine pests, as well as other pests and diseases, and to check on the general appearance of the fruit in terms of quality (spots, discoloration,

infection, nibbling, bruises, scrapes, etc.). Also, the fruit should be checked to make sure it has the characteristics of the variety being harvested.

10.3. PACKING PROCEDURE

The following steps should be followed when packing, preserving, and transporting the fruit:

- The fruit is subjected to an initial grading, where fruit that doesn't comply with the minimum requirements of the packing facility are removed. These requirements vary according to fruit destination, namely whether the final market is international or domestic. Also, each packer uses different standards, as they may or may not have introduced quality control practices.
- The fruit is washed with a fungicide solution containing Thiabendazol or Tecto (according to the requirements of the final market) in order to prevent diseases. After that, the fruit is dried and lightly brushed to acquire a shiny appearance.
- The following step is to grade the fruit by size (diameter) or weight according to the machinery used. During this step of the process, fruit is graded by caliber, in other words, by the number of fruit filling a packing box.
- A second grading is performed based on fruit quality and appearance for packing. Depending on the final market, packing containers for avocados might be 11-13 kg (25-26 lb.) wooden crates or cardboard boxes with 6.0 kg (13-13.5 lb.) capacity.
- Individual boxes are then placed in pallets for transport. The size of these is dictated by the measurements of the containers used for transport. The number of boxes per pallet varies among packing plants, but it generally consists of a little more than 200 boxes that weigh 4 kg each and less boxes when 6 kg boxes are used.
- Pallets are then moved to refrigerated chambers where they will be pre-cooled using the process mentioned above. After pre-cooling, pallets are moved to the cold chambers where they will be kept until they are loaded for transport. Preservation temperature ranges from 5.5 to 6.5 °C with 90-95 % relative humidity.

Respiration Rate

Avocados do not ripen on the trees and ethylene production does not start until after the harvest, increasing as maturation increases.

Respiration rates for avocados are as follows:

Temperature	5 °C (41 °F)	10 °C (50 °F)	20 °C (68 °F)
ML of CO ₂ /kg/h	10-25	25-80	40-150

Treatment with 1,000 ppm ethylene at 20 °C for 30 minutes induces ripening in 3 to 6 days depending on the maturation state and cultivar. Maturation indicators such as softening of the flesh and color change of the skin depend on the cultivar.

10.4. PRESERVATION AND TRANSPORT

During preservation and transport to international markets, temperature should not vary more than ± 1°C, and the cold chain should not be broken.

The threshold at the mentioned temperatures before cold damage occurs is three to four weeks of refrigeration. This should be taken into account for long-term maritime shipping and once the fruit arrives

at the destination port it should be sent to the retail distribution channels immediately so that refrigeration is not prolonged.

A shelf life of up to 60 days can be reached for avocados by using controlled or modified atmospheres, with 2.5 % oxygen levels and 5 % carbon dioxide.

Shipping temperatures used will depend on the Cultivar and fruit maturity. Usually start the seasons shipping at +7 °C in containers. As the season progresses and fruit oil content decreases, susceptibility to chilling injury decreases. Thus end the season beginning storage at +5 °C and with really mature fruit dropping to e.g. +4 °C or 3.5 °C in the last week of shipment on vessels destined for Europe. Various markets may demand certain temperature regimes in mitigation of phytosanitary challenges e.g. Fruit fly, FCM, etc., that the packing and logistical service providers are geared to comply.

Gradual cooling from harvest and packing of fruit within e.g. 6 hours of harvest is ideal. Once cooling at the desired regime based on fruit maturity, the cold chain must not be broken (a massive challenge in the Tanzanian logistical context).

10.5. PHYSICAL FACTORS

Major external symptoms for mature green avocados include pitting, scalding, and blackening when they are kept below 2 °C for more than seven days. Avocados stored at temperatures ranging from 3 to 5 °C for more than fifteen days experience ripening issues and increased damage caused by microorganisms.

10.6. POST-HARVEST DISEASES

Usually damage by *Antracnosis* caused by the *Colletotrichum gloesporioides* fungus appears when it starts attacking the flesh of the fruit softening it. Also, circular black spots appear that blacken and oxidize the flesh.

Peduncle rot caused by the *Botryodiplodia theobromae* fungus starts with a black rot of the peduncle that progresses towards the flowering tip until completely covering the fruit. Control methods include scheduled monitoring at the farm, post-harvest fungicide applications, avoiding damage during handling, rapid cooling, and optimal storage temperatures.

10.7. INSECT CONTROL

Low-temperature treatment for insect control at 1 °C for 14 days can be tolerated without cold damage if the fruit was initially kept at 38 °C for 12-18 hours. Avocados do not withstand high temperature treatment.

10.8. BUYER REQUIREMENTS

Size	Range in grams	Range in ounces (AV)
Mexico		
Super extra	266-365	9.45-12.97
Extra	211-265	7.5-9.42
First	171-210	6.08-7.46
Medium	146-170	5.19-6.04
Commercial	135-145	4.80-5.15
United States		
36	326-354	11.58-12.58
40	269-326	9.56-11.58
48	213-269	7.57-9.56

60	177-213	6.29-7.57
Europe & Canada		
14	266-305	9.45-10.84
16	236-265	8.39-9.42
18	211-235	7.50-8.35
20	191-210	6.79-7.46
22	171-190	6.08-6.75
Japan		
18	300-320	10.66-11.37
20	260-299	9.24-10.62
24	213-259	7.57-9.20
30	176-212	6.25-7.53
35	148-175	5.26-6.22

II. PRODUCTION COSTS AND REVENUE ANALYSIS

A. Avocado sprinklers Irrigation Cost per Acre

Items	Quantity	Price per Unit	Total
Main pipes PVC	11	20,000	220,000
Filter 2"	1	250,000	250,000
Micro sprinklers 50l/hr radius 2mm	120	14,000	1,680,000
Blind pipes 20mm	571	1,000	571,000
Ball Valve 2"	2	45,000	90,000
Elba2"	13	10,000	130,000
T - Connector 2"	1	10,000	10,000
Female Socket 2"	2	10,000	20,000
Glue	1	35,000	35,000
Drip Connector 20mm	7	1,500	10,500
Pumping Machine (Pressure Pump)	1	450,000	450,000
Installation cost	1	200,000	200,000
Transport cost			
Sub Total			3,666,500

B. Cost of production per acre

Items	Quantity	Unit	Price	Total
LAND PREPARATION				
Farm assessment/ Evaluation	1	1 Acre	50,000	50,000
Farm clearing	1	1 Acre	250,000	250,000
Farm Ripping	1	1 Acre	70,000	70,000
Disc Plough	1	1 acre	50,000	50,000
Agriculture Lime	800	1 Kg	200	160,000
Liming	5	1 Acre	6,000	30,000
Soil analysis	1	1 sample	87,500	87,500
Line and Plant hole Making	1	1 Acre	40,000	40,000
Hole Digging	120	Holes	1,000	120,000
Live berries/Wind break	1	1 Acre	50,000	50,000
Transport cost				-
Pegs making	120	1 Acre	100	12,000
Sub total				919,500
PLANTING				
Avocado seedlings	120	tin	3,000	360,000
Minjingu	3	100kg	35,000	105,000
NPK	75	100 seedlings	1,500	112,500
Hole mixing	120	1acre	300	36,000
Planting	120	1acre	200	24,000
Mulching	120		400	48,000
Sub total				685,500
ORCHARD MANAGEMENT				
Mulching	120	1acre	400	48,000
Watering 60L/tree per week average 20L = 300	120	1acre	300	36,000
Top dressing fertilizer (NPK, Zinc, Boron, CAN) for 2 weeks maximum	1,450	1acre	26	37,700
Chemicals Fungal and Insect side	2	Applications	90,000	180,000
Weeding (Hand or Herbicide)	1	1acre	30,000	30,000
Trees poles	120	1acre	100	12,000
Transport cost				
Labour				
Sub total				343,700
Harvesting cost (500 @ 25kg crate)	80	Crate	500	40,000
Pruning	100	Tree		-
Grand Total				1,948,700

*NB: This cost is not including farm hiring or purchasing and cost varies according to the location

C. Profit and loss analysis

Item	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Yield per Trees (Kg)	-	-	-	20	45	60	100	150
Number of trees 100	100	100	100	100	100	100	100	100
Total Kg Per Acre	-	-	-	2,000	4,500	6,000	10,000	15,000
Price per Kg	-	-	-	1,500	1,500	1,500	1,500	1,500
Total Revenue	-	-	-	3,000,000	6,750,000	9,000,000	15,000,000	22,500,000
Cost of production	1,948,700	343,700	343,700	383,700	433,700	463,700	543,700	643,700
Profit	(1,948,700)	(343,700)	(343,700)	2,616,300	6,316,300	8,536,300	14,456,300	21,856,300
Cumulative profit/loss	(1,948,700)	(2,292,400)	(2,636,100)	(19,800)	6,296,500	14,832,800	29,289,100	51,145,400

NB: Orchard management cost increases with pruning and harvesting cost

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ANNEXES

ANNEX I: AVOCADO NURSERY PRODUCTION- MINIMUM STANDARDS.

Established by South Africa avocado growers association (SAAGA)

Site selection and design
Site must be isolated and well drained (preferably raised).
Not closer than 10 m from <i>P. c.</i> host plants.
Waste water must not flow through the nursery. Provision has to be made for sufficient furrows and / or drainage channels at the top end and sides of the nursery area.
The nursery area has to be sanitized and kept as clean as possible.
Facilities where every person entering the nursery can wash their hands must be placed at convenient sites and provided with a cleaning agent.
The nursery area must be suitably fenced to keep out vehicles, people and animals.
Entry to the site must be restricted, with preferably one entrance only. Visitors should be accompanied.
Each entry point must have a footbath with a roof containing an effective fungicide such as copper sulphate or copper oxychloride. Footbaths must also be established between the different sections where the possibility of recontamination exists in the nursery, e.g. between bag fill and planting areas.
Implements must be restricted to a certain part of the nursery, e.g. the fumigation or planting area, and be sterilized before use.
The nursery floor and especially the footpaths must be well drained, preferably cemented or covered with crushed stone.
Permanent, sturdy raised platforms - minimum of 200 mm high - are necessary for placing the plant bags or pots on. The design has to prevent water running out of the plant bags coming into contact with other bags. Cross contamination must be prevented during irrigation and rainfall.
Roads in the immediate vicinity (within 10 m) of the nursery must be kept dust free.

Planting medium
The medium where seed germinate or trees are planted must be well drained with air filled porosity (AFP) of $\geq 20\%$.
The planting medium should be sterilized, pasteurized, composted or certified clean by the supplier before being brought into the nursery to ensure that the medium will be free of <i>P. c.</i> (phosphate and pH corrections should be done before sterilization) OR
Planting medium that has not been through above mentioned processes should at least be tested per batch for the presence of <i>P. c.</i> before being brought into the nursery.
Equipment and implements at risk of contamination when used in handling planting medium should also be decontaminated.
If the medium is stored, it has to be kept covered until such a time that plant bags are filled.

Water source (10 points):
Irrigation water must be tested at least twice a year by the area representative of SAAGA for the presence of <i>P. c.</i> and the water should have a pH of 5.0 – 7.5; and EC of less than 75mS/m).
Borehole water should preferably be used. The borehole must be deeper than 30 m and preferably in an area where <i>P. c.</i> host plants do not occur OR

Dam, canal and river water must be tested for *P. c.* and if positive purified and treated to ensure that it is free of pathogens. Filtration and/or water treatments can be used to achieve this.

If irrigation is done by hand, the spray nozzles of the hosepipes must not come in contact with the soil surface. Provide suitable hooks on which to hook nozzles when they are not in use.

Seed and budwood (13 points):

All mother trees from where seeds and bud wood are used should be tested for ASBVd at least once every 3 years.

The seed (fruit) must only be harvested from healthy trees and must not be soiled.

When seeds are removed from the fruit it should be heat treated (warm bath or steam) at 50 °C for 30 minutes or immersed in a 0.5 % Oxyacid™ (hydrogen peroxide) solution for 30 seconds to protect the seed against *P. c.*

After treatment the seed has to be dipped in a broad-spectrum fungicide.

If the seed is stored before heat treatment, it has to be placed in clean bags and stored at approximately 5 °C.

Bud wood and rootstock material must be taken from approved and indexed trees selected for vigour, productivity and health status and must be free from ASBVd.

The planting area

The filled plant bags must at all times be kept above soil level and transported in previously sterilised wheelbarrows / carts from the filling area to the planting area.

The bags may not touch the soil before they leave the nursery. And no persons are allowed to step onto the platforms.

Bags must have enough holes - up to 50% of the bottom surface area - for sufficient drainage.

Bags may not be used more than once.

Monoculture is preferred. If other subtropical crops are propagated in the same nursery, the standards as set out in ANA NIS are applicable to these plants. The inspection procedure will include these crops.

Weak plants must be removed from the nursery and destroyed away from the nursery, as they are a potential source of *P. c.* contamination.

Old, healthy plants (+12 months after planting date) should be kept separate from younger plants in the nursery (in separate rows without any physical contact), as they are also a potential source of *P. c.* contamination.

The area should be cleaned regularly and be free of weeds.

The pathways in the nursery must be sterilized monthly e.g. sprayed with 1% copper sulphate solution.

As soon as plants leave the nursery, the structures on which they stood must be cleaned and sterilized before other plant bags are placed on the site.

General nursery procedures

Plants from another nursery must not be brought into the nursery area.
Vehicles must where possible not be allowed to go into the fenced area of the nursery. A drive-through bath containing a suitable sterilizing solution should be used if vehicles have to drive into the nursery area.
Visitors should be limited and not be allowed to enter the in the nursery unaccompanied.
The nursery must comply with all the regulations as described by the Directorate of Plant Health and Quality.
Nursery regulations and latest star rating must be displayed at the main entrance.
Roots, tree size and tree condition should be regularly randomly inspected per batch to make sure they meet the APIS minimal requirements for a certified tree when ready for sale.
Batches should be kept as uniform as possible.

ANNEX 2: NUTRIENT DEFICIENCIES SYMPTOMS



Boron (B) deficiency symptoms: Yellowing of leaf edges on young avocado growth (left) and typical shot-hole symptoms in spring flush leaves (right). Photo from: Agrichem (left) and E. Joubert (right).



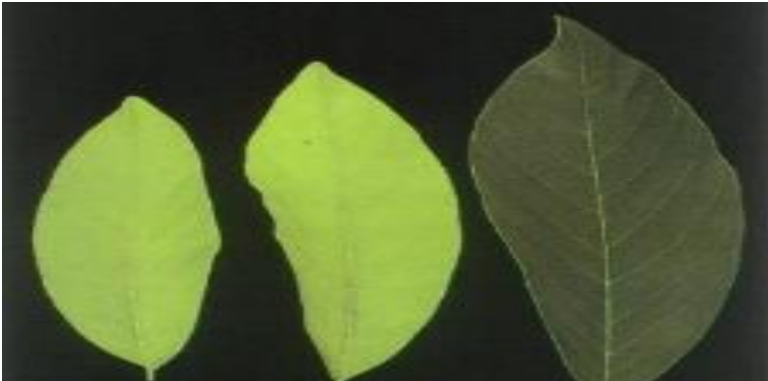
Manganese (Mn) deficiency symptoms: Interveinal chlorosis of young, fully extended avocado leaf. Photo from: Agrichem.



Zinc (Zn) deficiency symptoms: Little-leaf and "rosetting" of new avocado growth. Photo from: Agrichem.



Iron (Fe) deficiency symptoms: Green veins and interveinal chlorosis of young avocado leaf. Photo from: Agrichem.



Sulphur (S) deficiency symptoms: Yellowing of young avocado leaf in comparison to healthy leaf on the right. Photo: Agrichem.



Potassium (K) deficiency symptoms: Interveinal chlorosis and later the formation of light brown spots scattered across the narrow leaf. Photo: Agrichem



Magnesium (Mg) deficiency symptoms: Interveinal chlorosis spreading towards the base and midrib of the avocado leaf. Photos from: Agrichem (left) and E. Joubert (right).



Phosphorous (P) deficiency symptoms: Bronze colour and small leaf size of young avocado leaves. Photo: Agrichem



Nitrogen (N) deficiency symptoms: Uniform yellowing of leaves, some with curled-up margins. Photo: Agrichem

ANNEX 2: LIST OF STAKEHOLDERS REVIEWED THE MANUAL

No.	Stakeholders Names	Designation
1	Kanali Mkisi	J Mark Avocado Farm - Mufindi
2	Jason Founier	Kibidula farm Iringa -Mufindi
3	Donald Westcot	Westfalia Fruit
4	Tulole Bucheyeki	Uyole Reseach Institute - Mbeya
5	Kisalala Damas	TAHA
6	Kumwa Shehemba	DAICO - Kilolo -DC - Iringa
7	Gudelida Tsere	DAICO - Iringa DC - Iringa
8	Damas Lubuva	DAICO - Mufindi DC - Iringa
9	Marselin Mlelwa	DAICO - Busokelo DC- Mbeya
10	Aldegunda Matunda	DAICO - Rungwe DC- Mbeya
11	Bernadeta Fiwavo	DAICO - Wanging'ombe DC - Njombe
12	Lyzanile Maria	For TAICO - Njombe TC - Njombe
13	Thaudensia Massawe	TAICO - Mufindi TC - Iringa
14	Stephen Mruma	FTFT MnM Staff
15	Chesco Ng'ande	FTFT MnM Staff
16	Godwin Elisa	FTFT MnM Staff
17	Aristarick Lyimo	FTFT MnM Staff
18	Ruben Yanes	FTFT MnM Staff
19	Ferdinand Mgaya	FTFT MnM Staff