HortiFresh

FRUITS & VEGETABLES WEST AFRICA

Citrus production manual

GUIDE FOR CITRUS PRODUCTION FROM ESTABLISHMENT OF PLANTATION TO HARVESTING

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All photos in this manual were taken by the author, photos from other sources have been duly acknowledged.

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Table of Contents

List of tables and figures

1. Citrus planting material production in Ghana

A strong potential exists for the country to earn substantial higher economic value from increased production and exports of key tree crops such as citrus. To achieve this vision, the contribution and importance of high-quality planting material in terms of genetic purity, true to type and vigour to early field establishment, high yield and early returns to the grower cannot be over-emphasized. Citrus production in Ghana has not been given the adequate attention in terms of improvement, it deserves. Although there is lack of citrus budwood indexing, the industry achieved some success, i.e. using tolerant rootstock to address the prevailing virus diseases such as tristeza, until the advent of the devastating fungal diseases, citrus black spot and *Pseudocercospora* fruit and leaf spot diseases caused by *Guignardia citricarpa* and *Pseudocercospora angolensis* respectively, that have caused significant damage to the citrus industry. Citrus fruits were exported to neighbouring countries and provided raw materials for the local processing factories. However, the production of these citrus planting materials was mostly one-sided (Late Valencia on Rough Lemon rootstock). Other nursery operators jumped unto the production of these materials without much technical knowledge of the various reasons and methods that are needed to achieve good planting material. Furthermore, there is the need to broaden the production window such that fruits can be produced throughout the year. This objective requires that more scion and rootstock varieties are introduced to farmers. Enough information is available, and this guide summarises the basis and the good agronomic practices that can be used by extension agents, students, farmers and other stakeholders to produce good citrus planting materials in the country.

1.1 Types of citrus species cultivated in the country

Citrus varieties of commercial importance in Ghana include lime (Mexican lime), *Citrus* × *aurantiifolia*, the sweet orange, *Citrus sinensis* (Linn.) Osbeck and the mandarin or tangerine, C. *reticulata* Blanco. It is however important to note that grapefruit and other citrus hybrids (tangelos; tangors) are also cultivated although not in commercial quantities.

1.1.1 Sweet oranges

The sweet orange is by far the most important citrus species and includes the common dessert and juice oranges, represented by such varieties as the Late Valencia, Washington Navel, Mediterranean Sweet, Obuasi, Hamlin, Pineapple and Shamouti.

Sweet oranges may be separated into three recognizable groups. Within these groups, there are several varieties, which cannot be easily distinguished.

The groups are:

1. Normal fruits such as Late Valencia, Pineapple, Mediterranean Sweet and Obuasi;
2. Abnormal or navel fruits such as the Washington Navel; and
3. Red or red-streaked pulp commonly called "blood" oranges such as the Ruby red and Tarocco varieties. The "blood orange" is noted for its low acid content, compared to other sweet orange varieties, and is popular among consumers in the Ashanti region.

Among the sweet oranges, three maturity groups are cultivated. These are, early season varieties, maturing in August–October, with examples like Ovaletto and Sekkan; mid-season varieties maturing in October-December, with examples like Pineapple, Obuasi, Mediterranean Sweet; and late season varieties maturing in January to February, with examples like, Late Valencia, Natal and Olinda Valencia.

The total available heat units during the growing season have a marked influence on the rate of growth of oranges and could largely account for the differences in maturity of sweet oranges grown in the Central, Eastern and Ashanti regions. Thus, the Central region produces mature fruits earlier than those in Ashanti and Eastern regions.

The major rootstock used is the rough lemon (90%). Other promising rootstocks that has been successfully evaluated include Cleopatra mandarin, Rangpur lime, Volkameriana, Swingle citrumelo, Lake tangelo, and Shekwansha.

1.1.2 Mandarin

There are two groups of mandarin, or loose-skinned oranges of commercial importance. (1) The Satsuma group composed of several varieties ('Owari' Satsuma, Silverhill' Satsuma) and (2) the tangerine group commercially developed in Florida which include varieties such as Dancy and Clementine. Some varieties were introduced into the country several years ago and are known by the towns where these were popularly grown such as Aburi and Adeiso varieties. Satsuma has however maintained its name. Satsumas are softer in texture, easier to peel as they have a looser skin and have a lighter citrus flavour, whereas clementines are firmer, relatively easy to peel and have a sweeter flavour than satsumas. Other authorities have grouped mandarins into four groups: (1) satsuma group (*Citrus unshiu*), (2) the King group (*C. nobilis*), (3) the Mediterranean group (*C. deliciosa*), and (4) the common group (*C. reticulata*). Andersen and Ferguson (https://edis.ifas.ufl.edu/publication/CH116)

Tangerines and its hybrids that have been evaluated successfully in Ghana include Murcott, Orlando tangelo, Minneola tangelo, Satsuma, Ortanique (tangor), Ponkan. Local tangerines include Adeiso and Aburi.

The recommended rootstocks for the mandarins include the Cleopatra mandarin, Clementine and Rangpur lime. Rough lemon is not recommended as a rootstock for the mandarins. The major constraint to mandarin type of citrus production in Ghana is the high levels of fruit drop caused by fruit fly attacks.

1.1.3 Some commercial citrus varieties

The following grapefruits have been successfully evaluated in Ghana; Walters, USSR, Prestea. The Mexican lime is the popular lime that is planted in Ghana. For the hybrids, the following varieties are suitable for Ghana: Lake Tangelo, Minneola tangelo, Kara des Semis, King des Semis and Ortanique. See Table 1.1 for important commercial varieties in Ghana from which scions could be taken.

Table 1.1 *Maturity period of some sweet oranges, grapefruits and mandarins in Ghana*

Sweet orange		Grapefruit		Mandarin/Tangerine	
Variety	**Maturity period**	**Variety**	**Maturity period**	**Variety**	**Maturity period**
Washington navel	April/Nov	Walters	December	Satsuma	April/Sept
Pineapple	April/Nov	Thompson Pink	December	Ortanique (tangor)	November
Sekkan	April/Nov	Prestea	December	Ponkan	May
Ovaletto	April	USSR	December	Kara des Semis	November
Jumapo	Nov	Aburi	December	Kara des Semis	November
Mediterranean Sweet	December				
Red Blood	November				
Natal	Jan/Feb				
Late Valencia	January/September				

1.2 Citrus nursery

The nursery is an area where young seedlings are maintained under intensive care for up to their planting stage. It is a managed site, designed to produce seedlings grown under favourable conditions until they are ready for planting. The most basic function of the nursery is to provide an environment that allows seedlings to develop quickly into healthy plants ready for field planting. The nursery must provide protection from intense sunlight at the young seedling stages (30% shade is best i.e. 70% of full sunlight), wind and rain, provide adequate water and nutrients, and in response to plant growth needs, protection from pests, diseases and weeds. This will facilitate the production of high-quality seedlings to satisfy the needs of farmers and other users. No standard blueprint exists for designing a citrus nursery. On the contrary, each nursery will have a unique design based on distinct needs, resources, and requirements that meet minimum standards.

1.2.1 Site selection

The success or failure of any orchard is largely dependent on the quality of the planting material (genotype, rootstock/scion compatibility, healthy planting material and quality of the growing media) and how well the propagating and growing of the crop has been done at the nursery.

Avoid low lying areas or depressions that are likely to gather rainwater at the nursery site, because the nursery may be prone to flooding after heavy rains. This could affect several agronomic practices at the nursery. Generally, one must make sure that running water will never accumulate in the nursery. This can be avoided by improving the drainage for instance by digging small channels to allow the water to run off.

There are two main types namely: ground nursery and polybag nursery. For commercial production, polybag nursery where the planting material is raised in polybags is recommended.

Agronomic practices such as sowing, mulching, pruning, sorting, budding, water and nutrient management, data collection, arrangement of planting materials are better organized under polybag nursery than for the ground nursery. Large quantities of planting materials can be raised in a relatively smaller area. Furthermore, transportation of planting materials, early establishment and higher survival rate are recorded when plants are raised in polybags, because the roots are held intact during transplanting.

Generally, seedlings raised in 17.5 cm × 25 cm polybags produced bigger and taller seedlings, more leaves, longer tap root length, and had significantly higher ($P < 0.01$) total dry matter per seedling than those raised in 12.5 cm × 15 cm polybags.

Conduct proper seedling selection during transplanting of the seedlings. Select vigorous and healthy seedlings with roots properly developed. Avoid seedlings with curled root system. Transplant seedlings when it is about 4 to 5 weeks old.

1.2.2 Structures for the establishment of nursery

The poles and cross bars can be constructed with wooden poles, bamboo and galvanized steel pipes (Fig 1.1, 1.2 and 1.3). Shade nets and palm fronds are usually used as shades (Fig 1.2B).

- Install quality water supply or an irrigation facility to nursery site for watering (Fig 1.3A).
- Mark out positions and install nursery poles or posts.
- Install shade nets for side netting and roofing.

1.2.3 Accessibility of site

It is very important to site the nursery at an area where it is easily accessible to traffic. This will facilitate the movement of potting media and other agro inputs to the site. In addition, it will facilitate the marketing of the planting materials to consumers. The site should be accessible to vehicles to transport inputs and planting materials especially during the rainy season.

Figure 1.1 *Different types of nursery structures, with walkways, and seedling arranged in blocks with walkways. Vertical and horizontal (A and B) metal poles and types of overhead shade nets (B).*

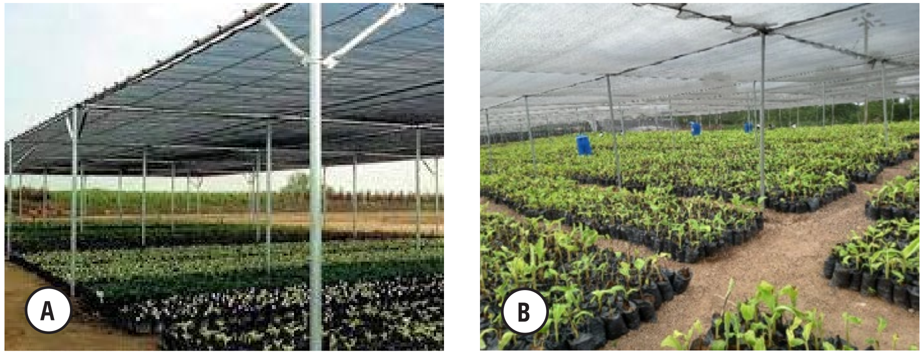
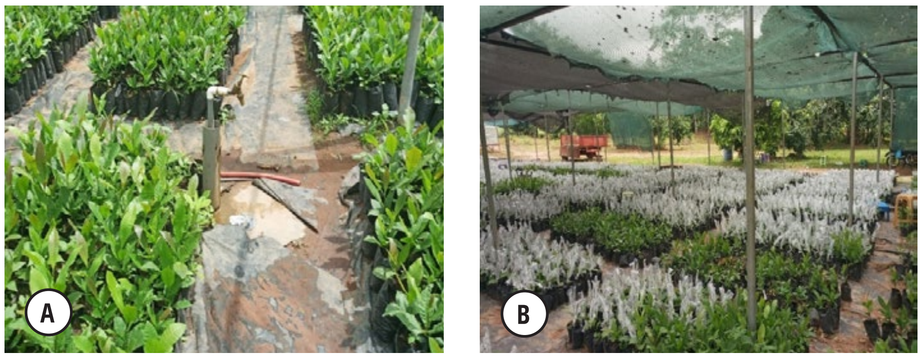


Figure 1.2 *Different types of nursery structures, with walkways, and seedling arranged in blocks with walkways. Wooden (A) and Bamboo poles (B) used as vertical and horizontal poles and shade net (A) and palm fronds used to provide shade (B).*

Figure 1.3 *Citrus nursery with ground lined with polyethylene sheet to serve as root pruner and standpipes to provide water for irrigation at vantage points (A) and seedlings arranged in blocks or segments (B).*



1.2.4 Nursery layout

The nursery should ideally be located on representative land where climatic conditions are similar to the area where the budded citrus plants will be ultimately planted. The nursery site should not be shaded by tall trees but should be exposed to full sunlight after the germination or transplanting period. However, Ofosu-Budu (unpublished) observed very low incidence of leaf scab, when overhead shade was provided that prevented continuous wetting of the leaves of rough lemon rootstocks at the nursery. The nursery should be located near a regular or permanent water source or standpipes should be erected at vantage points (Fig 1.3A).

The appropriate layout of the nursery site indicates the location of nursery beds, replacement section, warehouse, transport road, irrigation, and other facilities. In determining the nursery layout, the function of each facility to be built should be considered to support the smoothness of seedling production process.

The most important thing in determining the nursery layout is to create a right distance among the production units and seedling transportation to ensure the health and safety of the seedlings.

The nursery layout and design specification should include type and level of shade, drainage, plant spacing and support, bag size and potting mix.

Layouts are provided to enable operations flow logically through the nursery to save labour and time. A nursery layout is usually arranged in a series of beds with pathways of about 1.5 m between them to facilitate the movement of nurserymen and operations, movement of wheelbarrows, in the daily activities such as watering, pruning, budding, nutrient and pest management and seedlings arranged in blocks or segments (Fig 1.2A, 1.3A).

The nursery should have blocks, where the seedlings are arranged. Each block should have a specified number of rows and columns to facilitate the estimation of citrus seedling populations (Fig 1.2B, Fig 1.3B). Ideally, the seedlings should be placed on level land to avoid erosion problems especially when heavy rains occur or as a result of irrigation. Preferably, the number of seedlings in a row (width) should range between 8 and 10 polybags, depending on the size of the polybags, to facilitate easy work within the inner parts of the block. The column (length) could be variable depending on the erosional hazards of the site. The arrangement of the blocks should be aimed at controlling erosion.

The nursery blocks should have signpost indicating among others, type of rootstock, date of transplanting of the seedlings, date of budding and the type and name of the scion.

Figure 1.4 *A typical citrus nursery with walkways but without overhead shade to regulate wetness of the leaves. Predisposes the plants to foliar fungal and bacterial diseases.*

1.3 Vegetative propagation

1.3.1 Importance of vegetative propagation

Commercial citrus orchards are established using budded materials. This is because if the seeds of the selected citrus is used the resultant plant cannot tolerate most of the diseases prevailing in that environment, and will be difficult to manage such diseases if it is caused by virus. Furthermore the horticultural characteristics of the parent material will not be wholly inherited in the new plant; the plant will take a long time to fruit and delay returns on investment; the yield is most of the time lower than the budded material; the trees grow very tall and harvesting and other cultural practices become difficult.

The vegetative propagation method is preferred because it:

- reduces the immaturity period from 7 to 3 years;
- overcomes certain problems associated with the environment; diseases (tristeza), drought, soil acidity;
- produces true-to-type material like the parent (close to the parent in terms of yield and quality);
- reduces height of the plant.

1.3.2 Rootstock

A rootstock is that part of the budded or grafted planting material that is in the soil. The rootstock has immense effect on the performance of the scion, in terms of yield, disease tolerance, juice quality (soluble sugar content brix, total acidity, juice volume, juice colour) plant vigour and size (plant spacing), more than the effect of the scion on the rootstock.

Citrus rootstocks have well-known effects on tree size, crop load, disease tolerance and fruit size and quality, making the choice of rootstock for a citrus orchard an important consideration. Inherent differences among rootstocks that affect plant–water relations are associated with differential fruit development and sugar accumulation of citrus fruit and are considered a primary cause of differences in vigour, crop load and fruit quality among citrus rootstocks. Rootstocks differ genetically and this affect its characteristics in terms of plant water relations such as root distribution, water- and nutrient-uptake efficiencies.

Rootstocks differ in their effects on the performance of the scion such as canopy size, plant height and yield. Rootstocks differ in their effect on the canopy and, morphology disease tolerance, brix, acidity, juice content of the scion. Rootstocks also differ among themselves physiologically with respect to water relations and nutrient uptake, tolerance to drought, tolerance to low pH, and salinity.

A good rootstock should have the following attributes, in addition to performing the normal root functions.

- Confer compatibility with the selected scion;
- Promote high yield with the selected scion;
- Provide some degree of disease tolerance especially to the prevailing viral disease in that environment, such as tristeza, exocortis in Ghana;
- Adaptable to the soil and climatic conditions of the selected environment;
- Tolerant to drought (roots should be able to grow deep to absorb soil moisture and nutrients from deeper depths of the soil);
- Should produce high quality fruits;
- Should exhibit polyembryony.

Factors to consider in rootstock selection include the ability of the rootstock to supply water and nutrients to the plant basically, have influence on fruit development in citrus trees, determining the vigour of the scion cultivar and its tolerance to water stress. Therefore, the characteristics of the rootstock are also an important consideration when determining the response of citrus trees to water stress drought conditions along the landscape/top sequence.

Rootstocks vary in their tolerance to the prevailing constraints in the environment, such as disease, drought and on fruit and juice quality among others. Therefore, it is important to select the appropriate rootstock that will best suit the farmer's needs. This include but not limited to the following.

- tolerance of the rootstock to the prevailing citrus diseases in the environment, especially to the virus diseases (tristeza, exocortis), or bud transmissible diseases;
- tolerance to soil factors such as salinity, drought, pH, nematodes;
- effect of rootstock on yield (not every rootstock will give high yields);
- effect of rootstock on juice quality (juice content, brix value, etc.);
- peel colour.

Some rootstocks which have been found promising as commercial rootstocks for the citrus industry in Ghana are: Rough lemon (C. *jambhiri* Lush), Rangpur lime (*C. reshni*), Cleopatra mandarin (*C. reticulata* Blanco), Lake tangelo, Swingle citrumelo, Shekwansha, and Volkameriana (*C. volkameriana* Ten and Pasq.).

Sour orange is not recommended for use as a rootstock in Ghana because of its susceptibility to citrus tristeza virus disease, which is prevalent in Ghana.

The most commonly used rootstock, Rough lemon, induces a larger canopy size than Swingle citrumelo. Consequently, the planting distance for the same scion on these two rootstocks would not be the same. Similarly, Swingle citrumelo, induces higher brix content in juice of the scion than that of rough lemon. Rootstock type has important implications on the success of the orchard and the cultural practices.

1.3.2.1 The functions of the rootstock include

- to anchor the tree in the ground, absorb and transport water and nutrients to the aboveground parts of the tree;
- to serve as sites for syntheses or conversion sites for growth regulators and as storage structures for food reserves;
- to be useful, the rootstock must meet these basic requirements.

In addition to the following:

- it must be compatible with a chosen scion cultivar, adaptable to the soil and climatic environments;
- impart productivity and some disease tolerance to the scion; and
- have a high level of nucellar embryony.

1.3.2.2 Major Rootstocks and their characteristics

Recommended rootstocks include Rough lemon, Cleopatra mandarin, Volkameriana, Swingle citrumelo and Rangpur lime. The main characteristics of the rootstocks are given below.

Table 1.2 *Characteristics of the major rootstocks*

Characteristics of the major rootstocks	Fruits from rootstocks
A. Rough lemon	
• Promotes high yield of scion • Has a high degree of polyembryony. • Highly adaptable to deep infertile soils • Deep rooted and drought tolerant • Moderately tolerant to high salinity • Adapted to a wide range of soil pH • Tolerant to citrus tristeza virus, exocortis and xyloporosis to scab diseases, especially when soil fertility is low • Highly susceptible to citrus blight and gummosis *Caution:* • Not recommended for mandarins as fruits tends to dry out and spongy.	

Characteristics of the major rootstocks | **Fruits from rootstocks**

B. Cleopatra Mandarins

- Suitable for mandarins and other varieties
- Tolerant to diseases such as tristeza virus, exocortis and xyloporosis
- Adapted to different types of soils, ranging from light sands to heavy clays
- Tolerant to high salinity and high pH
- Total soluble contents of fruits on this rootstock slightly better than rough lemon

Caution:

- Bud rootstocks at tender age using the chip technique to achieve high bud take.

C. Rangpur lime

- Is a mandarin-type hybrid
- Promotes high juice quality than rough lemon
- Susceptible to exocortis virus diseases
- Chances of development of die back in trees is high

D. Citrus volkameriana

- Is a lemon hybrid
- Vigorous growth at early growth stages
- Imparts dwarfness to scion
- Tolerant to citrus tristeza
- Yields moderate quantities of moderate to poor quality fruit like rough lemon

Characteristics of the major rootstocks | **Fruits from rootstocks**

E. Swingle citrumelo

- Is a hybrid of grapefruit and trifoliate orange
- Shallow root system
- Has trifoliate leaf
- Highly polyembryonic
- Tolerant to tristeza
- Resistant to root-rot and citrus nematode
- Suitable for most soils except heavy clay or lime rich soils
- Imparts dwarfness to scion
- Produces high quality fruits and gives high brix than rough lemon
- High yielding

Caution:

- Requires good nutrient management to produce good yield

1.3.2.3 Raising rootstocks from seeds

Fruits for seed extraction should be collected from the preferred rootstock type like rough lemon, cleopatra mandarin. Fruit should not be cut throughout but halfway to avoid the destruction of the seeds. In the case of rough lemon, seeds must be extracted when the fruit colour is about changing to orange because if the fruits is over-ripened, the seed content is reduced significantly.

Seeds should be washed to remove mucilaginous coating. Remove all off-types and underdeveloped seeds by putting the seeds in water and rejecting those seeds that float.

Seeds may be stored in polybags at a low temperature if not to be sown immediately. Soak seeds for 10 minutes in water at 50°C to control seed borne diseases. Proper seed storage is essential for adequate seed survival and germination. The seeds can be sown directly to the potting media in a polybag or sown in a wooden box that has been filled with loamy well drained soil. The box for germinating the rootstock seeds should promote drainage, with a depth of 15 cm or more. After germination, the seedlings are transplanted into the polybag containing the potting media. The latter method, where the seeds are sown in a pre-nursery box and allowing the seedlings to attain a three-leaf stage is recommended, since this will offer the nurseryman, the opportunity to select high quality i.e. uniform and vigorous, material for establishment. Raising seedlings in boxes or beds will also allow the nurseryman to cull out malformed seedlings, and avoid the damage to the polybags, during thinning out of seedlings to one seedling per polybag.

1.3.4 Scion

The scion is that part of the budded citrus plant from where the farmer will harvest the fruits. Like the rootstock, it is important that the grower is made aware of the horticultural characteristics of the scion, such as the maturity period, potential yield, and juice quality of the selected scion. Scion selection is primarily an economic decision involving the choice of specific cultivars in response to or anticipation of market demands. Improved planting materials are the most important input in citrus production because it determines the potential yields and therefore the ultimate productivity per unit area.

It is important that the nurseryman guarantees the authenticity of the cultivars selected as any mistake made at this initial stage will not be evident until later when trees are bearing fruits. The selected scion will determine the type of citrus variety (sweet orange/grapefruit/mandarin/tangor) and maturity group of the plant (see Section 2.3, Table 2 for choosing a suitable variety). Trees raised through seeds/seedlings do not result in true to type materials, resulting in wide variations in yields, growth habits and in pest and disease resistance/tolerance. Such variations can be eliminated by propagation of plants through grafting methods. The interactions (relationships) between these two plant parts (rootstock and scion) are of much significance in the citrus industry. Combining two different plants (genotypes) into one plant by grafting or budding can produce growth patterns that are different from those that would have occurred if each component part had been grown separately.

Some of these effects are of major importance in horticulture and, while others are detrimental and should be avoided. Factors to consider in selecting the scion include:

- compatibility with the rootstock
- the maturity periods
- potential yield
- juice quality of fruits produced.

The different types of rootstock/scion incompatibility systems in citrus can be identified at the orchard. During budding two different plant parts with differing genetic composition are brought together. These two different materials grow at different rates.

When the scion and stock grow at the same rates, there is a perfect union, while if the stock grows at a faster rate (Swingle citrumelo as rootstocks), there is dwarfing of the composite tree. These two conditions do not pose problems to yield of the crop. On the other hand, when the scion grows at a faster rate than the stock (Rotuma on Cleopatra mandarin), there could be a possibility of the shoot giving more weight to the stock which might break. In selecting scion or budwood, proceed as follows:

- Pick scion/budwood disease-from disease free and high yielding mature trees (about 10 years old) with desirable characteristics.
- Select mature budwood from previous season's growth with swollen buds.
- Cut bud wood 10–15 cm long using appropriate tools (secateurs and knives).
- Keep budwood fresh through
  - wrapping in neat and wet newsprint or wet towel/cloth/jute sack to prevent desiccation
  - holding in moist sawdust
  - holding in ice Styrofoam box (sprinkle water on the budwood before covering).

Note: Budwood of varieties can easily be mixed up when picking different varieties from the orchard at the same time. To avoid this, label batches immediately and keep proper records of each batch.

Caution: Avoid keeping budwood for more than 5 days after harvesting/cutting: do not cut bud wood with broken buds; picking bud wood from trees that are than 8 years old; taking bud woods from tress that are showing signs of greening, dieback of trees and gummosis infection.

Specialized tools are required to carry out budding successfully. These include:

- well sharpened budding knife
- secateurs for cutting budwood
- sharpening stone
- budding tape
- basin or bucket
- ice chest or styrofoam box.

1.3.5 Budding

It is important to ensure that the selection of the rootstock and scion materials fit into the overall objective of the citrus grower's target. This is due to the fact that vegetative propagated materials are true to type, and any error made in the selection of these materials cannot be corrected Generally, rootstocks are selected for various reasons including its tolerance to the prevailing virus disease in that particular environment, drought tolerance, salinity, yield and fruit quality, time or season of fruiting. For example, although sour orange is a very popular rootstock variety in Brazil, it is not suitable to be used in Ghana, because of the prevalence of the tristeza virus disease in Ghana. Again, since rootstocks exert significant influence on fruit yield and quality of the scion, and differences in water and nutrient uptake exist among various rootstocks, it is important to select the most suitable rootstock for the purpose. There are differences in the heat units required for the scion to produce fruits to maturity. Thus, we have early mid- season and late maturing varieties. Failure to select the budwood of the suitable variety can bring yield and loss in revenue to the grower. For the above reasons and others, it is not advisable to obtain citrus planting materials from unrecognized institutions. Recommended recognized institutions where one can seek information on citrus or buy planting materials include University of Ghana Forest and Horticultural Crops Research Centre Okumaning-Kade, Asuansi Agriculture College, CSIR-Plant Genetic Resources Institute at Bunso, CSIR-Crop Research Institute in Kumasi.

Different techniques are adopted in budding/grafting. These include:

1. Shield ('T' or inverted "T")
2. Chip

Steps in shield budding:

- Bud rootstocks at 20–30 cm above soil level to minimize disease infections of the sprouting scion/budwood.
- Make a slit in the bark in the shape of "T" or its inversion.
- Lift the bark from the cambium.
- Similarly shape the bud and push it between the bark and the cambium.
- Hold in place and tie firmly together with a bring tape.
- Inspect budded plants two weeks after budding to determine bud take:
  - a green bud signifies successful take
  - a brown bud signifies failure in which budding needs to be repeated at a different position on the root stock.

  If bud is green (taken), cut the entire rootstock (2–3 cm) above the bud union, to promote sprouting and optimum growth.
- Regularly prune any shoots that appear on the rootstock below the bud.
- Tag individual budlings indicating variety and date, and arrange in batches.
- Label each batch of seedling indicating variety, day budder, source of budwood and number of budlings.

Avoid:

- Touching exposed cut surfaces
- Using dirty tools
- Contamination of buds with soil.

Care of budded seedlings:

- Water adequately and regularly to keep soil or growing medium moist.
- Remove all shoots below the bud union.
- Monitor for pest and disease and apply appropriate management interventions as necessary.

Budding should be done when the girth of the rootstock or seedling is of pencil size. This will depend on the agronomic practices at the nursery including the quality of the soil.or growing used, adequate watering and nutrient management. Generally, it takes about 4 months to reach this size.

Requirements for high bud take:

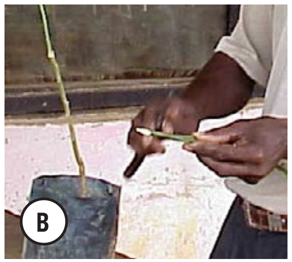
- Bud during the dry season to promote high bud take.
- During the rainy season, if it is necessary to bud, place budded materials under shed to prevent soaking of the bud.
- Treat bud wood by dipping in fungicide (1% Benlate) as a preventive measure.
- Tie the upper part of the bud more securely or tightly in the rainy season, than you would have done in the dry season.
- Ensure that the age of the budwood correspond to that part of the rootstock where you are going to insert the bud.

Note: Budlings are ready for field after second flush (whorl) have hardened (2–4 months).

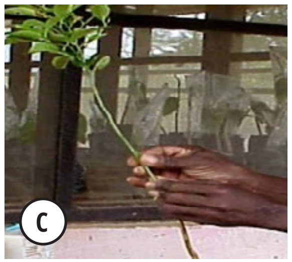
1.3.5.1 Stages in the budding of citrus

Figure 1.5 *Materials used (A) and the steps (B-F) involved in the budding process in citrus*

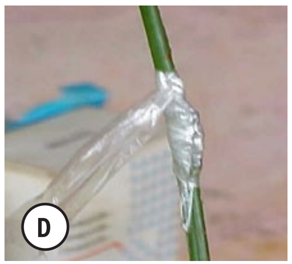
(A) Polyethene tape and budding knife



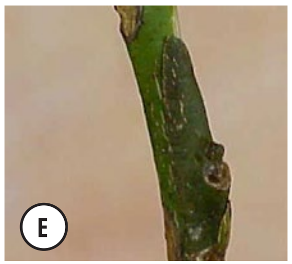
(B) Removing bud from the budwood



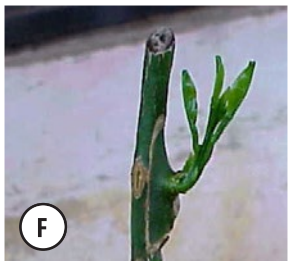
(C) Insertion of budwood to the rootstock



(D) Tying of bud to the rootstock using a transparent polyethene tape



(E) Bud showing green after two weeks, indicating bud take



(F) Sprouting bud that will develop to become the scion

1.3.5.2 Post-budding pruning

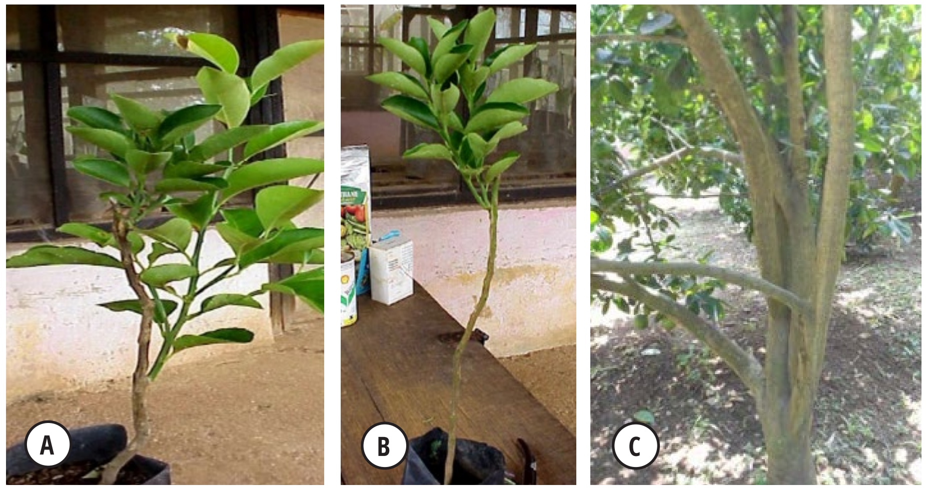
Most often there is growth on the rootstock after the bud take and topping of the seedling. Since the growth on the rootstock is part of the rootstock, this interferes with the growth of the scion. It is important to ensure that the offshoot on the rootstock is pruned regularly to promote the translocation of water, nutrients and photosynthates to the scion. This will ensure the vigorous growth of the scion.

1.3.5.3 Pruning offshoot on the rootstock

- The offshoot on the rootstock should be pruned before planting or check for such offshoots on the rootstock at early growth to avoid the rootstock overgrowing the scion (Fig 1.7A).
- Recommended planting material, without any offshoot growth on the rootstock. Allow the single stem growth up to 1 m before promoting branching of the scion (Fig 1.7B).
- The rootstock overgrowing the scion. The rootstock should have been pruned much earlier (Fig 1.7C).

Figure 1.6 *Vegetative growth on the rootstock part of the planting material that should be pruned (A), recommended citrus planting material without growth on the rootstock part (B).*

Figure 1.7 *Challenges to encounter if rootstocks are not properly pruned.*



- During the first two years of field establishment, identify offshoots on the rootstock and prune immediately.
- Differences in leaf colour or leaf morphology between the rootstock and scion can be used to identify the offshoot on the rootstock.
- Maintain a single straight stem up to a height of 100 cm, and pinch or break the main shoot to encourage side branching.
- Allow 3 to 4 main branches to form the framework of the tree.
- Remove any extra side branches including those growing inwards.
- It may be important to prune the trees to promote spreading rather than vertical growth of the canopy.

1.4 Nursery management

A potting media can be defined as a solid substrate that replace the natural soil for plant development on which roots grow regularly by extracting water and nutrients. The potting medium provide physical support, good drainage, porosity, storage of water and supply nutrients to the plant.

The characteristics of a good potting mix include: well drained, which means an air-filled porosity of at least 15% re-wets easily – some peat and bark media are difficult to re-wet if they dry out. does not shrink away from the side of the pot as it dries.

Seedlings need to be well nourished to ensure steady and healthy growth. The potting medium should be well drained and fertile enough to ensure good bud-take and sustain seedling growth. A good potting medium should include, topsoil, well-decomposed manure/compost and river sand/biochar.

When biochar is used as a soil amendment, a significant portion of the recalcitrant carbon biochar carbon can resist degradation, thus creating stable carbon pools. Biochar can have other benefits on soil including increases in the general fertility and water-holding capacity, reduction of bulk density, reduce acidity, provision of additional cation exchange sites and for enhancement of microbial activity due to biochar-sourced carbon.

1.4.1 Preparation of potting medium

Prepare medium using the following combinations:

- Where topsoil is clayey, use 1 part topsoil: 2 parts sand or biochar: 2 parts decomposed manure.
- Where topsoil is loamy, use 1 part topsoil: 1 part sand or biochar: 1 part decomposed manure.
- Where topsoil is sandy, use 1 part topsoil: 0 part sand: 1 part decomposed manure.

For each medium mix the components thoroughly and sterilize where necessary.

Polybags are bought either already cut or in rolls. If a roll cut and seal one end to obtain a size 5–6 cm × 7–9 cm in preparing potting bags, both sealed and unsealed bags may be used. However, for easy handling and transportation, bags with one end sealed is preferred.

To ensure proper growth and development of seedlings, it is important to apply supplementary nutrients, especially nitrogen at regular intervals. Prepare a starter solution as follows:

- Dissolve l g of NPK (15-15-15) and 1 g of ammonium sulphate in 1 litre of water and apply to plants as and when necessary.

Caution: Avoid fertilizers containing urea for polybag nurseries, as it may damage /scorch leaves and cause stunted growth.

1.4.2 Weed management

Weeds compete with seedlings for nutrients and sunlight and may harbour pest and diseases. Weed management begins with site clearing and land preparation. Some methods in management of weeds in polybag series include:

- Clearing site of all weeds prior to arranging polybags.
- Mulching soil in polybags with appropriate materials (e.g. carbonated rice husks, sawdust or any such organic materials).
- Regularly picking weeds as they sprout in the polybags.

To control weeds in open spaces within the nursery, hoe or apply appropriate herbicides using spraying shield.

1.4.3 Insect pest and disease management at the nursery

Citrus seedlings are susceptible to attack by diseases and insect pests. Several soil-borne diseases including damping off caused by *Pythium* spp. Scab caused by *Elsinoe fawcetti* and leaf spots caused by *Xanthomonas campestris* attack seedlings at the nursery. Timely application of fungicides and adequate drainage can control these fungal infections. Insects of economic importance at the nursery include aphids, grasshoppers, leaf miners and caterpillars.

The most prevalent diseases at the nursery include Alternaria leaf spot on rough lemon, citrus scab and *Pseudocercospora* fruit and leaf spot (Meghan and Timmer, 2009). These diseases can be controlled by providing structures to protect the plants in the nursery. Providing a simple structure with a roof to protect the foliage from the rain – thereby reducing the leaf wetness – is essential to improving the success of the nursery. Leaf wetness is necessary for these diseases to complete the infection process (Meghan and Timmer, 2009)

Good agricultural practices for nursery pest and disease management:

- Avoid areas with recent history of crop pest and disease contamination.
- Sterilize potting media before use.
- Use sterilized tools during budding.
- Select disease-free trees for scions and budwood.
- Provide adequate nutrition to the seedlings.
- Ensure adequate aeration to reduce humidity.
- Avoid heavy shading.
- Monitor and control insect pests and diseases as necessary.
- Keep nursery clean of weeds and plant debris.
- Remove and destroy diseased plants.
- Use clean water for watering and irrigation.
- Keep plants adequately watered.

Traceability of planting material:

Traceability to the ISO 8402-1994 standard, traceability is the ability to trace the history or location of an article or an activity, or similar articles or activities, means of documentation.

The purpose of traceability is to:

- Prove that you comply with specification requirements, or that you have taken all necessary measures.
- Trace the historical records of a product in case of a problem.
- Comply with regulations, store, and run the history of the processes of supply and of company to improve the overall operations.

Traceability is mandatory for all exporters doing business with the European Union. Other countries outside the EU have their own requirements like the EU. Citrus growers have guaranteed the traceability of their produce and is in the interest of the nursery man to producer documentary evidence of traceability of the planting material supplied.

After identification and selection of rootstock, data such as the variety name and source of seeds must be collected and recorded. All other relevant information including date of sowing and treatments given during the growth of the seedling should be well documented and easily retrievable.

1.4.4 Nursery records

Records of all activities undertaken in the nursery must be kept and properly documented, this is also important for traceability, effective planning, and budgeting, facilitates cost analysis, facilitates tax assessment and facilitates access of financial support. Where seedlings are produced in batches, separate data must be kept for each batch. Ensure that proper records such as the following are kept in place in front of the rows of each batch:

- name of rootstock
- date transplanted
- name of scion and date budded
- source of the scion
- number of plants in that segment/block
- date of untying the polythene tape
- data on source of budwood, rootstock of the budwood.

Proper record taking include:

- The ease of monitoring activities
- Traceability of resources and outputs (Tracking and Tracing)
- Financial considerations in nursery management.

Before starting a nursery business consider the following:

- Possible marketing avenues
- Estimate financial outlay
- Determine sources of finance
- Assess availability of skilled labour
- Prepare a business plan.

2. Citrus field establishment

2.1 Areas in Ghana suitable for citrus cultivation

Citrus is cultivated under rain fed conditions. Suitable areas for cultivation include areas with rainfall amount not less than 1500 mm per annum and distributed in a bimodal fashion.

Places in the Western, Western North, Ashanti, Eastern, Central regions are suitable for citrus production, in terms of rainfall amount and distribution. It is important however to check on other factors, such as distance to accessible road, and soil depth at where you are going to cultivate the crop to make your final decision.

2.1.1 Toposequence

Soil should be deep, i.e., should not have an impervious layer within 1 metre depth. Avoid swampy areas, select mid slopes, avoid hilly and sharp sloppy areas that are liable prone to severe soil moistures stress conditions during the dry season.

Select deep rooted rootstocks such as rough lemon for hilly and mid slopes, especially due to climate change.

2.1.2 Soil depths

See Fig 2.3.

Figure 2.1 *Map of Ghana showing the rainfall distribution (mm) at various zones.*

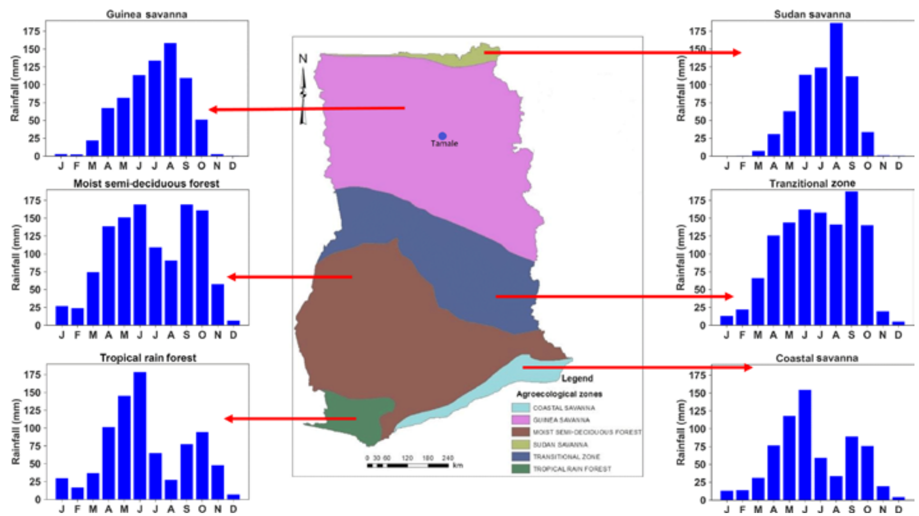


Figure 2.2 *Characteristics of a typical toposequence in the forest region. From the upslopes to the valley bottom.*

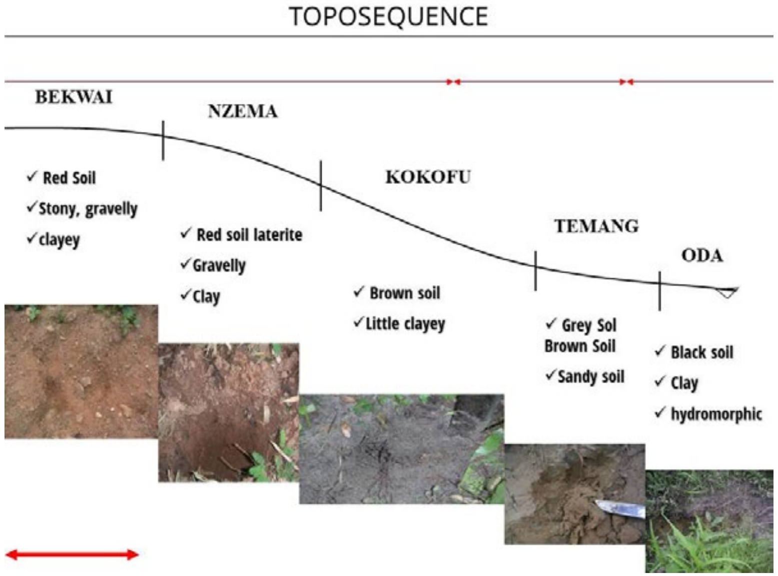
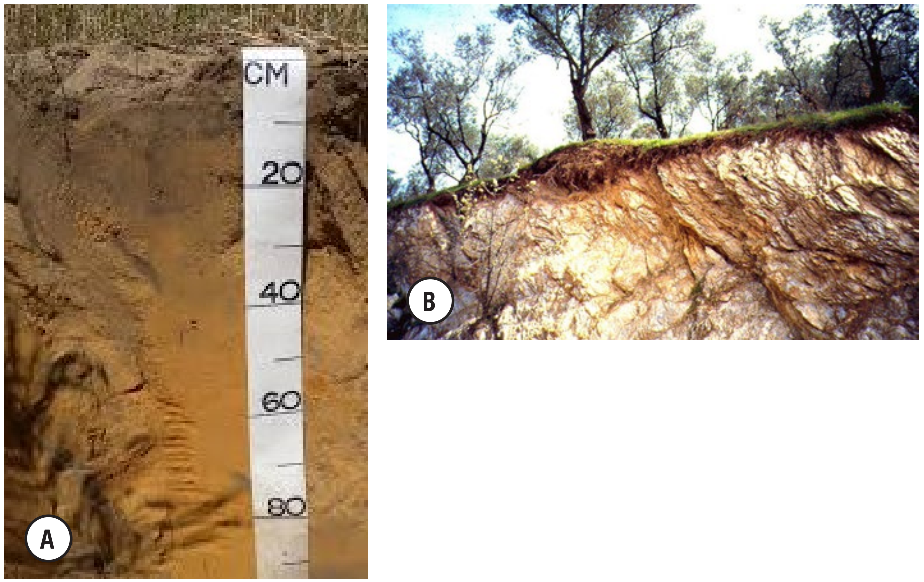


Figure 2.3 *Deep soil (A). Suitable for citrus cultivation as there is no hindrance to root development within 100 cm depth. Shallow soil (B), not suitable for citrus cultivation as there is hindrance to root development (rock) within the 100 cm depth zone.*



2.2 Characteristics of a good land for citrus production

- Site should be accessible to road.
- Undulating land, avoid steep slopy lands.
- Avoid waterlogged and swampy areas.
- Select areas with big trees, indicator of deep soil.

2.3 Lining and pegging

This is the process of identifying or selecting the potential planting positions for the citrus plants in the field. This activity enables the farmer to determine the number of plants for the farm. Sometimes, the land will have areas that cannot be planted with citrus such as rocky and swampy areas. These positions will be identified during the lining and pegging. It is important to make available areas for traffic lanes, to facilitate transportation of harvested fruits during the lining and pegging. It is recommended to arrange between eight and ten trees in a row, to facilitate harvesting and aggregating of fruits on the farm.

2.4 Significance of planting distance in citrus

- The planting distance is dependent on the type of rootstock used. The rootstock affects the tree vigour and the size of the canopy. Vigorous rootstocks such as Rough Lemon should be spaced at 6 m × 6 m, while Swingle citrumelo should be spaced at 5 m × 5 m to increase the plant density.
- Importance of correct planting distance promotes good exposure of plant to sunlight.
- Roots to spread out properly.
- It leads to good fruit quality and sweet fruits.
- Effective weed control.
- It allows optimum number of plants/unit area.
- Easiness in implementing cultural practices and estimates yield per hectare.
- Good revenue to the farmer.

2.4.1 Factors affecting citrus planting distance in Ghana

- The planting distance depends largely on the type of rootstock and its compatibility with scion.
- Certain rootstocks are more vigorous and imparts bigger canopy on the scion compared to others. Rough lemon has big root system and imparts big canopy than C. *volkameriana* or *Swingle citrumelo*.
- Late Valencia budded unto Rough lemon has a bigger canopy compared to Late Valencia budded unto C. *volkameriana* or *Swingle citrumelo*. The root system of Swingle and Volkameriana is smaller than that of Rough lemon.

Caution: Do not use Sour orange as rootstock in Ghana because of the prevalence of citrus tristeza disease. Sour orange is highly susceptible to the disease. The disease is transmitted by an insect

The planting distance for Late Valencia on *Swingle citrumelo* should be shorter (5.0 m × 5.0 m) than that of Late Valencia budded unto Rough lemon (6.0 m × 6.0 m). Generally rough lemon as a rootstock induces bigger canopy than swingle citrumelo.

2.5 Intercropping in citrus

2.5.1 Importance of intercropping in citrus

1. Intercrops are crops that are grown alongside the citrus and may be harvested earlier than the citrus. Intercrops can be an annual or perennial crop. If it is an annual or biennial crop, such as maize, plantain, pineapple, the intercrop can provide food to the smallholder farmer.
2. Provides early income to the farmer.
3. Controls weeds.
4. Control soil erosion.

Figure 2.4 *Citrus-pineapple intercrop, promoting biodiversity (A); Citrus-cowpea intercrop (Can improve soil fertility, through biological nitrogen fixation) (B).*

Figure 2.5 *Examples of crops that should not be intercropped with citrus; (A) chilli; (B) cassava.*

2.5.2 Suitable crops that can be used as intercrops with citrus

- Crops like *maize, plantain, cowpea, cocoyam, pineapple* can be intercropped with the young citrus plant once the correct planting distance for the citrus has been taken care of. Elsewhere citrus and coconut intercrop (tree crop/crop) is also practiced.
- Avoid using crops like chilli pepper as intercrops because they have common insect pest (the fruit flies). Avoid intercropping with cassava because of possibility of damaging the young citrus roots during harvesting of cassava, especially in the dry season.
- Chilli pepper have similar insect pests (fruit flies) and cassava compete for nutrients and farmers destroy the citrus roots while harvesting the cassava. The intercrop should not compete with citrus, thus should be planted about 1 m from the citrus tree.

3. Pruning in citrus orchard

3.1 Pruning

Pruning is the selective removal of unwanted vegetative parts on the rootstock at the early growth stage, dead branches that interfere with the productivity of the tree, and to promote light penetration into the tree canopy.

Proper control of vegetative growth is essential for the maintenance of healthy, productive citrus orchards. Crowded canopy result in poor light penetration in the canopy, loss of lower foliage and bearing wood, relocation of fruiting to the upper tree canopy areas and reduction in fruit yield, size, and external fruit colour/quality and creation of humid microclimate in the canopy. Sunlight influences flowering and fruit set and enhances fruit quality and color development.

3.2 Importance of pruning in citrus

It is important for the citrus tree canopy to intercept enough sunlight, get adequate amount of aeration to prevent creation of microclimate with high relative humidity within the canopy to prevent diseases and promote high quality fruit colour and taste.

Light becomes a limiting factor in crowded citrus canopies and pruning improves light penetration. Adjustments must be made in tree height, row middle width, and hedging angle to maximize sunlight that is reaching the tree canopy. Sunlight influences flowering and fruit set and enhances fruit quality and colour development.

The pruning process should aim at adjusting tree shape and the ratio of framework to fruit bearing shell of the canopy, Alters the top/root ratio, and changes the carbohydrate (food storage) status of the tree.

The benefits of pruning include:

- Fruit quality improvement;
- Ease of harvesting;
- Removes diseased plant parts and dead branches
  - Pruning removes dead wood that could harbour pest and disease.
- Stimulates growth and flushing of new leaves and branches;
- Removal of mistletoe that compete with plants for nutrients and harbour insect and nuisance pests;
- Improved pest and disease management
  - Pruning promotes aeration and sunlight penetration to the tree canopy and orchard, reducing pest and disease infestation.
  - Enhance spread of (insecticide and fungicide application coverage thereby reducing pest and disease infestation and cost.

3.3 Appropriate time of pruning

3.3.1 When to prune

The leaves of citrus trees act as important food storage area, and heavy pruning causes the tree to produce vegetative growth at the expense of fruit production. Proper use of pruning tools (such as Secateurs, pruning saw, loppers, ladder, grease (Fig 3.1), tree height, handling of pruned twigs.

Figure 3.1 *Some equipment that are used in the citrus pruning process: lopper (A); ladder (B); small chainsaw (C); secateur (D).*

3.3.2 Early pruning after transplanting in the field

The planting material is made up of the rootstock and the scion. It is important that the farmer ensures that there is no outgrowth on the rootstock (Fig 3.2A), as this will affect the growth of the scion and productivity of the orchard. Furthermore, the offshoot will bear fruits of the rootstock if allowed to grow to maturity. This will affect the productivity of the orchard. Planting material should be without outgrowth on the rootstock (Fig 3.2B).

Pruning to remove outgrowths on the rootstock in the field should be done as early as possible. The farmer should ensure that there is no offshoot on the rootstock 6 months after planting in the field.

Figure 3.2 *Planting material with outgrowth on the rootstock (A) and preferred planting material (B) without growth on the rootstock.*

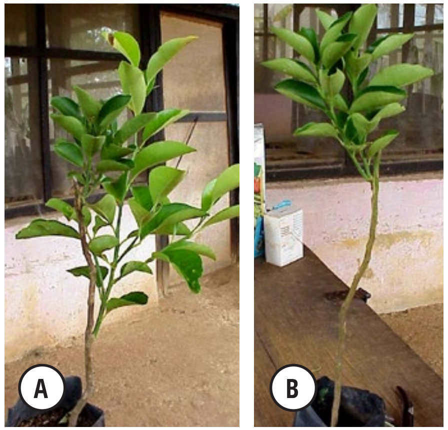
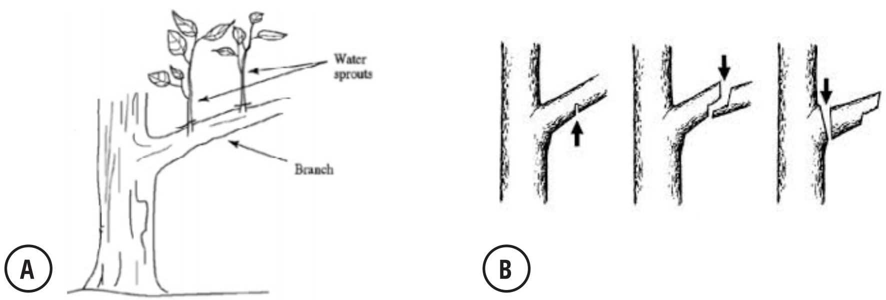


Figure 3.3 *These water sprouts should be pruned (A); Steps to be followed in the pruning of citrus branches (B).*



In citrus, carbohydrates are stored in leaves, twigs, and branches with only a minor amount going to the root system. The maximum amount of stored food is reached just before the onset of growth flush activity. The foliage of citrus trees therefore acts as an important food storage area, and heavy pruning causes the tree to produce vegetative growth at the expense of fruit production.

3.4 Types of pruning

1. General maintenance pruning

This is done to remove dead, damaged and diseased branches or wood from the tree. Remove all water sprouts.

2. Heading back

Tree height is maintained under 2.5 metres to facilitate pruning, spraying of agrochemicals and harvesting. This approach keeps costs down, as less quantities of agro-chemicals are used. Cut back your citrus tree so that it does not become too tall. Look at the ideal picture of a citrus tree You want to have 3–4 main branches which grow up in a 45-degree angle (V-shape) and produce a wide canopy. Remove those branches which grow verti-cally up towards the sunlight. Also remove branches that grow inside the canopy into the centre of the tree (instead of growing outside).

3. Canopy thinning

Citrus needs sunlight to develop flavours and juice. Dense canopies may not allow enough sunlight to reach fruit, so thinning is needed at least once every two years. A good way to judge canopy density is whether you can see dappled sunlight on the ground beneath the tree. Do not encourage dense canopies with fruits growing only at the top where there is enough sunlight.

4. Skirting out

"Skirts" are pendulous branches that hang to the ground. They provide pathways for termites and black ants to the trees. Skirts should be removed whenever they appear.

5. Suckering

Suckers are shoots that grow from the rootstock and will not be productive. Suckers should be removed as soon as they appear.

3.5 Pruning to remove parasitic plants

Parasitic weeds such as the mistletoes (*Loranthaceae*) cause significant economic loss in citrus and can sometimes cause the death of the plant. The common mistletoe *Tapinanthus bagwensis* and other genera (*Phoradendron, Pthirusa* and *Psittacanthus*) of the mistletoe family are important parasitic weeds in Ghana. The African mistletoe is a semi-parasitic plant because they are found on citrus trees. The plant is characterized by match-stick-like flowers that vary from pinkish to yellowish in colour.

The leaves of the African mistletoe contain chlorophyll and can manufacture food through photosynthesis. Injuries inflicted by mistletoe on citrus plant and the farmer include growth and yield reduction, and harbouring of nuisance insect pest which leads to shortened life span.

Citrus species at every growth stage is susceptible to parasitic plant attack, except at the nursery stage. Birds spread the parasitic plant on citrus trees. When birds eat the fruit, the seed adheres to their beaks and feet and through their droppings, the seeds of these parasitic plants are carried to other plants. The seeds germinate and attach itself to the citrus tree. Over 60% incidence of mistletoe in citrus orchards has been reported.

Control of mistletoes is achieved by cutting the affected branch., preferably just before the major rainy season. This is done to avoid creating too much opening in the canopy.

Figure 3.4 *The African mistletoe growing on citrus tree.*

4. Integrated nutrient management in citrus

4.1 What is integrated nutrient management?

Citrus requires good nutrient management to grow and produce high quality fruit. This can be achieved through the application of inorganic fertilizers only, organic fertilizers only or combinations of these two fertilizer sources.

- Citrus plants need plant food, nitrogen (N), phosphorus (P) and potassium (K) (required in large quantities; primary-macronutrients), Calcium (Ca), Magnesium (Mg) and sulphur (S).
- Nutrients that are required in smaller quantities (micronutrients) include Zinc (Zn), Manganese (Mn), Copper (Cu), Boron (B), iron (Fe) and Molybdenum (Mo).
- Application of fertilizers increase fruit yield and quality.

4.2 What are fertilizers?

Fertilizers are chemical substances that are supplied to crops to increase yield. Fertilizers contain the essential nutrients required by the plants, including nitrogen, potassium, and phosphorus. Fertilizers can be organic or inorganic materials added to the soil to supply plants with nutrients. Inorganic fertilizers are chemical fertilizers that contain nutrient elements for the growth of crops made by chemical means. Organic fertilizers are biological in origin, and comprise animal and crop wastes, such as poultry manure, guano, compost, empty fruit bunch as these contain plant nutrients.

4.2.1 Features of organic fertilizers

- They comprise animal and crop wastes, as these contain plant nutrients.
- Generally, the nutrient content of animal wastes is higher than crop residues.

Figure 4.1 *Examples of organic fertilizers: poultry manure (A); compost (B).*

A

B

- Combination of the two sources like poultry manure and cocoa pod husk or empty fruit bunch is recommended.
- Organic manures contain mostly nitrogen, phosphorus, potassium, and micronutrients, which are important for plant health, and not only specific nutrients only like in inorganic fertilizers.
- Organic materials/fertilizers have a large volume in relation to the nutrients it contains. Most organic fertilizers act as fertilizer and soil amendment (material added to improve soil conditions).
- They are normally applied to increase the level of organic matter and the abundance of micro-organisms in the soil, thus improving soil biodiversity and the physical properties of the soil.
- Organic fertilizers slowly release nutrients into the soil that plants can easily absorb over a long period.
- Determining the correct amount of nutrient from organic sources to supply a specific amount of nutrient is difficult.
- Part of the organic N becomes available to citrus plants through mineralization during the growing season.

4.2.2 Features of inorganic fertilizers

- Easy to transport, store, and apply.
- Important for supplying a specific nutrient (e.g. N, P and K). Can supply specific nutrients like N (urea), P (triple superphosphate), K (muriate of potash).
- Fertilizers are water-soluble and can easily dissolve in the soil, and easily absorbed by the citrus plants.
- They have a rapid effect on the crops.
- The nutrient supply are predictable and reliable.

4.2.3 Why should farmers apply fertilizers?

Farmers should apply fertilizers to replace nutrients that are harvested and taken along with the fruits to the markets and to support new growth. It is important for farmers to replace these nutrients that have been taken away from the farm. For every ton (1000 kg) of harvested fruit the following nutrients are removed: 9 kg of Nitrogen (N); 3 kg of Phosphorous (P_2O_5); 15 kg of Potassium (K_2O); 2 kg of Magnesium (MgO). From the above it is evident **potassium** needs to be replaced in large quantities for fruit bearing citrus trees.

Figure 4.2 *Examples of inorganic fertilizers: UREA (A); NPK (B).*

A

B

Significant quantities of the potassium can be given via organic fertilizer sources. About 100 kg of empty **fruit bunches** of oil palms contain 1 kg. The EFB ash contains about 40% K_2O. Other locally available organic materials that are rich in potassium include cocoa pod husk, and rich husk biochar. Poultry manure can provide complete nutrient requirement of citrus in Ghana, including the micronutrients, especially Zn. Compost is a good nutrient source for citrus.

4.2.4 Importance of soil fertility maintenance in citrus production

- Nutrients that leave the orchard with the harvested fruits need to be replaced.
- The most deficient nutrient determines the overall yield.
- Nutrients influence fruit size especially Phosphorus (P) and Potassium (K).
- Nutrients influence the taste of the fruit: Potassium (K) produces the fruit acids needed for the right flavour, while Nitrogen (N) and Magnesium (Mg) make the fruit sweet.

4.3 Methods of fertilizer application

Fertilizer can be applied in bands near where the developing roots of citrus are located. This can be located at the drip zone (canopy end) Fig 4.4A.

Fertilizer application to citrus can be achieved through spraying on the leaves (foliar mainly micronutrients) or through the soil. Spread the fertilizer around the base of the tree as far as the canopy reaches.

Figure 4.3 *Band application around the tree at the drip zone (A); Band application of organic fertilizer in between rows (B); Inorganic fertilizer application in ring form at the drip zone (C); Foliar fertilizer application to citrus trees (D); Band application around a matured tree (E).*

Fertilizer application for young non-bearing trees usually differ from those required for matured and fruit bearing trees. The objectives in a young tree fertilization program are to increase rate of growth, promote bigger canopy size and bring trees to fruit bearing as early as possible. Fertilization for fruit bearing trees may differ from region to region and from year to year depending on crop load and rainfall distribution.

Inorganic fertilizer application rates ranging between 3–6 kg N, 1–2 kg P, 3–8 kg K/tree and foliar spray of micronutrients (especially Zn and B) gives higher yields in Late Valencia budded unto Rough lemon.

Fertilizer application to mature citrus bearing trees is important to replenish nutrients lost during harvest and leaching or volatilization to maintain tree vigor and to obtain optimum yields.

4.3.1 When, where and how to apply fertilizers

- On flat land, apply granular fertilizers around the base of the tree using the canopy "drip circle" as a guide.
- On slopes, apply fertilizers only on the upper side of the slope using that part of the "drip circle" as a guide.
- Fertilizers should be applied to mature citrus orchards at the beginning of the rainy season because the demand for nutrients for citrus is highest in early rainy season, when vegetative growth is more intense, and extends until early fall, when nutrient reserves in the trees must be maximum to ensure optimum flowering and fruit set.
- The application of N and K in 3 or 4 splits during the year increases fertilizer efficiency by reducing losses of soil nutrients with water drainage.
- Knowledge of the nutrient status and pH of the soil in the orchard is important to enable a farmer to develop a management program that would optimize fertilizer applications. Soil and/or plant tissue analyses will help to determine: whether the plant is lacking any of the essential elements? How much of the deficient element is required?
- The fertilizer application rate for citrus trees varies according to the age of the tree, fruit load, soil fertility and the nutrient status of the tree.
- Apply fertilizers at the beginning of the rainy season.

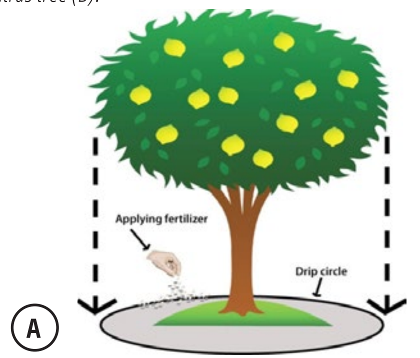
4.3.2 Micronutrients

- Micronutrients are easily absorbed by the leaves and can be applied as foliar sprays (on the leaves) from the third year onwards.

4.3.3 Where to apply the fertilizers

All fertilizers (both inorganic and organic sources) should be applied on the drip line zone around the tree in a 1□m wide circular band, as the active roots can be found in this area. If there is no sign of rain in the following week, dig the fertilizer into the soil.

Figure 4.4 *Fertilizer should be applied along drip circle of tree (A); Application of empty fruit bunch to young citrus tree (B).*



4.3.4 Fertilizer recommendations for full bearing trees

- For a bearing tree, the amount of fertilizer required is based on the production of the tree. However, a complete granular fertilizer such as 12:12:17+2 at a rate of 454 g per tree, twice per year is recommended. Apply dolomitic limestone (Ca and Mg) at a rate of (114 g) per tree, once per year and Epsom Salts at a rate of 114 g per tree, once per year.
- Epsom salts are a form of magnesium, and they are an effective and convenient soil amendment for treating magnesium deficiency in citrus.
- Depending on availability and cost the following nutrient sources can be applied to citrus orchards; 9 t/ha oil palm empty fruit bunches (EFB); 4-5 t/ha poultry manure (PM) or
- NPKZn at 90 kg/ha N, 60 kg/ha P, 80 kg/ha K and 4.8 kg/ha Zn. Application of locally available organic materials gave high benefit/cost ratio, because of lower cost.
- Organic materials serve as mulch that conserve soil moisture, when applied, in addition to releasing the much-needed plant nutrients.
- Fruiting trees should be fertilized during first rains when the dormant roots have started regrowth before the trees are in full flowering.

4.3.5 Micronutrients application through foliar application

Foliar fertilization has been the most important practice used to apply micronutrients in citrus. The amounts required are small, and to avoid adsorption of metal elements to soil colloids, which reduces the availability of metal micronutrients to the plants. Micronutrients such as Mn, Zn, and B have low mobility in phloem. Generally, it is recommended to apply micronutrients as foliar application to citrus.

Prepare mixtures of salts and urea (5 g/l), in the concentrations (mg/l) of Zn (500 to 1000), Mn (300 to 700), B (200 to 300), and Cu (600 to 1000).

Foliar applications should be made when leaves are young and have a poorly developed cuticle. This facilitates absorption and supply to developing organs.

4.4 Zinc deficiency

Deficiency of zinc (Zn) is widespread in many citrus orchards in Ghana. Zinc deficiency is characterized by chlorotic leaf spots ('mottle leaf') and/or white interveinal areas with green veins. (Fig 4.5A). New leaves are significantly stunted and often occur in rosettes because the twig internodes are shortened

Zinc deficiency significantly reduces growth and yield potential. Low zinc levels reduce fruit number per tree. Low zinc levels reduce fruit number per tree and, to a lesser extent fruit size, resulting in decreased yields.

Soil and foliar zinc applications are both effective in increasing citrus production yield. Twig die-back can be corrected using foliar sprays. Trees can be sprayed with 0.6% zinc sulfate onto the newly enlarging young leaves to correct the deficiency.

Figure 4.5 *Citrus leaves showing zinc deficiency symptoms (A); Zinc fertilizer to correct Zn deficiency (B).*

4.5 How to conduct soil and foliar analysis

1. For soil fertility monitoring, Identify and demarcate your toposequence (i.e. Summit, Upper slope, Middle slope and Valley bottom).
2. Sample at the above-mentioned depths in each toposequence in zig-zag, S-shape or X-shape pattern into buckets, mix thoroughly, bag and label for laboratory analysis.
3. These soil samples are generally called Composite samples. Put these composite sample together to form the Bulk samples for each block or toposequence. Remember to label soil samples anytime sampling is conducted properly to identify samples clearly.
4. Always take soil samples just outside the canopy of each tree and not under it.

4.5.1 Leaf sampling

1. Take leaf samples within each strip/treatment block as well.
2. Trees selected for comparison sampling should be of the same age, scion type and rootstock.
3. Collect leaves from four- to six-month-old newly matured flushed leaves from non-fruiting branch. This must be disease-free without insect damage.
4. Send the soil and leaf samples for oven drying, grinding and analysis. The results of the soil and leaf analysis will inform you of the status of the plant and the soil. The interpretation of the results and its implication is shown below.

Laboratories in Ghana that conduct soil and leaf analysis include University of Ghana, ECOLAB, Legon and Ghana Atomic Energy Commission, BNARI, Kwabenya Accra.

Table 4.1 *Soil test interpretation guide for citrus*

Soil Nutrient	Soil fertility class					
	Excessive	Very high	High	Medium	Low	Very low
pH 1 : 2.5 Soil : water ratio		5.5 (acidic)	6.5 (good)			
Electrical Conductivity (dS/m)		> 8.5	2.91–8.5	1.51–2.0	0.45–1.5	0.01–0.45
Soluble Salt (ppm)			< 1,280	640–1,280	< 640	
Total N (%)		> 1.0	0.5–1.0	0.2–0.5	0.1–0.2	< 0.1
NO3-N (ppm)		> 30	20–30	20–10	< 10	
Available P (ppm) Bray P_1		> 100	40–100	20–40	< 20	
P (%)			> 0.15	0.15	0.09	
K (%)			> 1.57	1.57	< 0.72	
Available K (ppm) Bray P_1		> 800	250–800	150–250	< 150	
Organic carbon (%)		> 3.5	2.51–3.50	1.26–2.51	0.60–1.26	0.6
Calcium (ppm)			> 2,000	1000–2,000	< 1000	
Calcium (meq/100 g)			> 10.0	5.0–10.0	< 5.0	
Magnesium (ppm)			> 180	60–180	< 60	
Magnesium (meq/100 g)			> 1.5	0.5–1.5	< 0.5	
Sulphur (S-SO_4) ppm	> 20.0	10.0–20.0	5.0–10.0	< 5.0	< 0.17	
Mn (ppm)				> 2.0	< 0.6	
Cu (ppm)				> 2.0	< 0.6	
Fe (ppm)			> 5.0	2.5–5.0	< 2.5	
Zn (ppm)				> 1.0	> 1.5	
Boron (B) ppm			> 2.0	0.5–2.0	< 0.5	

Table 4.2 *Guidelines for interpreting sweet orange tree leaf analysis based on 4–6 month-old spring flush leaves from non-fruiting twigs (Koo et al., 1984). Culled from Obreza et al., 2010.*

Element	Unit	Deficient	Low	Optimum	High	Excess
N	%	< 2.2	2.2–2.4	2.5–2.7	2.8–3.0	> 3.0
P	%	< 0.09	0.09–0.11	0.12–0.16	0.17–0.30	> 0.30
K	%	< 0.7	0.70–1.10	1.2–1.7	1.6–2.4	> 2.4
Ca	%	< 1.5	1.5–2.9	3.0–4.9	5.0–7.0	> 7.0
Mg	%	< 0.20	0.20–0.29	0.30–0.40	0.50–0.70	> 0.7
Cl	%			< 0.20	0.20–0.70	> 0.7
Na	%				0.15–0.25	> 0.25
Mn	mg/kg or ppm	< 1.8	18–24	25.0–100	101–300	> 300
Zn	mg/kg or ppm	< 18	18–24	25.0–100	101–300	> 300
Cu	mg/kg or ppm	< 3.0	3.00–4.00	5.00–16.00	17–20	> 20
Fe	mg/kg or ppm	< 35.0	35.0–59.0	60.0–120.0	121–200	> 200
B	mg/kg or ppm	< 20.0	20.0–35.0	36.0–100.0	101–200	> 200
Mo	mg/kg or ppm	< 0.06	0.06–0.09	0.10–2.00	2.0–5.0	> 5.0

5. Weed management in citrus

5.1 Pre-planting weed management

Because it is easier to tackle weeds in open ground than amongst established trees, a serious effort should be made to suppress, or if possible, eradicate, major weed issues before planting a new orchard. This is especially important with infestations of perennial weeds like couch grass (*Cynodon* spp), kikuyu (*Pennisetum clandestinum*), Johnson grass (*Sorghum halepense*) and nutgrass (*Cyperus rotundus*), given that organic producers cannot use systemic herbicides.

Organic citrus farmers usually identify weed control as one of their biggest problems, and citrus producers are no exception. Growers considering a switch to organic citrus management also rate weeds as their major concern. This concern may relate to the ease with which weeds are controlled with herbicides in conventional orchards, compared to the need for organic producers to achieve effective control of weeds without using synthetic herbicides.

5.2 Importance of weed control in citrus orchard

A good citrus farmer controls weeds on his/her orchard because:

- Weeds compete with citrus at all stages of growth for nutrients and soil moisture.
- Weeds reduce the flow of air throughout the orchard and create high humidity and favourable conditions for fungal disease infections.
- The dried weed biomass could serve as fuel for bush fires during the dry season.
- Severe weed pressure impedes harvesting operations (harvesting and aggregation).
- Weeds may harbour insect pests.

5.3 Weed management practices

5.3.1 Mechanical weed control

A. Hand weed control (with a cutlass/machete)

Weeds are slashed with cutlass/machete (Fig 5.1A). It is the most popular method of weed control in Ghana.

- Advantages includes:
  - Low investment cost
  - Environmentally friendly
  - Effective against all types of weeds
- Disadvantages includes:
  - Hand weeding is time consuming and labour-intensive.
  - Weed regrowth is high and weeding needs to be repeated every second month.
  - Takes relatively more time to manage weeds.

Figure 5.1 *Mechanical weed control using cutlass or machete (A) and motorized brush-cutter (B).*

B. Motorized weed control

Motorized weed control is done with the use of a machine with a brushcutter to clear weeds in orchard (Fig 5.1B). This method is fast, efficient, and reliable. Mechanical weeding is only necessary 3 times per year, because weeds are cut at their base. The initial cost of brushcutter may be too high for one farmer. It is recommended that farmers employ the services of trained weeding gangs.

5.3.2 Chemical weed control

This is the use of herbicides (post emergence; contact or systemic herbicide) for the control of weeds using a knapsack sprayer (Fig 5.2).

A systemic herbicide *moves from the treated foliage to other plant parts, including the roots*. In this way, the herbicide kills annual and perennial weeds. Glyphosate is an example of a systemic herbicide and non-selective. This means a single herbicide can be used to control most weeds – grasses, sedges and broadleaves. Systemic herbicides are generally slow acting and kill plants over a period of days.

Paraquat is one of the most widely used herbicides. Paraquat is a relatively non-selective foliage-applied contact herbicide, that acts at point of contact and not translocated to other plant parts. Paraquat, often referred to as Gramoxone, is an important herbicide that is used for the control of weeds in many agricultural settings including citrus orchards. It is inactivated on contact with almost all naturally occurring soils meaning that no biologically active residues remain in the soil, thus allowing planting or sowing to be carried out almost immediately after spraying.

- Advantages include:
  - Chemical weed control is easy to apply, and very effective if done properly.
  - Chemical weeding can prevent the emergence of weeds (with pre-emergence weedicides).
- Disadvantages include:
  - Chemical weeding is not very effective to kill mature weeds – as most of the post-emergence weedicides are only effective for *small weeds which are actively growing (green).*

Figure 5.2 *A farmer using a knapsack sprayer to control weeds using a herbicide.*

Figure 5.3 *Examples of herbicides: paraquat (A); glyphosate (B).*

  - Chemical weed control may be very expensive, especially if weed is high.
  - Herbicides have negative effects on the environment, on water bodies and on beneficial insects.
  - Investment cost is relatively high (cost of herbicides, knapsack sprayer, technical knowhow in calibration).

  - Continuous use of herbicides changes the flora diversity and eventually promotes soil erosion.
  - Improper mixing and application of herbicides may lead to serious health consequences.

Note: Please check on the labels on the herbicides for instructions and expiry dates of the chemicals.

5.3.2.1 Tips for effective use of herbicides

- Planning – to ensure the right chemicals are used with the appropriate equipment in a safe manner.
- Target species – to ensure that appropriate herbicide is used for a particular species of vegetation. The correct rate of application must also be considered.
- Topography – this will determine the type of application (hand, knapsack hand spray).
- Climate – spraying is only conducted during calm conditions, as overspray caused by wind drift may affect nearby plantation crops or adjoining vegetation.
- Proximity – to dwellings and crops. Allowance should be made for the proximity of water ways, streams and stream life, and of non-targeted species.
- In certified organic production, chemical weed control is not allowed.

Caution:

- It is important to wash off and rinse the knapsack sprayer to remove residual chemicals immediately after completion herbicide application.
- It is also important to wear protective clothing during herbicide application (Fig 5.2).
- It is recommended not to be smoking or eating during herbicide application.

5.3.3 Cover crops as weed control method

Cover crops can influence weeds either in the form of living plants or as plant residue remaining after the cover crop is killed. In citrus orchards, weed life stages are affected by the cover crop acting during its living phase. The management of the cover crop is influenced by its goal to suppress weeds during the living phases. Vigorous living cover crop will suppress weeds growing at the same time as the cover crop. *Mucuna bracteata* or *Pueraria phaseoloides* is a popular example of a cover crop used to control weeds.

- Advantages include:
  - Environmentally friendly.
  - Improves soil fertility through biological nitrogen fixation.
  - Add organic matter to the soil, improves on water infiltration, reduces soil erosion.
- Disadvantages include:
  - Regular and constant management of cover crops to prevent the strangulation or covering the canopy of the citrus tree is very important.
  - The cover crop may impede harvesting and collection of fruits.
  - The cover crop may harbor snakes and other nuisance pest.

Figure 5.4 *Weed management using cowpea during early citrus orchard establishment.*

Figure 5.5 *Weed management in matured citrus orchard, using* Pueraria phaseoloides. *Courtesy GOPDC.*

5.3.4 Integrated weed management

Integrated weed management makes use of any appropriate methods to deliver the best outcome. The integration of several weed control techniques into a program makes sense, as no one method can control all weeds cost-effectively, all the time.

This is because:

- some weeds are easier to control than others;
- some weeds are annual and some perennial;
- some are spread by cultivation, others by wind or water;
- some are avoided by grazing animals;
- some are very competitive against cover crops;
- some weed management methods are cheaper but not sustainable (use of herbicides).

The continuous use of herbicides negatively affect the flora and fauna diversity, reduces weed biomass and predispose orchard to soil erosion. A combination of weed control techniques helps to reduce the risk of weeds dominating the orchard.

Weed growth are suppressed by competition by leguminous cover crops for water, light, nutrients and space. Many weeds are poor competitors, and their establishment, growth or seed production can be reduced by competition from other plants. The annual cover crops are used in organic citrus to improve soil structure and fertility and suppress weeds in the mid-row. Perennial and Annual crops may be more effective in some situations (intercropping) because of their rapid growth and the effect of the cultivation required for their sowing.

6. Insect pests of citrus

6.1 Fruit flies

6.1.1 Overview/description of insect

These are a group of insect pest that attack the citrus fruits by laying their eggs in it (Fig 6.1A). The group include *Ceratitis capitata*, *C. cosyra*, and *Bactrocera invadens*, Fruit flies cause significant fruit loss by puncturing the fruit (Fig. 6.1B). The female lays eggs just below the skin or surface of the fruit., after mating with the male. The eggs hatch and the larvae feed off the inside of the fruit. This causes the fruit to drop, and the life cycle is completed in the soil (Fig 6.1C).

Susceptible citrus varieties include Late Valencia orange, Pineapple orange, Ovaletto, Mediterranean sweet lemon, Satsuma tangerine and Ortanique orange.

6.1.2 Control

By setting up control and monitoring traps (Fig 6.2A), spraying of food baits (Fig 6.2B and 6.2C), collecting and burying affected and dropped fruits (Fig 6.2D). Avoid growing of alternative host crops like chilli pepper, tomatoes, papaya, mango, avocado pear, etc near the citrus orchard. Correctly apply protein bait like GFFB and GF 120. Promote the presence and activity of weaver ants on citrus trees which feed on fruit fly maggot or disturbs the puncturing of the fruits by fruit flies.

Where citrus orchards are not managed properly, there could be total fruit loss due to fruit fly attack. Fruit losses less than 30% can be salvaged if control measures are adequately applied. In many cases, the damage predisposes the fruit to infection by other opportunistic organisms like fungi and bacteria.

Figure 6.1 *Picture of a fruit fly (A); fruit flies puncturing citrus fruit (B); infested fruits dropped on ground to complete life cycle (C).*

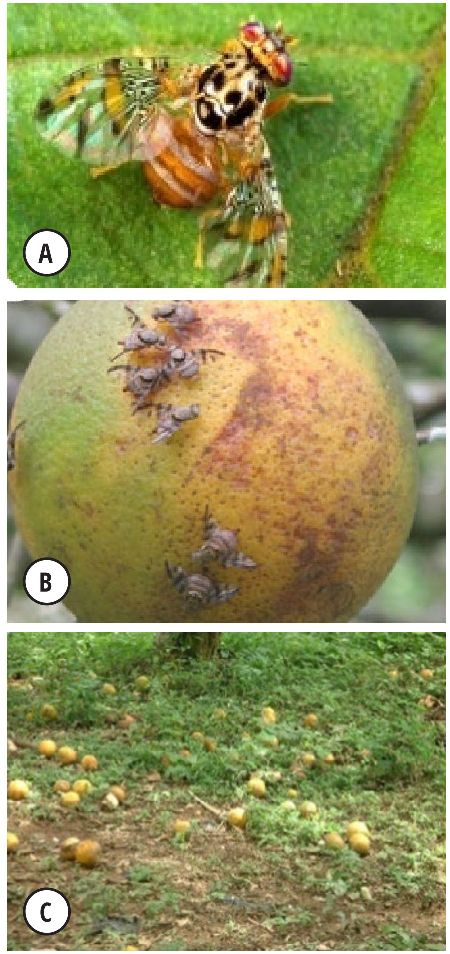


Figure 6.2 *Monitoring the population of fruit flies with methyl eugenol (A); sample of food bait (Success (R)Appat) (B); spraying of food bait on 1m² area of citrus foliage (C); and collected dropped fruit in polythene bags (D).*

Fruit flies are attracted to the smell of rotten or spoilt fruits. Always remove any rotten, stung or spoilt citrus fruit from the tree and from the ground below the crop as these will attract fruit fly.

By using Fruit fly traps, one can control the male fruit fly before it can mate with the female. This will prevent the fruit from being punctured. Methyl eugenol, a para-pheromone, is used worldwide for monitoring and management of fruit flies. Mix methyl eugenol with water at 3:1 ratio.

Baits (protein hydrolysates) GF120 attract and kill both male and female fruit flies. Mix at ratio of 5:1 GF120 to water. Spray 1 m^2 of citrus foliage and alternate trees after three to four weeks intervals if fruit fly population is still high.

Although the use of insecticides (carbamates and organophosphates-based insecticides to control fruit flies is not recommended) because of the high cost, environmental pollution, effect on beneficial insects and contamination of the fruits, some farmers still use it out of necessity. Cypermethrin + dimethoate or chlorpyrifos (Dursban) is applied 6 months after petal fall in the major and minor seasons for the control of fruit flies.

Farm sanitation and crop hygiene are the main cultural approach methods that are used to control the fruit flies. This method focuses on the life cycle of the fly.so that the larvae do not grow in the soil. It is best to hang more than one trap on the tree to protect the fruits.

6.1.3 Economic importance

Fruit flies are insect-pests of international importance, due to their significance in quarantine procedures. Fruit flies cause a lot of fruit loss from puncturing the fruit. The female lays eggs just below the skin or surface of the fruit., after mating with the male. The eggs hatch and the larvae feed off the inside of the fruit. This causes the fruit to drop, and the life cycle is completed in the soil.

Figure 6.3 *Chlorpyrifos is an organophosphate insecticide that is used on crops to kill a number of insects. It acts on the nervous systems of insects. Common brand on the market is Dursban.*

6.2 Aphids

6.2.1 Description

Aphids are small soft-bodied sap-sucking insects that feed by sucking the nutrient-rich liquids out of plants. In large numbers, they can weaken plants significantly.

Aphids feed on flower and leaf buds and on the underside of leaves, causing leaves to curl toward the stem. Adult wingless aphids vary in colour; some are black, others brownish-black or reddish brown.

6.2.2 Damage caused

Aphids have long piercing mouthparts which they use to suck sap from shoot tips and young leaves (Fig 6.4A). All growth stages of citrus are susceptible to aphid attack. Aphids feeding on new flushes, cause severe curling and deformation of young leaves and stunted growth. Aphids also excrete large amounts of plant sap (honeydew) that leads to the development of black sooty mould on leaves and fruits. Sooty mould affects photosynthesis, plant vigour and fruit quality (Fig 6.4B).

6.2.3 Control

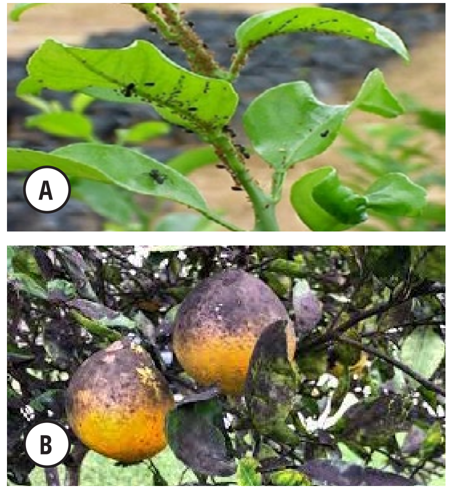
Spray neem oil, hot water, chilli pepper extracts or any synthetic insecticide targeting the underside of new flushes and new shoots, that will have direct contact to the aphids.

6.2.4 Damage caused

Aphids have long piercing mouthparts which they use to suck sap from shoot tips and young leaves (Fig 6.4A). All growth stages of citrus are susceptible to aphid attack. The feeding by aphids on new flushes, cause severe curling and deformation of young leaves and stunted growth. Aphids also excrete large amounts of plant sap (honeydew) that leads to the development of black sooty mould on leaves and fruits. Sooty mould affects photosynthesis, plant vigour and fruit quality (Fig 6.4B).

Aphids spread Citrus tristeza virus (and other viruses), sometimes called quick decline virus; *Toxoptera citricida* is important because it transmits Citrus tristeza virus so efficiently, better than other aphids.

Figure 6.4 *Aphids attacking new shoot (A) and resultant effect (secretion of sap on fruit) promotes sooty mould development on fruit (B).*



6.2.5 Natural enemies

Several kinds of natural enemies exist, including parasites, predators and pathogens. These usually keep populations low. The most common are ladybird beetles (adults and larvae).

6.2.6 Control

1. Spray neem oil, hot water, chilli pepper extracts or any synthetic insecticide targeting the underside of new flushes and new shoots, that will have direct contact to the aphids.
2. If insecticides are necessary, use any of the following on aphids:
   a) White oil (vegetable oil):
   - 3 tablespoons (1/3 cup) cooking oil in 4 litres water.
   - ½ teaspoon detergent soap.
   - Shake well and use.

   b) Soap:
   - Use soap (pure soap, not detergent).
   - 5 tablespoons of soap in 4 litres water, or
   - 2 tablespoons of dish washing liquid in 4 l water.
3. Commercial products of horticultural oil contain petroleum oil; follow the instructions on the product label. Make sure the oil can be used on citrus trees, otherwise, it may damage the foliage.

6.3 Mites

6.3.1 Description

Citrus mites are small, usually a fraction of a millimetre long. They are found in a range of colours from brown, yellow, rust, and red. On orange trees, look out for rust mites on young foliage at new flushes early April after early rains; by late June, most of the population will be on fruit.

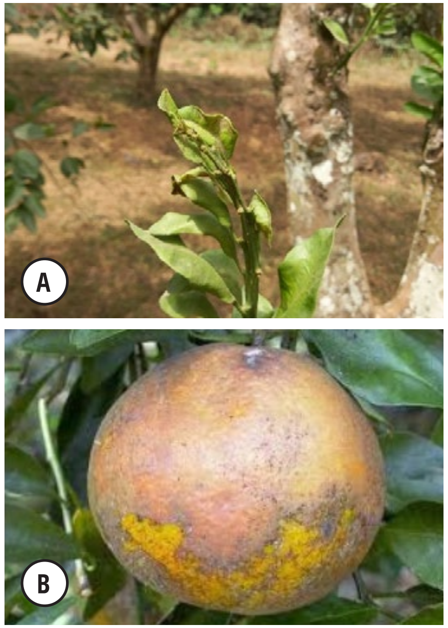
6.3.2 Damage

All mites damage results from feeding by piercing and sucking mouthparts. The citrus bud mites cause malformed twigs, leaves (Fig 6.5A) and fruits (Fig 6.5B) from feeding on flowers and buds. Malformed leathery leaves caused by mites affect photosynthesis. On fruits, the blemishes affect the fruit quality.

6.3.3 Control

Horticultural oil sprays and insecticidal soaps are effective on citrus bud mites when applied before flowering. They are of not effective after development of galls or after fruits are infested. Wettable Sulphur and chlorpyrifos (Dursban) may be used to control mites. Spray the underside of leaves and respray after three to four weeks.

Figure 6.5 *Damage caused by activities of mites on shoot and leaves (A) and blemishes on the fruit (B).*



7. Fungal diseases

Fungal diseases affect different parts of the tree; leaves, fruits (developing and developed) and main stem/trunk.

7.1 *Pseudocercospora* fruit and leaf spot (PFLS)

Pseudocercospora fruit and leaf spot (PFLS) is a fungi disease that affects leaves and fruits of citrus. PFLS is caused by *Pseudocercospora angolensis* and has spread throughout the citrus-growing areas of the country.

7.1.1 Symptoms

PFLS is characterized by necrotic leaf and fruit spots with light brown centres and dark brown margins surrounded by a yellow halo (Fig. 7.1A and B). Affected fruits become hard with deep cracks in the rind (Fig 7.1D). These cracks are predominantly observed on young fruits compared to old ones. All citrus varieties grown in the country are susceptible to *P. angolensis*. Every fruit infected by the disease is not suitable for consumption or processing and the diseased fruit may eventually drop leading to yield loss, which may reach total loss of 100%.

This destructive fungal disease primarily attacks the leaves, fruits and young seedlings that cause many spots leading to premature fruit and leaf drop. The devastating nature of the disease is heavy defoliation of leaves and fruits. Fruits can be attacked at all growing stages, whereas leaves are less affected as they got older.

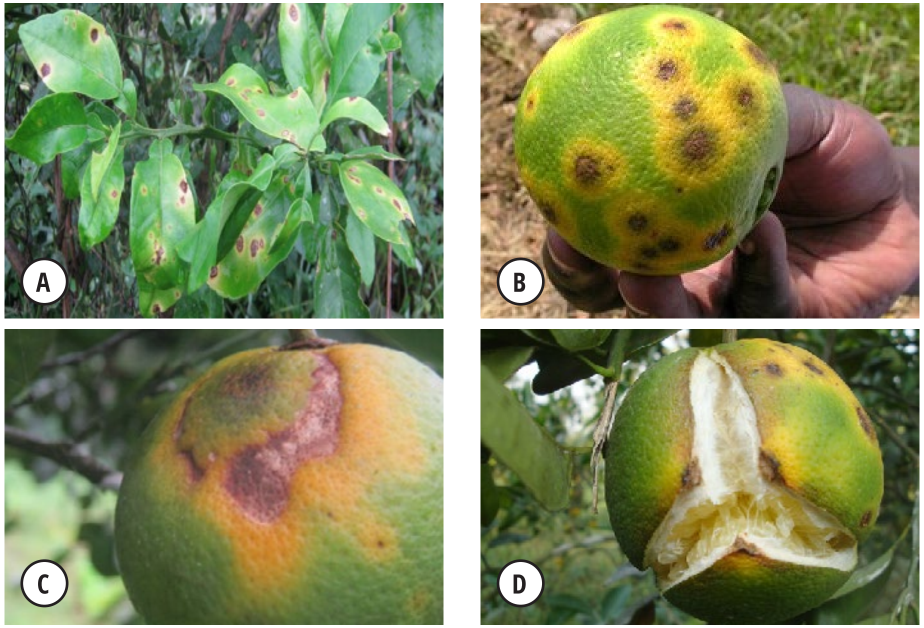
The disease is currently spread in citrus growing areas in the Eastern, Central and Ashanti Regions, with incidences estimated over 95% and yield losses of about 50 to 90%.

The fungus produces circular, mostly solitary spots, on leaves which often coalesce, up to 10 mm in diameter, with a light brown or greyish centre when dormant and non-sporulating during the dry season but becoming black with sporulation after the onset of the rainy season. Leaf spots, especially on younger leaves, often coalesce and together cause generalized chlorosis, followed by premature abscission and defoliation of the affected tree. Young leaves and fruit appear to be more susceptible than older mature leaves.

On fruit the spots are circular to irregular, discrete or coalescent, and mostly up to 10 mm in diameter. On young fruits, infection often results in hyperplasia, producing raised tumour-like growths surrounded by a yellow halo; these develop central necrosis and collapse.

Lesions on mature fruit are normally flat but sometimes have a slightly sunken brown centre. Mature lesions on fruit extend inwards causing brown discoloration and cracking of the rind. Severely affected fruit became hard and juiceless and premature fruit drop is frequent. Diseased fruits ripen prematurely and drop or dry up and remain on the tree. PFLS lesions penetrate beyond the fruit rind causing internal decay and so infected fruit are not marketable as fresh fruits for consumption nor for juice processing. In some cases, affected fruit in the canopy had cracks and the locules exposed (Fig. 7.1D).

Figure 7.1 *Symptoms of PFLS on the leaves (A) and on fruits of citrus (B, C and D)*



7.1.2 Favourable conditions for disease spread

The disease is favoured by prolonged wet weather conditions followed by dry spells coupled with moderately cool temperatures of 22–26 °C. Disease incidence varies with the amount of rainfall.

Old lesions appear to be the source of inoculum when conditions favour infection. Long-distance dispersal of the fungus is by windborne conidia; locally dispersal is primarily by rain-splash or raindrops. The fungus can be transported in or on infected fruit or propagative material. Infection by the fungus seems to predispose the fruit to secondary infection.

7.1.3 Economic Impact

Pseudocercospora angolensis causes a significant disease of citrus, the most devastating effect being the premature abscission of young fruit and leaves. The development of even a few fruit lesions renders the fruit unmarketable. The loss of leaves and desiccation of shoots can have a significant debilitating effect on the tree, which will affect subsequent fruit yields. The amount of rainfall and its distribution are very important environmental parameters that affect the progress of the disease. The yield loss associated with the PFLS disease ranged between. 84–87% of fruit dropped.

7.1.4 Prevention

Prevention of the transport of infected plant part and fruit from contaminated areas is an important measure for preventing the spread of the pathogen.

A. Cultural control and orchard sanitary measures

- Collection and destruction of infected fruits by burying and/or burning of all fallen fruit and leaves in affected orchards. This may drastically reduce the inoculum pressure in the field.

- Discouraging intercropping in affected orchards with mature producing trees, that will promote a microclimate of relatively cool temperatures and high relative humidity thus preventing disease development.
- Judicious pruning of shoots, particularly those that have died back, to allow light penetration into and promote free aeration within the tree canopy, thus making the environment less conducive to disease development i.e. shorter leaf wetness period, lower relative humidity, moderate temperatures.

B. Chemical control

Treatments with copper-based fungicides, Funguran or Kocide, may be applied at two-week intervals beginning a week after the onset of rains. Most effective fungicides tested on fruit and leaf spot of citrus include copper oxide. Recommended to spray after rainfall, rather than on a fixed schedule, because rain stimulates spore production and favours infection. Fungicide applications can be made to run-off (~2.5 l tree−1) with a motorized back-pack sprayer. Spray fungicide to coincide with the appearance of new flowering flushes (two weeks after onset of rains).

The 6-week schedule would be recommended for PFLS control in Ghana. The 6-week schedule a total of 8 and 9 sprays were applied in the major and minor season.

7.2 Citrus black spot disease

The citrus black spot (CBS) disease attacks the fruit and is caused by a fungus called *Guignardia citricarpa*. The disease symptom is characterized by spots with black margins on fruits (Fig. 7.2).

The disease affects mature green and ripe fruit and citrus orchards ages of between 8 to 34 years. Fruit at the margins of the canopy, which receive more sunlight, had higher disease severity, whereas fruit within the canopy of the same tree had lower scores or showed no disease symptoms.

Lesions on the fruit do not extend beyond the rind and the internal quality of the fruit is not affected. The disease does not cause postharvest decay.

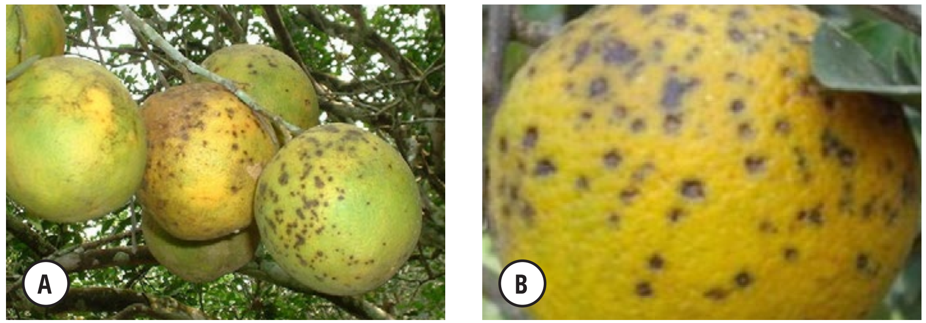
7.2.1 Symptoms

Affected fruits show reddish and dark depressed spots with brown margins. These lesions spread and coalesce, especially on fallen and harvested fruit. Severely affected fruit ripen prematurely and drops. In some cases, infected fruit that are asymptomatic at harvest may develop the symptoms in transport or storage. When severe symptoms develop before maturity, fruit often drop resulting in significant yield loss.

7.2.2 Prevention

Remove dead twigs on which the pathogen may be resting, apply regular preventive copper based sprays.

Figure 7.2 *Fruits showing symptoms of citrus black spot (CBS)*



7.2.3 Economic importance

The disease can cause about 22% crop loss. The disease does not cause postharvest decay and the internal quality of the fruit is not affected, Disease incidence and severity is higher on mature than on young citrus trees.

Infections is detected from November to February for the minor cropping season and from May to November for the major season. Fruit of Valencia Late sweet orange is susceptible to *G. citricarpa* infection for up to 7 months after petal fall. Crop loss due to the disease alone or in combination with fruit fly is about 80%.

7.2.4 Control

- Given the very favourable conditions for disease development in Ghana, fungicide spray schedules for the control of CBS will be mainly determined by the duration of fruit susceptibility. The occurrence of two blooms, with fruit in different stages of development on the tree at the same time complicates disease control.
- Apply a copper-based fungicide such as copper hydroxide (e.g. Funguran OH 50WP) Rate: 60 g/12 l of water using a motorized mist blower.
- Timely and complete harvesting of ripe fruit to reduce disease inoculum. Removal of diseased fruits and burial of fallen diseased fruit from the ground helps to reduce disease inoculum.
- Prune to remove unproductive and diseased branches in the canopy after harvest to reduce humidity and increase air circulation in the orchard.
- Start a preventive fungicide regime after petal drop. Infection occurs when the fruits are young, but symptoms don't appear until maturity.
- Monitor fruit for symptoms close to maturity, including small hard sunken brown/black spots.

7.3 Citrus trunk disease (Gummosis)

The citrus gummosis disease is caused by a fungus, *Phytophthora*, that attacks the trunk. Infection may occur from soil or nursery plants due to extended periods of moist and wet conditions. Gummosis is one of the main diseases that contribute to citrus decline.

Symptoms: This is a fungal disease that infects the trunk and is characterized by the exudation of gum from the trunk (Fig 7.3A). The affected bark becomes necrotic, firm, and harder. The dead bark dries, cracks and shreds, leaving a dark-brown dead wood surface. As the disease develops, it girdles the trunk and eventually kills the plant.

The other major symptoms of the disease are usually not different from those of other disorders affecting the vascular system including chlorosis, leaf-fall and die-back of twigs of branches.

On removing the infected bark, the cambial surface reveals a dark-brown colour which reduces in intensity to a healthy cream surface. (Fig 7.3B). Before the plant dies, there is heavy crop.

7.3.1 Damage caused by citrus gummosis disease

Most often the trees are lost to the gummosis disease, through girdling the trunk, resulting in insufficient flow of nutrients and metabolites to and from the shoots to the roots.

7.3.2 Susceptibility

Gummosis disease infection is more frequently located on the scion than on the rootstock.

Rough lemon rootstock is more susceptible and severely affected by the gummosis disease than plants on cleopatra mandarin, rangpur lime, volkameriana rootstocks.

The activities of termites on the trunk have been associated with the incidence of gummosis disease in Ghana. Infection could possibly occur through the termites carrying infected soil and introducing the pathogen to the trunk through wounding of the surfaces of the bark by abrasion. Disease susceptibility increases with plant age.

7.3.3 Prevalence

The disease affects seedling of lemons, tangerines, grapefruits, and especially sweet oranges.

7.3.4 Factors favouring the development of the disease

Several factors favour the prevalence and severity of the gummosis disease and include:

a) continuous wetness of the collar of the tree;
b) high level of soil moisture due to inadequate internal drainage;
c) injuries made to the lower trunks by tools during cultivation;
d) high relative humidity around the collar of the tree due to lack of proper weed control, heaping of soil or mulch around the collar and higher plant densities;
e) activities of termites on the tree trunk.

7.3.5 Economic importance

Gradual reduction in total fruit yield and fruit size reduction and eventual plant death.

7.3.6 Disease control

Gummosis is controlled by removing the affected bark until the whitish non-infected area is reached. Apply a paste of metalaxyl (Ridomil Plus) 40 g and 60 g ai /l in water mixture using brush, up to the whitish portion of the infected stem area (Fig. 7.3C). Two applications within a year is more effective than single application. Callusing forms within a month (Fig.7.3D).

Figure 7.3 *Citrus tree infected with citrus gummosis disease and exuding gum (A); Removal of infected bark exposing the necrotic and uninfected (white) areas (B); Treating of gummosis with the application of Ridomil plus paste at the whitish and necrotic areas on the trunk (C); Callus formation on trunk infected with Gummosis and treated with Ridomil plus (D).*

8. Harvesting of citrus

8.1 Introduction

Harvesting at optimal stage of the fruit development using the right techniques has a pronounced effect on income of farmers. When fruits are harvested too early there is incomplete use of the yield potential of an orchard and optimum quality of fruits is not attained. On the other hand, delaying harvest results in losses due to fruit abscission and softening, leading to shortened shelf-life, reduced storage, and increased internal disorders. Inappropriate harvesting (such as shaking of trees violently, harvesting with the wrong implements) techniques causes physical injury to fruits making it unsuitable for the fresh market. Appropriate harvesting approaches and postharvest handling of the fruits are needed to optimize the yield and fruit quality of citrus.

8.2 Description of the right stage for fruit harvesting

The time to harvest is dependent on several factors including fruit Colour, weight, juice content, brix, and number months after flowering.

- The colour of the fruit should have started changing from its pure green colour to patches of yellow, greenish yellow.
- The fruit should feel heavy and look big and sizeable depending on the variety. Although this may not be a good parameter for assessing the maturity of fruits the thickness of the rind reduces as the fruit matures.
- Fruits should be juicy. A sample cut of a fruit will reveal juice in the sacks in the individual segments. The juice content of a matured fruit should form about 45–50% of the fruit weight. This will depend on the weather, juice volume is higher in rainy, than in dry season.
- The brix (total soluble solids) content should be high. Refractometer (proper calibration is important) is used to take the brix content of the juice.

Figure 8.1 *Matured fruit ready for harvest*

- Fruits should be ready for harvest 7–8 months after flowering (mid-season) and 10 to 11 months (late maturing) depending on variety of citrus.

8.3 Importance of harvesting of fruits at the right time

Harvesting at the proper period of fruit development maximizes the revenue of the farmer. Harvesting should not be done too early or too late. When fruits are harvested too early, the orchard's productivity potential is not fully utilized, and the best quality of fruit is not achieved. Delaying harvest, on the other hand, results in fruit abscission and softening losses, resulting in delayed shelf-life, lower storage, and higher internal diseases.

8.3.1 The best time for harvest

- The best time of harvesting is when the weather is dry and not moist (during the cool of the day) and not likely to rain. Harvesting whilst raining causes fruits to rot easily.
- Harvesting in the very early mornings is not advisable as fruits may be wet due to dew from the previous night. Late- evening harvesting is not very advisable because, infested fruits can be picked as well as green immature fruit.

8.4 Importance of brix in the citrus industry

Brix is a *measure of the sugar content of juice*. Brix values are important because they can be measured objectively, and they relate to a subjective criterion that buyers and eaters use to assess sweetness.

8.4.1 Steps for determining the brix level in fruits

1. Randomly select fruits from a diagonal section of the farm and pick about 6 fruits, two per tree. (*Note:* Brix varies with topography, season and within tree). The brix content of fruits exposed to sunlight is higher than fruit in the shade. Fruits in east better than fruits in western part of the tree.
2. Cut each of the selected fruits diagonally into two. Squeeze the juice content into a cup and stir for a uniform mixture (*Note:* In checking the brix of a fruit, only one fruit is cut and small amount of juice smeared on the prism of the refractometer) If you want to determine the brix of the orchard, squeeze all the harvested fruits into a glass/container, and stir vigorously. Use this representative sample for an estimate, after calibration with distilled water.
3. Calibrate the refractometer with distilled water and adjust it to read zero (0) (Fig 8.2A).
4. Put a small amount of the mixed juice unto the prism of the refractometer, to wash off the water, and again put fresh juice to determine the brix, and read through the eye piece whilst pointing the prism in the direction of good light (Fig 8.2B).
5. Focus and take the reading from where the base of the blue line sits on the scale and record. A brix of about 9 and above is most suitable.

8.5 Preparation towards harvesting

- Collect all dropped fruits, to reduce contamination with good fruits.
- Ensure that you have at least the equipment; ladder, secateurs, harvesting bag and crates.

Figure 8.2 *A refractometer (A) used in determining brix content in juice (B)*

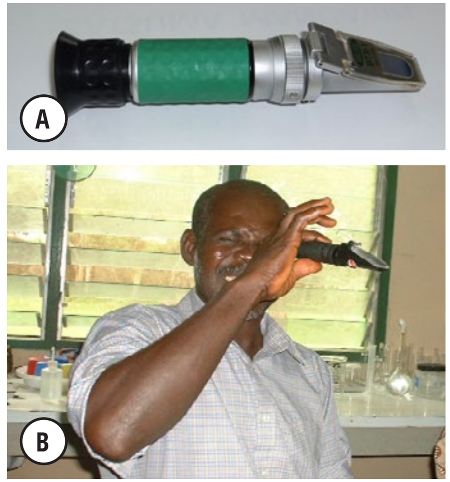


Figure 8.3 *Harvested fruits gently poured into basket (A); Collection of fruits from the ground (B)*

- Remember that the fruit is still living after harvesting. Do not hit the fruit with stick to harvest or shake tree to induce fruits to fall. The impact of the fruit to any external force during harvesting, will predispose it to postharvest loss. Any damaged caused to the fruit will affect postharvest loss. Do not twist the fruit during harvesting but cut the twig holding the fruit about 2 cm away from fruit using secateur. Twisting may bruise the calyx end of the fruit.

8.5.1 Collection of dropped fruits

Causes

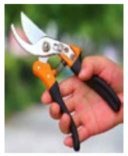
Fruit drop may happen as a result of nutrient deficiency, pest or disease infestation and water stress.

Importance of collecting dropped fruits

This will ensure good farm hygiene and reduce fruit contamination.

Note: Collection of dropped fruits should be done 2 days prior to actual harvesting from tree and should be well disposed off.

8.6 Important harvesting tools



Secateurs

Small hand-held tool like a plier, used in cutting fruits off the tree. The blade should be sharp and clean before used to prevent contamination.

Harvesting bag

They are bags with pockets in front to contain harvested fruits at a time when clipping fruits. They are slung over the shoulders of the harvester, in front of the belly. It also has clips which when opened allow fruits to drop into collection area.

Ladder

These are only used in harvesting fruits that cannot be easily reached from the ground.

Crates

Fruits in harvesting bags are emptied into it and then sent to a general collection site for transporting.

8.7 Techniques in picking fruits from tree using appropriate tools

- Fruits should always be clipped off the tree with the aid of a secateurs.
- Double clipping is best; *the first cut* and then *the second.*
- Button located at the part of the fruit popularly known as the head should be left on the fruit and not the tree as it may become an entry point for diseases.
- Ensure fruits are not bruised or no rind wounds created when there is the intension of exporting or selling fresh fruits
- Harvest fruits into bags, slung around the harvester to prevent fruits dropping over long distances and falling to the ground.
- Avoid using any harvesting method that will allow the fruit to hit the ground. Gently transfer fruits from harvesting bags into crates.
- Avoid direct contact of fruits to the soil.
- Harvested fruits should always be kept under shade to minimize loss of vitamins. Keeping fruits in the sun makes fruit warm and may begin to rot.
- For processing, they should also be kept on tarpaulin, or any vegetation cut from nearby, to prevent them having direct contact with soil.

The actual causes of post-harvest loss are several but can be grouped into two main categories; physical and quality loss.

Physical loss arises from structural damage or microbial wastage that can leave the tissue of the produce degraded to a stage where it is not acceptable for presentation, fresh consumption, or processing. Physical loss can also arise from the evaporation of inter-cellular water, which leads to a direct loss in weight. The resulting economic loss is primarily due to the reduced weight of produce that remains available for marketing.

Loss of quality is the second cause of post- harvest loss, and this can be due to physiological and compositional changes that alter the appearance, taste or texture and make the produce less attractive and desirable to the consumer.

Figure 8.4 *Inappropriate harvesting techniques (A); appropriate harvesting method (B); and sorting of fruits from heap (C) after harvesting on the farm.*

Figure 8.5 *Various sweet orange storage conditions. Wooden structure lined with perforated polyethylene sheet (A); storage trials in the laboratory (B) showing fruits enclosed and exposed conditions; and recommended wooden structure for transporting citrus fruits to reduce postharvest loss (C).*

Storage

- Fruits stored under ambient conditions but enclosed lost around 5% of initial weight within 18 days.
- Fruits stored under ambient conditions and exposed lost over 20% of the initial fruit weight within 18 days.
- Fruits stored under Fridge lost about 10% of the initial fruit weight within 18 days.
- Fruits stored under ambient and exposed condition began to shrivel and lost market quality quickly.
- It is recommended to treat sweet orange fruits and keep them in an enclosed environment (Fig. 8.5) in box for storage.

8.8 Postharvest management practices

8.8.1 Sorting of fruits

Sorting is the process to remove all the debris (leaves, twigs, spoilt or damaged or bruised fruits, immature fruits) which would promote the deterioration of the fruit. It also reduces the cost of transportation to the marketing centres. The fruit are inspected and unripe, immature, undersized, damaged, or decayed fruits are discarded.

8.8.2 Grading of fruits

Grading is the process to group fruits of similar sizes and colour together. This promotes the marketing of the fruits. Mixing of damaged, diseased fruits reduces the value and price of the product.

Grading is an important process because the presentation of the produce, is often judged based on uniformity. This process is ignored by most producers in Ghana, but there is the need for improvement in this area, especially for citrus. Uniformity is important as it presents a standard product for handling. Produce should be graded based on size, color and defects or combination of these factors.

8.8.3 Packaging

Sweet oranges are normally heaped and sold out in multiples of hundred fruits by market women. The author has developed boxes that can hold 10 kg, 20 kg, 50 kg, and 500 kg fruits for haulage purposes to reduce postharvest loss. These can be used to package fruits and assess the yield per unit area.

8.8.4 Transport

Transporting citrus from farmgate to marketing centres. Transporting the fruits to the market in this manner predispose to postharvest loss (Fig 8.8B). Most often the vehicles break down and the weight of the top part affects the fruits on the floor of the vehicle.

Putting the fruits in boxes and transporting them in strong vehicles that will not break down, will reduce postharvest losses.

8.9 Fruit blemishes

8.9.1 Factors causing fruit blemishes

Fruit peel blemishes are caused by several factors, such as fungal (fruit spots, sooty mold) and bacterial diseases, insect pest (scale insects). Armoured scales such as red and purple scales feed on the peels and their armour may remain on the fruit even when the insects have died. Thrips produce a distinctive ringing at the stem end of the fruit and may also cause russetting similar to mites. Mediterranean fruit flies, mites etc. all cause different forms of damage to the fruits thus losing its aesthetic value.

Figure 8.6 *Washing to remove blemishes (A); Sweet oranges fruits washed and waxed (B); Waxed sweet orange fruits packed in a carton (C).*

8.9.2 Washing to remove blemishes

Washing is important to remove dirt and fungal propagules on the fruits. The use of clean water for washing is important because fungal and bacterial levels might increase if the water is dirty. A series of two or three washes may be beneficial, preferably with an approved disinfectant applied to the last wash. Chlorine is commonly added to wash water to kill bacteria and fungi.

8.9.3 Cleaning

This process reduces the number of organisms that destroy the produce and improves on its aesthetic value.

8.10 Importance waxing and waxing materials

Citrus fruits lose weight and changes in fruit and juice quality after harvest. As the fruits lose water, they shrivel rapidly and lose consumer appeal. Postharvest waxing is one of the methods that is used to control moisture loss, and is needed to supplement or replace natural wax, to impart gloss, and to increase consumer appeal.

Applications of commercial wax coating usually replaces these natural waxes and offer protections to fruit during storage. It enhances the overall appearance and quality of the fruit to the consumer by reducing water loss and preventing shrinkage. Beeswax application at 20% concentration was most effective in reducing weight loss. The peel moisture loss was significantly and positively correlated with fruit weight loss. Generally waxed fruits were judged to have better appearance in terms of colour than non-waxed fruits.

8.11 Current citrus postharvest challenges in Ghana

Poor harvesting methods, poor on-farm storage, poor on-farm aggregation and storage, minimal sorting, minimal grading, poor packaging, no waxing, fungicide treatment.

Figure 8.7 *Fruits looked fresh at 68 days after harvest when treated with 2, 4- d and kept at 10°C (A); while fruits were shrivelled and unattractive 22 days after harvest when kept under ambient conditions in the room (B).*

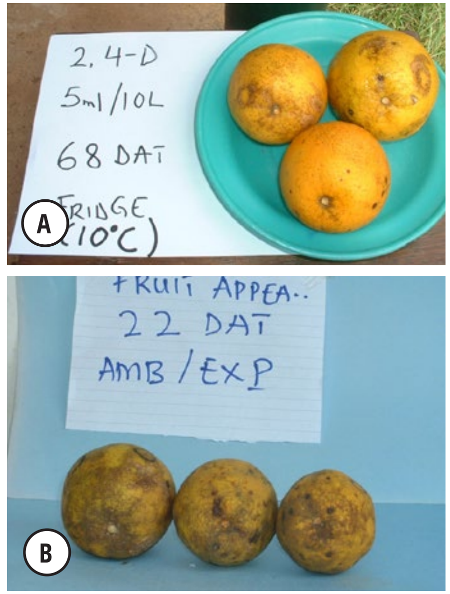


Figure 8.8 *Trader scouting for good fruits (A) at the market, stepping on fruits. Typical haulage of fruits in trucks (B). The fruits on the floor of the truck suffer from the weight of the fruits above leading to postgarvest loss.*

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Appendix 1 – Establishment of citrus plantation: estimated cost of production (1 ha): *economic life of plant: 25 yrs*

Item/Activity	Qty of input	Unit cost	Total cost
Capital			
Land Rent	1 ha	1,500	1,500
Knapsack Sprayer	1	500	500
Motorised Spraying Machine (Solo spraying machine)	1	2,500	2,500
Earth Chisel	2	50	100
Pruner	1	3,000	3,000
Brushcutter	3	1,500	4,500
Secateur	10	282	2,820
Ladder (aluminium)	5	3,000	15,000
Plastic crates	10	450	4,500
Spring weighing scale	1	700	700
Metal tripod (local fabrication)	1	300	300
Harvesting bag	5	360	1,800
Refractometer	1	966.7	966.7
Land Preparation			
Weeding (Initial vegetation)	1	300	300
Weeding (maintenance) (200 × 3 × 2.5)	500	3	1,500
Cost/litre (GHS110) for 2 l	110	9	990
Farm hand cost (50)	50	9	450
Stumping (GHS20 / man-days) / arboricide	1	80	80
Ploughing and Harrowing	*4*	*250*	*1,000*
Lining and Pegging 4 man-days @ GHS25	4	25	100
Holing/Digging 5 man-days GHS25	5	25	125
Planting			
Citrus Seedlings @ GHS3 per seedling	3	277	831
Transportation of seedlings @ GHS2 per seedling	2	277	554
Planting 4 man-days @ GHS25	4	25	100
Pruning 2x/yr, 4 man-days/ha @ GHS25 / man-days / round after harvest for 4–25 years	200	25	5,000
Spray against insect chew 3 litres / ha/ GHS45	3	45	135
Labour, GHS 30 / ha / 5 man-days / 2x for 4–25 yrs	300	21	6,300

Item/Activity	Qty of input	Unit cost	Total cost
Manure/Chemical application			
Poultry litter, 50 kg bag@45 + 200 T&T			
NB. 27 bags / 2 yr interval @ 1 bag / 10 plts for yr 1–3	27	45	1,215
NB. 13.5 bags / yr interval @ 1 bag / 10 plts for yr 4–25	13.5	45	607.5
Muriate of potassiun for yrs 4–25 @ 93 kg/plant, 35 × 0.093 × 277 / 1.8, 2 year intval @ GHS35 / 1.8 kg	501	11	5,511
Ammonium sulphate: 30 g / plt for yr 1–3, 8.1 kg/yr times 3, 0.030 × 277 / 1.8 ×34	156.9	3	470.7
NPK 15:15:15: 30 g/plt for 1–3 years, approx.	0.16	150	24
NPK 15:15:15: 500 g/plt for 4–25 years, approx. 3 bags, 135 kg, 135 / 50 × 150	405	3	1,215
Fungicide: e.g Mancozeb (kg) (1kg) for yr 1–3	40	3	120
Fungicide, 3 kg/yr yr 4–25	40	20	800
Herbicides (Glyphosate) 3 litres/yr	75	50	3,750
NB: Average of 30 g/plant, 2 times@ GHS50/btl for yr 1–3	100	3	300
NB: Average of 500 g/plant for 4–25, 2 times@ GHS50	100	20	2,000
Soil analysis: for fertility	3	610	1,830
Maintenance			
Slashing/brushing, twice/yr: 22.5 md/ha, GHS20/man-day	45	20	900
Agrochemicals: 2 times/yr: 3 md/ha @ GHS30	6	30	180
Pruning: 2 times/yr: 5 md/ha @ GHS20/md/ 4–25 years 2x	200	20	4,000
Collection/burying of dropped fruits, 2×/yr/10 mandays, 4–25 yrs @ GHS20	400	25	10,000
Methyl Eugenol for insect control GHS1000	22	1,000	2,200
Harvesting charges: 5–10% of prevailing fruit price	4	250	1,000
Currently GHS3,500 for 10,000 fruits each year from 4–25 years (about 42 harvests)	3,500	42	147,000
Aggregators 100 fruits for GHS5 for far away fruits, avg. of 10,000 for about 42 harvests	500	42	21,000

Appendix 2 – Actual yield & revenue projections: 1 ha citrus plantation using conventional method

Year	Fruits yield/tree	Fruits yield/ha (277 trees/ha)	Weight kg (0.25 kg per fruit)	Weight in tonnes	Revenue: Citrus sold @ GHS540/tonne
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	50	13,850	3,462.5	3.4625	1,869.75
5	300	110,800	27,700	27.7	14,958
6	380	110,800	27,700	27.7	14,958
7	400	138,500	34,625	34.625	18,697.5
8	500	166,200	41,550	41.55	22,437
9	890	332,400	83,100	83.1	44,874
10	1,100	415,500	103,875	103.875	56,092.5
11	1,000	554,000	138,500	138.5	74,790
12	1,100	415,500	103,875	103.875	56,092.5
13	900	360,100	90,025	90.025	48,613.5
14	840	332,400	83,100	83.1	44,874
15	640	277,000	69,250	69.25	37,395
16	500	274,230	68,557.5	68.5575	37,021.05
17	440	249,300	62,325	62.325	33,655.5
18	440	249,300	62,325	62.325	33,655.5
19	440	246,530	61,632.5	61.6325	33,281.55
20	330	221,600	55,400	55.4	29,916
21	330	138,500	34,625	34.625	18,697.5
22	330	110,800	27,700	27.7	14,958
23	330	96,950	24,237.5	24.2375	13,088.25
24	300	94,180	23,545	23.545	12,714.3
25	300	91,410	22,852.5	22.8525	12,340.35
Total	11,840	4,999,850.00	1,249,962.50	1,249.96	674,979.75

Appendix 3 – Actual cash flow analysis (benefit cost analysis): 1 ha citrus plantation (conventional)

Year	Fruits yield/tree	Fruits yield/ha (277 trees/ha)	Weight kg (0.25 kg per fruit)	Weight in tonnes	Revenue: Citrus sold @ GHS 540/tonne
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	50	13,850	3,462.5	3.4625	1,869.75
5	330	110,800	27,700	27.7	14,958
6	385	110,800	27,700	27.7	14,958
7	440	138,500	34,625	34.625	18,697.5
8	550	166,200	41,550	41.55	22,437
9	906	332,400	83,100	83.1	44,874
10	1,133	415,500	103,875	103.875	56,092.5
11	1,188	554,000	138,500	138.5	74,790
12	1,133	415,500	103,875	103.875	56,092.5
13	906	360,100	90,025	90.025	48,613.5
14	847	332,400	83,100	83.1	44,874
15	646	277,000	69,250	69.25	37,395
16	550	274,230	68,557.5	68.5575	37,021.05
17	440	249,300	62,325	62.325	33,655.5
18	440	249,300	62,325	62.325	33,655.5
19	440	246,530	61,632.5	61.6325	33,281.55
20	330	221,600	55,400	55.4	29,916
21	330	138,500	34,625	34.625	18,697.5
22	330	110,800	27,700	27.7	14,958
23	330	96,950	24,237.5	24.2375	13,088.25
24	330	94,180	23,545	23.545	12,714.3
25	330	91,410	22,852.5	22.8525	12,340.35
Total	12,364	4,999,850	1,249,963	1,249.963	674,979.8

Appendix 4 – Achievable cash flow analysis: citrus plantation (with advanced implements)

Year	Outflow (Cost) GHS	Discounted Outflow (Cost) GHS	Inflow (Benefit) GHS	Discounted Inflow (Benefit) GHS	DF= 1/(1+r)^n (r=22%)	Undiscounted Cost Flow (UCF) GHS	Present Value (PV) (DF×UCF) GHS
1	12,008.58	10,007.15	0	0	0.83	−12,008.58	−10,007.15
2	1,501.38	1,042.63	0	0	0.69	−1,501.38	−1,042.63
3	2,959.38	1,712.60	0	0	0.58	−2,959.38	−1,712.60
4	51,721.7	24,942.95	27,700	13358.4	0.48	−24,021.7	−11,584.54
5	19,362	7,781.15	18,282	7347.1	0.40	−1,080	−434.03
6	24,762	8,292.74	21,329	7143.0	0.33	−3,433	−1,149.70
7	19,362	5,403.58	24,376	6802.9	0.28	5,014	1,399.32
8	21,762	5,061.15	30,470	7086.3	0.23	8,708	2,025.20
9	19,362	3,752.49	50,192.4	9727.6	0.19	30,830.4	5,975.14
10	21,762	3,514.68	62,768.2	10137.4	0.16	41,006.2	6,622.73
11	19,362	2,605.89	65,815.2	8857.9	0.13	46,453.2	6,252.04
12	21,762	2,440.75	62,768.2	7039.9	0.11	41,006.2	4,599.12
13	19,362	1,809.65	50,192.4	4691.2	0.09	30,830.4	2,881.53
14	3,378.6	263.15	46,923.8	3654.7	0.08	43,545.2	3,391.59
15	21,114.6	1,370.45	35,788.4	2322.9	0.06	14,673.8	952.41
16	24,714.6	1,336.76	30,470	1648.1	0.05	5,755.4	311.30
17	20,634.6	930.07	24,376	1098.7	0.05	3,741.4	168.64
18	21,714.6	815.62	24,376	915.6	0.04	2,661.4	99.96
19	21,114.6	660.91	24,376	763.0	0.03	3261.4	102.08
20	21,714.6	566.40	18,282	476.9	0.03	−3,432.6	−89.54
21	21,114.6	458.96	18,282	397.4	0.02	−2,832.6	−61.57
22	21,714.6	393.34	18,282	331.2	0.02	−3,432.6	−62.18
23	21,114.6	318.72	18,282	276.0	0.02	−2,832.6	−42.76
24	21,714.6	273.15	18,282	230.0	0.01	−3,432.6	−43.18
25	21,114.6	221.34	18,282	191.6	0.01	−2,832.6	−29.69
Total		**85,976.28453**	**709,895.6**	**94,497.77433**		**213,687.36**	**8,521.489797**
				BC=1.1	**ROI=9%**	**IRR=24%**	**NPV=8,521.48**

Discounted Outflow (Cost) = DO
Inflow (Benefit) = B
Discounted Inflow (Benefit) = DI
Discount factor = DF
Undiscounted Cost Flow = UCF
Present Value = PV
Net Present Value = NPV (Sum of Present Values)
ROI = Return on investment (NPV/DC)
IRR = Internal rate of return is the discount rate that makes NPV zero. This is the rate of return of income into the business.

From the indicators computed, it can be concluded that investing in the citrus plantation is viable even when advanced equipment such as pruner, brushcutter, secateur, ladder, metal tripod and refractometer are employed in the project. For smallholder conventional, farmers mostly use local implements such as cutlasses, hoes, baskets among others for their farming activities.

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