



# COCOA NURSERY MANUAL

## PLANT PRODUCTION AND NURSERY OPERATIONS FOR COCOA NURSERIES IN THE PHILIPPINES.

EDITION No. 1

*The following manual is based on preferred or best nursery practices, developed for SUCCESS Alliance in Asia. These practices will be relevant to many countries according to available materials, resources and budgets. This current manual draws heavily from the Cocoa Nursery Manual of SUCCESS Alliance Vietnam, September 2007, but with modifications for the conditions and practices as used in the Philippines. It will be used to guide cocoa plant production under the CoCoPAL Program funded by the USDA. It is intended to update it regularly, as new data and practices are uncovered.*



VALUE CHAINS  
FOOD SECURITY  
INCOME GENERATION  
INTEGRATED FARMING SYSTEM



## **Acknowledgements**

ACDI VOCA wishes to acknowledge the contributions of a wide range of people who have worked in cacao nursery development and extension in South East Asia. Their contributions have been in developing best practices, developing new techniques, introducing new materials and technologies, developing extension and training materials and programs, relating to cocoa plant production.

These people and groups include:

Mr David Lim, Malaysia, Consultant with World Cocoa Foundation  
Huynh Van Thanh, Nursery Coordinator, SUCCESS Alliance Viet Nam  
Dr Pham Hong Duc Phuoc , Viet Nam, Nong Lam University Cocoa Leader  
Nursery operators in Ben Tre, Tien Giang, Binh Phuoc and Ba Ria Vung Tau Provinces  
of Viet Nam.

SUCCESS Alliance staff in Viet Nam and the Philippines  
Mr Peter Cruz and staff of the MARS Cocoa Development Centre, Philippines  
Nursery Operators Mindanao, Philippines.  
CoCoPAL Staff Philippines

Author:

Nicholas Richards  
Chief of Party, ACDI/VOCA Philippines

# **CONTENTS OF THIS MANUAL**

## **Introduction**

A cocoa seedling or grafted rootstock produced in a nursery has potential to make money for the farmer it is sold to, and the nursery operator who produces it. This potential is governed by:

1. type and condition of planting materials used- approved clone bud wood, approved hybrid seed
2. the age and health of the seedling or rootstock
3. the efficiency of nursery management and operations
4. the method of transportation from the nursery and pre-transport treatment
5. what happens to the plant when it arrives onto the farm

Points 1-4 are covered in this manual, through photographs and discussion, to summarise the main steps and practices to follow to produce consistently high quality, healthy plants. Point 5 is determined by the climate, soil, farming practices and management skills of the farmer who plants the seedlings or clones.

To ensure success in cocoa farming we must plant healthy plants, of the right age, at the right time, in the right place and free of pest, disease, nutrient or other defects. This manual will show the techniques and practices that will help farmers and nursery operators to achieve success in the production of healthy cocoa plants. It will also demonstrate common problems and how to deal with them or avoid them.

Regardless of the size of the nursery, these steps should be followed. All nurseries should commit to such practices, regardless of the size of the operation. From the very beginning, quality control needs to be enforced. It will help to reduce losses, increase returns and to off set risks.



## Section 1: Nursery Planning and Selection

### 1a: Site selection criteria

- 1) Minimum area for plant production should be 600 square metres ie 30m x 20 m or similar. This can accommodate about 24,000 plants. A good bag density and lining of bags, is about 40 plants per square metre of nursery floor. Additional area (about 5%) for potting mix preparation, bag filling, grafting operations and so on is required.

Smaller nursery areas than this tend to have problems such as:

- Plants are crowded together and grow poorly
- Diseases and pests can be harder to control
- Shade control may be more difficult
- There is often not enough space for working in.
- Access through the nursery is difficult
- It may be difficult for the owner to provide enough time and labour to manage the nursery properly
- The profit to the owner may not be big enough

- 2) The site must be easily accessed by road or canal
- 3) The site must have a good supply of fresh water, not salty at any time
- 4) The operator of the nursery must be experienced in fruit tree nursery management and operations. Experience with a cocoa nursery is highly desirable.
- 5) The nursery will use only approved planting seed and bud wood (approved by NSIC National seed Industry Council, or BPI)
- 6) The operator must be prepared to apply and use best practice nursery techniques and quality control measures (as outlined in this manual).
- 7) The operator must be prepared to change nursery layout and design to match CoCoPAL design specifications, including type and level of shade, drainage, plant spacing and support, bag size and potting mix, seed planting, grafting methods, plant maintenance.
- 8) The nursery must be reasonably close to cocoa growing areas.
- 9) The nursery area should be fenced off.
- 10) The area should not be exposed to frequent strong winds or storms.
- 11) Ideally, the nursery will be 100 metres or more from existing cocoa trees

## **1b: Nursery costs and returns**

It is important that the production of seedlings and clones is a profitable venture for those who invest into it, otherwise poor practices and low quality plants will result, in an effort to cut costs. This has been a noticeable trend in the Philippines thus far, with mostly smaller nurseries producing often inferior quality plants.

The costs of plant production and nursery construction have been collected from several small to medium sized nurseries in the Philippines, and based on large nurseries in Vietnam. To date we thus have a reasonable picture of nursery operational costs, but this needs to be updated for large (75,000 plus capacity) nursery production costs in the Philippines. The estimated costs of setting up a large cocoa nursery in the Philippines are detailed in ANNEX 1, together with a bill of materials to make a nursery to house 100,000 plants, covered with shade cloth. At the time of writing this manual, these costs are being validated, and will be revised in the next edition in about six months time. Until then, ACDI/VOCA is confident the costs presented are reasonably accurate, and that a selling price of 18 pesos per clone is highly profitable. For this reason CoCoPAL is promoting the price of 18 pesos per clone, to make more plants available to more farmers.

Cocoa seedling production is profitable when done correctly. It will cost about 10 to 12 PhP (pesos), to produce good quality, grafted plants aged 4-5 months. This cost does not include the overheads of the nursery business, and establishment and capital expenditure costs. It is simply the direct costs of labour and materials to produce each grafted plant. So selling about 100,000 plants a year at about 18 pesos each, will result in a profit of about 600,000 pesos. Regardless of the size and capital investment for each nursery, to produce quality plants, operators should have a well constructed and fully net-shaded nursery. Regardless of nursery size, it will still cost about 10 pesos to make a good quality cloned seedling.

## Section 2: Establishing and Managing Nurseries

### *2a: Site preparation and size*

Having selected a suitable area, it needs to be marked out and cleared. The steps involve:

- 2.1 Design nursery and check for area and specifications
- 2.2 Mark out the four corners, the entrance, the fence line and water supply inlet
- 2.3 Remove trees, rubbish, and other obstacles

Photo 1: cleaning the nursery site



2.4 If necessary plough the land then level it off -Photos 2

Photo 2





Photo 3: a level site facilitates good management.



2.5 Provide 2m, all-weather access path through center

Photo 4:





2.6 Install drains and drain outlets

Photo 5:



2.7 Repair or install a perimeter fence

2.8 Check/ repair/ install water supply to nursery- check water quality first

Photos 6, 7: Check water quality and supply



2.9 Install irrigation supply pipe and hoses for watering



2.10 Mark out positions and install nursery poles or posts.

Photo 8:



2.11 Install shade cloth- side to side and roof. Use moveable wire frame or similar, to allow partial removal for plant hardening off.

Photo 9:



## **2b: Nursery construction and design**

The most basic function of the nursery is to provide an environment that allows cacao seedlings to develop quickly, into healthy plants ready for field planting. The nursery must provide:

- Protection from sun (30% shade is best ie 70% of full sunlight), wind and rain
- Water and nutrients frequently, and in response to plant growth needs
- Protection from pests, diseases and weeds

Several designs are possible according to the materials used and the budget available.

Photo: 10: Timber post and wire frame nursery



Photo 11: Simple steel pole nursery, between buildings





Photo 12: Greenhouse style nursery, insect proof.



Photo 13: Pruned trees as scaffold for nursery shade cloth (short term only)





Photo 14: Igloo style, steel framed nursery



Photo 15: simple small plot style, short term only





## **2c: Nursery materials**

For a cheaper nursery, use bamboo or log posts, and wire to make the frame, and stretch shade cloth over this frame. For a longer lasting nursery, use steel posts embedded in concrete, with a wire frame or steel tubing framework. Timber posts are susceptible to termites and rotting.

It is also possible to use PVC piping for small nurseries, and galvanised pipe and fitting for any size nursery. In some cases, widely spaced, well pruned upright growing trees (ie Glyricidia, Erythrina), can be used as the posts, with a wire frame between them. This is only good for shorter term only ( less than 12 months) as the trees grow back and become difficult to access for pruning.

In all cases, green or black shade cloth with 60- 70% sunlight strength is used ie 30% shaded. The shade cloth must cover the entire roof and all sides of the nursery.

The use of coconut palm leaves as shade material is not recommended, nor is the use of shade trees such as large fruit or forest trees. If high winds are expected at some time, ensure that there is sufficient wind protection for the nursery and the plants it holds.

Photo 16: Using timber poles as the scaffold frame



Photo 17: Coconut leaves and bamboo style nursery: NOT RECCOMENDED





Photo 18: Using bamboo poles as scaffold, with wire supported shade cloth.



Photo 19: Using concrete posts as scaffold, with wire supported shade cloth





Photo 20: Using GI pipes as scaffold and as frame work for shade cloth

Van Loi Jan13 2005



Photo 21: Using PVC pipes as scaffold and framework





Photo 22: Using steel channel as scaffold and framework



### ***2d: Nursery layout***

Photo 23: Install an effective drainage system





Photo 24: Use ropes to mark out nursery beds and access pathways.,



Photo 25: Example of a well designed, planned and constructed nursery. NOTE: 8 bags per bed and 40 cm gap between beds, with regular walkways repeating





Photo 26: Central access pathway, with walkways between beds.



Photo 27: Simple construction but well designed for easy access and operations.,





Photo 28: Work management and planning area, with record keeping.



Photo 29: Examples of a poorly built and poorly maintained nursery.





## **2e: Water supply**

This needs to be readily available, of sufficient quantity and good quality. To estimate your maximum water needs, use the following rule:

- Number plants x volume each bag x 0.05 = litres water per day maximum required.

*So for 25,000 bags with 1.8 L volume, watered twice per day with 5% volume watered, we need about 2250 litres of water per day. This is about 225 buckets of water, or about 20 minutes with a pump and hose. For only one irrigation per day, halve this amount.*

- Water quality to be tested as discussed in section 7e

Photo 30: use a bore and pump or water tank to supply water



## **2f: Labour and supervision**

The bigger the nursery, the more labour is required. More labour means more supervision and management. However even small nurseries must be planned and managed well to achieve targets of quality, quantity, cost and time. Running a nursery is a business, and deserves the full attention of the farmer or operator to make it a success. Part time nurseries are almost always unsuccessful and rarely produce quality plants. Labour needed will fluctuate according to the nursery operations. More labour is needed for bag filling and grafting, less for other operations, As a rule of thumb, you will need at least five labourers per day, every day for a nursery of 100,000 plants capacity, with a manager or foreman to manage the nursery.

## **2g: Recording and data collection**

Closely linked to section 2f is the need for good nursery record keeping and monitoring of all things going on in the nursery. In order to manage something, we must be able to observe and record performance, problems and progress. Records show these facts and figures we observe and measure. See Annex 2 for an example.

## **Section3: Planting Media**

### **3a: Soil based potting mixes**

Top soil of good physical properties (loams) is used, when artificial potting mixes are not available. Blend about 10% manure and 10% organic matter with 80% of the sieved soil. It is important to dry the soil, break the soil up and sieve out stones and large lumps, and form it to a uniform texture. Clay based soils are difficult to work with and not suitable for potting mixes.

Photo 31: Using dried and ground top soil and rice hull with manure

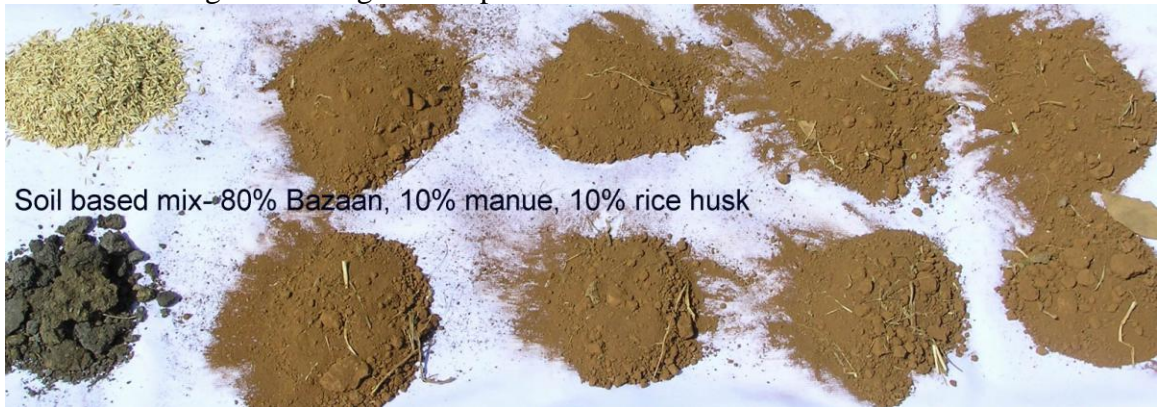


Photo 32: Heaping potting mix components ready for mixing





### **3b: Artificial potting mixes**

These are preferred over soil based mixes. Typically these are about 20% each by volume, of soil, coconut fibre, rice husk composted, and rice husk burnt (CRH). To this about 10% each of river sand and dried manure is added.

Artificial potting mix components suitable for cocoa seedlings include- 20% coco peat, 20% rice hull, 20% CRH, and 20% soil, 10% sand and 10% manure. To this add about 2 kgs limestone or dolomite per cubic meter of mixture, to balance acidity.

Photo 33: coco peat 20% of mix , and rice husk (composted) 20% of mix



Photo 34: CRH (carbonized rice hull) 20% of mix, and soil 20% of mix



Photo 35: River sand 10% of mix and manure (composted/dried) 10% of mixture.



A mixture commonly used in the Philippines is based on equal amounts of sieved soil, CRH, cocoa peat and sand.

### **3c: Potting mix sterilisation**

All potting mixes should be sterilized before being planted with seed. It is important to kill bacteria and fungi that can infect plant roots, and also weed seeds that can germinate and become a problem. The easiest and cheapest way is to spread the mix onto clear plastic sheets and cover with clear plastic and leave in the sun for a day or two. This is called solarisation. Lightly wet the mix so that steam is produced inside the plastic cover, and make sure the mix is no more than 7 centimetres deep. Also ensure the plastic cover is well sealed to prevent heat loss. The mixture should reach 56 degrees centigrade for at least 30 minutes. You can check this with a thermometer.

Photo 36: Solarisation of potting mixtures, in heaps or in lined bags (less effective)





Photo 37: Bag filling with potting mixture.



Photo 38: Potting mix stored ready for usage.



Photo 39: Using a cement mixer speeds up mixing and makes it more uniform.



### 3d: Types of bags

Black plastic bags, thickness gauge 150 -200 are preferred. Do not use clear plastic bags as this promotes algae growth. Suggested sizes are indicated below- use the smaller bag for short nursery periods of less than five months. Use the bigger bag if you expect plant will be in the nursery for five months or longer. This is important as more soil in contact with roots will produce healthier plants and less nutrient problems.

Bag height x width lay flat	Bag height x width filled	Bag volume filled, litres	Approx bag weight filled, wet
27 cm x 8.5 cm	22 cm x 10 cm	1.8	0.9 kg artificial mix 2. kg soil mix
30 cm x 10 cm	26 cm x 12 cm	2.9	1.5 kg artificial mix 3.2 kg soil mix

Photo 40: lay flat black plastic bag 26 x12 cm



The usage of small bags causes problems in growth and root structure. In small bags, seedlings have to be watered and fertilised more often to stay healthy. Their roots have space to expand in, resulting in bent, twisted and deformed tap roots.



Photo 41: Small bags result in root bound plants, with defective tap roots.



## Section 4: Seed Propagation

This refers to the process of raising seedlings from seeds. There are a number of steps to do this successfully to ensure good results, to minimise diseases and to reduce wastage. These steps are discussed in sections 4a to 4e.

### 4a: Seed selection

All cocoa seeds are not the same- there are good ones and bad ones. Seed selected for propagation, must come from healthy ripe pods. This is a vital step. If we use poor seeds i.e. that which is very small, comes from green pods, is damaged or diseased, we will get lower germination rates. We will also produce poorer quality rootstock and seedling plants, and grafting success will be lower, than with healthy seed.

For rootstock we can use any tree as long as the tree is healthy, and the pods of the right age with good quality seed inside. However it is common to use a few trees only for rootstock, which we call rootstock trees, and mark them. These trees produce seed of good size and seedlings which are fast growing and healthy, and do not show susceptibility to pests and diseases.

Cocoa seed cannot be stored. Use it within 4 days of opening the pod. Pods should not be stored either. (***Do not follow the process as you may do for bean fermentation***). The seeds are easily killed by heat and in dry conditions. They do not have any dormancy period.

*Of course before you do any seed propagation make sure that you have your potting mix ready and the bags filled and ready for seed planting, in a protected part of the nursery.*

### 4b: Seed preparation

The main steps in seed preparation are:

- 1) Select pods that are ripe and healthy

Photo 42:

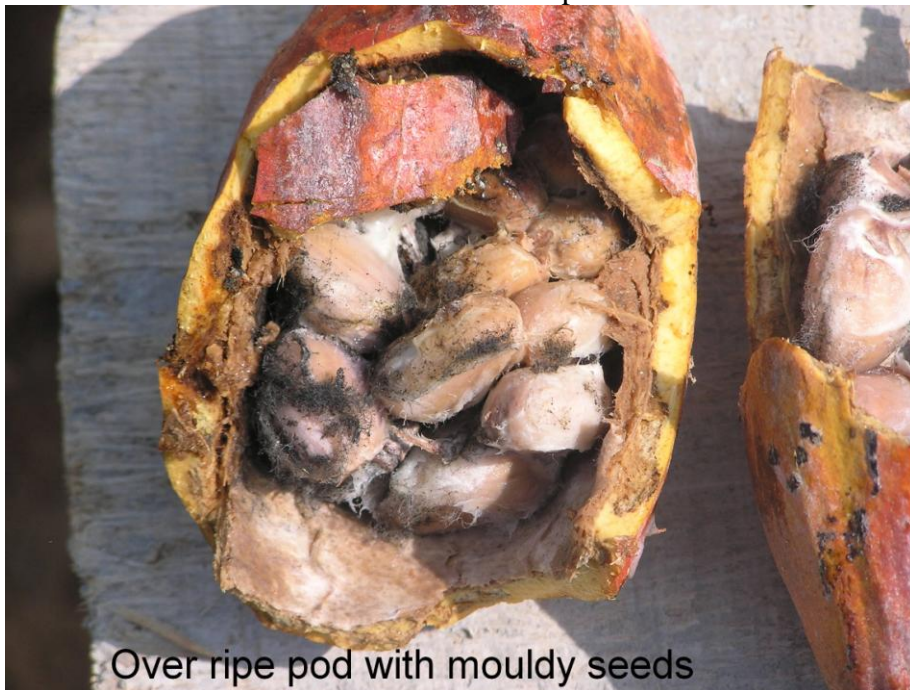




Photo 43: unsuitable pod types for seed selection



Photo 44: defective seeds inside a diseased pod.



- 2) Open the pods using a wooded mallet. Do not use a knife as you may cut the seed.
- 3) Remove seed from pods and separate seeds from placenta and pulp
- 4) Discard any flat seed, damaged, germinated seed or very small seed.

Photo 45: Usable seed.



- 5) Rub the seed in saw dust or coconut fibre to remove the pulp from outside of the seeds
- 6) Wash the seeds in water and drain

Photo 47: Properly cleaned beans ready for soaking



- 7) Soak the seed in a fungicide solution for about one minute - Benlate or Dithane,  
**Use about                    in five litres of water**
- 8) Drain the seeds and place onto a tray or sack in a shaded and cool area, protected from wind and rain, to drain for about 10 minutes



#### **4c: Seed germination and pre-germination**

Seeds can be planted (after cleaning) straight into the bag but this is not the best practice. It is better and you get better results if you pre-germinate the seeds. By this we mean forcing the seed to germinate before we place into the bags. The main steps to follow to produce pre-germinated seeds are:

- 1) Place the seed in a single layer on clean jute bags out of the wind, sun and rain. Cover with another jute bag. For a small quantity use a plastic tray with plastic cover.

Photo 48: Cleaned seed being pre germinated in trays



Trays covered with plastic bags

Photo 49: for larger quantities, use a damp and clean jute sack



- 2) Record the date seed was placed onto tray, i.e. when germination started
- 3) Every day for up to 4 days inspect the seed and remove any seed that has germinated. This will show as a white 'button' on one end of the seed. These seeds are ready to plant into the pots, and you should plant them straight away. Do not wait to get a large amount ready before you plant them.

Photo 50:



Photo 51: seeds with buttons showing, ideal for planting.



- 4) After 3 to 4 days, seeds will start to have long shoots or 'pig tails' on them and these should be discarded, as they can result in stem and collar deformations and root problems. So make sure that you inspect seed every day and discard all remaining seed after 4 days. (It cannot be fermented either).



Photo 52: Unsuitable for planting due to long or bent radicles (roots)



#### **4d: Seed planting**

Place the pre-germinated seed with the root tip pointing down, into the potting mix in the bag. Make a small hole about 1 cm deep for this and leave about half of the seed poking out of the potting mix.

After planting use a fine spray to water the potting mix.

Photo 53:



Photo 54: Example of a healthy and properly prepared seedling, emerging from a good potting mixture, about 10 -14 days after seed planting into the bag.



Photo 55: Good, uniform seedling germination and emergence, resulting from good potting mixture and correct pre -germination practices.



#### **4e: Seedling losses-culling, rejection and diseases**

On average, we expect about 20% of the seed that we plant as rootstock to be of inferior quality, and we remove these from the nursery. If we allow them to stay then we may have problems such as:

- Bent and twisted roots or stem collars
- Slow growing or unhealthy plants
- Plants with white or very pale yellow leaves, genetic mutants
- Plants with weak root systems

Photo 56: Example of a defective emerging seedling, to be removed.



The plants that we reject should be destroyed. Do not stockpile them to see if they grow better over a longer period of time. But before you do destroy them make absolutely sure that they are reject plants and not suffering from lack of water, nutrients or sunlight. You can test this by looking at all plants in the nursery. If all plants appear weak and slow growing you need to investigate why. If only a percentage ie 10 to 20%, these are the reject plants to remove. Start to remove reject plants (culling) from about week 2 after planting, and repeat regularly. Look for physical defects first, i.e. twisted stems, bent collars, benched roots and so on. Also look for the white leaves or diseased plants. We can also have problems with seed diseases such as damping off or seedling dieback, in very young plants, which results from over watering, bad potting mixture, or exposure to rains (see Photos 54-56).

Photo 57: Example of seeds rotted in bags





Photo 58: Examples of seeds that emerged then died off, due to disease.



Photo 59: The end result of poor germination or low survival rate of emerged seedlings- low success rate.



After grafting or budding, we also need to do further culling, to remove:

- Bent and twisted roots or stem collars
- Slow growing or unhealthy plants, which are probably diseased
- Plants with white or very pale yellow leaves, signs of genetic mutants/ grafting disease
- Weak or slipped grafts



## Section 5: Budding and Grafting Methods

Vegetative propagation refers to the techniques we use to produce a cloned plant. A cloned plant is identical to the plant from which it is derived. The best methods for cocoa clone production are:

- side grafting (modified epicotyl grafting)
- top grafting
- patch budding.

In all cases we need two parts: a rootstock and a scion. The rootstock is the seedling raised to become a clone through grafting or budding. The scion is the bud wood stick or bud patch we collect from the mother trees (NSIC clones) to graft onto the rootstock.

In grafting and budding, we try to fuse the cambium tissue of the scion with the cambium tissue of the rootstock, to make a new plant. If we do not get this fusion, we do not produce a successful graft, and the scion will die.

Photos 60: Rootstock seedlings and scion shoots or bud sticks



ROOTSTOCK



SCION

*Reading this manual will not make you expert at grafting or budding- you need to be shown first how to do this properly. Then practice a lot!*

*If you follow the practices in this manual, you will boost your success rate, however.*

### 5a: Key practices for vegetative propagation

The success indicators and key practices to follow for the three methods of clone production, and their indicators are listed as Table 1. If you take shortcuts to save time and money, you will get lower success rates that is for certain.

Table 1:

Success Indicators	Key Practices
<b>Rootstock age</b>	Side grafting- 2-3 months old Top grafting- 4 months +CHECK this Patch budding -3 months +
<b>Rootstock preparation</b>	Side grafting: cut leaves to 1/3 rd size and remove growing tip, just before grafting Top grafting- cut tip off near to where bud wood and rootstock are same thickness Patch budding- cut off tip only
<b>Bud wood collection</b>	Same day collected is used, wrapped in paper toweling and keep in shade, labeled with clone ID Green brown wood (recently hardened flush) for grafting, more mature wood for budding.
<b>Grafting tents used or plastic sleeves</b>	Large nurseries use tents, small nurseries tents or large plastic bags <b>Not required</b> for patch budding, or for top grafting.
<b>Type grafting tent used</b>	Clear plastic on wire or bamboo frame
<b>Tent Size</b>	5 sq. m- 400 plants, 15 sq. m – 1200 plants
<b>How tents are shaded</b>	2 layers of shade cloth across the top
<b>Number of days plants stay in tents</b>	21 days before opening tents
<b>Plant rest period after tent opened</b>	10 – 15 days, before being lined in nursery beds---keep 2 layers of shade on top
<b>Grafted plant bag lining</b>	Do this about 10 – 15 days after tent is opened (ie end of rest period). For one month keep two layers of shade cloth, then remove 1 layer.
<b>Plants watered</b> - before grafting - after grafting	1 day before grafting fully wetted When tents are opened, carefully water without wetting leaves All types of grafting/ budding: keep scions dry at all times
<b>Grafting/ budding team</b>	At least 5 people, split tasks
<b>Plants grafted in one day</b>	300- 400 per person, grafting skilled or about 200 per person budding.
<b>Clone marking</b>	Recorded on tents and in rows when transferred to nursery bed
<b>Total number months required to produce grafted or budded plants, from rootstock seed planting</b>	Side grafted: 4-5 months Top grafted: 5- 7 months check Patch Budded: 5-6 months

The success factors for all types of grafting and budding are:

- 1) Make a secure nursery, evenly and adequately shaded (30%).
- 2) Follow the practices outlined in table 1
- 3) Use healthy bud wood with active buds

Photo 61: Suitable bud wood with active bud at top and missing bud below



Photo 62: un suitable bud wood with no active buds (dormant)





- 4) Use bud wood within 2 days of collection and store and transport in moist and cool conditions
- 5) Do not collect bud wood from trees that are recovering from heavy cropping
- 6) Make sure bud wood is of right age and thickness for the rootstock
- 7) Only use a sharp knife and keep it only for grafting or budding- nothing else.
- 8) Clean knives and secateurs and other tools with alcohol, before and after grafting and budding, to minimise disease transfer
- 9) Do not place tools onto the ground
- 10) Avoid grafting in very hot and very dry periods, and also in very wet periods.
- 11) Make sure rootstock are the right age and condition for grafting and budding
- 12) Manage shade and water very carefully

### **5b: Side grafting**

Side grafting is probably the most reliable method to use and can be done on rootstock plants as young as two and a half months old. It involves fusing the bud wood stick (usually one bud with one third leaf intact) into a narrow cut low on the stem. The bud wood should be green / brown, i.e. near where the flush has hardened into mature leaves and the wood is greenish brown in colour. The plant needs about 3 months in the nursery after grafting.

Photo 63:



Photo 64: Inserting side graft scion into the rootstock cut.



Photo 65: Well wrapped and secured scion with grafting film.



Photo 66: using plastic twine in place of tape to secure the scion.



### **5c: Top grafting**

This requires older rootstock seedlings, usually at least four months old, as the bud wood is inserted much higher in the stem, at the ‘top’ of the plant. **Check with CRUZ** It is important to make sure that the diameter of the rootstock and the scion are of similar size, and that the wedge of the scion lines up neatly with the split in the rootstock. The plant needs about two months after grafting in the nursery.

Photo 67: Suitable rootstock age for top grafting.

With top removed Photo 68.





Photo 69: Rootstock opened by splitting the top, and the wedge of bud wood is inserted into it.

Photo 70: The scion is bound onto the rootstock



### **5d: Patch Budding**

This method usually requires older rootstock seedlings, as the plant must be thick enough (pencil thickness) to hold the bud wood patch securely. However, skilled budders can use seedlings from as young as two months old. The advantage of budding over grafting is that older bud wood (brown/ green) can be used, compared with grafting methods. It is generally thought to be slower and more difficult to perform than grafting, but does not need grafting tents. It uses less bud wood and older bud wood, and needs about 2 months in the nursery after budding.

Photo 71: preparing rootstock for patch budding



Photo 72: preparing the bud patch from the scion wood or bud stick. Note the active bud.

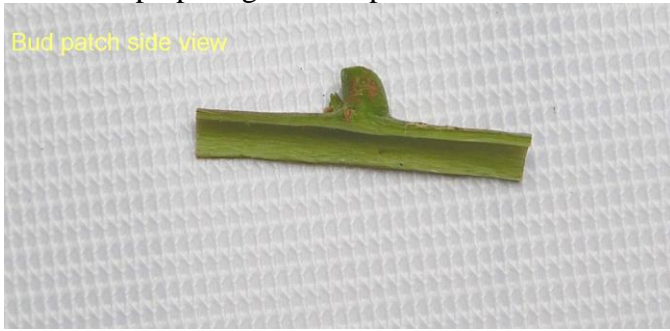


Photo 73: Inserting the bud patch into the rootstock flap.



Photo 74: Binding the bud patch with grafting film.



## **5e: Grafting management and productivity**

### ***NEED FOR SEED!***

*If we start with 100 seeds we get 95 seedlings – 95% germination rate.*

*From these we cull about 10 seedlings due to defects or growth problems (10%) to leave 85 plants.*

*We then graft or bud these and at 90% success rate we get about 75 plants.  
(Some of these may be grafted a second time to reduce seedling losses)*

*We might expect about 5% loss during post grafting culling. This reduces our plants to about 70 survivors from 100 seeds*

*So we need about 30 % more seed than seedlings for grafting, and about 20% more for hybrid seedling production.*

The above table illustrates quality control, not in efficiency of operations. It is completely unreasonable and undesirable to seek 100% successful germination and emergence rates of seeds and seedlings, without any defects or problems. That is not ‘natural’. So prepare additional space, bags and seedlings in order to reach your targets.

Photo 75: Healthy, newly grafted seedlings.





Photo 76: Example of a REJECT clone, with slipped graft



Photo 77: Example of a REJECT clone, with poor grafting technique



Photo 78: Example of a REJECT clone, diseased, and with scion too large for rootstock



Photo 79: Example of a REJECT clone, with dead scion material.





Photo 80: Example of a REJECT clone, insect infested and damaged



Photo 81: Example of a REJECT clone, with growth deformity of scion shoot.



Photo 82: Example of a REJECT clone, with dormant bud grafted.



### ***5f: Propagation tents and practices (for use in side grafting)***

There are a range of these to be used from simple plastic bags holding about ten plants (community grafting tent) to more elaborate structures that can hold 2000 or more grafted rootstock at one time.

Regardless of the structure used, the following are the critical success factors to maximize success rates of grafting:

1. Preparing plants

Photo 83: rootstock prepared just before grafting, by tipping and leaf trimming





Photo 84: Typical height and size for a rootstock ready for side grafting at about 20 cm height.



## 2. Build tents

Photo 85: making the frame for a grafting tent



Photo 86: Frames ready for multiple tents



3. Use clean, clear plastic, thick walled to keep high humidity air inside the tent

Photo 87: Example of well constructed grafting tents located inside the nursery, with double layers of shade.



4. Make sure the tent is well sealed to keep air humid inside the plastic

Photo 88: well sealed grafting tent.



5. Water plants thoroughly, just before grafting and placing into tents
6. Install a second layer of shade over the tents ie in addition to the nursery shade
7. After being in the tents for 21 DAYS allow plants to rest , after the tent is opened, before they are moved. Keep the plants rested for 10 to 15 days. This allows the



plant to adjust to the environment outside of the tent, without stressing the newly grafted scion.

Photo 89: Plants resting inside grafting tent after tent has been opened.



Photo 90: Small scale grafting tents and community nodal tents



Photo 91: Grafted plants transferred from tents to beds after ‘resting’.



Photo 92: Healthy well grafted plants, tipped some weeks after grafting





### 5g: Tools used for propagation

Photo 93: Disposable scalpel and NESCOFILM plastic tape used in grafting, alcohol for cleaning tools, and examples of grafting knives and secateurs.



## Section 6. Plant Health Management

The most effective way to control pest and disease problems is to prevent them happening, by close attention to the best practices indicated in this manual.

The next step is to do regular nursery monitoring or scouting, looking for signs of pests or damage caused by diseases and pests. When a problem is noted, apply a treatment to that area immediately- this is called spot treatment.

The third step is to use an *integrated approach* to pest and disease management. This recognizes that pests and diseases are not really controlled by chemicals, just slowed down for a while. True control comes from minimisation of the conditions that allow the disease or pest to establish and then develop. We call this approach IPM for pests or IDM for diseases.

### **6a: Common seedling pest problems and control measures**

The most common methods faced are insects such as thrips, mites, aphids and mirids, which suck plant tissues causing leaf and stem distortion and leaf drop. These can be treated with ‘softer chemicals’ such as oil based sprays (Summer oil or DC Tron) or pyrethroids ( Confidor). Other insects such as armyworms, loopers and grasshoppers eat leaves. Occasionally termites and root chafers may be a problem, especially if soil is used as potting mix, and was not solarised before use. Treat termites and root chafers with a drench of Chlorpyrifos, or insecticide granules.

Spraying chemicals should be part of an IPM approach to nursery insect pest management. This includes removing insects by hand, keeping insects out by having all sides covered with shade cloth, keeping weeds out of the nursery, and introducing insect predators.

Photo 94: Damage from cane grubs or root chafers.





Photo 95: Leaf eater damage.



Photo 96 : Sap sucker damage



Photos 97 and 98: Termite damage.



## **6b: Common seedling disease problems and control measures**

The most common problems seen are seed and seedling rots and seedling blight. Seed and seedling rots are best controlled by prevention: solarise the potting mix and do not over water. If chemical treatment is necessary, it is possible to try potting mix drenching with Mancozeb fungicide. Photographs 54, 55 and 56 show the effect of diseased seedlings due to seed rots.

Seedling blight is caused by *Phytophthora* fungi, and occurs if leaves are wet for long periods such as in heavy rains. It can spread very quickly by rain splash and leaf to leaf contact. It is essential to manage and prevent this disease by having good ventilation throughout the nursery, and good drainage to stop water collecting around bags. This is achieved by having a maximum of eight planting bags per bed and with walkways between beds. Crowding plants up, is a recipe for disaster especially in the wet season.

As a preventative measure and to treat outbreaks, and as part of a IDM approach, we can spray in wet periods with copper based sprays. Treatment with metalaxyl in alternation with copper sprays also works, for a short time. It is common for nurseries to spray every 7-10 days during the wet season.

Photos 99 and 100: Seedling blight disease of cocoa.



Vascular streak dieback VSD caused by a fungus, is less common, but nurseries should be monitoring for it. Infected plants must be removed and destroyed. Keeping nurseries at least 100 metres away from cocoa trees will help to minimise the problem.



Photo 101: Vascular streak dieback disease VSD.



Less common, is a post grafting disease or rejection, which features pale yellow or white leaves, and diseased tissue around the graft wound area. Keeping the plant dry, securing it properly with grafting tape and using clean tools will minimise this problem, to very low levels.

Photos 102 and 103: Post grafting disease or incompatibility of scion and rootstock.



### **6c: Controlling weeds**

Weed control is important in two ways. Weeds can compete with cocoa seedlings for water and nutrients in the planting bag, reducing cocoa growth rates. Weeds can also contain insects and diseases, thus continuing the life cycles of these organisms.

The best control is prevention, by using heat treated or solarised potting mix which kills most of the weed seeds. If there is a lot of viable weed seed in the potting mix, allow it to germinate and grow a little before cacao seed planting. The weeds can then be removed by hand or sprayed with a chemical, as long as there are no cocoa plants in the nursery.

Make sure you do not use a residual herbicide such as diuron as this will kill emerging cocoa seed. Wait about 1 to 2 weeks after spraying before you plant cocoa seed.

Photo 104: Weeds in potted bags



Photo 105: Weeds growing in walkways.



Photo 106: Severe weed infestation of cocoa seedlings.





Photo 107: Spray tank suitable for weed spraying.



*REMEMBER!!! You will need two spray tanks: one for weeds and one for nutrients, fungicides and pesticides. Don't ever use weed spray tanks for cocoa leaves spraying.*

## Section 7: Plant Nutrient and Water Management

### 7a: Controlling pH of potting mix

Control of pH is important as it affects the supply of plant nutrients in the potting mix. At low pH less than 5.5 and at high pH greater than 7.5, many nutrients are not easily available to plants. The best pH range for cocoa is about 6 to 7.

If pH is < 5.5 add 10g builders lime in 10 litres of water and add about 100 ml of this mixture to each pot.

If pH is >7.5, add iron sulphate at 3g/litre of water, and flood each pot.

Soil pH can easily be checked with a field test kit, or if available a pH meter. Make sure many pot mixes are collected into one sample and then sub sample from this.

Photo 108: pH Field test kit.



### 7b: Nutrient problems and corrections

Many of these result from high or low pH, or simply from lack of nutrients. It is important to add nutrients to the potting mix as it is made up. This should feed the plant for about 3 to 4 months, and will require top ups with foliar spraying, liquid feeds or slow release granules.

Foliar spraying should be done weekly for first 8 weeks or so. Add insecticides such as confidor if insects are a problem. Confidor is a synthetic pyrethroid based on natural plant insecticides.

Use a complete spray mix such as Biotec or Peters Professional Mixture, and do not exceed recommended dose as you could scorch the leaves. Make sure foliar spraying



or any nutrient application, is not done within 3 weeks of transporting plants to farmers.

Photo 109: Possible nitrogen deficiency



Photo 110: Possible zinc deficiency.



Photo 111: Possible iron deficiency.



Photo 112: Early signs of salt water spray or salty water damage



Photo 113: Symptoms of poor growth resulting from low potting mix pH



### ***7d: Watering schedules and methods of watering***

During sunny hot periods, watering morning and early afternoon every day is a good practice. Allowing the seedlings to dry out before night time will help with disease control. Do not over water- water to wet the top few inches of the potting mix.

When plants are more mature and the weather is overcast, watering every other day is usually enough. Use watering cans or hoses- if by hoses reduce pressure and use a water rose to sprinkle the water. Be careful not to wash out potting mix or wet the ground too much.



Photo 114: Watering can with spout and diffuser good for hand watering.



Photo 115: Irrigation supply main and hose for watering,



Photo 116: hand watering from hose.



### **7e: Water quality**

Good quality water is necessary to produce quality, healthy plants. The simplest indicator of water quality is the electrical conductivity, measured with a simple conductivity meter. The reading should be less than 700 micro Siemens per centimetre (uS/cm) for cocoa seedling irrigation. This is equal to about 0.5 g salt / litre of water.

If water greater than this level of conductivity is used, salts will accumulate on plant leaves and in the potting mix, leading to death ultimately.

Check water quality regularly, especially if you see browning of leaves, as shown in photograph 108.

Photo 117: Suitable conductivity meter to test for water quality.





### **7f: Nursery drainage**

Good drainage is essential to produce healthy and disease free plants. Effective drainage must be designed during the nursery construction phase, not after the nursery it is built and drainage becomes a problem. For drainage to be effective, there must be an outlet to carry drain water away from the nursery site. Good drainage also make it easier to move around and work inside the nursrey. Another way to improve drainage is to have raised nursery beds. These can be built up using layers of crushed stone, or having steel racks to hold pots on. Both these methods are more expensive, but may be suitable for long term nurseries.

Photo 118: Poorly drained cocoa nursery.



Photo 119: Good nursery drainage.



Photo 120: Water that is not drained causes weed and disease problems





## **Section 8: Plant Distribution**

### ***8a: Plant production cycles***

Use the flowing checklist to set up your nursery establishment and production tasks.

#### **GUIDELINES: TASK LIST FOR NURSERY ACTIVITIES**

##### **NURSERY CONSTRUCTION & REHABILITATION**

- 1.1 Design nursery and check for area and specifications
- 1.2 mark out area for nursery, potting, grafting tents etc
- 1.3 provide 2m access path through center
- 1.4 prepare ground surface-level off and install drains
- 1.5 repair perimeter fence
- 1.6 check/ repair/ install water supply to nursery- check quality
- 1.7 install irrigation supply pipe and hoses for watering
- 1.8 mark out positions and install nursery poles
- 1.9 construct new nursery framework (cross members, wire) or repair old one
- 1.10 install shade cloth- side to side and roof. Use moveable wire frame or similar.
- 1.11 Construct grafting tents OR plastic covers
- 1.12 Make grafting/ budding tables or benches for staff doing budding/ grafting

##### **NURSERY OPERATIONS**

- 2.1 **POTTING MIX PREPARATION**
  - 2.1.1 prepare potting mix (add lime and rock phosphate)
  - 2.1.2 solarise in plastic sheets
  - 2.1.3 fill bags (15 cm x 30cm)
  - 2.1.4 line bags in nursery (rows of 8, 40 cm air gap)
- 2.2 **SEED PLANTING**
  - 2.2.1 collect pods and remove seeds
  - 2.2.2 sort seeds- remove small and damaged and floaters
  - 2.2.2 clean seeds and put onto germination trays
  - 2.2.3 dip in fungicide ie Thiram. Mancozeb
  - 2.2.3 collect germ seed at 3, 5. days and plant into pots
  - 2.2.4 remove twisted, deformed seedlings and potting mix
- 2.3 **GRAFTING AND BUDDING**
  - 2.3.1 prepare trees for budwood collection
  - 2.3.2 prepare rootstocks
  - 2.3.3 collect budwood
  - 2.3.4 graft or bud rootstocks

- 2.3.5 post grafting treatment
- 2.4 PLANT WATERING (use local best practice)
  - 2.4.1 water plants daily, during first month depending upon rainfall (check potting mix moisture content at 5 cm depth)
  - 2.4.3 observe for water stress and diseases
- 2.5 PLANT NUTRIENT MANAGEMENT
  - 2.5.1 add slow control release fertiliser or pelletised NPK to bags
  - 2.5.2 weekly or fortnightly foliar spraying with macro and micro nutrients
  - 2.5.3 check regularly for nutrient problems
  - 2.5.4 check water quality and pH monthly through potting mix
  - 2.5.5 withhold nutrient 3 weeks before planting to field
- 2.6 PEST AND DISEASE MANAGEMENT
  - 2.6.1 scouting (inspection) weekly for pest and disease problems
  - 2.6.2 apply insecticide for insects/ mites as necessary (first month weekly)
  - 2.6.3 apply copper fungicides as necessary (first month fortnightly)
  - 2.6.4 apply Bayfidan for VSD control in wetter areas
  - 2.6.5 ensure adequate ventilation in nursery and drainage of nursery beds
- 2.7 WEED MANAGEMENT
  - 2.7.1 remove all weeds inside and around nursery (harbor insects and diseases)
- 2.8 SHADE MANAGEMENT
  - 2.8.1 check sides and roof of nursery properly shaded
  - 2.8.2 remove shade from seedlings 2 weeks before field planting
- 2.9 FIELD PLANTING
  - 2.9.1 soak seedlings in water before transporting to field
  - 2.9.2 ensure hardened off 1-2 weeks

## **NURSERY MANAGEMENT: STEPS TO FOLLOW**

- 2.1 PLANT INVENTORY RECORDING
  - 2.1.1 keep accurate, daily records of seeds planted, plants culled, plants died
  - 2.1.2 keep records of seed germination rates
  - 2.1.3 record locations of each batch grafted and location of seed batch in nursery
  - 2.1.4 keep record of clones used and where located in nurseries
  - 2.1.5 keep records of grafting/ budding success rates
- 2.2 GROWTH MONITORING AND PROBLEM SOLVING



- 2.2.1 record problems and treatments applied and effectiveness
- 2.2.2 monitor plant health and vigour
- 2.2.3 record major storms and rainfall periods

#### 2.4 QUALITY CONTROL AND MANAGEMENT

- 2.4.1 check that seed and seedling inspection occurs weekly for culling and rejection
- 2.4.2 check nursery record books weekly for compliance
- 2.4.3 inspect nursery weekly for structural problems and repairs needed
- 2.4.4 check water supply and quality regularly
- 2.4.5 check budding./ grafting techniques and success rate
- 2.4.6 adjust/ confirm delivery schedules of seedlings

#### 2.5 TRAINING AND EXTENSION

- 2.5.1 Check performance and training needs of nursery staff

### ***8b: Quality guidelines***

This manual has emphasized quality control and assurance at all steps in the production of nursery plants. At the final point of distribution to farmers, this quality needs to be checked, much like cars passing through a factory production line. We have developed quality guidelines to assist with this step, as photos to show acceptable and unacceptable plant examples for delivery to farmers. Plants which do not meet these standards should not leave the nursery, and in most cases be destroyed.

Photo 121: Good quality clone seedlings ready for field planting.



Photo 122: Quality control-clone of right size and condition, marked with tag to identify clone type



Photo 123: Examples of reject clones



### **8c: Marking clones**

Clone marking is important so that nursery operators know which clones and how many of each, have been grafted. It is also important for farmers so that each farmer is given a mixture of three or more clones, not just one clone. In this way, the performance of clones in different environments does not become a problem for farmers. Unless operators mark clones used, it is impossible to know what clones have gone to farmers.



Marking starts when bud wood is collected, and continues on through recording on grafting tents and finally when bags are lined after grafting. It is a good practice to mark different colored paints on each plant stem prior to plant distribution. So one clone is marked the same colour, different from other clones.

Photo 124: Different clones marked and loaded onto a truck for distribution to farmers.



Photo 125: Clone marked on stem, and Nursery supplier marked on the bag.



### **8d: Hardening- off plants**

This refers to the process of gradually exposing plants to more and more sun over a two week period, to harden the leaves and to minimise post planting shock and plant loss. This is best done by rolling back shade cloth for longer period each day. At 10-14 days before transport, remove about 50% of shade cloth and allow plants with hard green leaves to be placed in open. Plants with soft leaves should be gradually exposed to full sun. Do this by checking everyday plants that have hard green leaves and remove to full sun area, leaving only plants with soft leaves shaded. By the end of the second week, the shade cloth can be completely removed.

It is important also to not apply nutrient less than 3 weeks before field planting, as this promotes soft flush growth.

Photo 126: Hardening off plants by removing shade. Note shade cloth is moveable on wire frame and rolled up to the centre.



### **8e: Transport of plants**

For small consignments and for small nurseries, we can use motorbikes and tricycles with trailers and trays. For larger consignments we use trucks. Boats may also be used as long as they travel on fresh water only.

The important point about transport of seedlings is the method of loading. Multiple layered stacking causes plants to become damaged and root systems to be injured. This reduces the post planting success rate and growth the farmer obtains. It is best to have single layers of plants with wooden or steel partitions between layers to carry layers on top of the first level. The seedlings must be protected from wind and sun exposure during transport with canvass covers and so on.



Photo 127: Small motor truck transport of seedlings, in a safe manner, using two layers.



Photo 128: Side view.



Photo 129: Using a cart or wheel barrow to take from nursery to truck



Photo 130: Correct loading onto a truck



Photo 131: Larger truck, fully covered with two stackable layers for safe transport.





**Annex 1: NURSERY WEEKLY PRODUCTION FORM**

Nursery: \_\_\_\_\_

Location: \_\_\_\_\_

FROM \_\_\_\_\_ TO \_\_\_\_\_ YEAR: \_\_\_\_\_

	Number of bags filled	Number of bags planted with seeds	Number of rootstock seedlings aged:		Number of Seedlings grafted/ budded aged:	
			< 1 month	> 1 month	< 1 month	> 1 month
<b>Inventory at start of week (= e from previous week)</b> a					<i>Specify by clones</i>	<i>Specify by clones</i>
<b>Mortality during Period</b> b						
<b>Seedlings Distributed / sold during week</b> c						
<b>New stock planted during week</b> d						
<b>Ending Inventory = a+d-c-b</b> e						

REMARKS on pests, diseases, rainfall, problems

---



---



---