PAPUA NEW GUINEA

COCOA FARMER'S HANDBOOK

PNG Cocoa and Coconut Institute, Tavilo, East New Britain Province,
Papua New Guinea

Forward

This handbook summarises for farmers the important cocoa growing knowledge and methods developed at the PNG Cocoa and Coconut Institute and needed to greatly increase production of high quality cocoa in Papua New Guinea.

Dr. Eremas Tade
CEO
PNG Cocoa and Coconut Institute

Compiled and edited by Alfred Nongkas (Program Director, Information Management and Communication, PNG Cocoa and Coconut Institute Ltd.) and Philip Keane (School of Life Sciences, LaTrobe University, Melbourne) with advice from Eremas Tade, Josephine Saul-Maora, Paul Gende, Hosea Turbarat, Kenny Francis, Joachim Lummani, David Yinil, Peter Bapiwai, Chris Fidelis, James Butubu and Jeffrie Marfu. Steve Woodhouse (Farmset) helped prepare Section 12. Trevor Clarke helped prepare the section on solar driers and provided general advice.

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PPAP
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Contents

1: Getting Help to Grow Cocoa

If you need help contact the following organisations:

Cocoa Board of Papua New Guinea
P.O. Box 532, Rabaul, ENBP; Phone: (675) 982 9083

PNG Growers Association
Kokopo; Phone: (675) 982 9123
Email: growers.association.inc@gmail.com

Papua New Guinea Cocoa and Coconut Institute Limited (CCIL)
P.O. Box 1846, Rabaul, ENBP; North Coast Road, Tavilo
Phone: (675) 9839131/9839108,
Email: ccipng@datec.net.pg

CCIL Extension Officers in provinces
Cocoa Board Extension Officers in provinces
Provincial Administrations – Division of Primary Industries field officers

Kairak Vudal Resources Training Centre
University of Natural Resources and Environment
PMB Services Rabaul, ENBP; Phone: (675) 983 9737/9736/9735

NGIP-Agmark
P.O. Box 76, Kokopo, ENBP 611; Williams Road, Kokopo
Phone: (675) 982 9055
Email: gmcnally@agmark.com.pg

Outspan PNG Ltd.
P.O. Box 387, Rabaul, ENBP; Kokopo; Phone: (675) 982 3176

Farmset
P.O. Box 19, New Rabaul, ENBP; Kokopo;
Phone: (675) 982 8703
Email: rmngi@farmsetpng.com

2: Cocoa in Papua New Guinea

Cocoa originated in the Amazon River region of South America, growing under big trees and so is easiest to grow under the shade of other trees and in deep fertile soil.

Cocoa was first brought to PNG from Samoa in about 1900.

- This was Trinitario cocoa that was the main type grown until the 1980s, and has given PNG a reputation for producing 'fine flavour' cocoa beans.
- In the 1960s another type (Amazonian) was introduced from Trinidad and used to produce hybrids with Trinitario.

Cocoa can be grown in most areas of the lowlands that have had rainforest or secondary forest or good gardens - it is often grown under coconuts or other garden trees; now CCIL has shown that it can be grown in some highland valleys (Karamui) and on some kunai grasslands.

Fermented and dried cocoa beans are roasted and ground to make chocolate - the demand for cocoa beans is growing as more people around the world eat chocolate and so growing cocoa can be a good business for farmers in PNG.

Cocoa needs constant attention and the whole family can be involved in caring for it
Photo H. Turbarat

Cocoa has some serious pests and diseases that can kill trees and destroy pods - these can be controlled with good management, involving regular light work, as shown in this Handbook.

This Hybrid Clone (CCI-B1) is one of the new high yielding cocoa varieties made available by CCIL Photo Breeding Section CCIL

CCIL has produced new types of cocoa (above) that can give high yields if managed well following the advice in this book – these have come from crosses between Trinitario and Amazonian types. Selection and breeding of improved types of cocoa have been undertaken at CCIL and its predecessor institutes for over 80 years.

The clone in the above photo has been pruned to maintain a small tree so that all pods are within easy reach for spotting and removing sick pods, and for harvesting healthy ripe pods.

Smaller cocoa trees need less heavy work than large trees – in large trees it is impossible to control pest and diseases and more work is needed to harvest all healthy pods.

3: Cocoa Can Give a Good Family Livelihood

If cocoa is grown well and managed as a business it can give a good income so that farming families can live well.

A good house built by a cocoa growing family

Good cocoa growing needs as much knowledge, skill and regular work as any town job or profession – good cocoa farmers should be proud of their work and skill.

Growing cocoa as a business can give the same pay as a town job, enables people to stay in their home villages and do their customary and family duties and have a good life. It also allows them to be their own boss.

To give a good income, a cocoa farm must be worked as a family business - this means farmers have to plan ahead.

- Work done today (like pruning cocoa and shade trees, and cutting out and burying sick pods) will give more healthy trees and pods and more money in the future.

It also means members of a family have to do some work on the cocoa every day.

Once a cocoa block has been established or rehabilitated, it need not involve a lot of hard work, but more regular and more skillful work involving the whole family.

Farmers also need to keep records of their costs for producing cocoa and income from selling beans, so that they can work out their profit (their pay) and work out ways of increasing this.

Doing your own fermenting and drying of beans, rather than just selling wet beans, can add much value to the profitability of your farm. It is important that fermentation and drying are done well so that the exported PNG cocoa beans are of world standard. The methods for doing this are described in Sections 14 to 17. The whole family can contribute to this work, which can be done near your home and be fitted around other family duties. Fermentation and drying of cocoa beans are the first two stages in the manufacture of chocolate and they are very important for developing the chocolate flavour. People who do this can consider themselves to be manufacturers as well as farmers.

4: Growing Cocoa as a Small Tree

The new way of growing cocoa is to keep the trees small (less than twice a person's height – about 3.5 metres).

Tall overgrown trees (above) are hard to manage and pods are hard to find in order to identify and remove sick pods and harvest healthy ones – they need a lot of hard work

In overgrown, over-shaded, neglected bush cocoa, pests and diseases can destroy most of the pods.

Research at CCIL has shown how these problems can be managed so that farmers can make a good living from cocoa despite the presence of pests and diseases.

The new methods of growing smaller trees will make working on the cocoa much easier.

Smaller trees need less hard work once they are established but they need some light work nearly every day, just like food crops or a town job.

Secateurs are the most useful tool for cutting off sick pods, for harvesting ripe pods and for cutting out unwanted branches before they get too big.

Photo below shows an older tree kept small by regular pruning - sick pods are easy to spot and remove, and harvesting ripe pods does not need a lot of hard work like climbing trees or using a long hook

5: Cocoa Planting Material

The first step in good cocoa farming is to plant good types of cocoa that give a high yield of good quality beans (high fat content, large beans), and are not damaged too much by pests and diseases.

Trinitario was the main type grown in PNG until the 1980s.

- *This was planted as seed taken from pods on farms.*
- *Because the trees were often out-breeding, the progeny were very variable.*
- *Scientists in PNG selected the best types for supplying to farmers as seed, or clones made from cuttings.*

Then it was discovered that if Trinitario cocoa was cross-bred with Amazonian cocoa the offspring were fast growing and some were high yielding.

- *Pollen from one type was put on the female part of the flower of the other type and the pod grew to produce 'hybrid seed'.*
- *This seed was produced in Seed Gardens to give SG1 and SG2 hybrids that were distributed to farmers for planting as seedlings.*
- *These hybrids were widely grown but were not always popular with farmers.*
    - *They grew too fast and trees became very big.*
    - *They produced some trees with high yield but many had very low yield (they were very variable).*
    - *Their yield declined sharply after about 5 years.*

CCIL began a new breeding program in which they made clones by budding from the best SG1 and SG2 hybrid seedlings – these clones are better than SG hybrid seedlings because every tree gives a high yield. Every tree is an exact copy of its parent.

These are called 'Hybrid Clones' and are the type most strongly recommended by CCIL for growing on farms today.

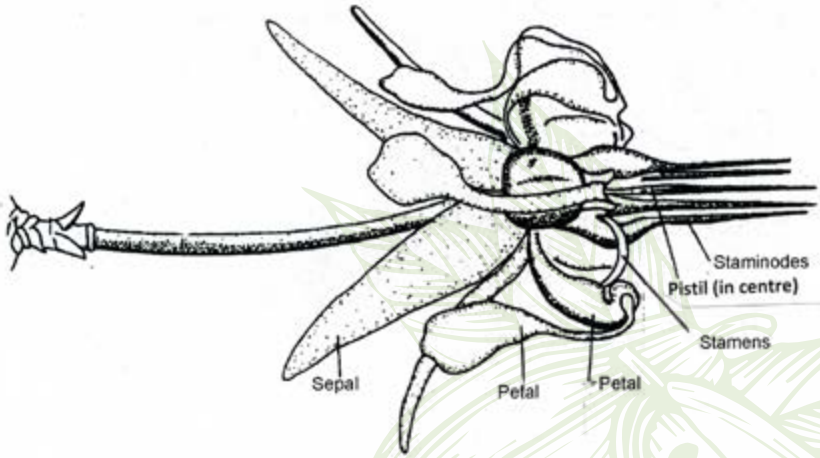
CCIL also produces a new type of 'Hybrid Seed' to grow good seedlings – this is produced by hand pollination of selected parent clones (one

Trinitario type and one Amazonian) and is better than the seed produced in 'seed gardens' because pollination is better controlled.

These two types of cocoa can be obtained from CCIL or a local nursery licensed by CCIL.

It is good to keep some of your older Trinitario or SG1 or SG2 hybrid trees if you know they produce a lot of healthy pods – you can take budwood from these to make more trees like them to improve your farm (see 5d and 5e below) but do not plant seed from these trees because they will not usually be like the parent trees.

A pod developing from a cocoa flower after pollination by a tiny insect (a midge) – without pollination by midges no pods will grow



Cocoa flower showing the male parts (stamens that produce pollen) and female part (pistil that grows to form the pod after pollination) – the pollen is carried to the pistil (often on flowers on other trees) by tiny insects known as midges

Drawing from van Hall CJJ, 1932, Cacao, Macmillan, London

5a: Hybrid Seedlings

The new type of Hybrid Seed produced by CCIL for supplying farmers is a good type produced by hand pollinating to make crosses between Trinitario and Amazonian types of cocoa.

These are useful for farmers in new areas where it is difficult to take budwood and clones and people don't yet have the skill to make clones from budwood or manage clones.

Seedlings are also easier to establish than clones because they grow with a single trunk up to about 1.2 metres high and then produce about 5 main branches that bear the pods – an ideal structure for a cocoa tree. Seedlings grow into a well-shaped tree with only a small amount of pruning.

Initial seedling stem growing as a chupon – leaves in a spiral around the stem

Fan branches formed at the jorquette with leaves growing in a flat pattern on branches

Seedlings produce a lot of pods on a tall trunk

Hybrid Seed from CCIL will include seed from several different crosses to ensure that a mixture of cocoa types is planted on a farm – this is needed to give good pod set and reduce the damage done by pests and diseases.

Because seeds are produced by sexual reproduction from the flower, they are genetically variable (i.e. they produce trees that may be different from each other).

Mature cocoa grown from seed showing tall trunk and large tree – these trees should be pruned to give small trees

5b: New Hybrid Clones

CCIL has made two releases of Hybrid Clones – First Series (released in 2003) and Second Series (released in 2013).

The Second Series has some resistance (tolerance) to Cocoa Pod Borer which means the borer doesn't invade them as much or do as much damage as in a very susceptible clone.

However, the pods of these clones will still be destroyed by Cocoa Pod Borer if they are not managed well.

Hybrid Clones Released by CCIL in PNG

Released Series	Size of hybrid cocoa clones	
	Big trees	Small trees
First Series 2003	1. 37-13/1	1. 17-3/1
	2. 36-3/1	2. 74-14/1
	3. 16-2/3	3. 34-13/2
	4. 73-2/2	4. 63-7/3
Second Series 2013	1. CCI-B1	1. CCI-S1
	2. CCI-B2	2. CCI-S2
	3. CCI-B3	3. CCI-S3
	4. CCI B4	4. CCI-S4
	5. CCI-B5	5. CCI-S5

The Hybrid Clones include types that grow into smaller trees or bigger trees – these should not be mixed in a block (a block should have all small or all big clones).

The small clones need less pruning to produce a small tree.

The bigger clones should be grown if the soil is poor – if grown on good soil they need more pruning to keep them small.

Small and big clones can give the same yield if managed well.

A farm should be planted with equal proportions of the 4 First Series or 5 Second Series clones – the First and Second Series clones can be mixed, as long as they are all Big or all Small clones.

New cocoa types from CCIL produce many pods with good beans - CCI-B2 on left and CCI-S2 on right. Photos Agronomy and Breeding Sections CCIL

Plant 2-4 rows of one clone and then plant 2-4 rows of another clone - plant 5 or more different clones in a block.

Clones are better than the SG1 and SG2 hybrid seedlings because all the trees of a particular clone (e.g. CCI-B1) are identical because they have been grown from vegetative buds from the mother tree (see the method of vegetative reproduction by budding and grafting below – 5d and 5e).

Big clones are planted on the usual 4m x 4m square spacing.
Small clones are planted on 3m x 4m (between rows) or 3m x 3m square spacing.

If trees are kept small (2x human height) by pruning, a 3m x 3m spacing is recommended.

It is recommended that farmers try planting a block of the new Hybrid Clones or Hybrid Seedlings and compare them with their current plantings – to see for themselves how they compare.

5c: Budwood Garden and Nursery

Hybrid Seed supplied by CCIL or its provincial nurseries has to be planted in polybags in a nursery and grown for about 4 months before being planted out in the field.

Hybrid Clones can be bought from CCIL as small plants or produced on farms from budwood supplied by CCIL or a certified budwood garden.

To make clones, mother trees (supplied by CCIL) are grown in a special garden to produce the budwood for budding and grafting onto seedlings raised in the nursery.

Farmer nursery in Malol, West Sepik, showing the use of shade cloth and palm fronds, bamboo to hold lines of polybags with seedlings for budding, gaps for wheelbarrow access, and a drain around the nursery

Seedlings for budding or grafting are grown from seed from any good vigorous tree (e.g. SG2) – they are grown for 2 – 8 weeks before budding depending on the type of budding (juvenile or mature).

Seeds should have the mucilage rubbed off with sawdust before being planted on their side, about one knuckle deep, in black topsoil from the bush (not too sandy, and not from cocoa groves with a lot of Black Pod infection) in polybags.

Budwood garden in Poro, West Sepik, with clear labels on the rows of different clones. *Photo courtesy of Wilson Miroi*

A budwood garden has to be started 2-3 years before the clones are required for planting in the field.

The minimum size budwood garden for planting out 1 ha in a year is about 2 trees of each of 5 recommended clones (a 3-year-old mother tree can give budwood to make about 350 clones in a year).

Budwood gardens can be planted at closer spacing (2 metres between trees, 3 metres between rows) than normal trees because they are being harvested for budwood (branches) not pods.

The budwood trees are tip pruned so that they produce a lot of branches for harvesting as budwood sticks.

Cocoa Model Farmer-Trainers or Village Extension Workers are being encouraged by CCIL to plant budwood gardens consisting of rows of 10 trees of each of the 18 latest release Hybrid Clones to produce clones to supply farmers.

5d: Budding to Make Clones

Budwood sticks are cut from trees in the budwood garden on the morning of the day they are to be used for budding.

Budwood stick cut from a mother tree in a budwood garden – note that the leaf blades have been cut off

Cutting bark with a bud and base of a petiole (a bud patch) from a budwood stick ready for budding; the most important tool is a very sharp budding knife. A cheap budding knife can be made by cutting a hacksaw blade on an angle and sharpening the edge

Cutting a window in the bark of a juvenile seedling (left – 2-wk old) and 2-4 month old seedling (right); the seedlings are well watered so that bark peels off easily; the seedling stems must be well cleaned with damp tissue paper or a sponge before being cut open

Inserting bud patch into window cut in bark of juvenile seedling stem (left) and mature seedling stem (right)

The inserted bud is bound with Parafilm, Nescofilm or Gladwrap tape to hold the bud tightly against the stem and keep it moist; rice bale plastic or plastic shopping bags can also be cut into strips, stretched to make them thin and used to bind buds

Tape is removed after 12 – 17 days and the bud begins to grow

Growth of bud on side of seedling (left) and seedling top cut off to allow bud shoot to grow into a new plant (right)

- the bud is growing as a fan shoot because it was taken from a fan branch on the mother tree

- this is the most common type of clone because fan branches are more common than chupons on mother trees

The clonal plants are ready for planting out in the field 2–3 months after juvenile budding or 3–4 months after mature (normal) budding.

To get a high success rate in budding and grafting:

- Clean dirt from the stems to be budded using tissue paper or a damp sponge.
- Use a very sharp budding knife.
- Work quickly so that the bud patch and window don't dry out.
- Remove the binding film as soon as the bud begins to grow or 14 days after budding when bud patch is still green in colour.

Clones require special pruning in order to make a good tree (see Section 7 later).

5e: Top Grafting to Make Clones

Top grafting of seedlings or chupon shoots is easier than bud grafting.

The top (about 20 cm) is cut off a 2 – 4 month old seedling and a slit is cut into the cut end; a wedge-shaped budwood stick is cut and inserted into the slit.

Budwood stick with two buds in axils of 2 petioles cut to a sharp wedge ready for inserting in slit in seedling that has had its top cut off

Budwood stick inserted right way up in slit in top of seedling, making sure the bark and underlying cambium of the budstick and seedling are flush together on at least one side

Budwood stick inserted in slit in top of seedling and bound tightly with Parafilm or Gladwrap or rice bale plastic or strips cut from plastic shopping bags

Top graft covered with a plastic bag to keep the buds moist; bag is removed as soon as the buds on the graft stick begin to grow

Top graft with 2 shoots growing after plastic bag removed

Top graft junction

Grafted seedlings ready for planting in the field – note the bulge where the clone top (the scion) is joined to the seedling (the rootstock)

Seedling or Shoot Blight caused by ***Phytophthora palmivora*** (the same fungus that causes Black Pod) is the most serious disease of young plants in nurseries.

Seedling Blight in young plants *Photo Pathology Section CCIL*

Spray with Ridomil Plus 72 or Laxyl Copper (10 g per litre water) – the same as for Black Pod
Seed can be soaked in the above solution before planting to control Blight.
Remove sick plants from the nursery.

Seedling Blight will be less if polybags are filled with clean bush soil from an area that does not have cocoa with Black Pod.

VSD should not be a problem in nurseries with a plastic roof.

About 2 weeks before being planted out, young plants must be exposed to more sun in the nursery in order to harden the leaves (remove some of the palm fronds covering the nursery).

6: Assessing and Renewing an Old Cocoa Block

To rejuvenate an old block the trees have to be made smaller, and the cocoa canopy and shade trees thinned out and cut back to let in more light and air.

This will stimulate growth and flowering of the cocoa, and help reduce pests and diseases.

If trees are not too big and have healthy trunks, they can be strongly cut back to the main trunk and branches and allowed to regenerate a new, lower canopy (3.5 m high).

If trees are big and unhealthy but have a healthy lower trunk (no Stem Canker) they can be cut back to a stump so that a chupon grows up for budding or grafting to renew the tree with a new clone.

Chupon growing at the base of a cocoa tree that has been cut back to one main branch

The chupon can be bud or top grafted with an improved clone and the old branch removed later

Chupon growing on a cocoa tree cut back to a stump; this chupon can be allowed to grow into a new tree or be bud- or top-grafted with an improved clone

When trees are cut back, usually more than one chupon will grow – keep the strongest one nearest the ground for bud or top grafting and cut out the rest; cut off the stump of the mother tree close to the grafted chupon to stop regrowth from the old tree.

Chupons stimulated to grow on stumps can be bud or top grafted using the same methods as for grafting seedlings (see Sections 5d and 5e above) – in this way new Hybrid Clones can be grafted onto older trees to improve the farm.

An old cocoa tree rejuvenated by chupon grafting – its top has been replaced with a new improved clone – note the trunk of the old tree

During rejuvenation of an old cocoa block, *Gliricidia* shade trees should be thinned out by killing some of them by ringbarking, or by partial de-barking to kill the tops but allow new shoots to grow up.

A Gliricidia shade tree debarked or ringbarked to kill the tree or stimulate growth of new smaller shoots below the cut that can be pruned to give lighter shade – if trees are cut down, the wood can be sold as firewood

When new shoots grow up from the pruned Gliricidia, choose one or two to grow to give light shade and cut out the rest

Gaps in the regenerated cocoa block can be in-filled with Hybrid Seedlings or Hybrid Clones in the same way as for planting a new block.

Don't plant young cocoa under old, sick trees unless the old trees have been cut back and cleaned up to remove sources of VSD and *Phytophthora* or insect pests.

7: Establishing a New Cocoa Block

If a cocoa block has become too old, overgrown and diseased it should be cut down and replaced by new young cocoa plants.

This is a chance to plant new Hybrid Clones or Seedlings produced by CCIL to give many more pods than the old trees.

Useful shade trees such as coconut and betel nut palms or nut (galip, pau) and fruit trees can be retained as long as the shade is not too dense.

Cut old trees as close to the ground as possible and poison the stump with a Garlon/Diesel (1:80) mixture – wear gloves (see Section 12).

Laying out the block – this can be done using 3m and 4m long bamboo sticks to get the right spacing between the shade trees and cocoa.

Big clones are planted at 4m x 4m spacing; small clones at 4m (between rows) x 3m (within row) spacing or 3m x 3m spacing.

Plant Gliricidia sticks (1 metre long, 5cm across with a sloping cut at the base) one hand length deep and sight along these to lay out straight rows of shade trees ready for planting cocoa.

Block marked out with Gliricidia sticks that will grow into shade trees

Here cocoa has been planted early and needs temporary shade for which coconut or saksak fronds can be used as shown here

If a block is prone to waterlogging, drains should be dug, sloping to a creek to take away excess water

Cocoa will not grow well on a very wet site

Seedlings planted with well-established Gliricidia shade trees – Gliricidia sticks take 6-9 months to grow big enough to give good shade for young cocoa

Before being taken from the nursery for planting in the field, plants must be 'hardened off' by being exposed to more sunlight; plants in polybags should be watered in the morning before planting in the field.

To plant out, cut the bottom off the polybag, lower the bag into the planting hole (40cm deep), surround with good soil and then slide the bag up over the plant and tamp down the soil; budded clones should be planted deep enough so that the soil covers most of the rootstock to stop shoots growing from it.

Cocoa being established under old coconut palms with some extra Gliricidia shade

Weed control around young plants is important after field planting – hand weeding is best when cocoa is young

Formation Pruning to Grow a Small, Balanced Cocoa Tree

Begin pruning young clones 6 months after they are planted in the field to give a good shape of tree and to begin keeping the trees small – this will give the most productive tree structure.

The aim of formation pruning of clones is to end up with a balanced tree with a trunk (up to 50cm high) with 5 main branches coming off at equal distances around the trunk (i.e. like the shape of a seedling tree) – the pods are formed on the main branches and are within easy reach.

The tip of the first fan branch on a clone has to be cut off to allow lower shoots to grow in the opposite direction to give a balanced tree. *Photo Breeding Section CCIL*

When other shoots have grown, often one fan branch will still become dominant – cut the top off this branch to allow the other branches to give a balanced tree

Pruning to shape the tree must be done repeatedly until the trees are two years old, when the main lower pod-bearing branches will have been formed.

Fertilising or Manuring to Establish Young Plants

Fertilising or manuring may be needed when young plants are being established on old cocoa or food crop blocks where soil nutrients may have been lost.

Fertiliser application will only be useful if the plants are well weeded - otherwise weeds around young cocoa plants will take up the fertiliser and grow faster.

Ring weed around young cocoa plants a month before applying fertiliser or compost or manure, and keep the weeds down after that.

Use of bag fertiliser (especially urea) on young plants must be carefully controlled because it may cause the plants to grow too rapidly and give long branches that have to be pruned off.

Recommended fertiliser applications per cocoa tree in the first 12 months after field planting (only useful in blocks with good weed and shade control)

Option	Period after planting			
	0 months	3 months	6 months	9 months
1	NPKMg 50g (12:12:17:2)	NPKMg 50g	NPKMg 50g	NPKMg 50g
2	150g rock phosphate + 15 g urea or 30g ammonium sulphate	15g urea or ammonium sulphate 30g	15g urea	15g urea or ammonium sulphate 30g
3	30g triple superphosphate + 15g urea or ammonium sulphate 30g	15g urea or ammonium sulphate 30g	30g triple superphosphate + 15g urea or ammonium sulphate 30g	15g urea or ammonium sulphate 30g
4	No application	Diammonium phosphate 30g	Diammonium phosphate 30g	Diammonium phosphate 30g

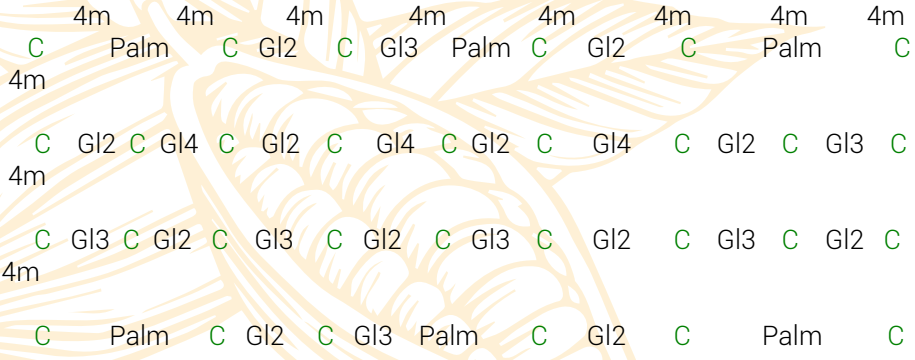
Shade Thinning

A higher density of shade is needed during establishment of young cocoa, but some shade trees can be killed by ring-barking or poisoning to reduce shade as plantings mature.

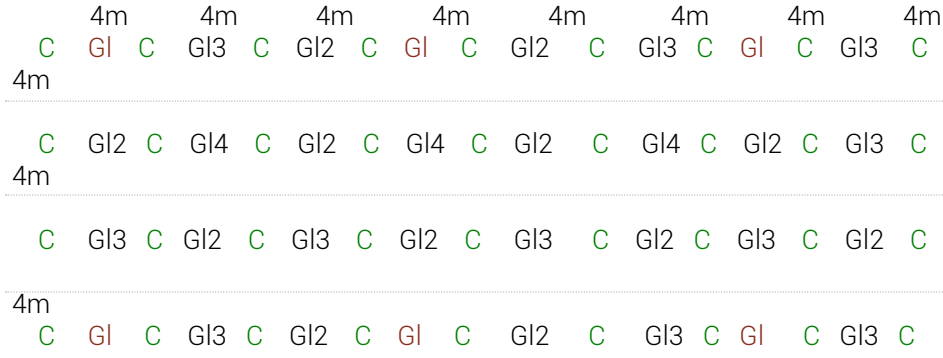
Thinning is best done at the start of the wet season to reduce the initial stress on the cocoa - there will be more cloud cover and soil water to compensate for the increased exposure of the trees following shade thinning.

- Thinning of shade trees (e.g. temporary shade) should be done in stages, not all at once, allowing the cocoa to adjust to the new conditions over time - if shade is removed too suddenly, cocoa may suffer sun scorch or bark cracking.
- Thinning should be done in a regular pattern so that the whole cocoa grove remains uniformly shaded and the trees can adapt slowly to reduced shade.
- Removal of shade trees such as *Gliricidia* has to take into account the occurrence of other valuable fruit, nut or palm trees that are desired on the farm – these usually make heavy shade for cocoa.
- Thin and prune shade trees before pruning the cocoa – if cocoa gets damaged by falling branches this can be corrected when the cocoa is pruned.

The block maps below show ways in which temporary *Gliricidia* shade trees can be removed at 2 - 4 years after planting a new block to leave the right amount of permanent coconut or *Gliricidia shade*



Initial layout of a cocoa plantation and the gradual thinning of ***Gliricidia*** (Gl2 killed after 2 years, Gl3 killed after 3 years, Gl4 killed after 4 years) where coconuts will later provide permanent shade – cocoa (C) in a 4m and coconuts (Palm) in a 12m square spacing



Initial layout of a cocoa plantation and the gradual thinning of ***Gliricidia*** (Gl2 killed after 2 years, Gl3 killed after 3 years, Gl4 killed after 4 years) where ***Gliricidia*** will later provide permanent shade – cocoa (C) in a 4m and ***Gliricidia*** (Gl) in 12m square spacing

Pest and Disease Control in Young Plants

(see Sections 9 and 10 for descriptions of the main pests and diseases)

Regularly inspect young plants for damage

The main pest of young plants during establishment is Grey Weevil that eats the bark of young stems and petioles – it will be a problem if the plants don't have enough shade and are not well weeded; the weevil larvae feed on the roots of weeds that should be pulled out by hand or killed with herbicide (slashing leaves the living roots on which the larvae feed).

Cocoa Root Chafers can kill young plants up to 2 years old – larvae (up to 4cm long) chew on roots and are more common in cocoa planted on or near old food gardens.

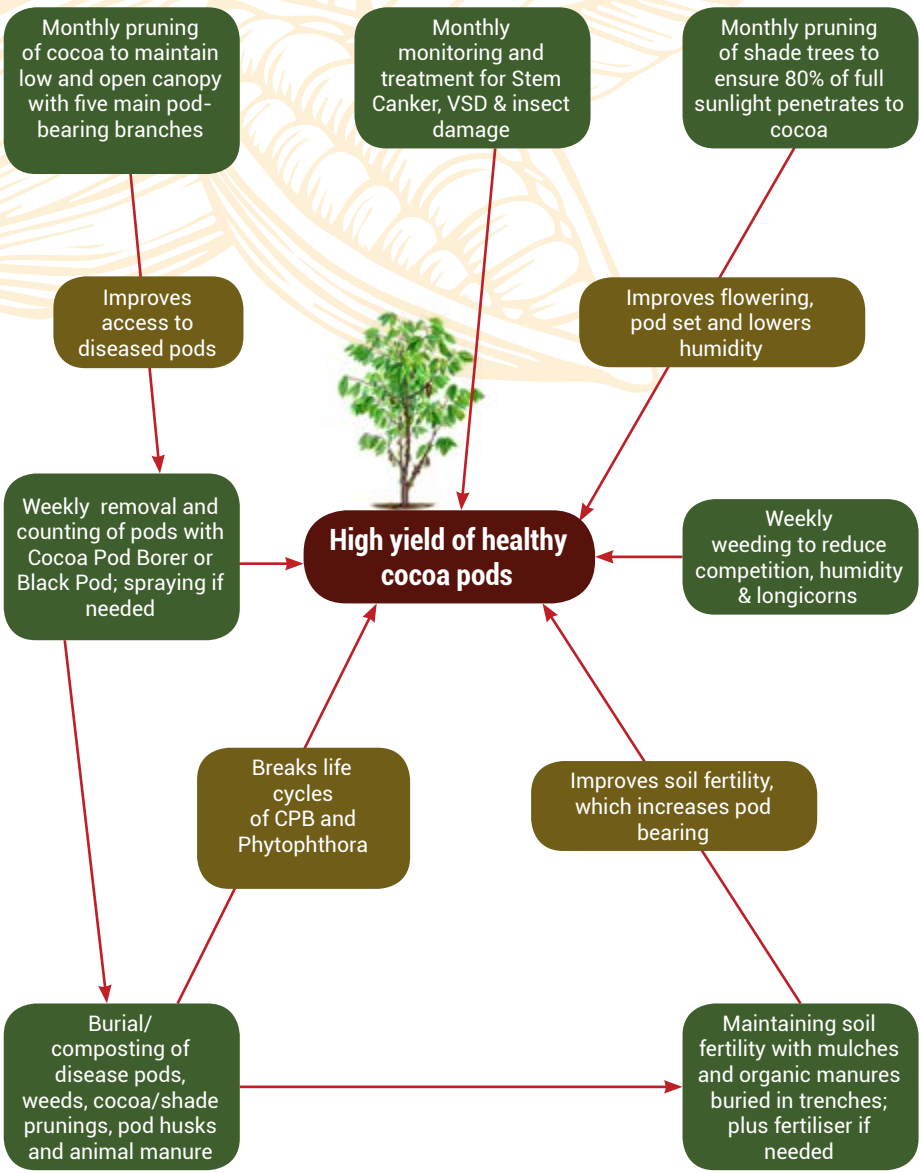
- They can be controlled by placing 2g Chlorpyrifos granules (Suscon Blue - 6mg/granule) in the soil around the roots when planting out (one matchbox full = 20g)

Longicorn Tip Borer, Coffee Stem Borer, Vascular Streak Dieback (photo) and Pink Disease can kill young plants if they infest the main stem

Control these problems by pruning off shoots about 30cm below the last sign of damage and allow new shoots to replace the damaged ones

8: Maintaining a Cocoa Block

The diagram below shows all the interconnected activities that have to be done regularly to get a high yield of cocoa – if one thing is not done it affects many other things and reduces the number of healthy pods.



The aim is to apply the same level of regular (daily) management to cocoa blocks as is applied to food gardens, involving mainly 'light work done regularly'

- Farmers know that it is not good to let weeds grow for weeks in a food garden and then try to control them in one round of heavy work.
- In the same way, it is bad to let weeds grow, or shade get over-grown, or sick pods remain hanging on cocoa trees for weeks or months and then try to correct the problem, which will then involve heavy work and lost production.

Checklist of 10 integrated management activities essential for maximum production on a cocoa farm

1. Establish the best type of cocoa and shade trees.
2. Hand weed around cocoa, especially during establishment, and don't let mulch touch the trunk.
3. Regularly prune to control the structure and height of the cocoa trees, beginning during their establishment, and regularly cut back shade trees to let through 80% of full sunlight.
4. Prune out and bury any diseased branches (VSD, Pink Disease, Tip Longicorn, Coffee Stem Borer, *Pansepta*) on cocoa during regular establishment pruning.
5. Control the spacing of shade trees (*Gliricidia*), thinning after closure of the cocoa canopy, and then controlling the amount of sunlight penetrating through to the cocoa.
6. Regularly monitor and treat Phytophthora Stem Canker and associated wood boring insects such as Trunk Longicorns and *Pantorhytes*.
7. Every week check and remove pods with Cocoa Pod Borer or Phytophthora Pod Rot (Black Pod), monitor trends and spray as indicated by monitoring (may not be needed).
8. As soon as they are cut off, bury (under 10cm soil) infested pods to kill Cocoa Pod Borer and *Phytophthora,* or compost (under a plastic cover sheet).
9. Regularly harvest healthy pods as soon as they are ripe.
10. Bury or compost healthy pod husks, placentas and cocoa and shade tree prunings to contribute to manuring of soil.

8a: Pruning Cocoa - to maintain a small balanced tree

When pruning, have in mind the shape of an ideal tree (photo below & p.13) - small with 5 main branches to carry pods.

To achieve this use secateurs to cut out any shoots that are beginning to grow in the wrong places or beginning to dominate the growth of other shoots and produce an unbalanced tree.

Cutting out an unwanted shoot growing into the centre of the tree

Cutting out chupons growing on the main trunk – this will reduce humidity in the canopy and allow more rapid growth of the main branches

Cut out unwanted shoots when they are small and soft; don't wait until they are big and require hard work to cut.

- Use secateurs to cut off shoots, and make sure cuts are as close as possible or flush with the trunk or main branch.

Cut out any shoots tending to grow higher than 3.5 metres to keep trees small and pods within easy reach. Especially cut out any lead branches that are dominating other branches; these often don't produce many pods.

Cut out any branches tending to droop down to within 1.2 metres of the ground to keep the under-canopy space open.

Cut out any branches that tend to grow across and interlock with other branches on the same tree.

Cut out any branches that are not producing pods and allow a more productive branch to grow in its place – this work may require a bow-saw because the branches will be quite big by the time they are seen to be unproductive.

Cut out any branches with VSD, Pink Disease or insect damage.

Make sure the jorquette and main pod bearing branches are not exposed to strong sunlight that might scorch them.

Strong pruning of mature cocoa trees to keep them small

This is needed twice a year – branches growing more than 2x human height are cut off, either right where they start on larger branches or towards their tips.

If trees have been pruned lightly every few weeks, then the main prunings will not be too severe.

Shade trees should be pruned before pruning cocoa – if falling shade tree branches damage the cocoa, this can be corrected when the cocoa is pruned to maintain a balanced tree.

Weeding should be done before any shade tree or cocoa pruning so that the weeds don't grow too strongly after more light is let through by pruning.

The timing of strong pruning is important or else it can interfere with pod production. It is best done just after the main harvest peaks (usually July after the May-June peak and December after the October-November peak, but this will be different in different places).

If done mainly in December, during the wet season, there will be less stress shock to the trees.

Strong pruning of shade trees is also best done at this time.

- Because it is the wet season, there will be less stress shock to the cocoa.
- The opening up of the canopy will stimulate more leaf flushing and flowering at the end of the wet season.
- *Gliricidia* should be cut back to one trunk that grows up above the cocoa and gives high shade.

The cocoa should be fertilised after strong pruning to help it recover.

Follow the following order of activities:

1. Weeding around cocoa.
2. Strong pruning of shade trees to let through 80 % sunlight.
3. Strong pruning of cocoa to keep the trees small.
4. Fertilising cocoa trees with organic or bag fertiliser.

8b: Pruning Shade Trees

Cocoa is easiest to grow under the shade of another tree, but gives the highest yield if the shade is not too dense.

If shade is too dense the cocoa doesn't get enough sunlight to stimulate flowering and grow a lot of pods.

Heavy shade also keeps the cocoa wet after rain and dew, which favours diseases, especially Phytophthora Pod Rot (Black Pod) and Canker, and Vascular Streak Dieback.

Well pruned Gliricidia shade trees letting through about 80% sunlight to the cocoa

Heavy shade also encourages some insect pests of cocoa – e.g. Trunk Longicorns (*Glenea* sp.) and Cocoa Pod Borer.

Gliricidia grows by producing multiple stems, and the amount of shade it provides can be controlled by cutting off old stems and allowing new stems to replace them – i.e. by having a rotation of stems.

- The amount of shade can be reduced in the cloudy wet season and allowed to grow back more densely in the sunny dry season.
- Larger stems can be killed by ringbarking or debarking – i.e. cutting a 'V' shaped groove in the bark right around the trunk to a depth of about 2cm that will break the flow of water to the leaves (see Section 6 above).
- Allow two or three regrowth shoots to develop from below the ringbarking, and later remove one or two to control the amount of shade.
- Cocoa Pod Borer moths rest on the larger, more horizontal branches and these should be removed.

Shade trees should be pruned to open up the canopy especially in January – February to stimulate flowering in April at the beginning of the main flowering period – this will result in more pods being produced during the main crop peak that begins in October.

The *Gliricidia* prunings are rich in nitrogen and can be:

- chopped into smaller pieces and left on the ground as mulch for the cocoa,
- chopped into smaller pieces and incorporated along with chopped up pod husks and diseased pods (and animal manure if available) into compost trenches dug between cocoa rows, contributing to soil fertility (see Box below on the trenching method of returning organic waste to the soil), or
- used as a rich source of fodder for livestock such as cattle, goats, pigs and chickens (*Gliricidia* was developed as a fodder crop for animals). Ruminant animals such as goats and cattle can thrive on the prunings of *Gliricidia* and cocoa and feeding these animals provides an added incentive to prune the *Gliricidia* and cocoa (see Section 18c).

8c: Weed Control

In a good cocoa block, a little sunlight should get through to the ground, allowing weak growth of weeds that can be easily controlled by hand weeding, slashing or spraying herbicides.

Weeds around the trunk must be removed – they favour damage by Stem Canker and Trunk Longicorns and increase humidity in the canopy

Hand weeding around cocoa and herbicide spraying around established shade trees – herbicides should never be used close to young cocoa as they can kill the plants

Hand weeding is done in a 1 metre diameter circle around cocoa trees and leafy mulch is allowed to accumulate over this area but should be kept 20cm away from the base of the trunk to avoid Longicorn damage.

Herbicide chemicals recommended for cocoa growing (usually mixed with a wetting agent to help wet weeds)

Trade Name Applicat'n Rate	Active Ingredient Mode of action	Tank mix	Target Weeds	Precautions for cocoa or special uses
Roundup, 1.84 L/ha	Glyphosate Systemic	80ml in 16Litre knapsack	Annual and perennial grasses and broadleaf weeds	Avoid contact with leaves and young stems
Basta 0.8 L/ha	Glufosinate ammonium Contact, slightly systemic in leaves	See container	Annual grasses and broad leaved weeds; perennials to some extent	Avoid contact with leaves and young stems; more dangerous to humans than Glyphosate
Diuron	Diuron Systemic	See container	Annual grasses and broad leaf weeds	Avoid contact with leaves and young stems
Fusilade	Fluazifop-p-butyl Systemic	See container	Annual and perennial grasses	Relatively safe unless leaves thoroughly wetted
Garlon	Triclopyr Systemic	Painted on to stumps	Broadleaf weeds only	Kills woody weeds and tree stumps (Paint 1:80 mix with diesel on stumps)
Ally or Farmet	Metsulfuron methyl Systemic	See container	Post emergent on broadleaf and some grasses; works well with Glyphosate	Relatively safe to humans; avoid contact with young plants
Amine or Farmine	2-4-D Systemic	See container	Broadleaf weeds	Avoid contact with leaves and stems
Starane or Flurane	Fluoroxypyr Systemic	See container	Woody and broadleaf weeds	Avoid contact with leaves and stems

Herbicides are sprayed with knapsacks with a Green Polyjet nozzle

See Section 12 below for safe use of pesticides

8d: Maintaining soil fertility

Recycling organic waste on the farm and returning it to the soil under the cocoa trees will help maintain soil fertility and pod production (as well as disposing of waste and infectious pods).

Growing a legume cover crop like *Pueraria phaseoloides* or *Calopogonium caerulium* under cocoa will put some nitrogen into the soil and suppress weeds – however, you have to stop them growing up the cocoa trunk.

Fertiliser from a bag is expensive and should be used only when indicated by poor growth of trees or signs of nutrient deficiency in the cocoa (e.g. yellowing of leaves due to nitrogen deficiency) or soil testing – try adding a recommended amount to some trees and not others to see if it gives any improvement.

You can make your own fertiliser on a farm by composting any organic waste such as cocoa and *Gliricidia* prunings, healthy pod husks and placentas, and pods infested by Cocoa Pod Borer or *Phytophthora* – adding animal manure from chickens, pigs or goats or a little nitrogen fertiliser from a bag to the compost mix will speed up the composting process.

Apply fertilisers or manures to cocoa at the end of the harvest period to promote flowering – 50g urea or 120g NPK per tree.

Cover compost heaps with soil or plastic sheet to prevent escape of Cocoa Pod Borer or Phytophthora, and keep the compost moist which will speed up composting

Application of fertilisers is useful only when applied to well-weeded trees.

Trenching method for disposing of organic waste among cocoa tree and improving soil fertility

One of the earliest cocoa researchers in Papua New Guinea (E.C.D. Green in 1938) suggested a method that is also promoted in Indonesia of burying organic waste (e.g. chopped up prunings from cocoa and shade trees, chopped up pod waste including pods damaged by Pod Borer and Black Pod), along with pig, goat or chicken manure in shallow trenches (about the depth and width of a spade) dug between rows of cocoa trees.

Cocoa Pod Borer or *Phytophthora* infested pods are covered with 10cm depth of soil and tamped down as soon as they have been placed in the trenches to stop escape of insects or *Phytophthora* spores.

The organic material undergoes decomposition and composting in the trenches and eventually becomes a focus for root growth and earthworm activity.

This is an effective way of disposing of waste material in the plantation while enhancing soil fertility.

It saves the labour involved in carting harvested or sick pods to a central location, and then carting the organic composted manure back to the cocoa plantings - the trenches are easier to dig, and distribute the organic matter better, than the deep pits that were previously recommended to bury pod husks.

Addition of animal manure to the trenches speeds up the composting process.

The trenches should be alternated between cocoa rows and directions (e.g. East-West in some years, then North-South in other years)

9: Main Insect Pests of Cocoa

Over 300 insects have been associated with cocoa in Papua New Guinea but only about 10 are serious pests

Cocoa Pod Borer (CPB, *Conopomorpha cramerella*)

This pest spread into Papua New Guinea from cocoa in Indonesia and was first detected here in 2006. It has become the most serious pest problem in cocoa; the adult is a tiny brown and white moth about 7mm long (Photo PNG UNRE Kairak CPB Training Workbook, 2014)

Signs of Cocoa Pod Borer - premature ripening and slight distortion of pods

Cocoa Pod Borer larvae leave brown tracks and dicolouration in the pod pulp and cause beans to stick together, making them hard to extract

Extracted cocoa beans clumped together due to Cocoa Pod Borer infestation of pods

Control

- Every week check every tree and remove and bury or compost every infested pod found.
- Prune to open up cocoa canopy and reduce over-shading.
- Spray pyrethroid insecticides onto developing pods and underside of larger horizontal branches (see Section 12).

Mirids (*Helopeltis* and *Pseudodoniella*)

Mirid damage is common on pods but may not be a problem unless very common

Mirid adult ((Helopeltis 7mm long) – like a mosquito

Control

Encourage Crazy Ants and Kurukum Ants in cocoa.
Spray pods with synthetic pyrethroid (Karate or Decis) if heavy infestation (if more than 10 live adults found per 100 trees) – see Section 12.

Pantorhytes weevils (different species in different areas; not a problem in Bougainville)

Adult (1.5cm long) and 'C'-shaped larva (1.5cm long) and entry holes in cocoa trunk often near branches; may allow entry of Phytophthora to cause Stem Canker

Control

Hand pick adults, especially looking in the heat of the day, encourage Crazy Ants, paint larval channels with a mixture of Chlorpyrifos, White Oil and Ridomil (see Section 12).

Pantorhytes is more likely to be a problem under *Leucaena* shade than *Gliricidia* shade.

Trunk Longicorn beetles (***Glenea*** sp.)

Adult (2cm long), larva (up to 3cm) in tunnel and entry holes in cocoa trunk

Trunk Longicorns are a problem in over-shaded cocoa in which the trunk is covered in weeds and branches droop to the ground

Control

Reduce shade, clear weeds from trunk, paint larval channels with a mixture of Chlorpyrifos, White Oil and Ridomil (see Section 12).

Longicorn Tip Borer *(Oxymargis horni)*

Only a problem in Bougainville attacking young cocoa up to 2 years old in which main branches can be killed.

Branch killed by tip borer showing bore holes

Larva of Longicorn Tip Borer (up to 6cm long)

Control

Prune off affected branches 30cm below damage and bury in compost trenches.

Coffee Stem Borer (*Zeuzera coffeae*)

Larva (4cm long) and bore holes in stem killed by Coffee Stem Borer in young cocoa

Control
Prune off stem 30cm below damage and bury in compost trenches.

Grey weevils

Grey weevil adult (7mm long) and chewing damage on stem and petioles of young cocoa

Control
Make sure young cocoa is well shaded and well weeded by hand pulling or with herbicides to kill roots on which larvae live; spray with pyrethroid (Karate or Decis) insecticide if needed – see Section 12.

Cocoa Webworm (*Pansepta teleturga*)

Branch damage, frass attached to web on larva channel with larva (3cm long) and adult moth (1cm long)

Control

Biological control by wasps and Crazy Ants; cut out branches 30cm below damage and bury in compost trenches.

Pests Eating Young Flush Leaves
Rhyparid Beetles and Caterpillars

Shot-hole damage on new flush leaves and Rhyparid beetle adult (4-6mm long)

Several types of caterpillar damage young flush leaves

Looper caterpillar (2-3cm long)

Control

Selective spraying with pyrethroid or other insecticide (Orthene 75 or Septene 80) if serious – see Section 12.

Cocoa Root Chafers (***Dermolepida*** spp.)

Damage to young cocoa plants caused by Root Chafer larvae; larvae can kill young plants; common in young cocoa planted on old food gardens

Control

Place 2g Chlorpyrifos (Suscon Blue – 6mg/granule) in the soil around the roots when planting out.

10: Main Diseases of Cocoa

Phytophthora Diseases

Diseases caused by the fungus *Phytophthora palmivora* have long been a serious problem in cocoa in Papua New Guinea, causing Seedling and Chupon Blight, Stem Canker and Pod Rot (Black Pod).

Chupon Blight caused by Phytophthora; note the dead shoot on the right - Phytophthora can spread from a dead chupon into the trunk and cause Stem Canker (see Section 5e for Seedling Blight)

Pantorhytes and longicorn bore holes are often associated with Phytophthora Stem Canker – they allow the fungus to get into the trunk

Stem Canker on trunk (arrow), and with bark scraped off to show red-brown discolouration of inner bark

Treatment – Scrape off the bark surface to reveal the extent of the canker and paint with a solution of 2% metalaxyl plus mancozeb (Ridomil Plus 72) or metalaxyl plus copper (Laxyl Copper) prepared by mixing 200 grams of the ingredient in 10 litres of water.

If Stem Canker is associated with an insect larva channel paint with 30ml Chlorpyrifos + 250ml White Oil + 15g Ridomil Plus + 700ml water (see Section 12).

Stem canker healing after painting with fungicide mixture

Stages of development of Black Pod showing fuzzy white growth of spore-forming structures of Phytophthora. Spores are produced and dispersed more commonly during wet weather and when the cocoa canopy remains wet after rain and dew

Spores are mainly dispersed by rain splash or can be carried by insect borers attracted to rotting pods.

Management of Black Pod

- Plant Hybrid Clones with some resistance to Black Pod.
- Maintain a low open cocoa canopy with light shade to speed up drying of the branches and pods after rain.
- Keep leaf litter layer under cocoa to stop spores being splashed up from the soil onto lower pods.
- Remove Black Pods every week and bury or compost them, along with pods infested by Cocoa Pod Borer.
- Spray pods with Ridomil Plus or Laxyl Copper (see Section 12) if necessary as indicated by monitoring the occurrence of disease.

Vascular Streak Dieback (VSD) – caused by the fungus *Ceratobasidium* (*Oncobasidium*) *theobromae*

In the 1960s VSD nearly destroyed the cocoa industry in Papua New Guinea – it was saved by the selection of resistant types of cocoa that survived the epidemic.

The planting of resistant types of cocoa is crucial for managing the disease.

All current Hybrid Clones and Hybrid Seedlings have some (but not complete) resistance to VSD.

Late symptoms of VSD – leaf fall, growth of axillary buds and eventual tip death; the disease does not occur in Bougainville, New Ireland, Manus, the Milne Bay islands, or the tip of West New Britain and the Bali Witu Islands

Photo Pathology Section CCIL

Early symptoms of VSD – leaves on the 2nd or 3rd growth flush behind the tip turning yellow with green spots, then becoming brown and falling off branch

Typical leaf symptoms of VSD – yellow leaves with green spots, leaf fall, eventual tip death and dieback

Browning of vascular tissue in junction of petioles and stem

This is a defining symptoms if leaf symptoms are not clear

Discolouration of wood and inner bark of VSD infected branch – sometimes infected leaves also develop black dead patches as shown here

White spore-farming growth of the VSD fungus formed during wet weather on exposed vascular tissue resulting from the fall of infected leaves or cracks in petioles and leaf veins

Spores of the VSD fungus are formed at night when the fungus is wetted by afternoon rain, and are spread by wind. The disease is spread by these wind-borne spores that infect young cocoa leaves on nearby trees.

VSD infection is more common during long wet periods.

Management of VSD

- Plant CCIL Hybrid Clones or Seedlings that all have some resistance to VSD.
- Maintain a low open cocoa canopy and light shade to speed up drying of the foliage after rain or dew.
- Cut VSD infected branches from trees during regular pruning rounds, especially just before the wet season when the fungus mainly forms spores.
- Cut branches 30cm below symptoms on branches and bury them in compost trenches.

Pink Disease (caused by the fungus ***Corticium salmonicolor)***

Branch killed by Pink Disease and branches (above) showing the growth of the fungus on the outside of the bark, later forming spore-forming growth on the bark (above right)
Photos Pathology Section CCIL

Control

Cut branches off 30cm below symptoms and bury.
If on large branches, paint infection with Macrupax (see Section 12).

Root Rots of Mature Trees Caused by Bracket Fungi

These fungi invade the roots and lower trunk and kill the whole tree – death occurs suddenly with all leaves still attached.

Root Rot fungus forming crust or bracket-like spore forming structures on base of trunk Photos Pathology Section CCIL

Root rot infected trees must be removed and burned as soon as possible; all roots down to pencil thickness must be pulled out

Thread Blight

This is a minor disease in which leaves die and remain attached to branches by fungus threads (affected branches should be pruned out during normal pruning rounds).

Cherelle Wilt

Many cherelles die at an early stage of development and these should all be removed regularly because some will contain *Phytophthora.*

Cherelles infected by Phytophthora (left, showing spreading black rot) or turning yellow overall and then black with Cherelle Wilt caused by physiological death of the cherelles (right) Photos Pathology Section CCIL

11: Integrated Pest and Disease Management (IPDM)

In Papua New Guinea, the fungus diseases Black Pod (Phytophthora Pod Rot), Stem Canker and Vascular Streak Dieback (VSD), and several insect pests including *Pantorhytes* and Longicorns have always been serious problems in cocoa.

Since 2006 the insect Cocoa Pod Borer has also become a very serious problem.

Together, Black Pod and Cocoa Pod Borer can destroy 80% of pods in poorly managed cocoa, and *Pantorhytes,* Stem Canker, VSD and Longicorns can cause trees to become sick.

All the management tasks described under Section 8 above will help control all pests and diseases in a cocoa block.

'Integrated' means all pests and diseases have to be managed together and all management methods have to be applied as a whole strategy – they all affect one another.

Constant monitoring and keeping records of the health of each tree in a cocoa block is the basis for IPDM - this can be done while working regularly in a cocoa block.

Biological Control of Pests

Many insect pests are controlled by other insects in cocoa blocks and these beneficial insects must not be killed by uncontrolled spraying of insecticides.

Crazy Ants and Kurukum Ants help control some insect pests.

Kurukum Ants on a cocoa pod (often seen under coconut shade) – they will deter Mirids

Crazy Ant killing a Pantorhytes weevil in a cocoa block
Photo J. Moxon

Benefical ants can be introduced to a cocoa block in bamboo packed with leaves – ants colonise leaves in an infested block and the bamboo is taken to a new block – the bamboos are placed facing down slope so that water can't get in

Cocoa often has fewer insect problems when grown under the shade of coconut palms that harbour Kurukum (Weaver) Ants – these chase away some cocoa pests.

Gliricidia shade trees attract Crazy Ants and cocoa growers sometimes leave them as part of mixed permanent shade for this purpose.

Coconut palms at the correct spacing (12m x 12m) provide ideal sparse shade for cocoa and this will also reduce pest and disease problems in the cocoa.

Disease Resistance

Hybrid Clones and Seedlings recommended by CCIL have been selected to have some resistance to VSD and Black Pod (and Cocoa Pod Borer in the 2nd Series Hybrid Clones - see Section 5).

But they are not completely resistant – they can still be infested but not as much as in very susceptible types of cocoa.

Resistance has to be combined with the cultural and biological control measures that are part of IPDM

IPDM can have different levels of input (Options 1 to 4) – farmers can test different options and choose the one that suits them.

(From 'Integrated Pest and Disease Management for Sustainable Cocoa Production' by John Konam, Yak Namaliu, Rosalie Daniel and David Guest, ACIAR, Canberra, 2008)

Option	Level of Input	Activity
1	Low	Current farm practice (low yields)
2 Increases pod production Reduces pod loss	Medium (requires increased labour only) Basically the 10 points of good cocoa management (see Section 8 above)	• Regularly prune cocoa and shade trees to maintain sparse shade and low open cocoa trees • Cut out shoots damaged by VSD, Pink Disease, Coffee Stem Borer, Pansepta and Tip Longicorn when pruning cocoa • Hand weed around cocoa • Inspect cocoa every week and remove and bury or compost all sick pods (CPB and Black Pod) • Harvest all healthy ripe pods as soon as they are ripe
3 Increases pod production	High (requires increased labour as for 2. and cost for fertiliser)	Option 2. plus application of fertiliser or manure
4 Further reduces pod loss	Highest (as for 3. plus cost for applying pesticides)	Option 3. plus use of herbicides, fungicides for Black Pod and Stem Canker, and insecticides for Cocoa Pod Borer, Mirids and trunk borers

Black Pod (left) and Cocoa Pod Borer (right), the big problems that together can destroy 80% of cocoa pods if not controlled with IPDM

Infested pods removed every week from cocoa trees must be buried or composted to kill Cocoa Pod Borer and Phytophthora; shallow trench on right is dug between rows of cocoa and pods and other organic waste are buried under 10cm depth of soil and tamped down – this not only breaks the life-cycles of the pests but also manures the cocoa.

Main pests and diseases of cocoa and main options for their control

Symptoms	Likely cause	Management options
Damage to woody trunks and branches of mature trees		
Vertical tunnels or channels in main trunk under the bark, gum exuded onto bark	*Pantorhytes* Weevil	Collect weevils by hand; encourage Crazy Ants; paint channels with mix of insecticide/fungicide
Horizontal tunnels in trunk or main branches; much frass pushed out onto bark	Trunk Longicorn (*Glenea*)	Reduce shade; remove weeds near trunk; paint channels with mix of insecticide/fungicide
Unthrifty tree with interlocking mass of fine channels in wood under bark	Giant Cocoa Termites	Open up trunk above nest and pour in insecticide solution
Water soaked patches on bark on lower trunk; red-brown colour when outer bark scraped off	Phytophthora Canker	Scrape off outer bark and paint with insecticide/fungicide mixture
Damage to main stem of young plants – will affect plant establishment		
Chewing damage to the semi-hardened bark and petioles of shoots	Grey Weevils	Ensure cocoa has some shade and is well weeded and mulched
Tip of shoots killed in young cocoa up to 2 years old	Longicorn Tip Borer (*Oxymagis*)	Cut out the infected stem 30 cm below the lowest symptoms (i.e. pollarding of young plants)
Unthrifty branch with tip dieback and occasional bore holes with frass	Coffee Stem Borer (*Zeuzera*)	Cut out the infected stem 30 cm below the damage and encourage growth of new shoots
Yellow leaves with green spots plus swollen lenticels on the main stem	Vascular Streak Dieback	Cut out the infected stem 30 cm below the lowest symptoms (i.e. pollarding of young plants')
Dieback of outer branches of mature trees		
Dieback of outer shoots, with wood frass attached to web-like covering of bore holes	Cocoa Webworm (*Pansepta*)	Cut out infected branches 30cm below damage; ensure that the cocoa has adequate shade; encourage Crazy Ants
Dieback of branches with leaves behind the tip turning yellow with green spots	Vascular Streak Dieback	Cut out infected branches 30cm below lowermost symptoms
Damage to very young plants or chupons		
Blight of young soft leaves and shoot tips, starting at the leaf tip	Phytophthora Shoot Blight	Use potting soil free of *Phytophthora*; immediately remove infected seedlings from nursery
Yellowing of leaves and swollen lenticels on stem	Vascular Streak Dieback	Grow seedlings in a nursery under a plastic or shadecloth roof
White powdery masses of insects often at shoot tip	Mealybugs	Can be sprayed with insecticide if serious

Damage to cocoa pods		
Pod begins to turn black in patches until whole pod is black	Phytophthora Pod Rot (Black Pod)	Remove and bury or compost infected pods as soon as they are seen
Pods begin to ripen prematurely and unevenly; slight distortion of pods	Cocoa Pod Borer	Remove and bury or compost infested pods as soon as they are seen
Many small black, blister-like spots on the pod surface	Mirids	Encourage Crazy Ants, but spray if needed
Holes bored in ripe pods with frass pushed out onto the surface of the pod	Husk Borer	Harvest pods as soon as they are ripe; encourage Crazy Ants
Large holes eaten in pods	Rats, flying foxes, parrots	Harvest pods as soon as they are ripe
Damage to leaves		
Many tiny 'shot holes' in soft flush leaves	Rhyparid Beetles	Severe outbreaks can be sprayed with insecticides
Uneven eating of soft young leaves	Caterpillars	Severe outbreaks can be sprayed with insecticides
Bronzing and wilting of leaves	Thrips	Ensure adequate shade, plants not stressed
Sudden death of whole plants		
Young plants collapse and die suddenly due to larvae eating through tap roots	Root Chafers	If a severe problem near old food gardens can be treated with insecticide granules
Whole tree dies suddenly with all dead leaves left hanging; crusty growth at the base of the trunk	Fungal root rots	Dig out and burn all the roots down to about pencil size

Integrated Pest and Disease Management Tasks (IPDM)

- Plant the latest recommended CCIL Hybrid Clones or Seedlings that have some resistance to Cocoa Pod Borer (CPB), VSD and Black Pod
- Plant cocoa at the appropriate spacing and under shade that can be maintained to allow 80% light penetration to established cocoa
- Identify any pest and disease problems using the Table above
- Use foundation and maintenance pruning to keep cocoa trees lower than twice human height with an open lower canopy and with most pods borne on the lower branches
- This allows pods and growing branches to be easily seen for weekly sanitation pod removal (CPB, Black Pod), branch pruning (VSD, Pink Disease, Coffee Stem Borer, Tip Longicorn, Pansepta) and hand picking of Pantorhytes

- Prune out any VSD, Pink Disease, Coffee Stem Borer, Pansepta and Tip Longicorn infested branches during maintenance pruning rounds
- Prune Gliricidia shade regularly to maintain about 80% of full sunlight hitting the cocoa canopy
  - This gives more flowering and pod production
  - It helps dry out the cocoa trees after rain and reduces infection by Phytophthora and VSD
  - It helps reduce CPB moth activity, which is favoured by heavy shade
  - It reduces Trunk Longicorn damage
  - It also improves access to the cocoa trees for sanitation and harvesting
- Control weeds
  - This reduces humidity in the canopy and reduces access of Trunk Longicorns and Grey Weevils to the cocoa trunk
  - It also improves human access for sanitation activities and harvesting
- **Remove all CPB and Phytophthora infested pods from every tree, at least weekly = Remove 'every sick pod, from every tree, every week**
  - Dispose of the infested pods by burying them in trenches dug between rows of cocoa or in central pits, or by composting them with other organic waste under a plastic cover
  - Don't leave infested pods uncovered in piles - CPB larvae can emerge from pod heaps, pupate and produce adult moths that can fly to infest healthy pods, and Phytophthora can sporulate on pods and be dispersed by water splash or pod boring insects
- Inspect lower trunks for Stem Canker during regular maintenance rounds and treat with a fungicide/insecticide paint if needed
- Once all the above cultural management activities have been done, targeted spraying of pods (for CPB and Black Pod) and underside of larger branches (for CPB) may be necessary to bring outbreaks under control; with good application of cultural control measures, spraying should not be necessary
- Monitor occurrence of pests and diseases to allow judgements about whether the IPDM is working or whether adjustments have to be made

12: Safe Use of Pesticides

Chemical pesticides are useful for controlling weeds, insect pests and diseases but they have to be used carefully as part of an overall IPDM program - without the cultural control measures of IPDM, pesticides are wasted, and often do more harm than good especially by killing beneficial insects.

Pesticides are poisonous chemicals and their use should be avoided as much as possible – if they have to be used, first get some special training in how to use them safely.

The photo shows all the safety clothing that has to be used when spraying pesticides – cap, face mask over mouth and nose, clothing covering arms and legs, rubber gloves and rubber boots – the sprayer should also use safety glasses to protect his eyes Photo CCIL

The knapsack sprayer shown on the previous page is the most useful spray equipment for a smallholder farmer – consult your agricultural supplier for more information on sprayers and nozzles.

Insecticide chemicals currently available for cocoa

Trade Name Strength	Active Ingredient Type of Action	Target Insects	Tank Mix (all with 2ml surfactant, 50ml sticker and 10L water) Final % and amount of a.i. applied/ha
Karate 2.5% EC	Synthetic pyrethroid, lambda-cyhalothrin 250g/L Contact, repellant, protective	Cocoa Pod Borer Caterpillars Ryparid beetles Mirids (*Helopeltis* Pod Suckers) Amblypelta Pantorhytes Grey weevils Thrips	Tank mix 28ml Karate (0.007% a.i.) 8g a.i./ha
Decis 2.5% EC	Synthetic pyrethroid, Deltamethrin 27.5g/L Contact, repellent, protective	Cocoa Pod Borer Caterpillars Ryparid beetles Mirids (*Helopeltis* Pod Suckers) Amblypelta Grey weevils Thrips	Tank mix 28ml Decis (0.007% a.i.) 8g a.i./ha
Malathion 50EC	Organophosphate Absorbed through skin Contact	Mealybugs Thrips	Tank mix 30ml Malathion (0.15% a.i.) +100 ml White Oil 330g a.i./ha
Septene 80EC	Carbaryl (Carbamate) Highly toxic to humans Contact	Ryparid beetles	Tank mix 75ml Septene (0.6% a.i.) 650g a.i./ha

Chlorpyrifos 500	Organophosphate	Pantorhytes larvae Longicorn beetles Coffee Stem Borer Root chafers – treat with granules in planting hole	Channel paint = 30ml Chlorpyrifos + 250ml White Oil + 15g Ridomil Plus/L water (used to paint insect channels in stems; Ridomil added to prevent Phytophthora Canker)
Orthene 75WP	Acephate (Organophosphate) Absorbed through skin Highly toxic to humans Contact, systemic	Ryparid beetles Thrips	Tank mix 40g Orthene (0.3% a.i.) 380g a.i./ha
Bifenthrin	Synthetic pyrethroid Contact	Grey weevils, and other pests as for Decis and Karate	Tank mix
Rogor 30EC	Dimethoate (Organophosphate) Absorbed through skin Highly toxic to humans Contact,systemic	Pansepta Web Worm	Tank mix 70ml Rogor (0.6% a.i.) 330g a.i./ha
Actellic	Pirimiphos-methyl (Organophosphate) Highly toxic to humans Contact	Caterpillars	Tank mix 60ml Actellic 330g a.i./ha

It is advisable to get an extension officer to give proper training in the safe use of pesticides, the best ones to use and the correct doses and mixtures.

If the same pesticide is used time after time, the weeds, insects or fungi will develop resistance to that chemical and it will no longer be effective. Therefore pesticides with different modes of action have to be swapped over from time to time

If a pesticide is used, it should be tested on part of a cocoa block and the results compared with the rest of the block.

Fungicide chemicals currently available and recommended for cocoa growing

Trade Name Application Rate	Active Ingredient	Type of Action	Target Fungi	Preparation and final concentration applied
Copper Nordox	Copper (Cuprous oxide)	Protective spray	*Phytophthora* (Pod Rot) Pink disease	Tank mix 200g Nordox + 5ml sticker + 10L water (2%)
Copper Sandoz	Copper (Cuprous oxide)	Protective spray	*Phytophthora* (Pod Rot) Pink disease	Tank mix 200g Sandoz + 5ml sticker + 10L water (2%)
Macuprax 2%	Copper (Bordeaux mixture)	Protective spray	*Phytophthora* (Pod Rot) Pink disease	Tank mix 200g Mucaprax + 5ml sticker + 10L water (2%)
Ridomil Plus 72	Metalaxyl (Phenylamide) + Mancozeb (Dithiocarbamate)	Protective and systemic spray	*Phytophthora* (Seedling Blight, Pod Rot)	Tank mix 30g Ridomil + 5ml sticker + 10L water (0.3% solution)
Ridomil Plus 72	Metalaxyl (Phenylamide) + Mancozeb (Dithiocarbamate)	Pre-germination seed treatment (seeds dipped in mix)	*Phytophthora* (Seedling Blight)	Mix 40g Ridomil + 2L water (1% solution)
Ridomil Plus 72	Metalaxyl (Phenylamide) + Mancozeb (Dithiocarbamate)	Mix for painting on Stem Cankers	*Phytophthora* (Stem Canker)	Mix 40g Ridomil + 2L water (1% solution)
Ridomil Plus Gold	Metalaxyl-M (mefenoxam) + Cuprous oxide	Protective and systemic spray	*Phytophthora* (Seedling Blight, Pod Rot)	Tank mix 30g Ridomil + 5ml sticker + 10L water (0.3% solution)
Laxyl Copper	Metalaxyl (Phenylamide) + Copper	Protective and systemic spray	*Phytophthora* (Seedling Blight, Pod Rot)	Tank mix 30g Laxyl Copper + 5ml sticker + 10L water (0.3% solution)

Laxyl Copper	Metalaxyl (Phenylamide) + Copper	Pre-germination seed treatment (seeds dipped in mix)	*Phytophthora* (Seedling Blight)	Mix 40g Laxyl Copper + 2L water (1% solution)
Laxyl Copper	Metalaxyl (Phenylamide) + Copper	Mix for painting on Stem Cankers	*Phytophthora* (Stem Canker)	Mix 40g Laxyl Copper + 2L water (1% solution)
Foli-R-Fos, Aliette	Phosphonate	Systemic	*Phytophthora* (Pod Rot)	
Garlon plus Copper	Triclopyr plus copper	Protective mixture for painting on freshly cut stumps	Root rotting basidiomycete fungi	One part Garlon and 2 parts Sandoz in 60 parts diesel or old engine oil.

A matchbox contains about 20g of chemical powder.

Metalaxyl fungicides to control Seedling Blight are sprayed with a napsack sprayer with a VLV100 nozzle.

Important points in using herbicides, insecticides and fungicides

These are all chemicals that can have harmful effects on human beings and their use must be kept to a minimum and they must be used with great care (see rules opposite).

Get advice from the supplier (e.g. Farmset, Agmark or other didiman store) on the use of a particular pesticide.

Carefully follow the instructions on the chemical container (information in the tables above are a general guide only).

Repeated use and overuse of the same chemical may result in the target weed, insect or fungus developing resistance to the action of the chemical, thus rendering the chemical useless. Chemicals with different modes of action should be used alternately (or in mixtures such as in Ridomil Plus 72 or Laxyl Copper).

Repeated and overuse of insecticides and fungicides can harm populations of beneficial organisms. This applies especially to insecticides which may kill beneficial insects that are antagonists of pest insects (e.g. ants, parasitoid wasps). Overuse of insecticides may also damage populations of the tiny midges that pollinate cocoa to produce pods.

STRICT RULES FOR USING PESTICIDES

- Keep chemicals in their original container, make sure they are marked 'POISON', and store in a locked place where children can't get near them.
- Never store pesticides in drink or cooking oil bottles in case they are consumed by mistake and kill people.
- Never store chemicals near food.
- Never eat, drink or smoke when spraying chemicals.
- Wash your hands and face with soap and water after spraying chemicals.
- Wear protective clothing as shown in photo when mixing and spraying chemicals.
- Always change your clothes and wash them with soap and water after spraying chemicals.
- Do not throw away unwanted chemicals or chemical containers near a water supply and do not burn them – arrange to take them back to the supplier.
- Do not wash out chemical containers and use them for another purpose – the plastic retains some of the poison.
- Spraying of pesticides should be done by men, and **never** by children, or women of child-bearing age.

13: Harvesting and Breaking Cocoa Pods

The cocoa cropping cycle in Papua New Guinea

Flower flushes follow leaf flushes, and both are influenced by the growth stage of the tree, the fertility of the soil, the amount of shade, and especially seasonal rainfall.

Hybrid Seedlings begin flowering a little more than 2 years after planting, while Hybrid Clones can begin flowering as early as 1.5 years after planting in the field.

At the end of the wet season (March) trees produce a flush of new leaves followed in April-May by a flush of flowers on the trunk and main branches.

If the flowers are pollinated, tiny pods begin developing and reach maturity after 5-6 months, therefore producing a harvest peak in Oct-Nov-Dec (beginning of the wet season).

A second flush of new leaves followed by flowers occurs in the early wet season (Nov-Dec), producing a second cropping peak in May-June (in the drier season).

The relative size and timing of the two peaks can vary with location and season – sometimes the October-November-December harvest is the main one, while sometimes the May-June harvest is bigger.

In very wet areas such as southern Bougainville, the flowering and harvesting period are two months earlier than given above.

Full production of trees is reached after 4-5 years; the SG1 and SG2 Trinitario/Amazon hybrid types of cocoa suffer a decline in production after this early peak (compared with the pure Tinitario types first planted in Papua New Guinea); the reason for this is yet to be determined. But high yields can be maintained for 15 years or more with good management.

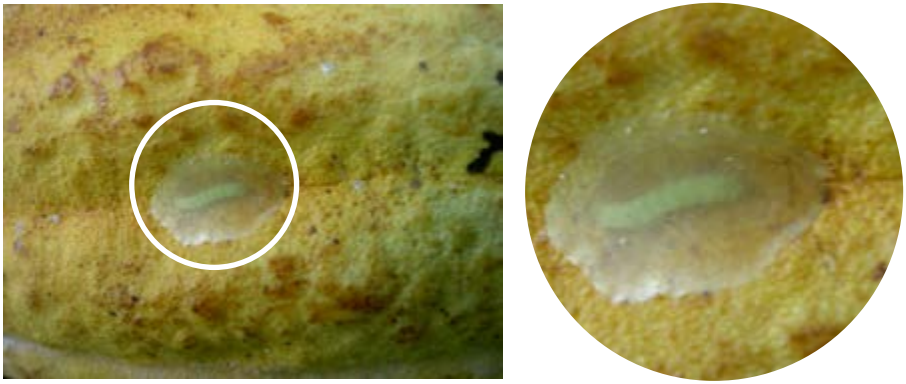
More intensive growing of cocoa will involve replacing cocoa trees after about 15 years, especially with rapid improvement in varieties in the cocoa breeding program at CCIL.

Harvesting

Harvest healthy pods as soon as they are ripe (green pods turn yellow; red pods turn orange colour) otherwise they will be damaged by flying foxes, birds or rats or may become infected by Black Pod and be lost; if they are infested by Cocoa Pod Borer, the insect will be able to emerge, pupate and infest other pods.

Beans can germinate within over-ripe pods, which reduces their quality (see Section 16 below).

Unripe pods must not be harvested (unless they are sick – see Section 11) as the beans will not ferment properly.



Cocoa Pod Borer forming a pupa on a ripe pod – if left in the canopy the adult moth can hatch out and infest more pods

Different tools should be used to harvest sick and healthy pods or else tools have to be washed thoroughly after cutting out Black Pod – tools can spread the fungus.

Sick or healthy ripe pods must be cut off the branches using a sharp tool – a secateur is best or a sharp pod hook on a stick. Pods should never be ripped off the branches by hand as this will damage the flower cushion that contains the flower buds needed to produce the future pods. Care must be taken not to damage the flower cushion with cutting tools. Flower cushions must be treated as very precious because their health determines the future crop.

It you are selling wet beans, the pods should be harvested on the morning they are picked up for delivery to the fermentary.

If you are fermenting your own beans, you have to collect in a day enough pods to fill a fermenting box or sweat box with beans so that you can get a good fermentation mass – boxes should be nearly full (at least half full in big boxes) to give good fermentation.

- About 8-10 pods give 1kg wet beans (depending on the cocoa variety) – you can determine this for your own cocoa.
- You may have to combine with other farmers to get enough beans to get good fermentation on a particular day.
- Harvested pods can be kept for up to 2 days before breaking – this may be needed to get enough wet beans to ferment (see Section 14).

The pods should be broken open with a blunt stick such as a kwila stick so that the beans are not cut, which reduces their quality.

If the pods are fully ripe the beans should come out of the broken pods easily and be easy to remove from the string (placenta) that holds them and the pulp should be slimy.

Pods should not be broken in the rain – rain will wash away the pulp that is needed to give good fermentation.

Beans must be placed in a fermentation box on the day they are extracted from pods – beans extracted on one day must not be mixed in the same fermentation box with beans extracted on another day.

Beans can be salvaged from Black Pods (especially if the pods are infected when nearly ripe) and from pods infested by Cocoa Pod Borer but they must be fermented separately from healthy beans otherwise they will reduce the quality of the healthy beans.

When harvesting pods, avoid damaging the flower cushion as this contains the buds for producing the future flowers and pods - harvesting pods on smaller trees can be done with secateurs, which won't damage the flower cushions as much as pod hooks.

Breaking pods and collected beans into a bag in the field, ready to be taken to a fermentary; it is better to break pods with a wooden stick to avoid damaging the beans (also it is safer than using a bush knife)

Exposed heap of pod husks likely to spread Cocoa Pod Borer and Phytophthora - these should be buried in compost trenches (see Section 11)

14: Fermenting Cocoa Beans

Wet cocoa beans have to be fermented and dried to develop the chocolate flavour needed by chocolate makers and to prepare the beans for export.

Fermenting and drying are special processes, and are just as important as growing the cocoa – if they are not done well, all the hard work of growing the cocoa will be wasted.

Fermentaries have to be registered with the Cocoa Board of PNG – inspectors from the Board will check that the fermentation boxes and drier are up to standard.

There are various sizes of fermentation boxes made from wooden boards that are quite thick (20 – 50mm) to retain heat as the fermentation mass heats up – there should be no gaps between the side boards, and 5mm-wide gaps between the bottom boards to let liquid ('sweatings") drain out.

The standard box size is 120cm long x 90cm wide x 90cm deep, but smaller miniboxes (60cm x 50cm x 60cm deep) have been developed at CCIL to hold smaller quantities of beans.

Fermentation boxes showing 3 compartments with removable boards for turning the beans

A small fermentation box 60cm x 50cm x 60cm deep – it has to be filled to at least 50cm deep with cocoa beans; it holds about 200 kg beans (from about 1600 pods)

Fermentation boxes are raised off the ground to allow liquid to drain out, and they must be protected from rain in a shed. New boxes should be inoculated (rubbed on the inside) with scrapings from the inside of an old box to add the microbes that carry out fermentation.

Sweat boxes can be used to ferment smaller batches (100 kg, 50 kg, 25 kg, 10 kg) – these are called 'sweat boxes' because when filled with beans they are wrapped around with several layers of banana leaves and old cocoa bags to keep the heat in and stop too much air getting in and cooling the beans.

Weigh batches of wet beans before they are put in the fermentation box and again after they are dried to calculate the wet to dry bean conversion rate (it should be about 40%).

Fermentation or sweat boxes should be almost full to achieve good fermentation (the mass should be at least 50–65cm deep in the larger boxes) – if boxes are not full enough the fermentation will not go well and the beans may go rotten.

The fermentation mass should be covered with 2-3 layers of banana leaves and then a layer of clean hessian bags (not bags that have contained copra, which will taint the cocoa) – this is needed to keep the heat in the fermentation mass.

Fermentation mass covered with clean hessian bags to keep the heat in (fermentation is just beginning – the mass is still white)

Fermentation mass turning brown, with a vinegar smell, and heating up to indicate a good process (note that the mass is covered with banana leaves to retain heat)

The fermentation mass has to be turned (i.e. tipped and shoveled from one box to another) every 24 hours – i.e. 5 times in a 6 day fermentation cycle. This aerates the mass and is the most important factor in obtaining good fermentation. It also breaks up clumps of beans to allow air to penetrate and mixes the cocoa mass to give a more even ferment and stop rotting of beans in the colder corners and bottom of the box.

When the mass is shoveled out of one box into another, the gaps in the bottom of the boxes must be cleaned by scraping with a bush knife to allow air to penetrate.

Because the mass of beans in sweat boxes is smaller, they just have to be stirred with a wooden paddle to aerate them rather than turned from one box into another – this is done only once, on day 2.

On days 3 and 4 of fermentation, several changes in the bean mass indicate that the process has been going well:

- The outer coat of the beans should be turning red-brown.
- The bean mass should be warm – it should reach a peak of about 50°C on day 4, which develops the chocolate flavor in the beans.
- The mass should smell of organic acids (mainly acetic acid – vinegar), and not have a rotten smell.
- There should be air spaces between the beans as they become 'dry-sticky'.

If the fermentation doesn't go well and the beans start to stink, turn them out and dry them immediately so that at least they can be sold as substandard beans and are not lost completely.

Fermentation should not go longer than 6 days or the beans will be over-fermented and will be of a lower quality (see Section 17).

If beans are under-fermented they will also be of lower quality.

If beans are dried more slowly by sun-drying, they may need a shorter fermentation time in the boxes as fermentation will continue for a short time after they are put on the drying rack.

15: Drying Cocoa Beans

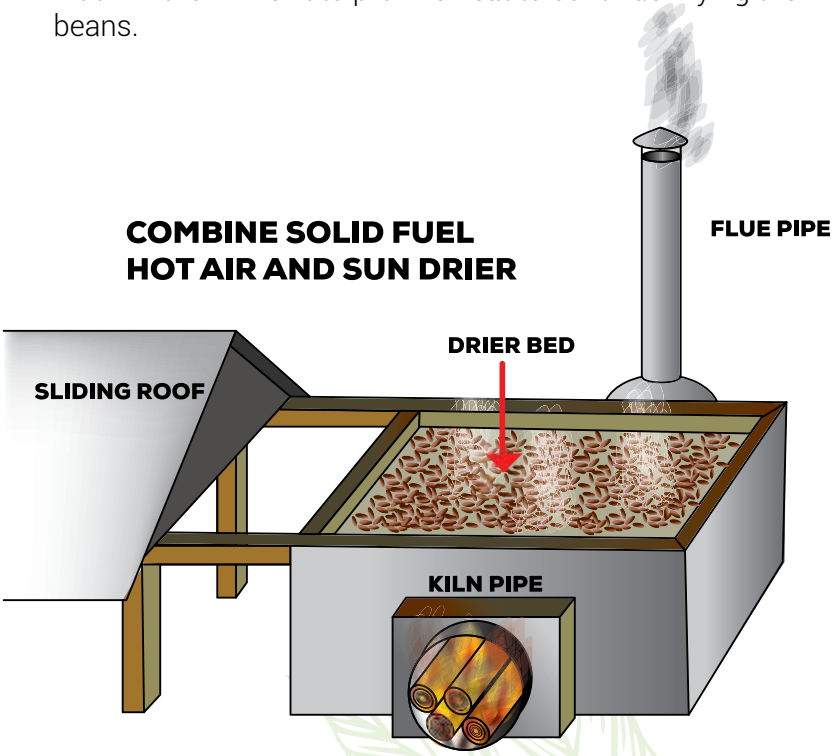
Correct drying of beans is as important as correct fermenting for determining the final quality of the beans for export.

Cocoa beans can be dried on simple platforms in the sun if the environmental conditions are not too wet; platforms are covered with tarpaulins or clear plastic sheets in the event of rain (see below); globally, most cocoa is sun dried.

However, in many places in Papua New Guinea it is too wet during the main harvest season for simple passive sun drying to be rapid enough to give good quality cocoa beans.

A wood-fired kiln drier on the design shown below has been developed in Papua New Guinea to speed up the sun drying of cocoa beans.

- A steel kiln pipe is built under a metal mesh drying rack on which the beans are spread about 5cm deep.
- A roof can be rolled off to expose the beans for sun drying when the weather is dry.
- During wet weather the roof is rolled over the drying rack and wood in the kiln is lit to provide heat to continue drying the beans.



Drawing of Post-harvest Section CCIL

The kiln pipes tend to rust and develop holes over time, and this allows smoke to pass up through the beans and give them a smoke taint that has reduced the demand for Papua New Guinea cocoa beans in the world market. Also fragments tend to fall down from the drying rack and burn on the kiln pipe, creating smoke.

Therefore kiln pipes must be cleaned and inspected regularly for holes and replaced as soon as holes are seen and smoke starts to go up through the beans.

The passive sun drying/kiln drying unit that is common in Papua New Guinea (this one has two kiln pipes)

- *The left hand photo shows the chimney designed to carry smoke away for the drying rack*
- *The right hand photo shows the kiln pipes in which wood is burned to provide heat to dry the beans*
- *The roof is covering the cocoa drying rack*

In an attempt to provide more solar drying of cocoa, CCIL has developed an active solar/wood-fired kiln combination drier as shown in the photo below

Black painted rocks in the wings on either side of the drying rack are heated by the sun; they are covered by polycarbonate sheets that give a glasshouse effect and heats up the rocks.

Air passes over the rocks in the two wings and is heated before it passes up through the central drying bed, thus boosting the solar drying (= active solar drying).

In the event of rain, the drying bed can be covered with a roof that slides on rails and the wood-fired kiln can be lit to boost drying.

Cheap solar driers made of timber and plastic sheet

- *the side plastic can be rolled down to protect beans during rain*
- *the gap at the top lets moist air escape and draws air through a thin layer of beans on the drying rack*
- *if the top vent is facing away from the prevailing wind, the wind will suck air up through the drying racks*
- *black rocks can be placed under the drying racks to heat up and help drying*
- *these driers are still under development by CCIL*

To get good drying with the simple solar driers above, only a thin layer of beans (2cm deep) is placed on the drying rack and the beans are raked every half hour until they are sticky dry and air can pass through the bean layer. If the drier is placed near the family home, women and youths can help supervise this.

If drying is slow during wet weather, the beans can be turned into a kiln drier; using a simple solar drier in conjunction with a kiln drier will prolong the life of the kiln pipes and reduce the demand for firewood.

The drying process

Beans should be spread on the drying rack in the early morning to take advantage of the full sunlight during the first day of drying.

For the combination solar/kiln drier, beans should be spread about 5cm deep on the drying bed – the thinner the layer the more rapid the drying process.

During the first 12 hours of drying, beans must be raked every hour until they become 'skin dry' and they should be allowed to rest without any kiln heating on the first night – this allows water and organic acids to move from the centre of each bean to the outer shell, resulting in higher quality beans (fatter beans with lower acidity).

After the first day of drying the beans should be raked four times a day (twice in the morning and twice in the afternoon) to ensure uniform drying – during raking, unwanted material such as pieces of placenta should be removed and double beans separated (see Section 17).

Kiln drying should not be applied for more than 6-8 hours per day during the day, and then the beans are allowed to rest during the night, when moisture and acid can move from the centre to the outside of each bean.

If there is no rest period or drying is too fast at too high a temperature there may be two problems:

- The outside of the beans becomes drier than the inside.
- Beans will be too acidic which is a problem on the world market (although some niche markets want more acidic beans).

Smoke tainting of beans can occur for several reasons:

- If the kiln pipes have rusted and holes in the pipe allow smoke to pass up through the drying rack,
- If beans or placenta fall through the drying rack onto the hot kiln pipe and catch fire, making smoke that then passes up through the beans on the drying rack,
- If the chimney is not high enough and allows smoke to drift back down onto the beans, or
- If the fermentation boxes are too close to the drier and in the path of smoke coming from the chimney.

Beans should have 6-7% water content at the conclusion of drying.

This should take from 4 to 10 days depending on the weather and the use of kiln drying.

Whether the beans are dry enough can be tested as follows:

- Squeeze a handful of cooled beans – if they are fully dry they should make a crackling sound.
- Crush a few beans by rubbing them between your thumb and fingers -
    - If they are fully dry the inner nibs will break into pieces but the skin will not break much.
    - If the inside of the bean is rubbery and does not break into pieces easily, it means the beans are not dry enough.
- Take a bean and try bending it with a thumb and forefinger on each hand– if the bean is fully dry it will snap; if insufficiently dry the beans will be rubbery and will bend without snapping.

16: Bagging and Selling Dry Cocoa Beans

Dry beans are now ready for sorting and bagging.

When they are delivered to an exporter they will be checked for export quality and may be rejected if they are sub-standard.

It is good to sort beans before bagging them to ensure that they will meet quality standards and be accepted by the exporter.

Six problems that lower bean quality are shown below.

Foreign matter and beans with any of these faults should be removed before they are finally bagged up for delivery to an exporter.

Broken beans – beans with parts missing but shell still attached
Photo CCIL

Double beans – due to insufficient raking and breaking of clumps during drying
Photo CCIL

Foreign matter in beans – e.g. stones, dirt, rat hair, sacking, twine, insects, placenta (must be less than 1%)
Photo CCIL

Flat beans – cotyledons too narrow for the cut test
Photo CCIL

A sample of good quality dry cocoa beans

Germinated beans – shell pierced, slit or broken by growth of the embryonic root Photo CCIL

Nibs – broken pieces of cotyledons (nibs) separated from their shells Photo CCIL

Bits of broken beans and loose nibs can be bagged separately for sale as 'nibs' – they will bring a lower price than good quality whole beans.

Beans must be bagged in new, clean hessian sacks marked as shown in the photo.

- Each bag must weight 63.5kg (62.5kg beans + 1kg weight of bag); 16 bags make 1 metric tonne.
- Old copra sacks must not be used or these will taint the beans and lower their quality.

Bags are sewn up with twine so that beans can't escape and must be stored in a clean dry place away from vermin and contaminating chemicals such as diesel and pesticides.

It is illegal to sell beans to anyone but an exporter licensed by the Cocoa Board of PNG.

A bag of dry cocoa beans marked 'PNG Cocoa Beans' with the fermentary name and registration number for delivery to the exporter such as Agmark

17: Cocoa Bean Quality

On delivery to an exporter the beans are inspected by a Cocoa Quality Assessor (CQA) who checks that the bags are new, clean and undamaged, weigh 63.5kg, are correctly stamped and are sewn correctly.

The CQA then takes a sample of beans from each bag with a stabber and subsamples are:

- Ground to powder and checked for unwanted smells such as smoke taint or diesel or rotten smells.
- Checked for moisture content (must be 5.5-7.5%).
- Checked for foreign matter content (must be less than 1%) and for bean size (must be less than 1000 beans per kg).
- Given a cut test in which beans are cut down the middle in a special tray to show the inner colour of the nibs (see the photos of beans cut longways next page).
- Checked for flats, double, broken or germinated beans (content must be less than 5%).
- Checked for mould or insect damage (must be less than 5%).

If the bag of beans meets all the above quality standards, the CQA issues a 'Quality Assessor's Report: Exporter's Acceptance' in triplicate - one copy goes to the grower or fermentary manager who can then collect payment for the beans from the exporter.

Then an officer of the National Agricultural Quarantine Inspection Authority (NAQIA) collects another sample of beans from each bag and does the same tests as above – if the bag is deemed to be of export quality it is stamped with a red triangle just below the mouth and sealed with a metal tag with 'PNG' stamped on it and sent for export.

If a bag is rejected it is painted with a green stripe across the mouth and can be sold only within Papua New Guinea.

A bag with incorrect weight, sewing or marking, or too much foreign matter can be sent back to be corrected and then re-submitted.

Cocoa bean quality as seen in a 'cut test' in which beans are cut down the middle:

'Slaty' (unfermented)
Cut surface is slaty grey
Interior of shell remains off-white
Flavour undesirable
Photo CCIL

Over-fermented
Results from too long fermentation or too slow drying
External surface of beans dark brown or almost black
Cut surface dull dark brown
Flavour objectionable
Photo CCIL

Mouldy
Internal mould visible to naked eye
Caused by insufficient drying, storing in a damp place or allowing dry beans to get wet
Photo CCIL

Insect damage

Beans contain insects at any stage of development or signs of insect damage

Mainly caused by prolonged (or poor) storage

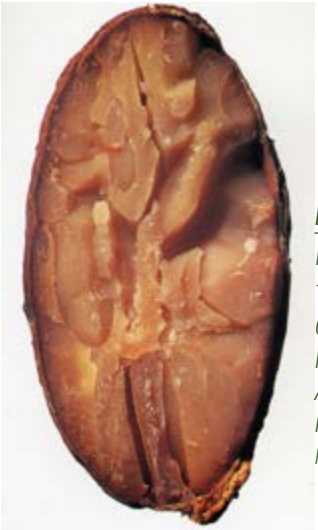
Photo CCIL

Fully fermented Forastero (Amazonian) type

Open Texture

Chocolate brown colour of cut surface

Photo CCIL



Fully fermented Criollo type

Is lighter brown then Forastero

Trinitario is a cross between Forastero and Criollo and so beans can vary in colour; the PNG hybrids are a cross between Trinitario and Amazonian (Forastero) and these can also vary in colour

Photo CCIL

18: Diversification of Income on a Cocoa Farm

Because cocoa grows well in the shade of other trees it can be combined with other crops such as shade trees that produce a commercial product or with food crops that can contribute to family nutrition or be sold for extra farm income.

18a: Cocoa and Valuable Shade Trees

Coconuts have always been an important shade tree for cocoa and can give added income as well as providing ideal shade for the cocoa. Other shade will need to be provided while coconuts are growing tall enough. Note that densely planted coconuts, betel nut or banana can severely reduce cocoa yields by 30% or more.

Cocoa under coconut shade

Cocoa under betel nut shade – they can be planted every second cocoa tree

Cocoa under banana shade

Cocoa under galip nut shade

Studies at LAES have shown that galip nut trees at 40 trees per hectare are ideal shade for cocoa and a valuable tree crop

18b: Cocoa, Other Crops and Food Crops

Some farmers are pulling out cocoa to plant other crops such as oil palm.

This could be done by intensifying cocoa planting on a smaller part of the block (e.g. 1 ha) while the rest of the block can be planted to oil palm, which requires less looking after.

Often it is best to plant food crops and fruit and nut trees around the edge of a cocoa planting; fruit and nut trees can grow very big and give too much shade for cocoa and cocoa can shade out the food crops.

Peanuts can be used as a cover crop in cocoa and provide a food source or extra income.

Kalava (*Ormocarpum orientale*) is a valuable legume that can be used as shade for cocoa (it is less aggressive than *Gliricidia* and so tends not to over-shade the cocoa); its leaflets are a valuable food and can be cooked like aibika, and can also be eaten by pigs and chickens.

Cocoa growing can be combined with food crop production, either during the early establishment of cocoa before the canopy has closed or in a more permanent system of adjacent or alley cropping.

Growing cocoa as a smaller tree enables it to be combined with food cropping – taro in this photo

Food crops being grown in a cocoa block while Gliricidia and cocoa are being re-established after clearing an old cocoa block – note the old cocoa tree cut back to a stump and regenerating chupons that can be budded or top grafted

Vanilla can be grown on the Gliricidia shade trees to give extra income in a cocoa block.

18c: Cocoa and Livestock

Cocoa farming can be combined with animal production, especially of a ruminant like goats that can eat weeds, *Gliricidia* branches, cocoa prunings and cocoa pod waste.

- This greatly benefits cocoa production by encouraging weeding and pruning of shade and cocoa trees to feed the goats.
- It also provides a valuable source of farm income and a source of meat to augment human nutrition.
- Intensified pig, chicken and duck production could be combined with cocoa farming to give some of the same benefits,

Penned goats feeding on Gliricidia prunings

Gliricidia shade trees heavily pruned to give feed for goats

This is an incentive to prune the shade trees which in turn benefits cocoa production

19: Greater Involvement of Women and Youth in Cocoa Farming

Many aspects of the new cocoa management methods described above make it easier for women and youth (the whole family) to be involved in cocoa farming and share in its benefits.

Growing cocoa as a smaller, more easily managed tree will make it easier for women and youth to contribute to its management.

The need to remove and bury every sick pod at least once per week from every tree requires the attention of the whole family.

The new way of growing cocoa requires more constant light work like that needed for food crops, but less hard or heavy work, which will allow women and youth to be involved in its constant management alongside food crops.

Combining cocoa growing with food cropping will assist the involvement of women and youth because the crops will be nearby.

Use of solar driers requires more constant raking of the drying beans and attention to the driers so that the plastic sides can be closed down if it rains. If the driers are located near houses, women can handle this work along with other chores.

Combining more intensive livestock farming with cocoa farming will help women become involved in cocoa farming because they are often in charge of livestock such as pigs and chickens.

Make a chocolate drink from your own cocoa beans

In Central American countries, and the Philippines and Samoa, farmers make a chocolate drink from their own cocoa beans using the following process:

- Take a batch of well fermented and dried cocoa beans and roast in an oven or on a hot plate until the shells become loose ('pop') and almost black – roasting is required to develop the full chocolate flavour
- Rub the shells off the hot beans while they are hot and collect the cotyledons ('nibs')
- Pound and grind the nibs to a paste with a stone mortar and pestle (like the ones used to prepare spices for Asian cooking) or use a hollow stone as the mortar and a rounded one as the pestle; the longer the grinding time the better the chocolate product (chocolate manufacturers use a grinding machine - a 'conche' – to grind the cocoa beans for many hours or even days)
- For the Central American recipe, add sugar and keep grinding to make a smooth sweet paste (the cocoa nibs are rich in cocoa fat and so the paste should become fatty or oily with prolonged grinding)
- Make tablespoons of the paste into tablets and let set
- To make a delicious and nutritious drink, place a tablet in a saucepan of water and boil until the cocoa and sugar are dissolved or well suspended
- Milk can be added if desired
- In Samoa, where they make a drink called 'Koko Samoa', the roasted beans are ground without adding sugar and the cocoa mass is eventually solidified into a block in a plastic cup
- To make a drink, a tablespoon of cocoa mass is sliced or grated off this block, added to boiling water in a saucepan with sugar, boiled for a while until well suspended and then poured into a cup for drinking

These drinks are probably a little different from the drink originally consumed by the Mayan and Aztec people in Central America, who didn't have access to cane sugar (which originated in Papua New Guinea); they mixed the cocoa with maize flour and chile.