COCOA TEACHING RESOURCE BOOK

FOR

GRADES 9 - 12

TEACHERS IN PAPUA NEW GUINEA SCHOOLS

Cocoa Coconut Institute
Papua New Guinea

Department of Education

First Edition

2013

Written and Developed by the Cocoa Coconut Institute (CCI) Ltd of Papua New Guinea,
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Mr. Alfred Nongkas was the CCI Industry team leader in the Cocoa Curriculum Project while Mr. Anton Varvaliu provided the administrative support and advice. Mr. Chris Fidelis of CCI provided some graphics and content input while Mr. Godfrid Hannett of NARI Keravat helped with some additional graphics. Their contributions are acknowledged.

The Secondary Cocoa Units for Grades 6-8 was prepared in collaboration with Dr. Apelis, First Assistant Secretary- Curriculum and Standards. The Assistant Secretary Curriculum Division Mr. Wesley Lakain and Mr. Ghandi Lavaki (Senior Curriculum Officer) for the National Education Department assisted with vetting the curriculum and their support were invaluable.

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Edited by Dr. Arnold C. PARAPI (PhD-Agriculture Education)
Cocoa Curriculum Consultant

Cover: **George Brown High School Students on field trip at the CCI – PNG Nursery**

CONTENT

THE SECRETARY OF EDUCATION'S MESSAGE

The National Department of Education has the responsibility on curriculum matters for the school system in Papua New Guinea. It is the Department of Education that implements government policies and sets the perimeters for school curriculum planning, implementation and evaluation. Therefore I have the duty to approve and recommend this industry and private sector developed cocoa curriculum for use in the school system of our country.

I am very pleased to recognize and welcome the assistance and support given by the commodity crops sub-sector of agriculture for developing the cocoa curriculum following on from the Coffee Industry initiative Corporation of Papua New Guinea. The Cocoa Coconut Research Institute's desire to produce this cocoa curriculum for use in the school is commendable. Admittedly, the Department does not have the personnel and resources to develop such curriculum and provide quality education for the country therefore, such an endeavor to partner with the Department is appreciated.

In this light of government direction to revert to the old objective based system of education in the country, the Department of Education is in the process of exciting the outcome based system of education. But until a formal decision on the exit strategy is made, the OBE system from which this cocoa curriculum is developed will be accepted by the Department. When the OBE exit strategy is finalized, the cocoa curriculum and any other such curriculum will have to be revisited with the view to publishing a second edition to reflect government and Departmental policies.

It has been noted many times that an increasing number students will leave school to return to the villages. In order to be productive and purposeful in the community, the school leavers have to be appropriately skilled with self-employment and entrepreneurial skills. It is the government, and indeed, Departments responsibility to provide a provision of quality and relevant education. This is the reason the Department will promote and welcome the private sector to support the Department in providing such quality and relevant education for our school leavers.

I am honored and privileged to approve and recommend this major commodity crop based cocoa curriculum for use in the school system in the country. Education is a complex process and the Industry based input to provide quality education is welcome. It is our sincere hope that the schools and teachers will use it effectively to appropriately skills our youth to be production and purposeful citizens of the country.

DR. MICHAEL TAPO (EdD)
Secretary for Education

THE CHIEF EXECUTIVE OFFICER OF CCI LTD MESSAGE

Cocoa is the second most important cash crop apart from coffee that actually touches the hearts and soul of the rural population. While many farmers along major roads and towns have other alternatives as a means of generating a cash income to support their social, economic and person needs, many rural households livelihood is depended only on cocoa for a cash income.

It is the CCI hope that the cocoa industry provides the scientific, managerial and entrepreneurial skills for farmers to earn a high income while meeting the needs of the market or consumers. Cocoa has to be farmed through an entrepreneurial approach by farmers. Cocoa entrepreneurship means growing cocoa to make money and in the process creating self-employment opportunities for growers. As many school leavers will be going home to the communities, this cocoa curriculum is designed to skill the school leavers with appropriate cocoa skills to support them when they leave school. When taught effectively by schools and teachers, it will enable school leavers with the entrepreneurial skills to make living in the communities worthwhile. It is for these reasons, the cocoa curriculum is developed and prepared.

In partnership with the National Department of Education, a partnership the Cocoa Coconut research Institute welcomes whole-heartedly, we hope that the coffee curriculum provides for appropriate and relevant entrepreneurial skills for the school leavers to utilize to grown cocoa successfully. It is the CCI's firm conviction that cocoa is and will, for the years after gas, oil and minerals are exhausted to be an important sustainable and renewable source of cash income for our rural population.

The schools should plan, use and evaluate students performances using the knowledge and skills in the cocoa curriculum and develop positive attitude among the learners to be enterprising in the communities. As the Chief Executive of the Cocoa Industry Research and Development, it is our duty that such knowledge and skills are appropriately packaged for use in the schools. I sincerely express the cocoa industry' appreciation to those who developed this curriculum and the National Department of Education, our major partner is commended for approving it for the schools in the country.

Students are encouraged to take an active part in learning to farm cocoa as a cash crop when they leave school. The CCI as a responsible organization remains committed to the empowering the cocoa farmers to grow and process cocoa of high quality to meet market demands while enjoying a reasonable cash income to support their livelihood.

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DR. EREMAS TADE (PHD)
Acting Chief Executive Officer

INTRODUCTION

The cocoa curriculum is a collaborative and partnership effort between the Cocoa Coconut Institute (CCI) and the National Department of Education (NDOE). The NODE is responsible for the curriculum in schools and the CCI is responsible for cocoa development so the partnership brings together both education and the industry to promote skills development while preparing the youth for life in the communities after they leave school.

The first edition is a trial edition. The cocoa curriculum trail edition will be trialled in five schools in the ENBP at all levels of schooling. Adjustments will be made to the content and the educational components after the field test of the cocoa curriculum. A second edition incorporating the field experiences in the context will be prepared and published in 2014.

The package (the teacher's resource book) is developed and packaged for grades 9-12 classes in the cocoa growing regions of the country. The package is designed for grades 9-12 classes as units of Agriculture in grades 9-10 and units of Applied Natural Resource Management in grades 11-12. Teachers should ensure that the required and appropriate units and subject matter are taught and the secondary level of education.

The cocoa units are designed for secondary schools to be taught as Agriculture and Applied Natural Resource Management and these builds on the foundational knowledge and skills of growing cocoa as an entrepreneurial crop in the communities learnt in grades 6-8. Students will learn in-depth knowledge and higher level of subject matter regarding growing, managing, processing and marketing cocoa as an entrepreneurial activity. Using these advanced knowledge and skills of growing cocoa, the student will proceed to either progress to further studies in agriculture or will return to grow cocoa as a major source of cash income to sustain their livelihood in the communities they will live.

The cocoa curriculum should see, over a period of time, the introduction of quality skills-based education for the students while helping to increase the yield and improve the quality of cocoa exported from PNG. It is for these reasons the partnership endeavour is conceived. Such collaborative public and private partnership should be beneficial to the organisations and the country.

TEACHING AND LEARNING

How the students learn

What I hear I forget
What I hear, see I remember a little
What I hear, see and discuss I begin to understand
What I hear, see discuss and do, I acquire knowledge and skills
(Active Learning Credo Statement by Silberman, 1996)

In support of these are the findings that we remember:

- 20% of what we hear
- 40% of what we see
- 90% of what we see, hear say and do so or what we discover for ourselves

A student-centred approach to learning

Different student learn in different ways. Some students learn best by writing, others by talking and discussing, others by reading and others by listening. Most students learn by using a combination of these. All learn skills through practicing and repetition. You need to use a variety of teaching strategies to cater for the different ways your students learn.

Teaching and Learning Strategies

To assist and encourage students to learn, you perform certain tasks. These are referred to as teaching strategies. You need to engage students directly in learning but there are times when you to take charge of the learning in the class and teach particular concepts ort ideas. These teaching strategies include:

- Group work
- Role Play/Drama
- Skills practice
- Direct assignment, research/inquiry
- Class discussion/debate
- Problem solving activities
- Teacher-talk – Instructions, explanations, lectures or reading aloud
- Direct question and answer sessions
- Audio Visual presentations
- Textbooks or worksheets
- Demonstrations and modelling
- Guest speakers/Resources persons

- Field trip
- Classroom displays

Using groups as a teaching and learning strategy

Using groups is an important strategy in agriculture as students learn from each other, not just from the teacher. Groups work encourages students to participate in achieving a shared goal and collaborative learning in deciding whether to use group or not, you need to consider:

- Your intended outcomes
- The extent to which the outcomes can be achieved by the group
- The lesson content
- The time allocated for the completion of tasks
- The classroom setting
- The materials and resources available
- The structure of the groups based on gender, ability, cultural background and student preferences

Groups work well when:

- The groups decides upon their goals, timeline and tasks
- Students realise that success depends on the achievement of the whole group and not just individuals
- The task is broken into subtask which must be finished to successfully complete the overall task
- The whole class is involved in the activity
- Everyone has a role to play, e.g. field trips
- Membership of small groups is changed regularly to provide a variety of learning experiences for all students

Strategies for organising and managing groups:

- Mixed-ability groups – the more able learners in the group can help the others to master the work so that you need not teach some parts
- Same ability groups – the teacher can leave the groups of faster learners to get on with the work on their own. You can give extra help to individual learners in a slower group of learners.

- Using group leaders/monitors – you appoint faster, more able learners as group leaders or monitors who can help slower learners.

DEVELOPING SKILLS

Principles and procedures

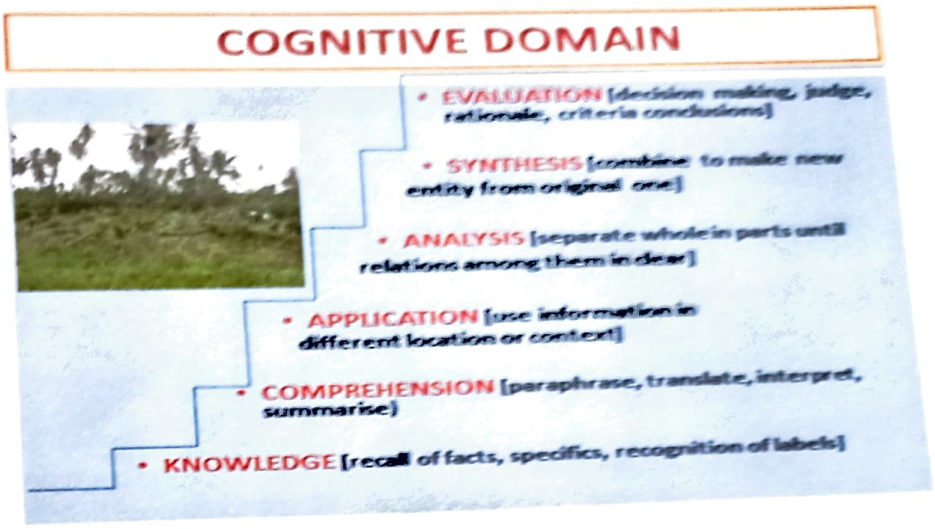
Students need to develop skills to help them learner. Skills development should happen as a part of a student's experience and the learning and practising of skills needs to occur in the context of units being taught.
Skills learning tend to be most effective when:

- Students go from the known to the unknown
- Students understand why it is necessary to gain mastery of specific skills
- Skills are developed sequentially at increasing levels of difficulty
- Students identify the components of the skill
- The whole skill and the components of the skills are demonstrated
- There are frequent opportunities for practice and immediate feedback
- Students are encouraged to record and diagnose their performance
- The skill is used in a range of contexts

To teach skills effectively you need to include learning activities that span the range from teacher-centred learning to using different groups of different sizes ranging from the whole class to small groups and use a range of teaching strategies which use higher order skills as your student's progress.

Blooms taxonomy (hierarchy) of theory skills

Blooms taxonomy is a way to classify skills, activities, or questions (or objectives/outcomes) as they progress in difficulty. The lower level questions require less in the way of thinking skills. As you move up the hierarchy, the skills or activities require higher level thinking.

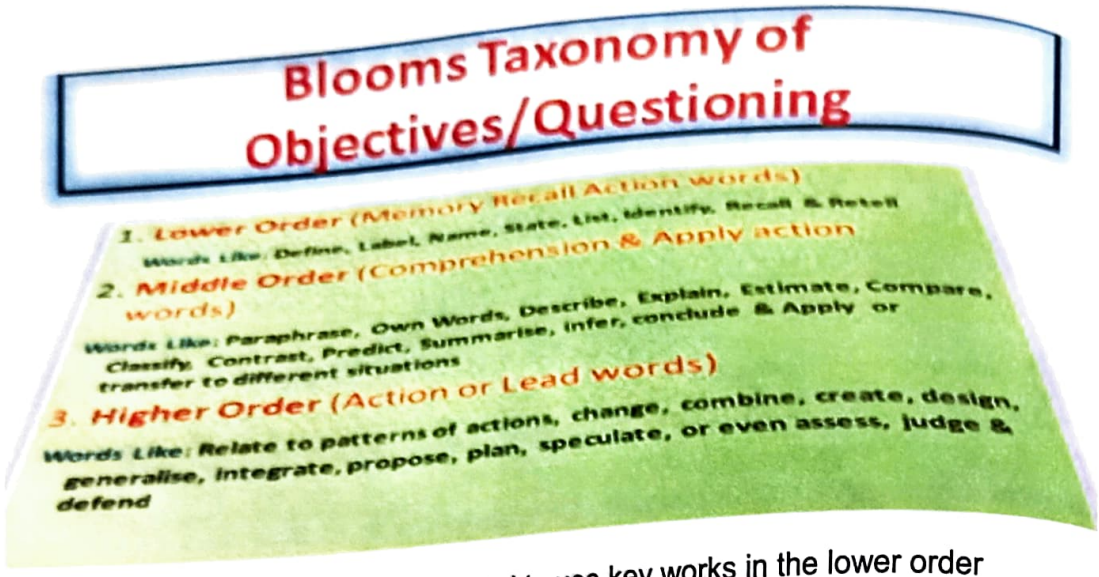


Recommended levels of learning

For students in grades 9-12, teachers are recommended to use teaching skills at the upper level of the middle order and at the high order level of skills and activities. Teachers should teach student to learn at analysis, synthesis and evaluation levels of learning. (see Blooms cognitive domain levels of questioning above). These higher order skills can easily be taught in the field and field based experience. Alternatively, student at this level of education should be taught by through projects based or community based education in which higher order skills and activities are much more relevant and appropriate

Examples of cognitive level of learning key words

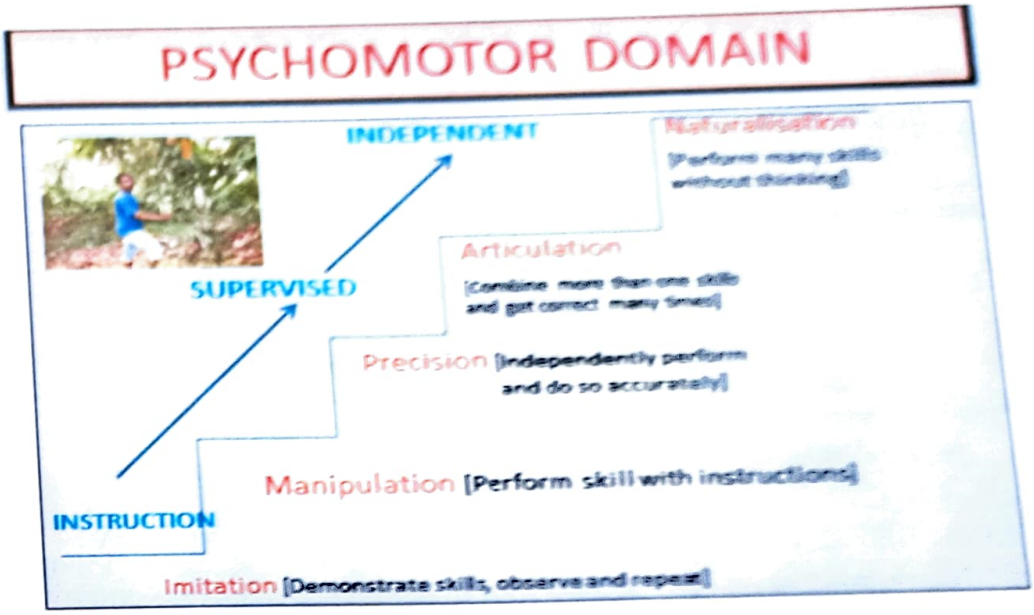
The following is a further subdivision of Blooms taxonomy of questions into lower, middle and higher order questions to assist teachers in preparing and to teach the cognitive domain effectively.



Teachers are recommended to use key works in the lower order performances and some middle order key performances to prepare and teach students. As seen from the taxonomy of outcomes or questions in Blooms hierarchy of questions, teachers should adapt their teaching according to the appropriate levels of learning for their students. Some of these outcomes are presented in each unit of learning in this teacher's resource book but teachers should feel free to adapt them for the class's ability to learn these skills.

Major Categories (hierarchy) of practical skills

The major categories of the practical skills and activities are shown in the diagram below. There are: imitation when demonstrating the skill, manipulation of the skill by the students until precision, articulation and the eventual naturalization of the skill.



Student at grade 9-12levels of schooling also need a teacher's guidance to perform the practical skills with accuracy. The above diagram shows major categories or levels of student learning according to Krathwont, Bloom & Masia (1964). This is important for practical subjects like agriculture. There are three categories:

- **Imitation - instructions through appropriate demonstration**: Teacher should prepare skills well and provide demonstrations to the student on an appropriate cocoa skills

- **Supervision:** Following the demonstration of a skill, teachers should provide opportunity for supervised experience by the students of the appropriate cocoa skill. Student can practice the skill demonstrated by the teacher or the expert individually or in groups depending on the level of resources available.

- **Independent practice:** Independent practice is the next step up and without this step the students will not gain mastery or be an expert. Teachers must prepare for and allow independent practice in the school cocoa garden or in their own family cocoa plots or in the communities. Practice makes perfect the skill being demonstrated and taught.

For students in grade 9-12 level of education, teachers must ensure that a lot of supervised experience and independent practice is

required because they will have acquired the foundational knowledge of cocoa production, processing and marketing. As well, they will have matured but importantly most of them will leave school as school leavers and will most certainly need these skills to make a living off growing cocoa in the communities.

Language skills for Agriculture

Students need to learn how to speak, read and write, view and observe carefully all the cocoa skills being taught and demonstrated. Students can learn oral language skills through, for example:

- Discussions
- Oral and written reports
- Interviewing opportunities

Provide opportunities for your students to listen and record information accurately. Guest speakers or teachers can, talk during the field trips or excursions, tapes, radio, television, CDs, videos, stories, and concepts about agriculture while students listen and record using listening resources. When students come to expect a listening experience as a regular part of their classroom routine, their ability to attend to details in what they hear about agricultural concepts is quite likely to improve.

Shift the responsibility

Introduce self and peer assessment: Develop in students the skills to evaluate their own work and that of their peers. Help the Students' use the performance standards, marking guides and assessment criteria against which work is judged. Self-assessment increase the amount of feedback students get .It can supplement teacher assessment.

Treat each task differently

Every piece of work need not be evaluated to the same degree. A mark needs to be the outcome in every case; and every piece of student work need not contribute to the final grade. Assessment is designed to enhance the teaching and learning experience for the teacher learner, not just to accredit students.

Use observation sheets and spotlighting

You might record student achievement while observing your students by using observation sheets. The most common observation sheets are individual student checklists and whole class grids. They can be used for all the project s that students undertake.

Spotlighting uses individual student checklists. This method can be used to focus on a few selected aspects of student performance, such as planning for a project. It is best to focus on five to six students at a time. Work through the class over time. Focused questioning you can gain a deeper awareness as to whether or not students understand the concept being taught.

Portfolios

Portfolios provide evidence for judgments of student achievement for a range of projects. In the option units students are required to present a portfolio for assessment purposes. It contains a specific collection of student work or evidence. This collection of work provides a fair, valid and informative picture of the student's accomplishments.

How to minimize marking times of portfolios:

- Specific the pieces of work and keep the number low
- Mark as you go – ask that one of the pieces of work be completed at the end of week 3 and mark it then. Do not leave the assessment of the whole portfolio until the end of term
- Use self-assessment-the student can self-assess some of the work.

The portfolio does not have to be a folder or binder; it can be in the form of an exercise book with the student marking the pages they want to have marked as part of their portfolio.

Reports

Reports are an authentic form of assessment. They encourage students to develop observation and recording skills, and require organization skills in both collecting and analyzing information and communicating information clearly.

Reports in Agriculture can be oral, written or in graphic form or a mixture of these. Duration of reports vary according to the task. Reporting in groups is a common strategy used in bi classes however each student should be allowed a turn at reporting during the year.

Experiments

There is a great deal of time involved in marking experiments and projects. However, the end result is that you have a better picture of what `students truly know, understand, and are able to do. To help you, generic performance standards and checklists are provided for assessing experiments.

Planning and programming units

The main purpose of planning and programming is to help you to arrange the presentation of the unit in an organized manner. This will help you to know what to teach and when to teach it. It is strongly recommended that you plan with the other teachers who teach the same grade. By planning together, you will all have better lessons and make better use of your limited resources.

Points to consider when programming

- Which unit learning outcomes are students working towards?
- What is the purpose of this unit/topic/learning experiences?
- Which learning experiences will assist students to develop their knowledge and understandings, skills, and values and attitudes in the subject?
- What are the indicators of student learning that you would expect to observe?
- How can the learning experiences be sequenced?
- How do the learning experiences in the unit relate to student's existing knowledge and skills?
- How individual learning is needs to be catered for?
- What are the literacy demands of this unit/learning experience?
- What authentic links can be made with the content of other subjects?
- How can school events and practice be incorporated in to the program?
- Do the assessment methods address the unit learning outcomes and enhance the learning?

- How can the assessment be part of the teaching and learning program?
- Which options and projects can be done to make best use of the school's resources?
- How can a balanced program be developed?

The planning process

In this teacher guide, ideas for programming and organizing each unit have been provided. These have been arranged in steps to help you teach the unit. The steps follow the thinking processes involved in the outcomes approach.

Steps 1 – Interpreting the unit learning outcomes

The first step is to read the unit description in the syllabus and then study the unit learning outcomes to determine what students will know and be able to do by the end of the unit.

You need to look at the action verb, concept and context of each learning outcome. This will help you see what skills and knowledge are embedded in the outcomes. Remember the unit learning outcomes link to the broad learning outcomes.

This teacher guide gives you a brief description of the main requirements of each learning outcome.

Step 2 – Planning for assessment

It is necessary to study the assessment requirements of the unit early in you planning to ensure that you teach the content and skills students need to achieve the unit learning outcomes.

The assessment tasks are described in the syllabus. They indicate what specific knowledge and skills students will need to demonstrate that they have achieved the unit learning outcomes.

You will have to decide when to schedule the assessment tasks to allow yourself time to teach the required content and time for students to develop the necessary skills. You will also need time to mark the task and provide feedback. Practical tasks may, for example, be broken into a series of stages that are marked over several weeks as students' progress with making their product. It is not appropriate to leave all the assessment until the end of the unit.

This teacher guide provides the performance standards and/or marking guide which you must use when you are marking the tasks. This is to ensure consistency with marks awarded to students in all schools in Papua New Guinea. However you must develop clear and detailed instructions for completing the task yourself and ensure all students know exactly what they have to do.

Step 3 - Programming a learning sequence

This step requires you to develop a program outlining a sequence of topics and the amount of time spent on each topic. You may follow the topics in the order they are listed in the syllabus or you may cover the topics through integrated activities or a thematic approach. If the unit involves a project for example, you may plan to teach some theory at appropriate stages during the project, rather than teaching all the theory before the students start the project.

To develop your program you need to study the topics listed in the syllabus and to think about the learning activities that will best provide students with the opportunity to learn the content and practice the appropriate skills, and how long the activities will take. You will have to think about some major activities that last several weeks and smaller activities that may be completed in a single lesson.

Once you have completed your unit plan you will have to consider each topic in more detail. For example, if you have allocated two weeks for a topic that means you have ten lessons available (five lessons per week). You will have to develop a plan for each topic that includes in more detail what you will cover in each lesson. Your topic plan must include a sequence of student activities and teaching points that contribute to the overall achievement the unit outcomes. Your topic plan should include what you think your students will do in each lesson, but you must remember that the individual lessons must flow logically, one from the previous and must be adjusted according to how students are processing through the topic. You may develop outcomes for the topic and for each lesson, but these must be related to the unit outcomes.

The teacher guides provides a sample program for each unit. It does not provide individual lessons plans.

Step 4 – Elaboration of content and activities

Once you have mapped out your program for the term you must then develop more detailed plans for each topic in the unit. All units require students to be actively engaged in learning, not just copying from the board. Make sure you develop a range of activities that suit all learning

needs-some reading and writing, some speaking and listening, some observing and doing.

Browse through the text books and teaching resources you have access to and list chapters, pages or items that you will use for each topic in your program. The text books should also provide you with ideas for activities related to the topic. You may have to collect or develop some resources for yourself.

Once you have sorted out your ideas and information you can then develop your more detailed weekly program and daily lesson plans.

This teacher guide gives examples in each unit of some activities you might like to use to ensure active learning. It also gives background information on some of the content.

Remember that option cocoa units should be taught alongside the core units in both Grade 9 and Grade 10 Agriculture and Grade 11 and 12 Natural Resource Management frame work.

Essential resources/equipment for Cocoa units	
All units that involve crop production	Land for cocoa gardens or nursery; soil samples; seeds and / or seedlings; cocoa plants; tools and machinery for planting , tilling and harvesting coffee beans; fertilizers; weed and pest control products;
Specialist options e.g. farm technology	Equipment and resources to driers and equipment

Guide to planning and programming Agriculture

Individual units

In Agriculture, how you program the core units together with the option coffee units will depend on the crop that your students grow, or the animals they raise for their project. There will be times when the students are very busy in the field, garden or orchard preparing the ground, planting, weeding etc., and other times when the crop is growing where they are not so busy outside. Collaborate with Design and Technology teachers to construct animal or plant housings in order for you and your students to have more time for actual growing or looking after animal activities. There will be other times when your students will be very busy

looking after young animals, and other times when they are not so busy with outside activities. You need to look at the growth cycle or life cycle calendar of the project crop, fruit or animals and plan your cocoa crop program around it.

It is possible that you will decide that the students could run two projects simultaneously – such as cocoa and animal project together - and then your program will be for four terms. It is also possible that you could combine a long term schools project, such as growing such as cocoa, coffee, oil palm or vanilla, with a short term class project such as growing a crop of tomatoes or cabbage. The short term project will enable students to experience the satisfaction of successfully undertaking and completing a small project while contributing to the long term school project.

As outlined in the syllabus document, each core unit is integrated over twenty weeks with option unit to allow sufficient time to complete the project.

A project

It is important to teach students how to plan when they are undertaking class or individual activities such as projects. Students can apply knowledge and skills from Business Studies and design and Technology to Agriculture. The process which students undertake when planning and undertaking a project is:

Planning

Research

- What to-do for the project?- decide on what plants or animals or type or simple farm machinery or equipment to produce
- Special requirements of the plant or animal or type or simple farm machinery or equipment chosen
- Time needed to complete the project
- Possible markets for the products
- Possible risks and problems
- Possible sources of help and support

Decide on the goals

- What and how much to produce?
- Timelines

Physical planning

- Select site
- Determine facilities needed
- Determine infrastructure needed eg housing, equipment, etc

Financially planning

- Start-up costs
- Sources of funding
- Estimates of profit
- Estimates of cash flow
- Determine how records would be kept

Implementation

When implementing the project students

- Organize the necessary tools or equipment
- Obtain the required seeds/plants/animals
- Learn and practice the appropriate skills
- Undertake the activities required to grow the crop or raise the animal over the required length of time
- Undertake the activities required to harvest and market the product
- Clean up the area, and dispose of, or use waste appropriately.

UNIT 1: COCOA ENTREPRENEURSHIP

Introduction

Cocoa is one of the major cash crops in the country. In terms of economic important to PNG, and as a cash crop, it is only third behind Oil Palm which is an agro nucleus estate crop and coffee which is a small holder based crop. Oil Palm exports over a billion kina each year followed by coffee that exports to the value of about 500-700 million kina per year while cocoa exports over 300 million kina in export earnings for the country.

In order of highest producers, the Autonomous Region of Bougainville, the East Sepik and East New Britain are highest producers of cocoa. Until about 2006 after the invasion Other cocoa growing provinces include: West Sepik, Madang, Morobe, Oro, Manus, New Ireland, Milne Bay, Central and Gulf. Using figures up to 2011, the ARB produces about 17, 632 tons, the ESP about 16, 202 tons and the ENBP about 7,148 tons of cocoa. The ENBP producer is a far cry from over the 23,000 tons is produced before the Cocoa Pod Borer devastation in 2009 when it started to drop in production.

Cocoa is grown as a cash crop only along the coastal Provinces in the country and is largely a small holder based crop. Like coffee where the plantation sector has all but collapsed cocoa small holder producers account for about 85% of the production. Cocoa production and the cash earned has become central to the economic livelihood of the small holders and as such, it remains an integral part of the social-economic, socio-cultural and socio-political life of the people.

Learning Outcomes

At the end the unit, students can:

A. Explain cocoa as a major cash crop in the economic life of the coastal rural population

B. Describe the role of cocoa as an integral part of the social, economic and political life of the rural dweller

C. Name the Provinces and the three leading cocoa provinces growing in PNG

D. State production capacity of wet and dry beans of a cocoa tree and per hectare

E. Describe the major inputs of cocoa production

F. Discuss the important management issues affecting cocoa production

G. Explain the marketing and pricing regime in cocoa marketing in PNG and how much a one hectare cocoa plot will contribute to family income

H. If we do not farm cocoa, describe the alternative scenario?

Content

Since cocoa is a huge economic crop, it has to be grown and managed in a sustainable manner, but more so, it has to be produced to help sustain the rural economy. Cocoa has to be producer and managed with an entrepreneurial spirit with growers encouraged to grow cocoa as a major cash crop with a supporting market system. The cocoa farmer should be motivated to grow, at the least, a one hectare cocoa: sustainably, through the entrepreneurial approach, making good investment in the farm and supported to establish a string banking culture to sustain their living.

A. Benefit to Cocoa farmer

In the final analysis, the benefits to the farmer who choices cocoa as a cash crop is most important to that he/she as a rural dweller who does not have regular salary or a social welfare benefits from the government can support their livelihood. It is recommended that cocoa farmer should be encouraged and well trained to grow a one hectare of cocoa to sustain his/her living. Without crops such as cocoa, life in the rural communities will remain dull and people will migrate to the urban areas in search for a better quality of life. Without cocoa to sustain and provide means for a purposeful living in a rural communities will lead to urban migration of un-skilled and semi-skills labour to the town and cities of PNG that will lead to disastrous social problems.

a) Cocoa income per hectare

We are given the following information on cocoa,

1. 625 tree per hectare
2. 40% is recovery rate for wet beans to dry cocoa beans
3. 60 pods per tree per year on an average
4. 23 pods per kg of dry beans
5. 26 dry bean bags in one hectare
6. One dry bean bag weighs about 63.5 Kg
7. Current year 2013 AgMark price of dry cocoa at K250 per bag
8. A average size family should be five including parents

We can calculate:

1. If there are 60 pods per tree, then in one hectare of 623 trees
   60 pods X 623 trees

   =37, 500 pods

2. If there are 37, 500 pods per year per hectare, them
   37, 500 divide by 23 pods per kg dry beans

   =1, 639.44 kg dry beans or 1.6 tons of dry cocoa beans

3. If there are 63.5 Kg per bag. There are 26 bags per heacture and there is K1,639.44 kg, then
   1639.44 kg divide by 63.5 kg per bag

   = 26 bags fry bean per hectare

4. Therefore at today's price (2013) by Agmark is K250 per bag
   26 bags dry bean X K250

   = K6, 500 per year in annual earning

5. **Fortnightly**
   K6, 500 per year divided by 26 fortnights

   = K250 per fortnight or K500 per month

b) Expenses

Expenses in a family owned and operated cocoa farm of one hectare

1. Wages (Labor)	= K190
2. Investment (farm input)	= K30
3. Savings Culture	= K30
Total	**= K250**

The benefits to the farmer are reflected in:

1. A wages for family
2. A small savings in a bank account of K30 per fortnight and annual saving of K780,
3. A nominal investment saved till needed for farm input at K780 per year.

It is recommended that the above expenditures be held or followed to appreciate the cocoa farming/growing as an entrepreneurial

Issues for discussion:

1. K190 per fortnight should be adequate for a villager/family to supplement the food crops
2. Only in cocoa can a family grow food crops unlike coffee and oil palm
3. K780 each per year for investment and savings will provide K1560 annually for school fees and other financial obligations
4. Family size should be encouraged to have 4-6 people per household. Family planning has to be an integral part of this entrepreneurial activity.
5. Consider the alternative to migrating to the towns and cities in search for job that do not exist. HOW DO YOU SURVIVE IN THE TOWN OR CITY WITHOUT MONEY?

B. Benefits to the school

Figures 1.1: Showing the Ten Series CPB tolerant varieties planted at George Brown

The schools have to teach the cocoa curriculum to the students so that they will impact positively on the life of a school leaver who has to return to the villages.

For a school leaver who is destined for the village must have some productive and employable skills to depend on to live a meaningful life in the village.

School shape society and once skilled, the attitude remain with the graduate for the rest of their life unless they are fortunate enough o receive additional education and training to change and to exhibit the desired behaviour.

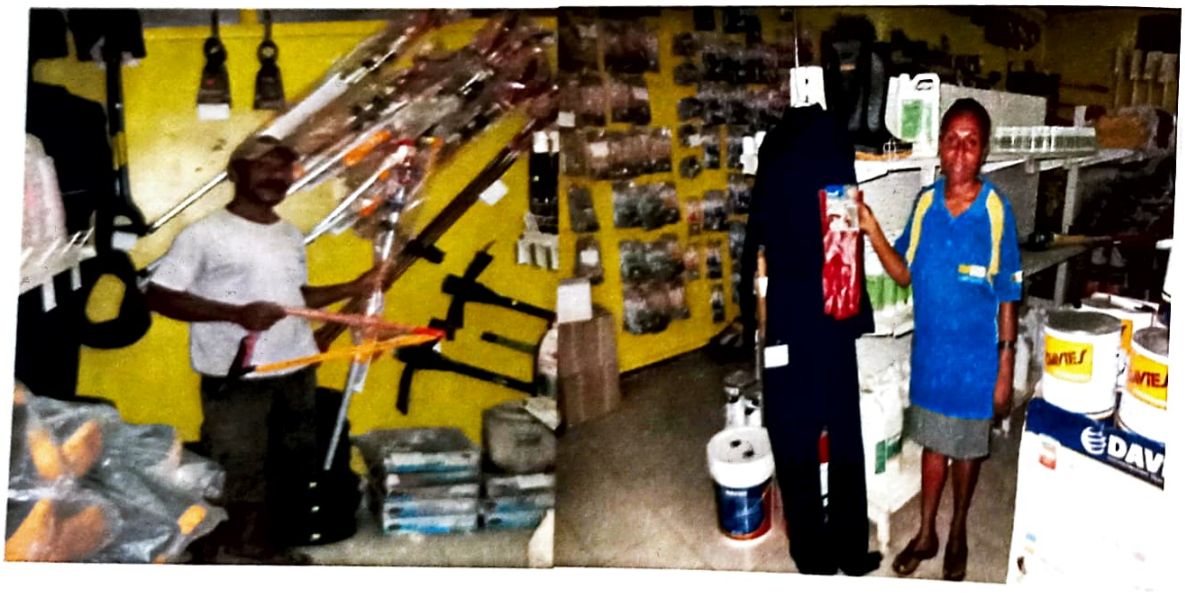
The school can also benefit from the community, if it has instilled the desired set of skills to school leavers. School leavers without a meaningful and purposeful life in the village next door will pose enormous social problems in the community that will invariably spill over to the school grounds.

Not only is the school that is charged with the moral obligation to shape positively the society but it can also earn and cash income to sustain it operations. Cocoa production at the school can also provide:

1. Employment opportunities for villagers next door
2. Cash income for the school to support its intra-curricular operation at about K6, 500 per year
3. Help provide a community based learning skills
4. Contribute to the welfare and life of the community next to the school

C. Benefit to Papua New Guinea
Contribute to national economy and to the national vision and mission

D. Cocoa Farm Input
Farm inputs refers to requirements like tools, equipment, material, fertilizers, etc use at the cocoa block to boast cocoa production



Figures 1.2, 1.3, 1.4, 1.5: Showing various Agmark Hardware tools and equipment for cocoa cultivation

E. One hectare cocoa production (It's value in Kina)

An optimum production by one cocoa tree and in a hectare in kilograms of wet and dry beans under the best practice conditions in a rural area has to be known by the farmer. This amount in kilograms is then converted to cash to be received by the farmer in the prevailing world market conditions. Such will inform the farmer of the likely scenario if he/she was to produce a one hectare of cocoa.

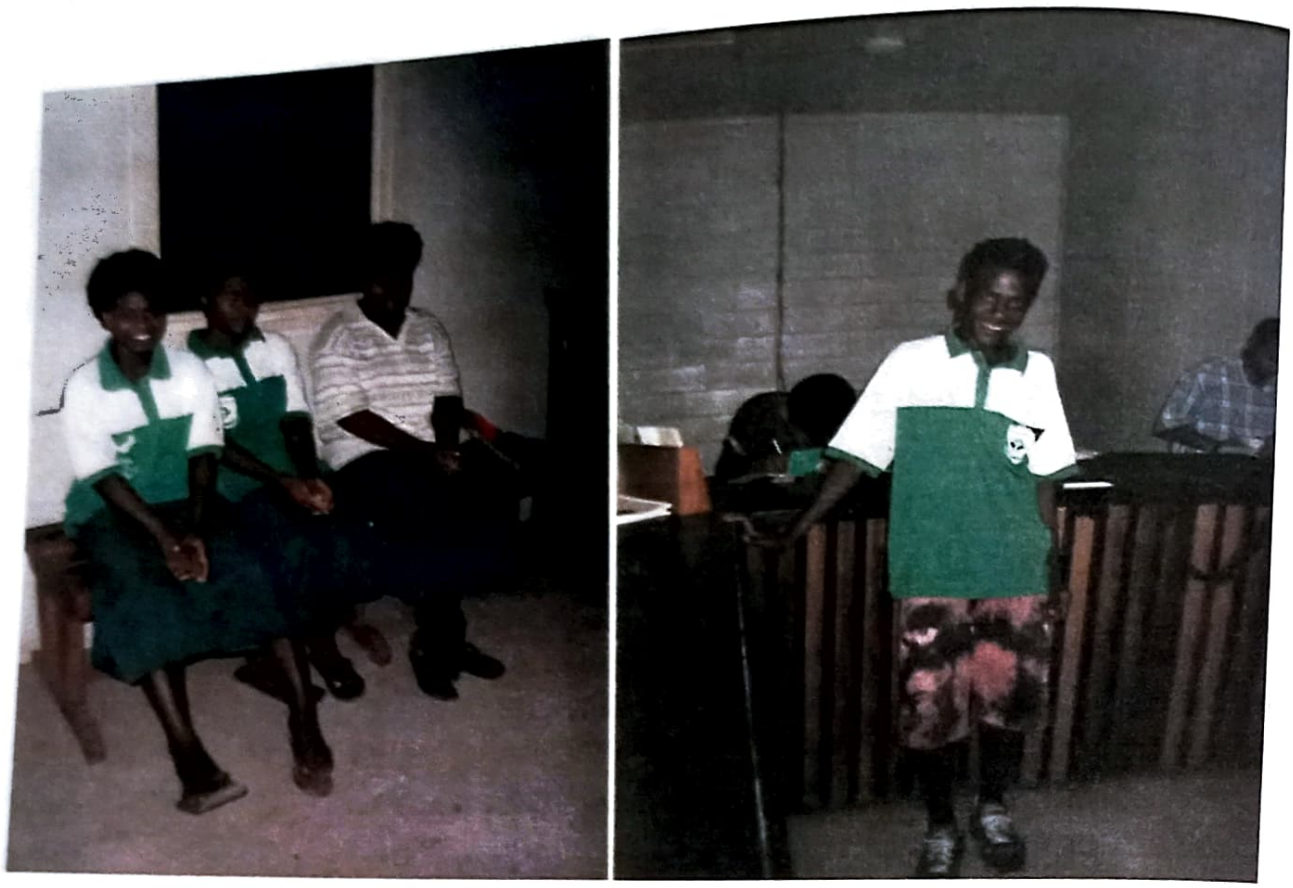
Table 1.1: Production per tree and a hectare

	Period of Production of cocoa	Wet bean yield per tree per year	Dry bean production tree per year	Wet bean yield per Hectare per year	Dry bean production per hectare per year
	Early Life				
Av.	**Mid-Life**	**2.6Kg/tree**	**1.04 per year**	**6,557.76 Kg per year**	**1,639.44 Kg (1.6 tons)**
	Later-Life				

F. Pricing of Cocoa

Cocoa varies according to worlds' cocoa products consumers. Prices are regulated international

G. Savings and Investment culture in cocoa as a cash crop



Figures 1.6 & 1.7: students of George Brown High School (ENB)opening personal accounts at the ENBP Saving and Loans Society- Kerevat Branch

Teaching Strategies

1. **Introduce/Motivation**

    1. Why do people move to the city?
    2. What problems do they face in the city without a job and regular income or without money?
    3. Why can't they stay in the village and not move to the city?
    4. How can we make life in the village?
    5. Consider the alternative to migrating to the towns and cities in search for job that do not exist. HOW DO YOU SURVIVE IN THE TOWN OR CITY WITHOUT MONEY?

2. **Body/Content/Subject Matter**

    1. Show table on cocoa production figures in unit 2: cocoa history and ask them to:
        a) Identify highest producers
        b) Why ENBP showed decline in production after 2009?
        c) What do the ENBP people think now?
        d) How can we help them and other improve and live with the problem?
    2. Use production figure in table 1 kin this unit and discuss how we can use cocoa for a good quality of life in the village
    3. Discuss how cocoa p improve a person's village life
    4. Discuss how cash can positively impact the family, community and nation
    5. Discuss how the man uses it to get drunk and impact the family
    6. Can we have a saving and investment culture through cocoa production

3. **Closure**

    1. The big questions if can cocoa positively impact the community
    2. Can cocoa be a useful, productive, employable and entrepreneurial activity in the village?
    3. Provide the four (4) activities in Practical/Experiential activities for homework to be presented and discussed in the next lesson.

Practical/Experiential Activities

1. Design an entrepreneurial activity through cocoa production on your family your family land

2. Find out from nearest farm suppliers as to what are the basic resources needed to grow cocoa in your community

3. Find out from the cocoa buyer in the area as to what is the current price of:
    a. Wet cocoa bean per kilogram
    b. Dry cocoa beans per kilogram

4. Calculate for one hectare (625 trees) and work out your net income minus cost of production (see example in the text)

UNIT 2: COCOA ANATOMY AND PHYSIOLOGY

Introduction

In this unit students will learn about the cocoa tree itself and its various parts. Therefore, they will learn the following:

- Cocoa growth habit
- Botany in various cocoa plant parts
- Cocoa compatibility
- Pollination and the Agents
- Fertilization
- The fruit
- The seed
- Seedling Germination and Growth

Learning Outcomes

At the end of this unit, the students can:

A) Describe the natural growth habit of a cocoa tree
B) Label the parts of cocoa
C) Explain compatibility of cocoa
D) Describe pollination of cocoa
E) State how fertilization of cocoa takes place
F) Describe seed development
G) Identify a cocoa seed
H) Demonstrate seed germination

Content

A) Growth habit

Figure 2.1: Showing the Cocoa Tree in its natural habitat

Natural habitat

1) The natural home of a cocoa tree is lower than tree storey of South American evergreen tropical rainforest.
2) It is subjected to a high mean annual temperature
3) Requires high annual rainfall
4) Grows well in a fairly high relative humidity
5) Needs low sunlight intensity
6) Survives under these conditions but yield is very low
7) Occasional pods give sufficient seed to ensure the survival of the species

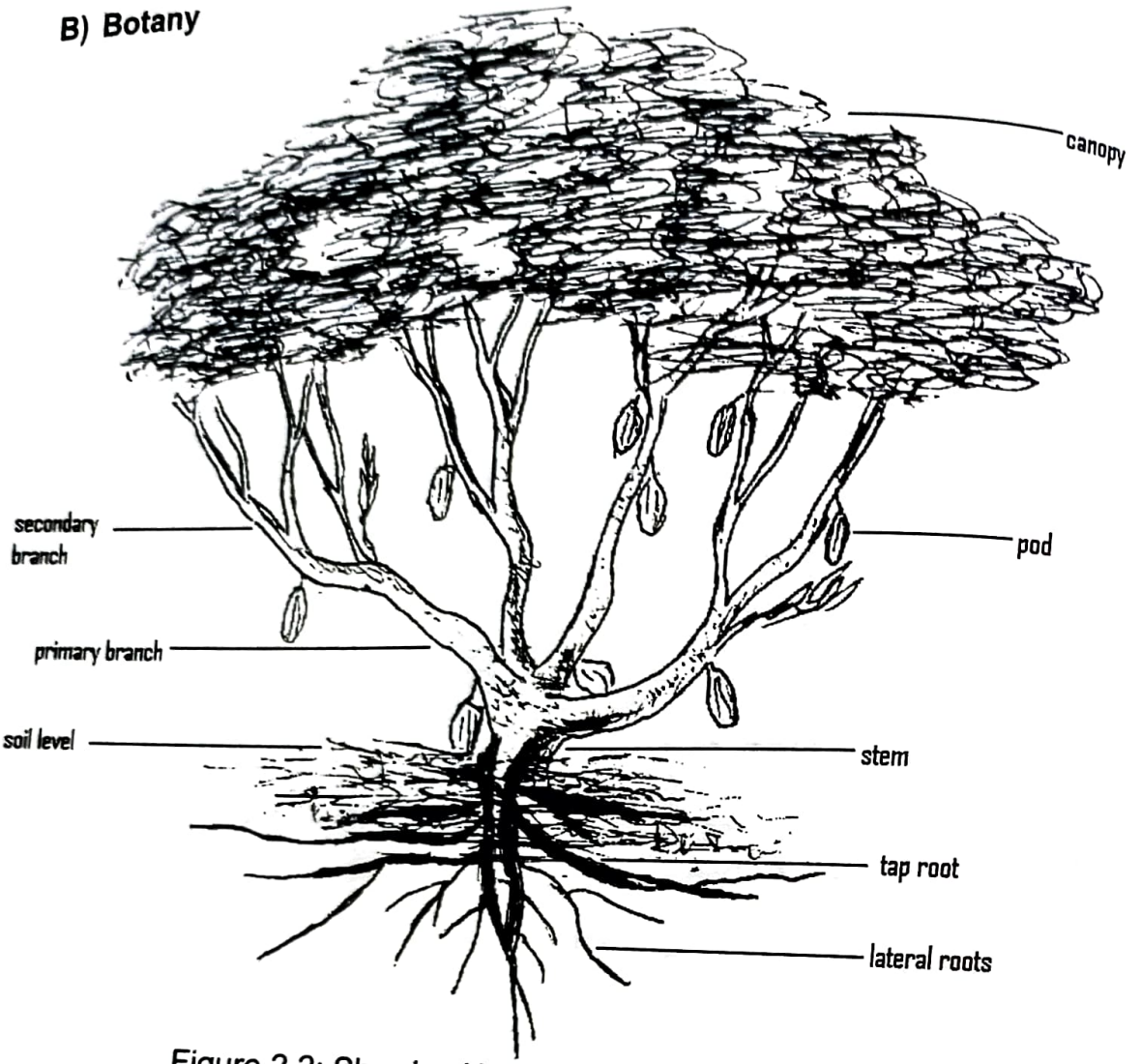


Figure 2.2: Showing Hybrid Clonal cocoa tree

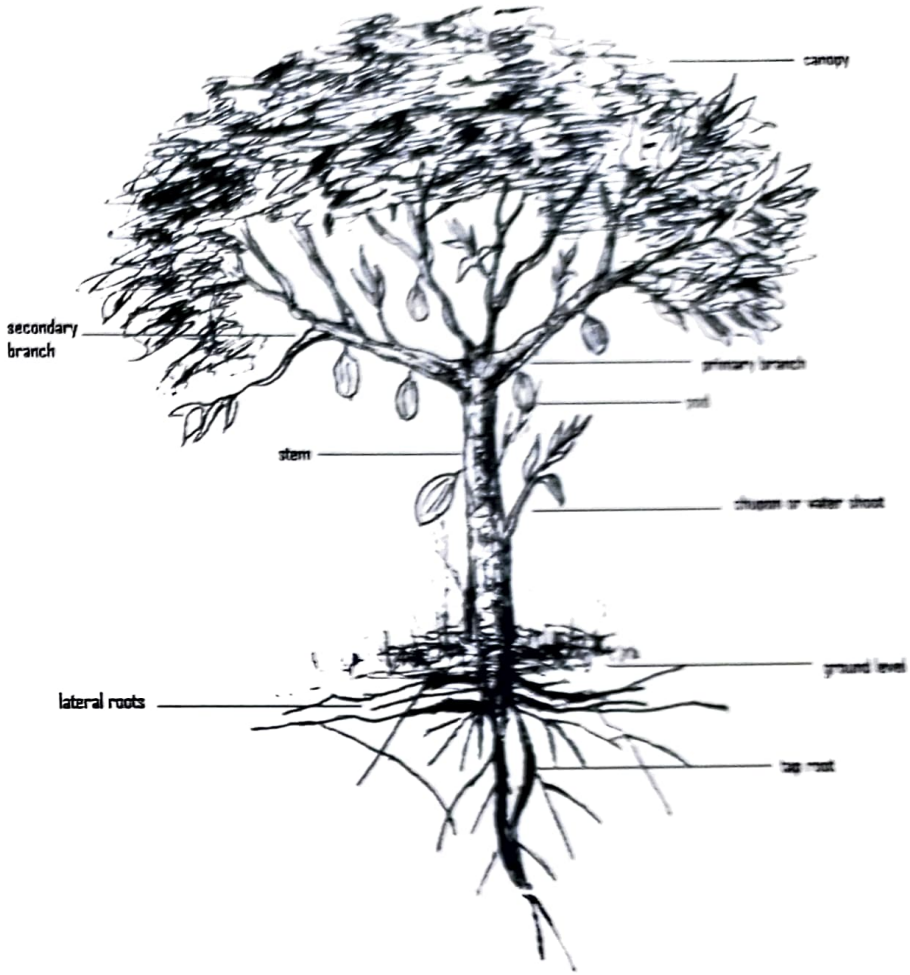


Figure 2.3: Showing Hybrid cocoa tree

a) **Root System**

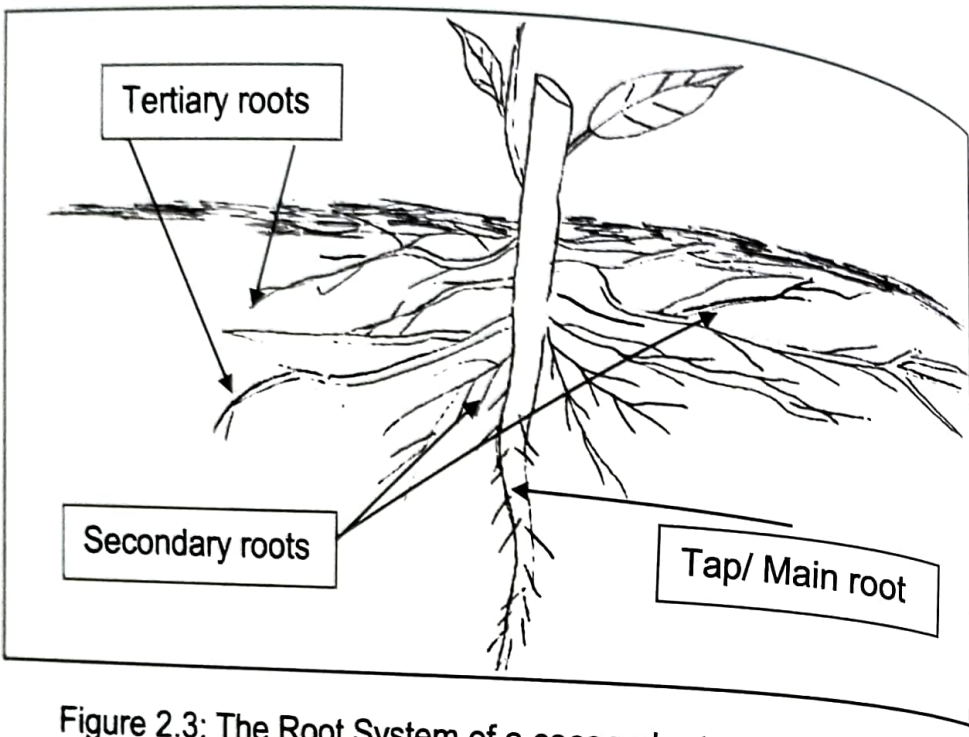


Figure 2.3: The Root System of a cocoa plant

a) The taproot of a seedling grows straight down into the ground for 1 to 2 meters or so. The main function is to anchor the tree.
b) At the very early stage, lateral roots arise in a collar just below the soil surface
c) In a mature tree most of the secondary roots grow with 15 to 20 centimetres of the surface
d) Absorption of water and mineral nutrients is done mainly by the laterals
e) Up to 10 main lateral roots can grow in this zone of top soil
f) These have many branches from which grow a mass of root hairs that can extent up to a radius of 6 meters around the tree
g) In established planting, the ultimate rootlets/root hairs from a dense layer just below the decaying leaf litter on the soil
h) Any form of tillage or surface cultivation is usually harmful to the tree because of this shallow root layer as can be seen in figure 2.2

2) Stem

a) In the natural habitat, a cocoa tree usually grows to a height of 8 to 10 meters.
b) It tends to be smaller when grown without shade. The habit of growth is characteristic and unusual
c) Seedlings grows as an unbranched single stem to a height of 1 to 2 meter

d) The terminal bud then ceases growth. Three to five lateral branches develop at the same level to form the jorquette
e) Further increase in height is made by the develoopment of a bud from below the jorquette into vertical growth.
f) This is a sucker, known as a water shoot or chupon will again form a jorquette a few feet higher up
g) In unpruned trees the process may be repeated 3 or 4 times and a number of chupons may grow at the same time.
h) In commercial cocoa tree is restricted to a single jorquette and all water shoots removed regularly
i) In the wild and unpruned cocoa tree, the process is repeated a number of times as many chupons grow.
j) This very quickly creates as mass of vegetative growth that becomes a thick

3) **Branches**

Two types of branches

a) Chupon

i. Grow vertically (upwards or orthotropically)
ii. Leaves on chupons have longer stems, 7 to 9 cm long

b) Fan branches. Up to five develop at the jorquette

i. Grow laterally (sideways or plagiotropically)
ii. Leaf stems on fan branches are about 1 to 4 cm long
iii. Petioles (stems) on fan branches are thicker then

4) Leaves

a) Cocoa leaves are entire, simple, pointed and veined in a feather like arrangement.
b) Leaf blade (lamina) of fully developed cocoa leaves are usually about 20cm long and 10cm wide at its widest point
c) Leaves of some cultivars growing in heavy shade can be up to 50cm long.
d) The leaves have stomata on their under surface only
e) The number of leaves per unit area is influenced by light intensity which also influences the size and thickness of leaves
f) Those that develop under shade are large, thicker and greener than those in full sun

g) The length and thickness of leaf stalks (petioles) depends on whether they are on chupons or fan branches
h) Chupons have longer and thinner petioles
i) All leaf stalks have swelling, called a pulvinus at each end which allows the leaf to be orientated in relation to the light
j) In seedlings and young trees leaves are produced on the (chupon) stem as it grows
k) Leaves are produced on the fan branches by a series of "flushes" of three to six pair of leaves which occur 4 to 5 times a year
l) Leaf colour varies from pale green to dark purple, depending on the variety
m) The young leaves are soft and hang down from the branch but gradually "harden" and take up their typical orientation
n) All leaves becomes green as they harden
o) Development of new leaves leads to a demand for nutrients which partly met by translocation (movement) from older leaves
p) Leads to older leaves being shuddered by the tree
q) A number of older leaves that fall when flushing occur is a good indicator of a healthy tree.
r) Leaves normally have a life of about 12 months and most productive in the first 4 to 5 months

5) Flowers

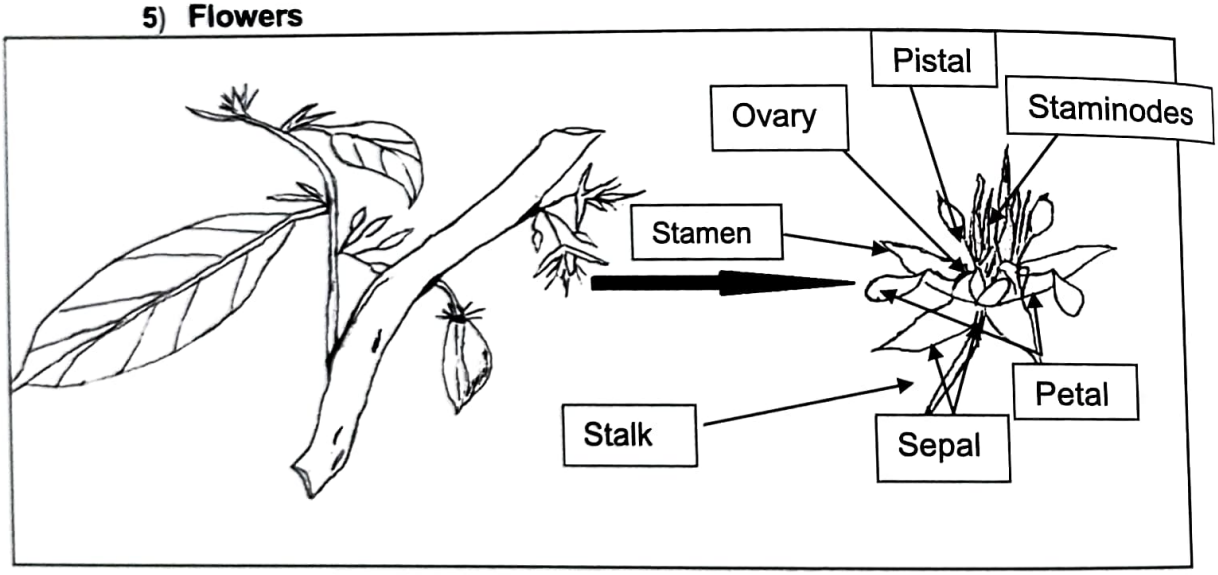


Figure 2.4: Showing a cocoa flower

a) Flowers develop from old leaf axils on the truck and branches on wood of a certain minimum physiological age
b) It can be as young as twelve months or less in very precocious hybrid clones, normally 18 months to two years
for hybrid planting material in Papua New Guinea

c) Leaf axils that have produced flowers for several years become thickened and are then called flower cushions
d) Cocoa trees produce large numbers of flowers at certain times of the year
e) In Papua New Guinea, there tend to be two main flowering flushes while some trees produce a few flowers and hence pods throughout the year
f) The small, usually pink flowers are borne on long pedicels (flower stalks) and have five sepals; five petals, ten stamens and an ovary of five united carpels
g) Petals have a narrow base but expand into a cup shaped pouch and end in a broad tip
h) Ten stamens are in two whorls or rings
i) An outer one of five non-fertile staminodes and an inner one of fertile stamens
j) A flower bud that is about to open can be identified by its round shape and the clear lines between the sepals
k) The bud starts to open in the afternoon and is fully open 12 hours later
l) The pollen is ripe by the time the flower is fully open and is released at this time
m) It remains viable for about 48 hours
n) The stigma matures a little later than the pollen
o) This is the best day for pollination and failure of fertilization on this day will cause flower to drop the following day
p) Individual trees carry large numbers of flowers with 50 or more developing on individual cushions
q) Only about 5% are pollinated and only a small proportion of these produce pods, i.e.: one in every 100 to 200 flowers matures into a ripe fruit

C) Compatibility

a) Certain trees called self- incompatible, cannot set fruit when self-pollinated because of genetically incompatibility
b) They need pollen from other trees, usually from self-compatible ones in order to set fruit
c) Self- compatible trees can set fruit with pollen from the same tree
d) The degree of incompatibility varies between different populations.
e) Amazon cultivars are self-incompatible, but are generally cross-compatible
f) Trinitario cultivars have a high proportion of self-incompatible trees requiring pollen from self-compatible trees for successful pollination
g) Cross-incompatibility may be limit yield, a risk that should be avoided with hybrids or clones cocoa by planting a mixture of the different hybrids or clones available rather than pure stands
h) The incompatibility is in the ovule (genetic incompatibility between the gametes) rather than the pollens incapacity to grow down the style

D) Pollination and Agents

a) Pollination does not necessarily mean that setting of fruit will result
b) Very small flying midges of the family Ceratopogonidae pollinate most cocoa flowers
c) Members of the genus Forcipomyia are most common in that family
d) They flourish in cool, dark and moist places and breed in rotting vegetation, including heaps of cocoa husks.
e) Other insects that are known to pollinate cocoa include ants of the genus Crematogaster, the dipteral Cecidomyiidae, thrips and leaf-hoppers.
f) These insects do not travel far, therefore, pollination is mainly between neighbouring tree

E) Fertilization

a) Cocoa fruit start to develop three days after the flower is fertilized
b) When the ovary is no sufficiently pollinated, flowers will drop off with 24 hours
c) As the ovary swells into a cherelle and ultimately a pod, the flower stalk develops into a stem sufficiently robust to hold the fruit
d) The early stage after fertilization is called the swollen ovary stage
e) From fertilization through to attaining full size, the fruit is cherelle. It takes up to 3 to 4 months. After this it becomes a pod and takes approximately another 2 months to ripen

F) Fruit

Figure 2.5: Showing a cocoa pod

a) After pollination the fruit develops and matures within five to six months.
b) Small proportion of flowers successfully pollinated, however, too many fruits often set for the tree to carry to maturity
c) Cocoa has a fruit thinning mechanism. Young cherelles do not drop off the tree
d) They stop growing, turn yellow a week later and blacken but remain on the tree
e) This is called cherelle wilt and occurs during the first half of the period of pod development
f) Cherelle wilting increase to a peak about 50 days after pollination, then decrease and rises to a second peak at 70 days
g) The peaks of cherelles wilting occur during the period of cherelle growing rapidly
h) Not all cherelles are lost to wilt. Phytophthora pod rot and other causes may also result in losses
i) Developing pods are called cherelles until no further wilting takes place. Become immature pods until they reach full size, become mature and ripe pods
j) Takes five to six months from pollination to ripening, depending on the variety and environmental conditions and weather
k) Unripe pods colour varies depending on the variety
l) Pod shape and size also vary considerably between different varieties

m) Most fully-grown pods are 15 to 30cm long and 10 to 15cm wide. Lengths and widths fairly common

n) Substantial variations, average pods weigh about 450 grams and contains about 110 grams of fresh weight beans

o) Inside the pod is filled with 5 rows of beans arranged length ways around central placental stem

p) Around the beans is the sweet viscous substance called mucilage

q) The fresh beans weigh at least one and half times as much as the mucilage

r) Pods usually contain 30 to 40 beans

G} Seed

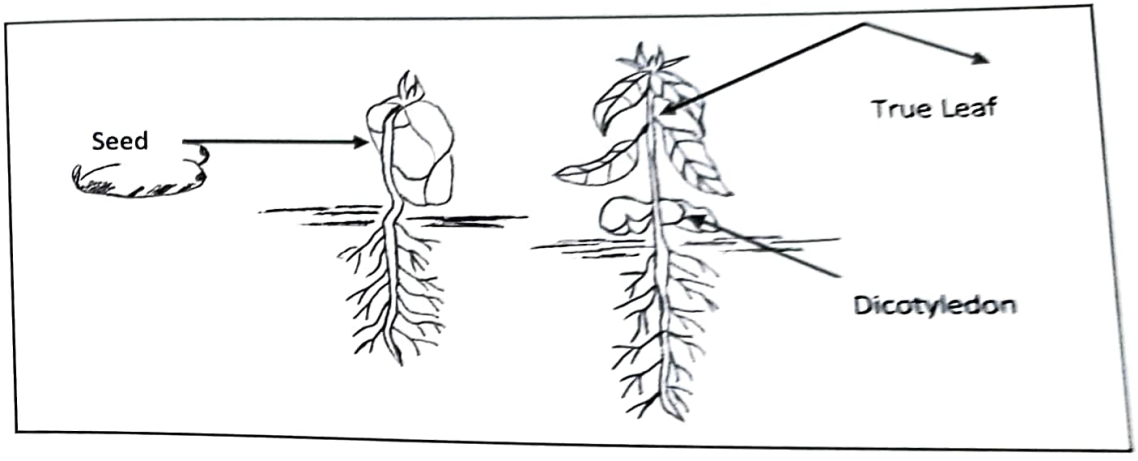


Figure 2.6: The cocoa Seed

a) Each seed or bean consist of two convoluted cotyledons and a small cylindrical embroyo, enclosed in the testa
b) Cotyledons colour varies from cream or very light mauve with criollo to deep purple with forasteros
c) Trinitarios (hybrid of the two) the cotyledon colour exhibits a broad range within those extremes of colouring but tends more often to be purple

H) Seedling germination and growth

a) Cocoa seedis non- resting as cannot be stored for very long
b) Mucilage contains a germination inhibitor and removing it with the testa speeds up germination
c) Healthy seeds from ripe pods usually give germination of 90 to 95%
d) Germination of cocoa is epigeal, where the cotyledons are lifted above ground level by the hypocotyls
e) In about 6 days after breaking through the soil surface, the hypocotyls grows 8 to 12 cm, where the cotyledons open up
f) This allow the plumule to start growing into the main stem
g) 15 days after sowing, the first four real leaves sprout
h) Internodes between the four leaves are very short so are at the same level
i) Stem continues to grow vertically and will become the main trunk

Teaching Strategies

A. Introduce unit/Motivational tool.
   1. Ask students to describe the habitat of Cocoa.
   2. Show a cocoa plant sample and ask to label its botany.
   3. Describe pollination.
   4. Show cocoa flower sample and ask to define functions of parts.
   5. Describe briefly the compatibility of Cocoa.
   6. Explain fertilization in Cocoa.
   7. Describe the development of a Cocoa pod.

B. Body/Content/Subject Matter

1. Use notes, Give correct habitat.
2. Use a cocoa tree sample to state correct parts.
3. Using notes, describe cocoa flower parts.
4. Use notes to define compatibility.
5. Use sample and notes to describe the fertilization of Cocoa.
6. Use notes and field trip/visit/exposure to explain pollination of Cocoa.
7. Use notes and field trip/visit/exposure, describe and explain Cocoa fruit development.

C. Closure

1. Orally ask students to:
   a) Give natural habitat
   b) Show botany of cocoa

2. Short test on habitat, botany, compatibility, pollination and fertilization, fruit to seed and seed germination.

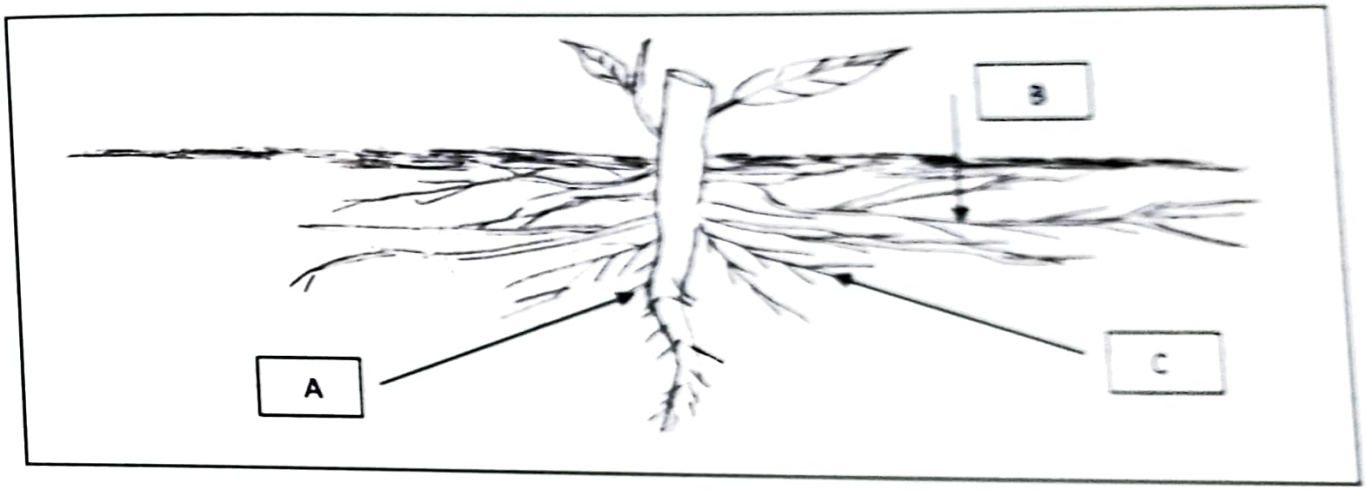
3. Mark (1 or 2) and evaluate student performance.

Student Activities

1. Describe the natural habitat of Cocoa

2. List and complete the botany of cocoa table below.

3. Label parts of cocoa roots



4. Describe the functions of the root system

5. Identify and label parts of a cocoa flower

6. Explain the process in of pollination

7. State the difference of self- incompatible and self- compatible.

8. Explain fertilization in a cocoa flower.

9. Write a page on fruit to seed development of cocoa.

10. Draw and label a Cocoa seed showing the cotyledons, the roots and the leaf

Practical/Experiential Activities

1. Teachers are encouraged to organize for resource people to come and discuss historical experiences

2. Teachers to arrange and organize field trips school cocoa plots, the nearby cocoa plot or to bring to the classroom cocoa tree parts to study the cocoa plant (examine the root system, leaves arrangements, flower parts, seed and tree formation).

UNIT 3: SOILS

Introduction

This covers the very essential medium for cultivation cocoa. Soil is a very complex field of study. The unit will give the students the basic knowledge on various factors of the soil and their importance. Thus the large area of field of study is brief given in the out comes

Learning Outcomes

End the end of this unit, the students can:

1. Physical Properties

A) Describe Soil Composition
B) Draw and label Soil profile
C) Explain Soil structure
D) Define Consistency
E) Work out Soil texture
F) Explain Moisture availability
G) Descried Root penetration
H) State Optimum soil texture for cocoa
I) Demonstrate Simple method of soil texture assessment
J) Carry out Method of soil texture assessment
K) Indicate Other soil characteristics- soil colour

2. Chemical Properties

A. Explain Soil reaction (pH)
B. List and state function of Soil nutrients (minerals)
C. Describe Organic matter content
D. Explain Cation Exchange Capacity (CEC)
E. Explain Base Saturation PBS
F. Define Exchangeable Bases
G. Compare soil Fertility

3. Drainage

A. Compare importance of Drainage
B. State Soil properties affecting drainage
C. Construct and explain the Soil depth
D. Show and describe a Slope
E. Assess stony ground for suitability for cocoa

Content

A) Soil Composition

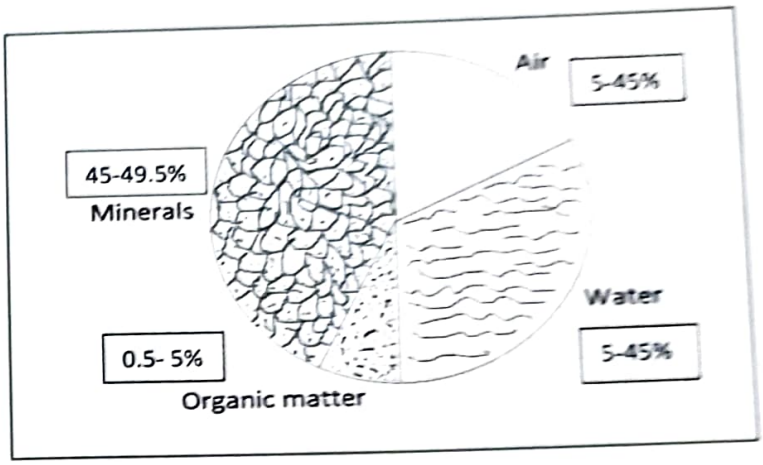


Figure 3.1: Soil composition of an average loam soil

Five main components

1) Mineral particles: inorganic fraction derived mainly from rocks broken by weather
2) Organic material: dead and decaying plants, animals and animal products
3) Water: the "soil solution" in which nutrient element for plants are dissolved
4) Air: which fills the space between soil particles not filled by soil solution
5) Living organisms: ranging in size from very small (micro-organism) to larger (macro-organisms) organism

Soils differ from one another because:

1. The components are arranged in many different ways
2. Particles in inorganic fractions differ in size, depending on the type and intensity of weathering and made up of many different minerals
3. The composition of organic material differ from soil to soil
4. Most soils have well-defined upper most layer or "top soil" merges sharply or gradually into other layers or horizons

B) Soil profile

Is the sequence of horizons designated surface, sub soils and weathering parent material as A, B, and C respectively where chemical, physical or biological properties of soil horizons may differ widely

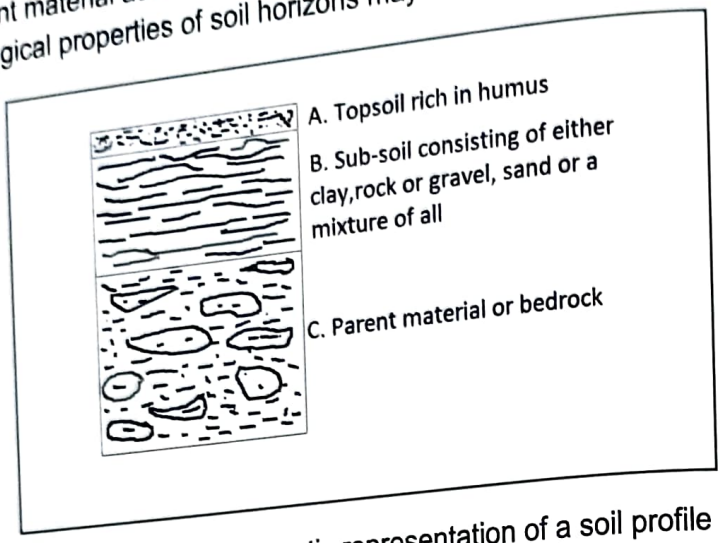


Figure 3.2: A diagrammatic representation of a soil profile

Figure 3.3: Soil Profile shown on a landslip

C) Soil structure

Refers to the manner in which primary soil particles (sand, silt, clay are arranged into group or clusters of primary particles. An important soil physical property for cocoa production

D) Consistency

It refers to the strength and nature of the cohesive forces within a soil and the resistance soil to mechanical disintegration, deformation and rupture. Consistency also depends on clay content and moisture content of the soil. Descriptive terms is the soil moisture conditions, wet, moist and dry

E) Soil texture

Soil Texture affects:

1. How easily roots can grow through the soil
2. The soil's water holding and drainage qualities
3. Its fertility and nutrient holding characteristics

F) Moisture availability

In relatively large surface area of clay particles (heavy textured) and abundance of micro- pores results in slower down ward water movement through the soil profile. Good for drier climates as retained water to sustain tree but a problem in wet climates, as roots will starve of oxygen as water fill all soil pores.

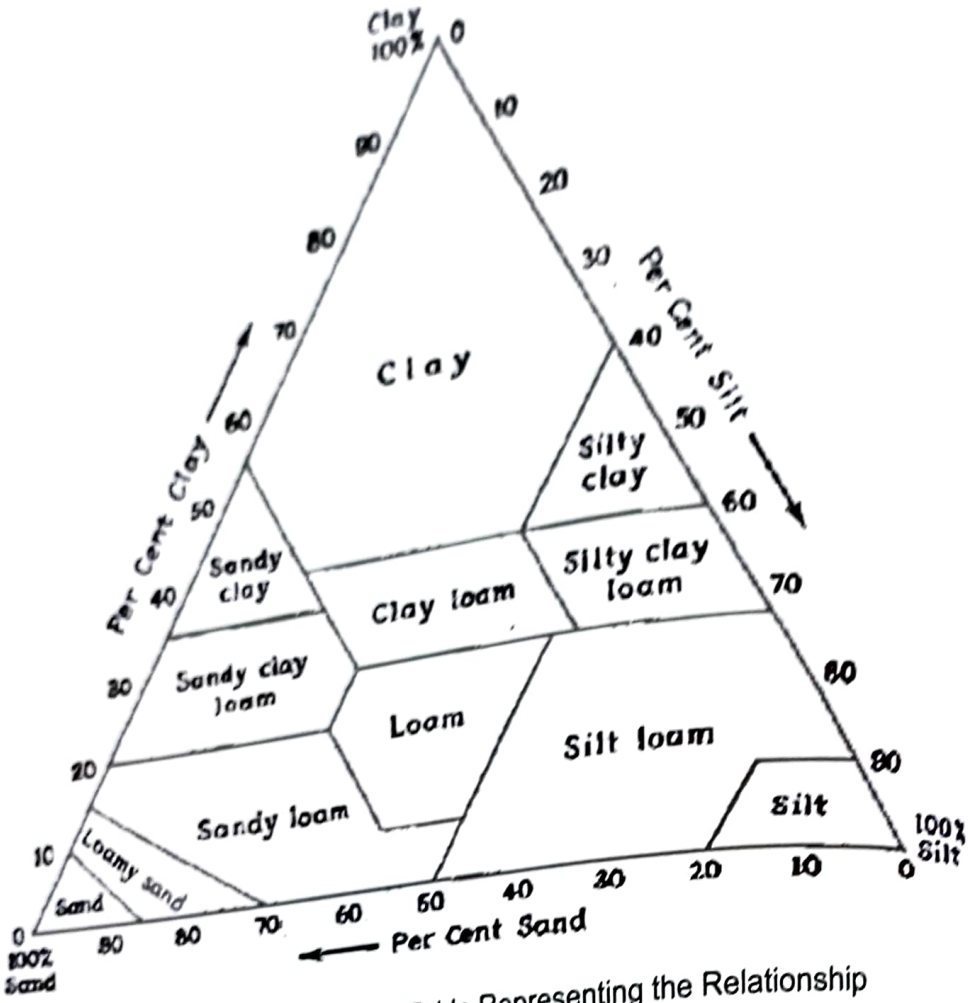


Figure 3.4: A Soils Classification Table Representing the Relationship between the class name of a soil and its particle size distribution

To use the diagram, the points corresponding to the percentage of silt, clay present in the soil under consideration are located on the silt and clay lines respectively. Lines are then projected inward: In the first case parallel to the clay side of the triangle, and in the second case, parallel to the sand side. The name of the compartment in which the two lines intersect is the class name of the soil

1. Lighter textured soils higher in percentage of silt and sand desirable in wetter climates as excess moisture can percolate down below the root zone fair quickly

G) Root penetration

Hard for roots to grow through heavier textured soil, soils with high clay conte
may restrict the development of the root system of cocoa trees, thus affect
aeration and root penetration

H) Fertility

1. Clay tend be more fertile, have more nutrients. Has greater cation exchange
2. Sands have a weak hold on nutrients because of the small total particle surface area and large pore size

I) Optimum soil texture for cocoa

The intermediate soil textures ranging from sandy clay loam to sandy clay are desirable. Soil of loamy is preferable because nutrients and moisture are retai

J) Simple method of soil texture assessment

1. Manipulate handful of soil between your thumb and forefinger with sufficient water to a state of maximum stickiness and plasticity
2. Working out all the lumps before applying the tests shown

L) Carry out Method of soil texture assessment

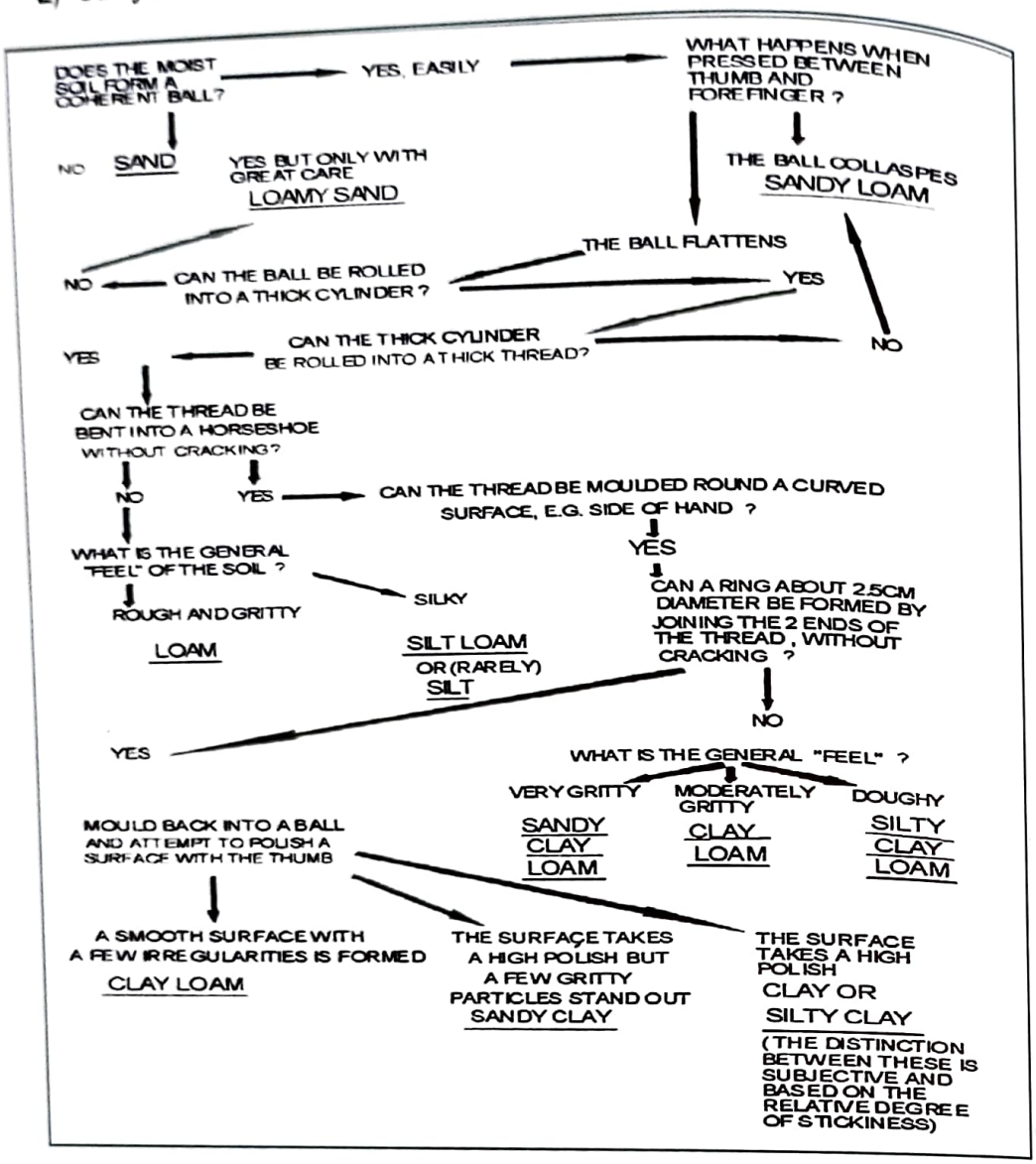


Figure 3.5: Shows the Soil Texture Assessment Method

L) Soil Depth

1. Mature cocoa tree grow on deep well drained soils, have bulky tap root penetrates a depth of 1.5 meters
2. Thin terminal roots penetrate deeper up to 3 meters in the soils
3. A high water table reduces effective soil depth

M) Soil reaction (pH)

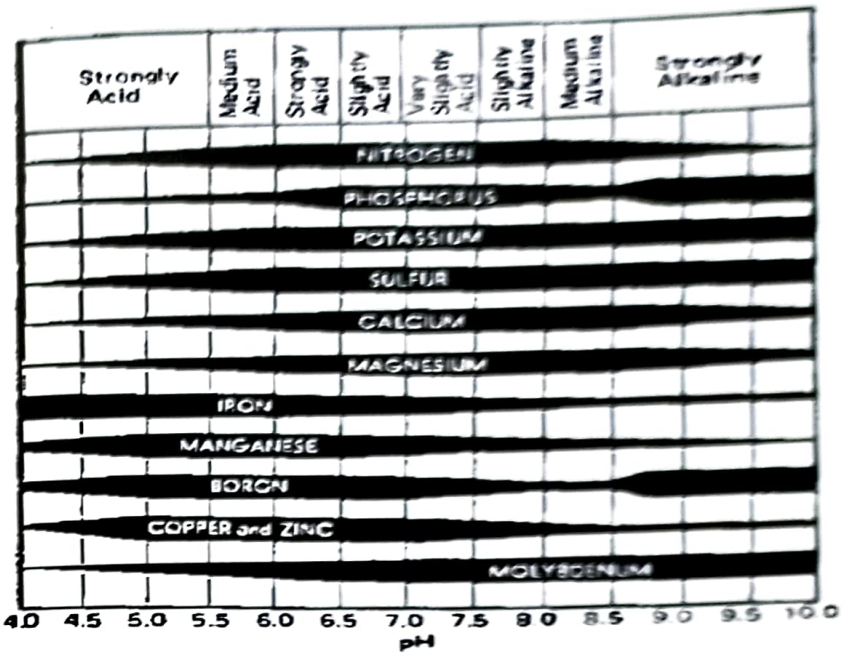


Figure 3.6: Showing Soil pH Effect on Nutrient Availability

1. The pH level has a large influence on the availability of most soil nutrients to plants
2. Most nutrients have their highest availability to plants in the pH rang of 6 to 8
3. PH value of close to 6.5 in the surface layer is ideal for cocoa cultivation but may have to select 5.5 and 7.5. Alkaline soils with free calcium carbonate often cause deficiencies of micronutrients such as iron, manganese, copper and zinc. Conversely, in very acidic soils these same micronutrients could have a toxic effect on cocoa

N) Soil nutrients (minerals) and fertility

Soils provide physical anchor for plants and a reservoir of the chemical elements essential for plant growth. Factors such as the pH level, organic matter content and cation exchange (CEC) of the soil affects the availability of nutrients

Soil nutrients

1. Fifteen elements are essential for plant growth and production

2. Three, carbon, hydrogen and oxygen are supplied by the atmosphere
3. Twelve by the soil. Each has a specific role in plant nutrient cycles

F) Macro-nutrients

1. Six macro-nutrients are used in relatively large quantities and are called major elements
2. These are Nitrogen, Phosphorous, Potassium, Sulphur, Calcium and Magnesium

Nitrogen features

1. Nitrogen is the primary element and an essential component of proteins which are the foundation material of all living cells
2. Nitrogen role is to make the plant green. The green colour of leaves and stems come from chlorophyll
3. Nitrogen is an essential ingredient of chlorophyll, the substance which plant use to process radiant energy from the sun into chemical energy in the form of carbohydrates
4. The pale and yellowy- green of leaves are deficient in enough nitrogen
5. Nitrogen supply will affect how much and how well a cocoa tree grows
6. The central role of Nitrogen in plants cells structure and physiology means the element need largest amounts
7. Nitrogen found in soils in different forms e.g. nitrate, nitrite, ammonia and ammonium that are of availability (to plants) and solubility
8. Plants absorb nitrogen in four forms, nitrate, ammonium ions, organic compounds such as amino acids and urea. Every tonne of dry beans produced, cocoa trees use about 35kg of Nitrogen

Phosphorous

1. Phosphorous is the primary element used by plants for cell division in the growth process and for energy exchanges in photosynthesis (getting the energy) and metabolism (using the energy)
2. Only available to plants in inorganic forms, primarily as phosphate
3. When tied up in organic compounds, has to be broken down by the soil bacteria before plants can use it
4. Inorganic form of phosphate can be unavailable if the soil pH is less than 6 or more than 8
5. Below pH 6, phosphorous is bound to aluminium or iron
6. Above pH 8 bound to calcium
7. For every tonne of dry beans produced, cocoa trees use about 7kg of phosphorus

Potassium

Potassium is the primary element and like nitrogen is needed by all living cells

1. Use in the physiological processes rather than as a constituent of plant structures like nitrogen
2. Play secondary role in structural development of a plant by facilitating the growth of roots, flowers and fruits and stem cellulose
3. Helps the plants take up and use nitrogen more efficiently
4. Enhances the efficiency of use of various other nutrients particularly phosphorus
5. Important for roles it plays in helping plants resist disease
6. Use soil moisture efficiently by plants using potassium to regulate osmotic pressure in cells to reduce evapo- transpiration and retain turgidity
7. For every tonne of dry beans produced, cocoa trees use about 65kg of potassium

Sulphur

1. One of three secondary major elements in most amino acids and most plants proteins
2. In structural function, sulphur also used by plants in physiological processes as a constituent of various vitamins and enzymes
3. In that capacity, sulphur used by plants to make chlorophyll but not a constituent of that substance
4. Sulphur is present in many organic form in the soil
5. Far more available for uptake by plants after soil organisms have converted it to inorganic sulphate form
6. Inorganic sulphate is soluble and this susceptible to leaching in light-textured sands and sand loamy
7. Deficiencies are best addressed with the application of gypsum (calcium sulphate) as does not change soil pH much, but displace sodium in the soil by cation exchange
8. For every tonne of dry beans produced, cocoa trees use about 7kg of sulphur

Calcium

1. Calcium is one of three secondary major elements on important cation in soil solution/ cation exchange complex of root zone
2. Like sulphur, it has structural and physiological roles
3. Found in cell walls of leaves and growing points of both shoots and roots
4. In combination with magnesium, it helps plants to regulate uptake of salts that has been dissolved in soil solution

5. Gypsum or Dolomite are good forms for applying this nutrient when is deficient in the soil
6. For every tonne of dry beans produced, cocoa trees use about 8kg of calcium

Magnesium

Magnesium is one of the three secondary element and important cation in the soil solution/ cation exchange complex of the root zone

Micro- nutrients/ trace elements

Required in smaller quantities. Zinc iron copper and manganese like potassium is import in the process of making chlorophyll but not found in the chlorophyll itself

I. Zinc

Plants need zinc to make proteins including enzymes that control growth and development. Water uptake is regulated by zinc containing substances. Over application of poultry manure or fertilizers containing calcium carbonate (lime) phosphorus or nitrogen can reduce availability of zinc. NPK fertilizer mixes and slow release of fertilizers contain sufficient concentrate of zinc

II. Copper

As in chlorophyll production, copper constituent of enzymes that play a role in metabolic process in plants

Deficiencies are rare but do in lighter sandy soil which receive a high rainfall due to leaching

III. Manganese

As well as chlorophyll production, manganese is important in the plant metabolism of carbohydrates and nitrogen. Deficiencies are rare

IV. Iron

As well as chlorophyll production, iron import in plant metabolism of carbohydrate in releasing energy from starches and sugars through a process of oxidization

Deficiencies are corrected by applying iron chelates

V. Molybdenum

Required in minute amounts, molybdenum is an important nutrient that enables plats to correct nitrate that they take up into amino acids which is key role in plant synthesis of protein

VI. Boron

Used in the uptake and efficient use of calcium. Important in plant physiology, cell reproduction and protein production. Has direct effect on crop productivity in its role in flower and fruit formation and pollen viability

Deficiencies shown as die back of terminal twigs, deformed leaves and flowers dying before opening and correct with borax

Some plants need extremely small amounts of chlorine, sodium and cobalt

Conjecture about the role of silicon plays in plant nutrition. In direct contribution, silicon can play a significant role in replacing phosphorus in bonds with aluminum in soils of pH lower than 6.0

Being released from these bonds, the phosphorus is free to be taken up by plants

These elements made available to plants through the breakdown of minerals and organic matter in soils

Availability of individual elements to plants in a particular soil depends on a number of factors:

1. The amount of nutrient present
2. The form in which it is present in the soil
3. Rate at which it is released from mineral particles or organic matter
4. Acidity or alkalinity of soil

O) Organic matter content

High contents provide high nitrogen level. This increases the cation exchange capacity (CEC) of the soil and improves soil structure. Helps bond mineral soil particles together in stable crumb structures that improve overall structure of soils

An average organic matter content 3.5% in the 15cm of the soil (1.75% organic carbon) considered as minimum requirement for cocoa

Carbon to nitrogen ratios (C: N ratios)

Is an indication of the type of organic matter present and the degree of humification or mineralisation

The value of C:N ratio of most PNG soils is within a range of 8-14:1 (8-14 parts carbon to one part nitrogen

C:N ratio greater than 30:1 will tend to starve plants

Undecomposed straws and leaf residues increase carbon ratio while legume residues high in nitrogen tend to reduce it

Sawdust has a 500:1 C: N ratio

P) Cation Exchange Capacity (CEC) Measurements

An N=measure of the total quantity of cations a soil can absorb through an exchange process (interchanging of a cation with another cation on the surface a soil particle). The measurement is usually expressed in units of mill equivalents per 100 grams of soil (meq%) or cmol/100g soil

C.E.C values vary from one soil type to another, depending on the type and amount of clay and organic matter

These soil particles are negatively charged and provide the attachment sites for the (positively charged) cations.

The more organic matter in a soil, the more attachment sites there for cations

C.E.C value varies from 10 meq%-20meq% for clay such as kaolonite in highly weathered soils in tropics and subtropical areas

To organic matter from 100 meq% to 200meq%

Organic matter also modifies the chemistry of volcanic soils, which further increases C.E.C. C.E.C values generally decrease with soil depth

For cocoa cultivation C.E.C values of 12-13 meq% of soil found on the surface horizon (0-15cm) and about 5 meq% at a depth 15-30cm (subsoil) are generally adequate

Figure 3.7: Diagrammatic representation of a colloidal clay crystal (micelle) with its sheet like structure, its innumerable negative charges and its swarm of absorbed cations

Q) Base Saturation PBS

A measurement expresses the proportion of the cation exchange capacity (C.E.C) that is saturated, or accounted for, by the exchangeable cations or bases (i.e. calcium, magnesium, potassium and sodium).

Does not distinguish between different bases and their relative proportion, gives a general indication of the soil pH, major minerals and weathering regime of the soil

Generally, availability of nutrients increases with their percentage of saturation

A value of 35% base saturation in the surface layer (0-15) can be considered adequate for cocoa cultivation

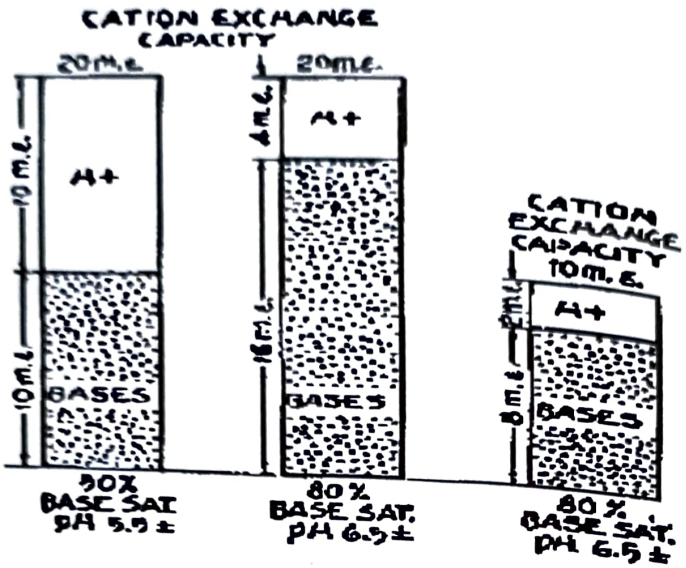


Figure 3.8: Diagram Explaining Percentage Base Saturation

There soils are pictured with percentage base saturations of 50, 80 and 80 respectively. The first is a clay loam, the second is the same soil satisfactorily limed, the third is a sandy loam with a cation- exchange capacity of 10 m.e. note especially that soil pH is correlated more or less closely with percentage base saturation. Also note that the sandy loam (right) has a higher pH that the acid clay loam (left) even though the latter contains more exchangeable bases

Note: Depending on the chemical methods used to measure exchangeable cations, some soils are base saturated at pH 5.0 which may explain why acid sensitive crops can be grown on such soil with pH value that 5.5 and why liming does not increase their yield

R) Exchangeable Bases

The lower limits for individual bases have set at about the following levels for the surface horizon for cultivating cocoa

1. Calcium – not lower than 8 meq/ 100g of soil
2. Magnesium – not lower than 2 meq/ 100g of soil
3. Potassium – not lower than 0.2 meq/ 100g of soil

Failure to meet these limits, suggest that problems of nutrition may not be easy to correct are likely to be encountered

S) Drainage

Soil properties affecting drainage

1. Soil moisture shortage
2. Poor soil aeration (caused by excess soil moisture)

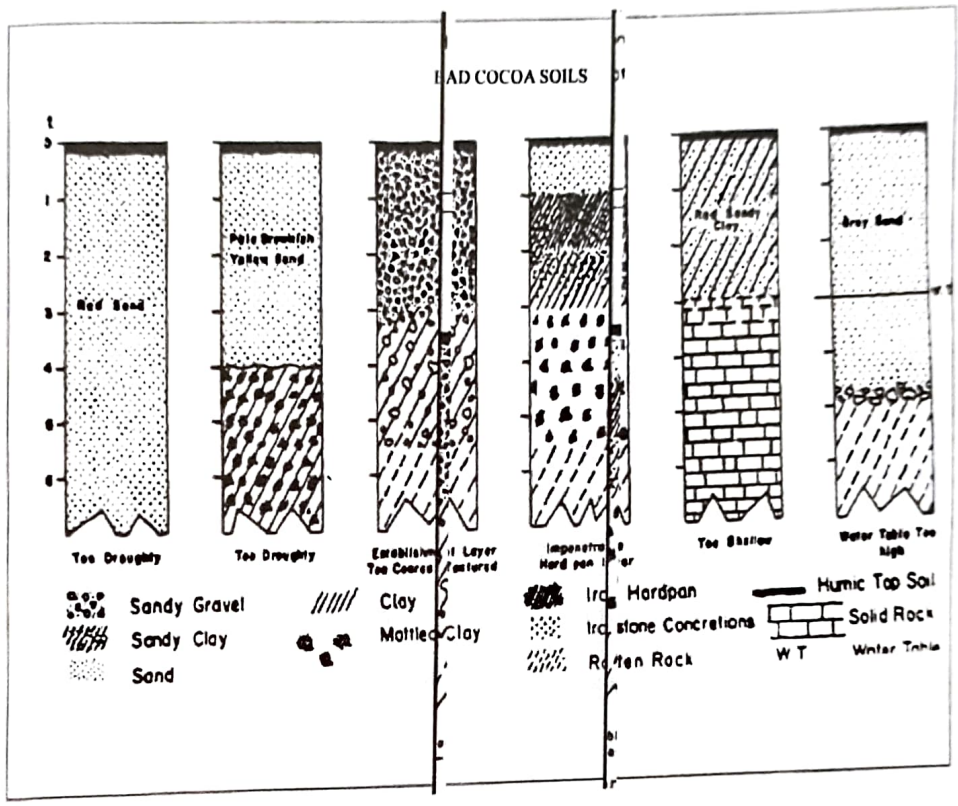


Figure 3.9: showing Bad cocoa Soils

Consideration is given to soils physical characteristics that determine the soil's ability to retain moisture. It is true in cocoa- growing areas with a wide variation rainfall amount received at different times of the year

Soil drainage qualities and related properties of moisture retention and aeration has to be considered in relation to prevailing climatic conditions and factors external to the soil as the topographical position which influence these qualities

Combination of

1. Adequate moisture retention
2. Good drainage
3. Good aeration (found only in strongly aggregated soils containing moderately high amounts of non-expanding clay minerals from the surface downwards- provides the ideal physical medium for cocoa in all situations

a. Soil with characteristics appreciably ideal is classified as "Good" (Class I).
b. Sandy textures soils in the top 40-50cm of the profile may have good properties of moisture retention only in the surface horizon, due to organic matter and in the deep subsoil. Such soils is satisfactory for cocoa and classified as "fairly good" (Class II) in areas where rainfall is moderately heavy and uniformly distributed
c. Soils be classed as "poor" (Class III) or even
d. "Unsuitable" (Class IV) in areas of marginal rainfall.

On the other hand, in areas of high rainfall, properties of aeration are of critical importance and soils with poor drainage, which may be desirably under dry conditions, would not be acceptable for cocoa planting

T) Slope

Cocoa trees may be able to establish on steeply sloping land:

1. Provided the soil is deep enough
2. Access later for weed control
3. Pruning
4. Harvesting may be difficult
5. Erosion during clearing and establishment in wet season, periods of intense rainfall

U) Other soil characteristics

Soil colour is

1. An important criterion in distinguishing soils of differing potential for cocoa
2. A valuable guide in judging the drainage characteristics
3. In the absence of exhaustive laboratory data, soil colour provides a crude measure of comparative nutrient status
4. Useful in the classification of soils into groups within which nutrient status is likely to be similar

"Good soils" (Class I)

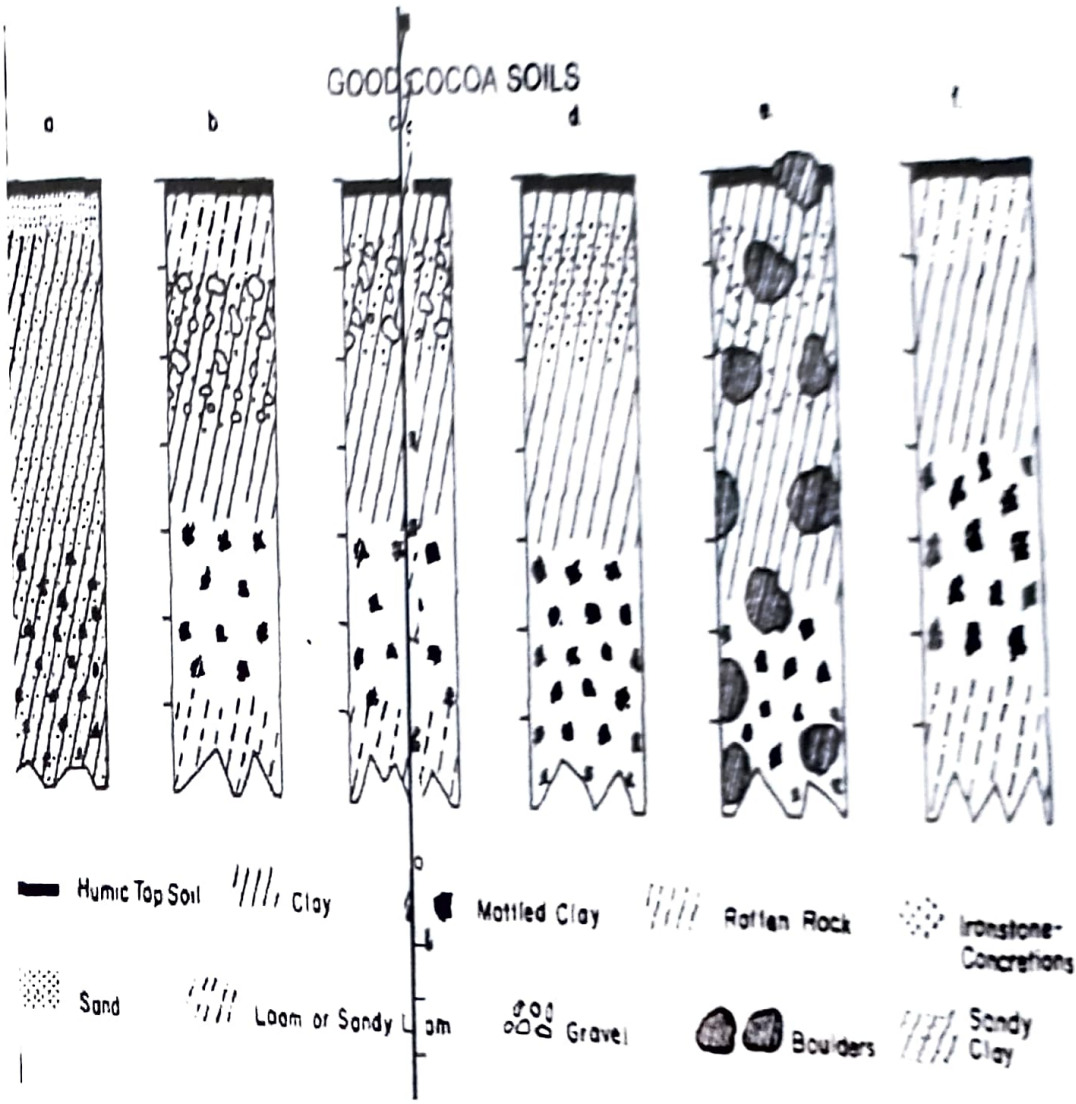


Figure 3.10: Showing Good Cocoa Soils

1. Show strongly developed red or dark-brown colours although, over calcareous rocks of recent alluvia, they may be dark brownish grey or even black.
2. "Fairly good" (Class II) Prudently classified as pale red, pale yellowish-red and yellowish brown soils
3. "Poor " (Class III) provisionally classified as pale yellowish brown and pale yellow soils
4. "Unsuitable" (Class IV) associated with very sandy textures and very pale colours

V) Assessing stony ground for suitability for cocoa

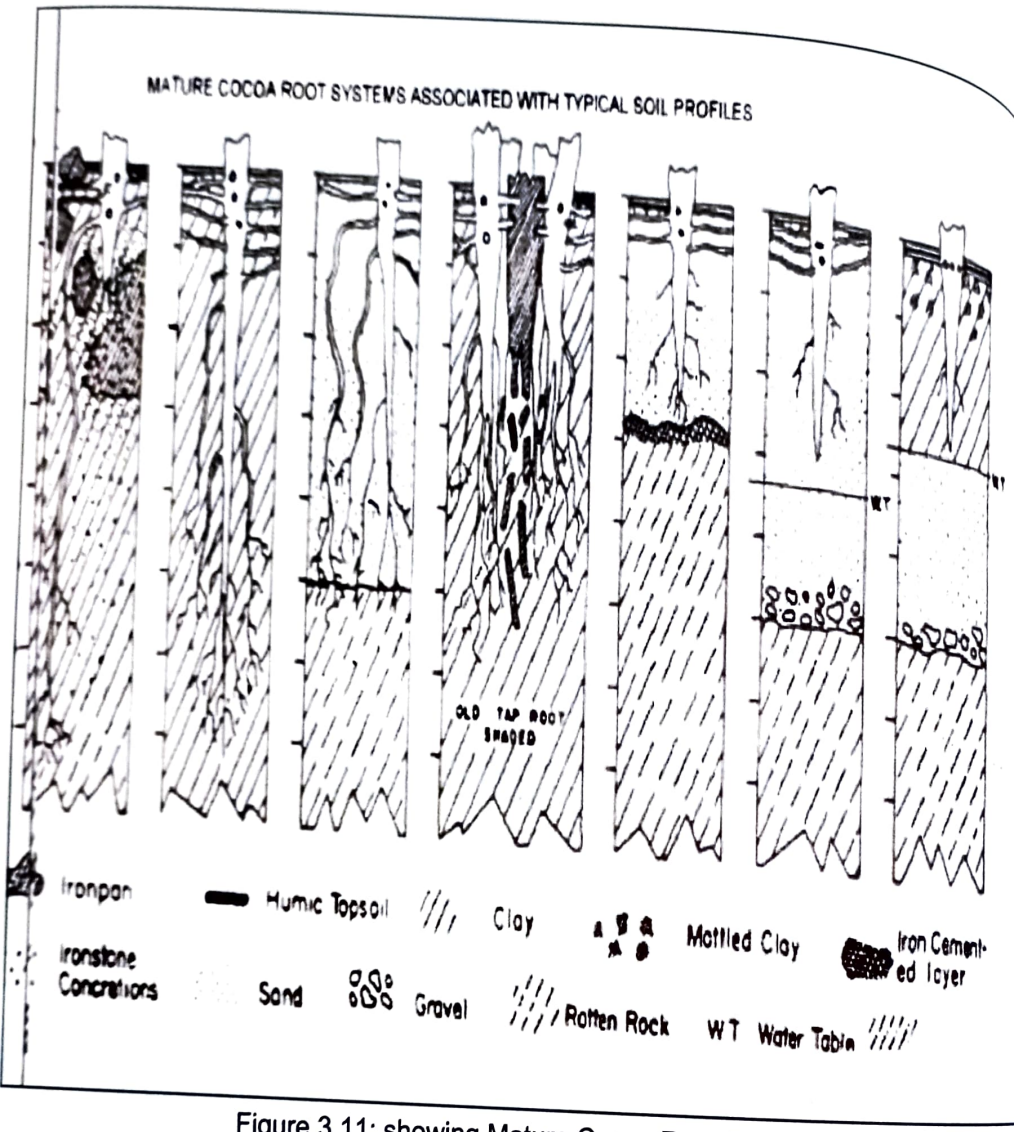


Figure 3.11: showing Mature Cocoa Root System

The amount of

1. Quartz stones
2. Gravel of ironstone concretions and of weathering rock and minerals are other criteria to be considered in assessing quality of soil for cocoa

Teaching Strategies

A. Introduction/Motivation

1. Prepare a soil profile in the cocoa plot or agriculture garden
2. Show and label soil profile with student
3. Take note of the special features of the soil profile

B. Body/Content/Subject Matter

1. Described soil textures of
    a) Sand
    b) Silt
    c) clay
2. Explain soil compositions
3. Demonstrate soil consistency
4. Outline well-structured soils

Use notes and field trip/site visits to describe and explain

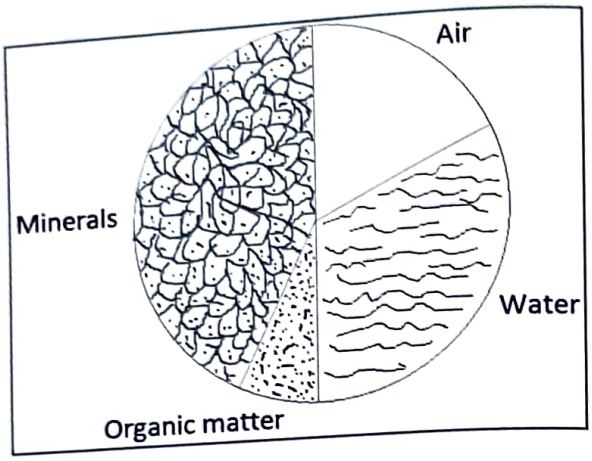
C. Closure

1. Orally ask students to:
    a) Give a describe soil profile
    b) Explain soil compositions

2. Short test on soil structure

Student Activities

1. Label the soil composition



3. Draw and label the Soil profile

4. Explain the Soil structure

5. Define Soil Consistency

6. Work out Soil texture

7. Explain Moisture availability in the Soil

---

8. State optimum soil texture for cocoa growing

---

9. Demonstrate a Simple method of soil texture assessment

---

10. Carry out the Method of soil texture assessment

---

11. List major soil nutrients (minerals)

---

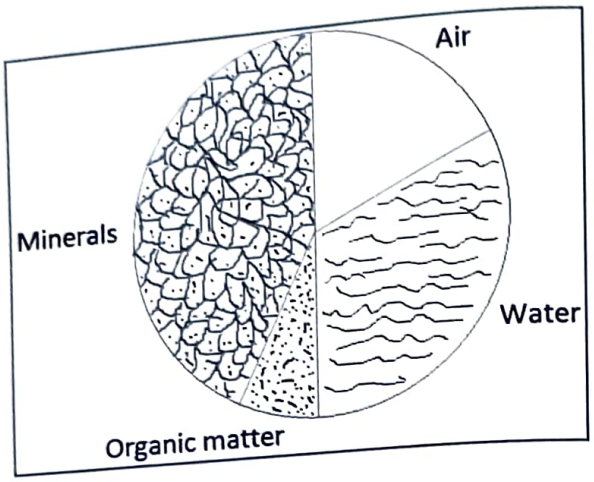
12. Describe

---

13. Organic matter content

Student Activities

1. Label the soil composition



3. Draw and label the Soil profile

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9. Demonstrate a Simple method of soil texture assessment

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10. Carry out the Method of soil texture assessment

---

11. List major soil nutrients (minerals)

---

12. Describe

---

13. Organic matter content

---

14. State Soil properties affecting drainage

15. Show and describe a Slope

16. Assess stony ground for suitability for cocoa

UNIT 4. COCOA BLOCK REHABILITATION

Introduction

Rehabilitation is the process of bringing a run down and unproductive cocoa block back into production

A cocoa tree can live for over 100 years but depending on how well it is looked after, may be productive for only 15 to 20 years. This is due to poor management such as pruning done badly or not at all leading to over shading, disease and insect infestation. If the block is not too run down rehabilitation may be achieved by restoring existing trees. This is typical involve one or more operation such as pruning, field grafting, fertilizer application, control of pest and diseases, weed control and shade thinning. However, if the trees are so bad, some degree of replanting will be necessary to rehabilitate the block. In the unit the student will cover the five main areas in the block rehabilitation. These are:

- Reasons for block rehabilitation
- Types of block rehabilitation
- Rehabilitation by replanting new tree
- Considerations in block rehabilitation
- Other operations associated with block rehabilitation

Learning Outcomes

At the conclusion of the unit, the students can:

A) Reasons for block rehabilitation
B) Types of block rehabilitation
C) Rehabilitation by replanting new tree
D) Considerations in block rehabilitation
E) Other operations associated with block rehabilitation

Content

A) Reasons for block rehabilitation

1. Increase the productivity of cocoa in an existing field without increasing the area occupied by the cropping new land
2. Less need for land

B) Types of block rehabilitation

Method one Pruning

Pruning open up canopy for sunlight and better aeration and improve access for management operations

(Refer to unit on pruning)

Method two Field Budding

If less than 10 years old, unproductive trees can be rejuvenated by grafting superior scion wood (preferably hybrid clones) on to them

Tools and materials for this operation:

1. Pruning saw or chain saw
2. Budding knife (must be clean and sharp)
3. Secateurs (must be clean and sharp)
4. Some copra sacks
5. Budding sticks
6. Budding tape
7. Rope or raffia for tying
8. Paint, fungicide (copper sulphate) and insecticide (Karate)
9. Paint brush

Selection of cocoa blocks for field budding

1. Blocks should not be older than 10 years
2. With a uniform stand of healthy looking trees
3. Unsuitable for blocks more than 15 years or
4. Heavily infested with VSD (Vascular Streak Dieback disease), ste canker and wood feeder insects Pantorhytes, Longicorn, Termite and Pansepta webworm
5. Neither suitable for blocks exposed to strong wind

Preparation of mature cocoa trees for budding

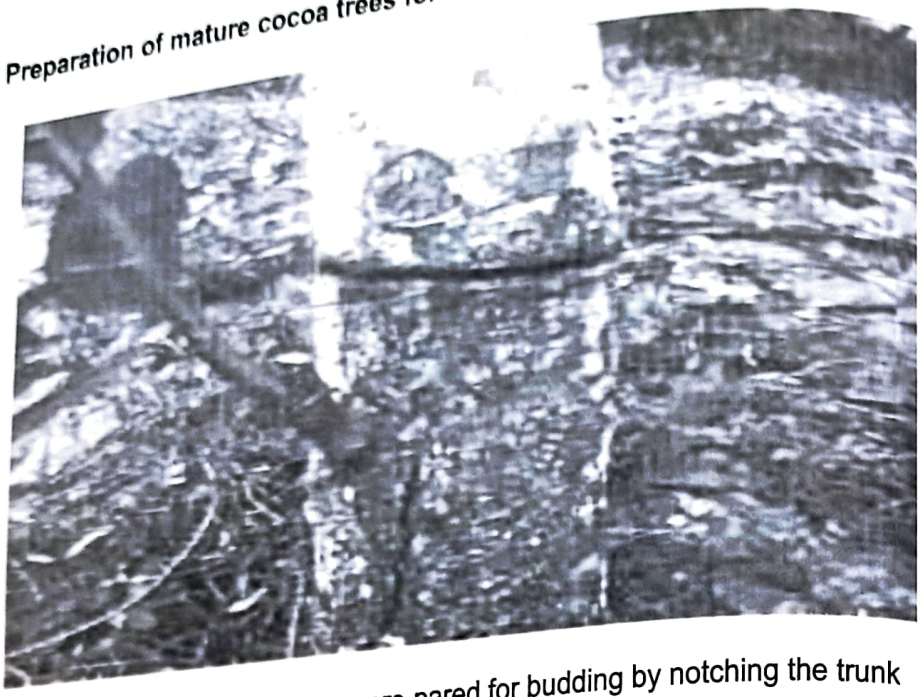

Figure 4.1 A mature cocoa tree pre-pared for budding by notching the trunk

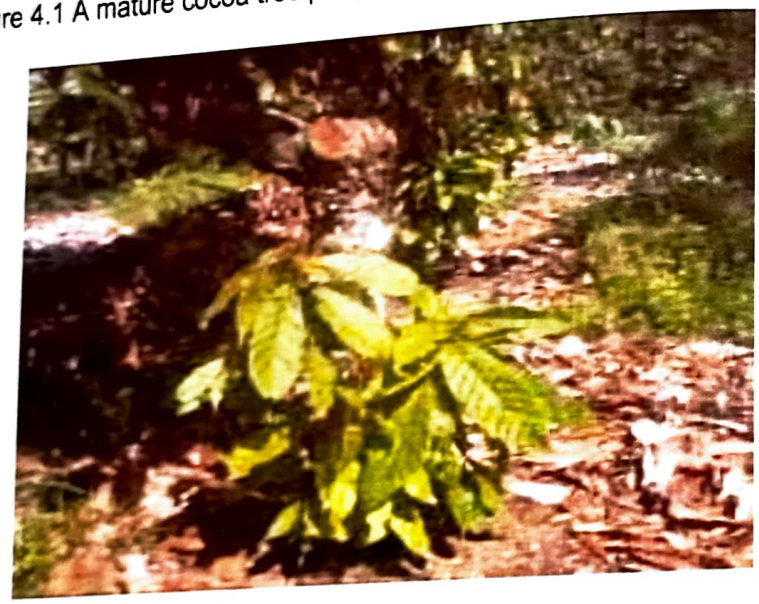

Figure 4.2: This chupon was induced by pruning off two of the main branches - the other way to induce chupons

Steps

1. Induce chupon growth by notching or
2. By cutting off one or two major fan branches with a chain saw or pruning saw

3. After one to two months after pruning select the 3 most vigorous chupons on the main trunk. Cut off rest with secateurs. Chupons from between ground level and 40 cm up the truck are best
4. Three to four months after pruning the chupons are ready for budding. They should be 8- 10 mm in diameter with hardened dark green bark that is starting to turn brown
5. Older chupons can be budded so long as older bud wood is used

Selection of bud wood

Figure 4.3:The bud stick before the leaves are cut off Figure4.4 The bud stick after the leaves have been cut off

Note the green and the brown colours on the bud stick

Always use 3-4 clones on the same block for pollination between self-incompatible trees and to maximise resistance to pests and diseases. You should never use only one clone!4. Collect the bud wood early in the morning and use it as soon as possible.5. Cut off the leaves from the bud wood stick immediately, but leave about 1.0 cm of the petiole. See **Figures 4.3** and**4.4**.6. Keep the bud wood moist by wrapping it in a wet copra sack or wet newspaper.

Bud Grafting the Chupons1.Select the two best developed chupons for budding.2. Remove all the lower leaves of the chupon for about 30 cm from its junction with the trunk.3. Prepare the bud wood by cutting a rectangular patch around the bud (about 6mm wide x 15mm long) but don't extract the bud patch just yet.4. Bud as close to the main trunk as possible. Make two vertical cuts about 20 mm long using a budding knife and connect them at their top ends by a horizontal cut so as to form an inverted "U" shape. The two vertical cuts should be about 7-8 mm from one another.

5. Peel the bark downward to form a "window" that is 17-20 mm long.6. Extract the bud-patch by holding the petiole and lifting it from the bud-stick using a gentle sideways and upward motion. Put the bud-patch into the "window" prepared on the chupon immediately.

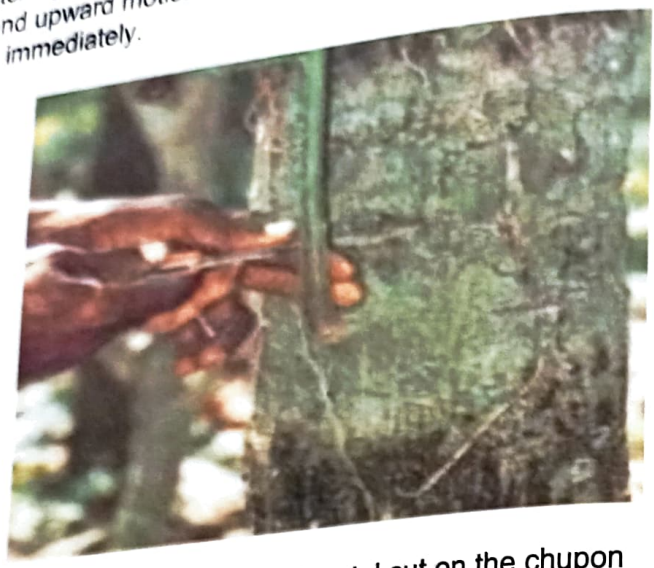

Figure 4.5: Making a horizontal cut on the chupon

Note how close it is to6-3the main trunk

Steps

1. Bud wood should be obtained only from authorized CCI or CCEA bud wood gardens
2. Follow CCI recommendations/ information on potential vigour of different bud wood material of which clones to use for field budding
3. Always use 3-4 clones not one on the same block for pollination between self- incompatible trees and to maximize resistance to pests and diseases
4. Collect the bud wood early in the morning and use it as soon as possible
5. Cut off the leaves from the bud wood stick immediately
6. Leave about 1.0 cm of the petiole
7. Keep the bud wood moist by wrapping it in a wet copra sack or wet newspaper

Bud grafting the chupons

Steps

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5. Peel the bark downwards to form a 'window' that is 17-20 mm long
6. Extract the bud-patch by holding the petiole and lifting it from the bud-stick using a gentle sideways and upward motion. Put the bud-patch into the 'window' prepared on the chupon immediately
7. Cut off the excess bark created by the inverted "U" cut on the chupon to leave a tongue of about 5 mm to hold the bottom end of the bud-patch. Similarly, cut the excess petiole above the bud eye
8. Tightly bind the bud-patch with budding tape, starting below the bud-patch and working upward to finish above the upper cut. Tie the tape off by pulling the end at the top under the previous turn. Make sure that there is sufficient over lapping of the budding tape to keep out moisture and that the bud patch is completely sealed
9. Remove the growing tip of the chupon leaving two or three leaves just below it so that moisture will be drawn through the chupon. This will help the bud

Showing bud patch removed

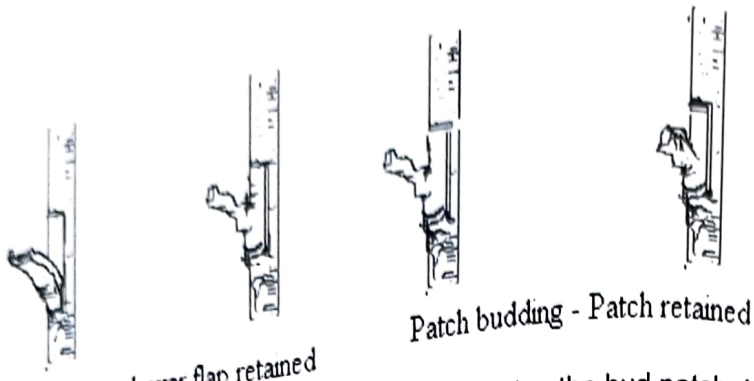


Figure 4.6 showing sequence of putch budding Extracting the bud patch. Note the window prepared on the chupon

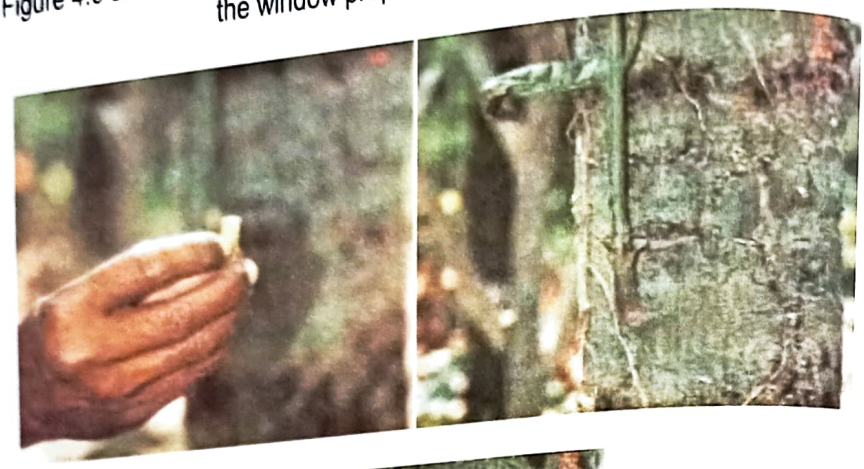


Figure 4.7: The extracted bud patch

Figure 4.8: Fitting the bud patch

Figure 4.9: Cutting off the excess of the chupon bark tongue

Figure 4.10: Initial wrapping with budding tape Figure 4.11: Wrapped bud-graft

Maintenance and care after bud grafting

Steps

1. Remove the budding tape 12-14 days after budding by cutting it with a budding knife on the opposite side of the chupon from the bud patch. If the bud has taken place it will still be green
2. If the budding is successful cut the chupon about 30 cm above the budding point
3. Check two weeks later. If the bud is dormant, cut a notch just above the bud patch to break the dormancy
4. Visit once a week and remove any new growth on the chupon to ensure the growth of only the budded clone (graft)
5. Tie the growing graft to the chupon stock using raffia to train it to grow vertically
6. If both buddings on a tree are successful remove the chupon with the least vigorous graft to allow the best one to thrive. If two shoots grow from a bud cut the lower
7. Cut back the chupon three months after budding or when the growing graft has fully developed (it will have some brown bark and dark green leaves). Ensure the cut is done at an angle 2-3 cm above the growing graft. The chupon is cut at an angle so water cannot sit on the cut and introduce disease
8. If the bud wood was taken from fan branches, cut the tip of the growing graft 3-4 months after budding or when it is about 50 cm long to induce lateral branching

9. Start formation pruning when the grafts are six months old
10. In windy areas, tie the graft to the main truck to prevent breakage

(See figure 4.13 below for a better appreciation of a finished bud grafted tree)

Figure 4.12: Remove the budding tape by the break dormancy

Figure 4.13: Cut a notch above to Cutting it on the opposite side of the chupon from the grafted bud

If necessary the chupon should be cut after removing the budding tape

Figure 4.14: Early growth of the bud graft. Figure 4.15: The chupon cut back 3months after budding

The lower graft branch should be cutit will have some brown bark and dark green leaves. Ensure the cut is done at an angle

Figure 4.16: Tie the graft with raffia rope. Figure 4.17: Cutting the tip of the growing graft

Figure 4.18: Side branches forming after the tip Figure 4.19: Root formation on the graft of the growing graft has been cut.

Figure 4.20: Pod production continues on the 'old' trunk. .Figure 4.21: Pod production continues on the new graft and branch while the new graft is growing.

Note the difference in the colour of the pods.

Treating the stock tree after bud grafting

Removal of main branches from the existing hybrid (or Trinitario) stock tree is done progressively until the new budded hybrid clones is producing pods.

Growers can harvest pods continuously

Initial heavy pruning induce chupon emergence

Progressive pruning after budding induces flowering and pod formation, especially on the old trunk

Steps

1. Progressively prune the remaining major fan branches at six monthly intervals starting six months after budding
2. Stump (i.e. cut off) the main trunk 16-18 months after budding, 60-80 cm above the union point. The cut should be at an angle to shed water
3. Paint freshly cut on the same day with a paint/fungicide/insecticide mixture to protect against canker and termites. The mixture is made by adding 30 g of copper sulphate and 30 ml of Karate (or any other suitable insecticide) to 4 L of paint. Repeat treatment if required

Method three: Stamping (Rejuvenation)

Involves complete stumping of mature trees suffering from physical damage or severe pest and disease attack to generate new healthy growth that can re-establish the productivity of the tree

The advantage is the speed of re-growth and relatively quick resumption of bearing

Main disadvantage, the original genetic material is re-growing rather than new clones that likely have higher yield or disease and pest resistant characteristics

Steps

1. Cut the trunk above 20 cm above the ground. Cut should be angled to shed water
2. Several chupon will grow out. When these are 10 to 20 cm tall, choose one healthy and vigorous chupon growing from the high side of the cut and remove the rest. This will encourage rapid callousing of the wound and the shoot will be less likely to break off. This shoot replaces the old growth of the cocoa tree
3. If the wood is infested with insects, remove it from the block.

B) Rehabilitation by replanting new tree

Removal of old unproductive cocoa trees and shade trees at same time

1. Stump the trees as close to the ground with axe or chainsaw
2. Cut surfaces of stumps should be painted with a mixture of Garlon and diesel (1 part to 80), or Kiltox and water (50:50), or Starane and diesel (1 part to 80), or Glyphosate ('Round Up') and diesel (1 part to 20) to kill stumps quickly and prevent root diseases building up
3. Garlon and diesel mixture is most effective but very expensive
4. Done on same day as tree is cut down to prevent root rot
5. On main land coconut can be poisoned by drilling a downward sloping hole into the coconut trunk with a brace and bit
6. Inject poison (such as Kiltox or even Gramoxone into the hole with a syringe and plug up the hole again
7. Or chop around the tree trunk with an axe and painting a 50% solution of Kilton and water on the axe wounds
8. In islands region, coconuts should not be removed due to too hard to re-establish due to beetles and Black Palm Weevils that kills most young palms

Methods of Block Rehabilitation by Replanting Trees

Various approaches to replanting diseased and senile trees

Method one: Complete block rehabilitation

1. Best but expensive
2. Clearing all old cocoa trees
3. Replanting with new clones under
4. Newly established shade trees
5. Sudden exposure of soil encourages weeds growth
6. Increases risk of soil erosion
7. Loss of income during the 2-3 years

Method two: Partial block rehabilitation

1. Overcome cash flow problems
2. Risk of soil erosion
3. Weed infestation
4. First replant either the worst affected individual trees scattered through the block or
5. All trees within a section of the block
6. When the new cocoa comes into production, other unproductive old trees can be replaced
7. Carried out over a number of years till all unproductive trees are replaced with high yielding hybrids or hybrid clones

Method three: Under planting

1. Existing old cocoa trees are pruned back to create about 50% shade
2. New clones or hybrid seedlings are planted
3. Old trees are gradually removed as new trees are established and come into production
4. Advantage is the ongoing production from old trees

C) Considerations in block rehabilitation

1. Problems with pests and diseases
    a. With partial replanting and under planting is diseases and insects can be passed onto the new cocoa
    b. When majority of cocoa trees are senile, diseased (VSD) or infested with Pantorhytes, all old trees should be removed and block completely replanted
    c. North Solomons is an exception where these problems are not present

2. **Over shading**
    a. Young seedlings planted under old trees with heavy canopy leads to the growth of young trees being weak and spindly from too much shade
    b. If black pod is present, seedling blight will be passed on to young trees

3. **Soil erosion**
    a. If soil lay bare by removal of old cocoa trees and shade, there will be loss of organic matter and nutrients
    b. Exposure of topsoil and a danger of erosion, especially in sandy loam soil

E) Other operations associated with block rehabilitation

1. Selection of materials for replanting from CCI PNG
2. Remarking
3. Reassessment of shade
4. Planting new shade

Teaching Strategies

1. Introduce unit/Motivational tool

State and describe reasons for block rehabilitation

2. Body/Content/Subject Matter

Demonstrate types of block rehabilitation
Use notes and field trip/visit/exposure, describe and explain

3. Closure

Orally ask students to:
Give reasons for rehabilitation
Show types of rehabilitation

Student Activities

Ring weeding base of plants	
Weeding between rows	
Removing chupons	
Infilling / replanting	
Earthing up at the base of cocoa tree	
All black pods removed	
Prune low hanging branches	
Harvesting up to date	
Weeds/grass used as mulch	
Structural pruning (remove diseased branches)	
Less lateral branches interlocking	
Shade planted and control	
Block mulched	
Pruning with right tools	
Disease pods removed	
Sufficient sunlight in the block	
Chupon regeneration	
Block generally neat and tidy	

2. Give the Reasons for block rehabilitation

3. Describe the Types of block rehabilitation

4. Demonstrate Rehabilitation by replanting new tree

5. State and explain Considerations in block rehabilitation

6. Describe other operations associated with block rehabilitation

UNIT 5: PLANTING MATERIAL

BREEDING

Introduction

Breeding is a complex process and it is the breeder's job to ensure that farmer must have the correct cocoa tree to produce cocoa in high numbers (hi.gh yield) and in the preferred quality by the market or consumers. They are other preferred characteristics such as pest or disease tolerant or resistance, taste type, pod color, adoptability to climate factors amongst others a breeder should look for when breeding cocoa. In this unit, the focus will be on understanding the basic principles of cocoa breeding

Learning Outcomes

At the end of the unit, the students can:

A. Define and explain breeding
B. Describe sexual or asexual (vegetative) reproduction
C. State features of Trinitaior, Criolo and Forestario
D. Describe the difference and the relationship between Trinitaior, Criolo and Forestario
E. Describe budded cocoa
F. Explain hybrid cocoa and how breeders achieve hybrid cocoa
G. Discuss how clone is obtained
H. Demonstrate breeders' role by selecting the appropriate pods size with high yielding and resistance clones.

Content

Genetic Materials

Criollo

Figure 5.1: Showing the features of criollo cocoa

Pool husk- soft, red in color and produces an average of 20-30 number of seeds per pod of cocoa. Other special features include:

1. White "ivory or very pale purple
2. Ferment quickly
3. Produce fine flavored cocoa
4. Nowadays, cultivated only on small scale
5. Difficult to establish, low yielding, sensitive to environment stress
6. Susceptible to insect pest and diseases

Foresterios

Figures 5.2 & 5.3: Showing features of Foresterio cocoa

The Foresterio cocoa produces:

1. Bulk cocoa, accounting for about 80% of the world cocoa production
2. Pod husk- hard, green, average number of seeds per pod- 30 or more
3. Beans=small, flat
4. Colour of cotyledon pale to deep purple
5. High yielding

Two knows Foresteros cocoa varieties are:

1. Upper Amazonian Foresteros
2. Lower Amazonian Foresteros (Ametomada)

Trinitario

1. Hybrid between Criollo and Forestero
2. Pod husk, mostly hard, variable in color
3. Number of seeds per pod- 30 or more
4. Cotyledon, variable in color
5. White beans rarely occur

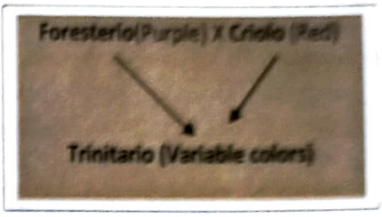


Figure 5.4: Illustration of the cross between Forasteros and Criollo to produce Trinitario.

Cocoa genotypes have been assigned to one of these groups on the basis of vegetative, pod and seed characteristics butany intermediate types are now known and the significance of classification is declining

Selection of Characteristics

1. Early high yielding capabilities is the main thing aimed for when selecting promising varieties of cocoa
2. Either for distribution to the growers or breeding purpose
3. Some of the significant characteristics are usually combined with good management

Therefore, the grower aim would include

1. Regain and desirable shape and size of plant
2. Resistance to pest and diseases like VSD, black pod and phantorhytes attack
3. Pods per tree
4. Good pod, beans size

Quality of beans

1- Governed by the like and dislike of the manufacturers and
2- Generally they look for the bean size greater than 1 g in weight, high fat/ low shell content

Clones/hybrids

Hybrid

Is an individual or type of cocoa produced from sexual union between two parents that are genetically not identical

Difference between HYBRID and a CLONE

1. A hybrid is obtained from sexual reproduction is involved in that the progeny have genes from the two parents (female and male). The male and female contribute genes that provide characteristics such as high yielding, early maturity, pest tolerance or resistance, color or taste of cocoa, etc.
2. HYBRID- Clones are produced asexually meaning they are produced from vegetative material that is a hybrid. Vegetative means that the seedlings are produced from parts of cocoa such as buds, cuttings and root stock.
3. In general terms- All individual produced through sexual propagation (except) in case of self-compatibility) can be considered hybrids, but in plant breeding the term is restricted to crosses between two very unlike parents of two different species, strains or varieties that produce a progeny with a profound characteristic like high yielding.
It is mainly VIGOUR of some kind such as high yielding that breeders are looking for which means to make the seedling (or tree) produce better and be sustained over a period of time.

Seed selection and treatment

1. Hybrid seeds for planting must be obtained from a certified source.
2. Authorized distribution nurseries are all supplied by CCI as it operates the only authorized seed garden in PNG.
3. There the pollination is all controlled by totally closed hand pollination techniques. (Therefore no room for accidental cross-pollination)
4. Batches of seeds prepared for authorized distribution nurseries are mixed so as to contain the full range of SG2B category. Hybrids in the correct ratios recommended by CCRI. SG2B category hybrids are preferable, because they produce vigorously growing seedlings.

Self-compatible means that they cannot set fruit when self- pollinated because of genetically incompatibility
They need pollen from other trees, usually from self-compatible ones in order to set fruit
Self-incompatible: Trees can set fruit with pollen from the same trees are used in cross-pollination

Cocoa hybrids produced by LAES were crosses between the Amazonians and the Trinitario types of cocoa. Those were the first seed garden parent materials selected mainly for VS Dresistance and Yield performance

This is summarized in table 4.1

Clones

A group of plants derived through asexual propagation from one original plant with characteristics preferred by breeders, and later by farmers. In this case, the characteristics of the parent cocoa are maintained

1. Because there is no sexual process involved in the multiplication members of the clone are genetically the same
2. They have the same inherit possibilities and will respond similarly to identical environment and management

Advantage

The desired parental characteristics are maintained for example pest and diseases resistance, high yielding and flavour among other characteristics are maintained. Uniform respond is obtained from the members given identical environment and management

Disadvantage

1. Pest and diseases out break will affect the whole population of plants in the same area
2. Undesirable characteristics is passed on
3. Planting material cannot be stored for a long time nor can be easily transported
4. May have serious incompatibility problems if the original plant is self-incompatible
5. Planting material can become scarce at times

Table 5.1: SECOND SERIES OF HYBRIDS RELEASED FOR RESISTANCE TO COCOA POD BORER

CLONE	CCI-P	CCI-B2	CCI-B2	CCI-B	CCI-P
PLANT CHARACTERISTICS					
Growth Habit	Semi-Erect	Semi-Erect	Erect	Semi-Erect	Semi-Erect
Trunk Circumference cm^2 (1)	42.8	42.0	43.9	44.2	44.2
POD AND BEAN CHARACTERISTICS					
Pod Length	15.6	16.3	15.8	20.1	20.1
Pod Width	7.7	8.5	7.6	8.4	8.1
Pod Apex Form	Acute	Obtuse	Attenuate	Acute	Caudate
Pod Weight (g)	415	526.8	375	414	455
Wet Bean (%) (2)	28.2	26.2	30	25.9	26.8
Average dry bean weight	1.2	1.2	1.5	1.2	1.04
Butter Fat Content (%)	56.7	55.7	59	56.3	56.4
YIELD					
Pod Value (3)	25.3	23.6	18	20	25
Yield Potential (4)	3700kg/ha	1800kg/ha	3500kg/ha	3700kg/ha	2500kg/ha
PEST AND DISEASE					
Black Pod(5)	MR	HR	R	MR	R
Vascular Streak Dieback(6)	MR	HR	R	R	R

Cocoa Borer – ADSI (7)			2.3	2.2	2.4
Pod Hardness (8)	4.5	5.0	3.1	4.7	3.8
COMPATIBILITY	Self-Compatible	Self-Compatible	Self-Compatible	Self-Compatible	Self-Compatible

1. DESCRIPTION OF THE BIG CLONES- (CCI-BIG series)

The CCI-B variety consists of five big stature hybrid clones as CCI- B1(K9),CCI-B2 (K4), CCI-B3(21-4-8), CCI-B4(K6) and CCI-B5(17-2-16). Three clones, CCI-B1, CCI-B4 and CCI-B5 have medium size pods while CCI-B3 has bigger pods and CCI-B2 has smaller pods. All five clones have good fat content with being the highest with 59% fat content. Shell contents for all five clones are generally less than 20%. The pod values for the five clones range from 18(CCI-B3)-26.8(CCI-B5).All five clones are self-compatible meaning that they can be self-pollinating.

Table 5.2: SECOND SERIES OF HYBRID COCOA CLONES, TOLERANT TO COCOA POD BORER

CLONE	CCI-5 	CCI-5 	CC S3 	CC 4 	CC S5 
PLANT CHARACTERISTICS					
Growth Habit	Semi-Erect	Erect	Semi-Erect	Semi-Erect	Semi-Erect
Trunk Circumference cm^2 (1)	34.9	34.5	37.4	42.6	41.2
POD AND BEAN CHARACTERISTICS					
Pod Length	14.7	17.1	19.7	15.8	15.5
Pod Width	8.0	8.1	9.1	7.8	7.6
Pod Apex Form	Acute	Mammilate	Acute	Acute	Obtuse
Pod Weight (g)	490	615	655	505	405
Wet Bean (%) (2)	25.1	28.8	28.8	33.4	24.9
Average dry bean weight	1.3	1,4	1.4	1.2	1.0
Butter Fat Content (%)	55.5	56.9	56.4	57.0	55.0
YIELD					
Pod Value (3)	22.3	20	22	17	25
Yield Potential (4)	3100kg/ha	2400kg/ha	2300kg/ha	3400kg/ha	2500kg/ha
PEST AND DISEASES					
Black Pod (5)	MR	R	HR	MR	MR
Vascular Streak Dieback (6)	R	R	R	MR	HR

Cocoa Pod Borer – ADSI (7)	1.2	1.5	2.6	1.2	1.1
Pod Hardness (8)	4.0	3.8	5.5	4.7	3.8
COMPATIBILITY	Self-Compatible	Self-Compatible	Self-Compatible	Self-Compatible	Self-Compatible

2. DESCRIPTION OF THE SMALL CLONES (CCI-SMALL series)

The CCI-S variety consist of five small sized hybrid clones and are classified as CCI-S1(15-4-7),CCI-S2(16-4-2),CCI-S3(37-2-10),CCI-S4(83-3-8) and CCI-S5(13-3-2).Average pod weights for the small clones ranges from 405g (CCI-S5) – 655g(CCI-S3). The clones CCI-S2 and CCI-S3 have big pods while the other three have medium and small pods. All five clones have butterfat contents of 55% and above with CCI-S4 being the highest with 57%. Shell contents for the five clones in general are less than 20%. Pod values for the clones also range from 17pods (CCI-S4) – 25pods (CCI-S5). All five clones are self-compatible meaning that they can be self-pollinated.

Figure 5.5: Small clones cocoa pods

Figure showing cocoa pods from small clones which will give the value of beans per pod per tree during harvest

Their Cocoa clones named and their tree size and the categories, which is further summarized in table 7.2.2

Figure 5.6:BigClones Cocoa Pods

Figure showing cocoa pods from big clones which will give the value of beans per pod per tree during harvest.

Big clones is referring to the size of tree as summarized in table 7.2.2

Table 5.3: Disease ranking of CCI released poly-clonal hybrids

Clone Name:	Size of Pods	Phytophthora resistance scale*	VSD resistance scale*
TA 101 16-2/3	Big	Resistant	Resistant
TA 102 36-3/1	Big	Resistant	Susceptible
TA 103 37-13/1	Big	Moderately Resistant	Resistant
TA 104 73-2/2	Big	Moderately Resistant	Resistant
TA 301 17-3/1	Small	Resistant	Moderately Resistant
TA 303 34-13/2	Small	Resistant	Moderately Resistant
TA 304 63-7/3	Small	Moderately Resistant	Resistant
TA 305 73-14/1	Small	Moderately Susceptible	Resistant

The table above is showing the two CCI final released hybrid clones. A comparative level of field infection with pod rot relatively to K82 (Resistant) and KA2-101 (Susceptible). This means that the clone will show this characteristics when mature and in production.

As a breeder, one will select the resistant variety when compared with susceptible varieties. From the table TA 101 16-2/3 is a recommended clone as it is resistant to both cocoa diseases and produces big pods. In the small size pods cocoa, if your cocoa plot is high in VSD infestation, you have to prefer TA 305 73-14/1 but if you plot is high in phytophofora infestation, you should select TA 301 17-3/1 or TA 303 3413/2.

Table 5.4: Canopy size of cocoa of released clones

Clone Name		Size (1)	Pod length(cm) (2)	Pod width (cm) (3)	Pod Value (4)	Yield Index (%) (5)
TA 101	16-2/3	Big	16.6	8.0	18.0	211
TA 102	36-3/1	Big	16.8	9.0	15.6	210
TA 103	37-13/1	Big	17.9	10.2	13.3	230
TA 104	73-2/2	Big	16.4	8.5	16.8	183
TA 301	17-3/1	Small	18.4	7.1	24.9	192
TA 303	34-13/2	Small	14.1	8.2	26.8	135
TA 304	63-7/3	Small	13.3	7.8	23.9	161
TA 305	73-14/1	Small	13.6	7.0	23.9	207

The above table shows results five factors of size, length, width, pod value and yield. TA 103 is preferred as it has higher yield index for big pods while small pods, TA 305 is the preferred type because it produces higher yield index.

The table 7.2.2: is showing some of the following features of the clones. The reasons for preferring large canopy are as follows:

1. Size of tree according to canopy
2. From the Penducle to the distil end
3. The diameter of the pod in the centre
4. Is the average number of pods required to produce 1 kg of dry beans
5. Is the yield across all sites from the start of production to the end.
   compared to K82 (100%),
   the high yielding clone.

Orders for seed should be directed to: Chief Executive Officer, C.C.I. – PNG Locked. Bag 1846, Rabaul 611, East New Britain Province. Phone: 938 9108 / 938 9131Fax: 983 9115

Important information for recipients of cocoa seeds are:

1. VSD free areas such as New Ireland, Bougainville, Manus, Bali & Witu Islands and the islands of Milne Bay must have a quarantine certificate with each shipment of seed.
2. Bud wood and pods must never be sent to these VSD free areas, as that is a breach of PNG Quarantine Laws.
3. When ordering hybrid seeds, ask for seeds that have been treated against seedling blight.
4. These seeds are soaked in metalaxyl fungicide at the rate of 10 grams in one litre of water for 10 minutes.
5. Treated seed can be shipped to all areas of the country.

TEACHING STRATEGIES

Introduction/Motivation

Teacher should ask students thought stimulating questions like:

1. Why is it that each child in the family is different in features?
2. Why is that, a twin in a family are similar in features?

Relate to cocoa or plants…

1. Why are cocoa seedlings from the same parents different in their features?
2. Why is that in plants like flowers and sweet potato, when cuttings are used, they produce flowers and tubers with similar features?

Now we shall study this unit in details but first review sexual and asexual reproduction in science class…

Body/Content/Subject Matter

Teacher can give this as homework prior to class for students to refer to science and get their meaning

1. Define sexual reproduction and asexual reproduction or vegetative reproduction
2. Do research into and describe meiosis and mitosis in genetic?
3. Explain pollination, self-pollination, hybrid, vigor, compatibility and uniformity?
4. Explain cocoa breeding and what features breeders look for in breeding
5. Discuss why in cocoa breeding we clone, graft and marcobit cocoa?
6. Name breeds that are recommended for cocoa and why?

Closure/Conclusion

1. Relate sexual reproduction in Human and animals
2. Discuss the differences in variations in sexual reproduction and relate to human example in motivational questions
3. Discuss variability and uniformity in the context of breeder selection of cocoa trees.

Student Activities

Complete the table by searching the definitions to the following terms

Terms	Definitions
Hybrid	
Clones	
Hybrid Clones	
Fertilization	
Self-Incompatible	
Self- compatible	
Pollination	
Resistance	
VSD	
Black Pod	

Match the definitions below with the terms listed below

Terms	Definitions
	Pool husk- soft, red in color and produces an average of 20-30 number of seeds per pod of cocoa.
	Bulk cocoa
	Hybrid between Criollo and Foresterio
	Natural pollination between flowers of the same tree
	The pollens and flowers come from another tree

Answers

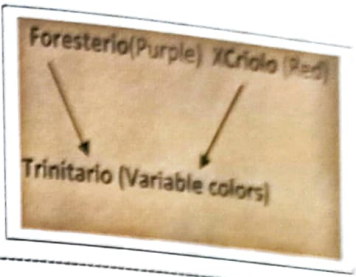
Open pollination, Cross pollination, Criollo, Trinitario, Foresterios,

Student Activities

A. Describe the features of a Criollo cocoa

B. Describe the features of Forestericia

C. Explain the diagram below (Consider is of breeding, hybrid and compatibility)



Explain this table and recommend which of the varieties and why?

Clone Name:	Size of Pods	Phytophthora resistance scale*	VSD resistance scale*
TA 101 16-2/3	Big	Resistant	Resistant
TA 102 36-3/1	Big	Resistant	Susceptible
TA 103 37-13/1	Big	Moderately Resistant	Resistant
TA 104 73-2/2	Big	Moderately Resistant	Resistant
TA 301 17-3/1	Small	Resistant	Moderately Resistant
TA 303 34-13/2	Small	Resistant	Moderately Resistant
TA 304 63-7/3	Small	Moderately Resistant	Resistant
TA 305 73-14/1	Small	Moderately Susceptible	Resistant

UNIT 6: GENERAL NURSERY MANAGEMENT

Introduction

Nursery management requires a number of important nursery practices. Because nursery is a place to look after small and young plants from seed germination to the stage they are ready for replanting to the field each management practice has to be discussed and understood well by students.

Learning Outcomes

At the end of the unit, the students can:

A. Name the management practices in a nursery
B. List the types of nursery to be built in the n
C. Describe water, shade, fertilizer, weed, pest & disease control requirements for cocoa seedlings in the nursery
D. Discuss control measures and the major management requirements of fertilizer, weed, pest & diseases occurrence in the nursery
E. Describe other management requirements in a cocoa nursery

Content

General nursery management of seedlings grown from seed:

1. Watering to keep soil in the seedling bag moist all times
2. Each seedlings should receive about 100mls of water at each watering, so every hectare's worth of seedlings (about 1000 seedlings) will need 100 litre of water for each watering
3. Use watering can or bucket and empty tin fish can (425 g) with holes punched in the bottom with a hammer and a nail from inside so water flows properly. Such tin-fish 'watering can' holds enough water for two seedlings
4. Seedlings should emerge about 6-8 days after sowing
5. Seedlings to be used as root stock for juvenile budding should be ready after two weeks in the nursery
6. At that stage the hypocotyls will have lifted the now open cotyledons at 10 cm above the soil and
7. The first true leaves will appear on the rapidly growing stem and
8. Till this stage seedlings will require watering every day
9. Beyond 15 days (seedling fully emerged), watering only every second day provided the soil stays moist
10. A germination rate of 90% is considered normal
11. Management and regulation of shade is important for young cocoa seedlings and involves use of correct type of shade cloth
12. Quick growing living shade species such as Gliricidia need regular pruning to keep shade at the right level

13. Four weeks before planting out, increase light levels to harden off the seedlings by progressively heavier pruning

Shade

If *Gliricidia* is used as shade, correct shade levels of 30-50% must be maintained by regular pruning. Similarly, if palm fronds are being used, they should be checked often to make sure that they are still providing the right amount of shade.

At least one month before the seedlings are planted out in the block, start removing the shade, a little bit at a time. This is to harden-off the seedlings.

Water Requirements

The buddings should be well watered - preferably every day. The shoots grow rapidly and water is needed to maintain steady growth. Growth will be severely affected if water is limiting.

Fertilizing

Growing the stock tree may deplete soil nutrients in the poly bag so the buddings may respond well to an application of fertiliser. After the leaves and stems of the buddings have hardened, apply 15 grams (approximately one matchbox full) of NPK fertilizer to the soil surface of each budding.

Weed Control

Weeds growing in the polybag compete with the developing bud for sunlight, water and nutrition. They can also harbor diseases and attract leaf eating insects such as grey weevils, which damage young cocoa leaves. Therefore weeding should be done regularly. Weed control can be done by hand or with chemical spray, but remember that careless use of herbicides (chemical sprays) can kill both weeds and crop seedlings. Therefore:

1. Never use a spray tank that has been used to spray herbicides to spray insecticide or fungicide. Herbicide residues can kill seedlings.
2. Don't spray on windy days as the spray may drift onto and kill the cocoa seedlings.
3. Chemical weed control is best done before seedlings are in the nursery. Use a broad spectrum

Contact herbicide such as Gramoxone or a systemic herbicide such as Fusilade or Round-up for weed control prior to the emergence of the seedlings. Control weeds by hand weeding when seedlings are in the nursery. The nursery area should also be weed free to minimise the chances of introducing any pests and diseases. Use mechanical, or with extreme care chemical measures for weed control around the nursery perimeter.

Disease Control

The nursery needs to be monitored for disease outbreaks on a daily basis, so that any problem can be treated early and quickly. Treating a problem early is usually cheaper and more effective, particularly as young trees in the nursery are at the most vulnerable stage of their life. Treat any significant disease problems using the control measures outlined in Chapter 9 and PNG CCRI

Information Bulletins 1-12.

Seedling Blight: Seedling blight is one of the major disease problems that occur in nurseries. It is caused by the fungus Phytophthora palmivora and can kill or seriously set back seedlings. A Phytophthorainfection will affect the seedling from the top down. The fungal spores infect the young leaf flush and green stems, causing dark brown spots that spread rapidly to kill the growing

point. The disease is often a problem during the wet season. It can be controlled by applying a spray mixture of 50 g of metalaxyl 0.5% WP (Ridomilplus 72 or Laxyl Copper) mixed with 10 litres of water all over the plant with a knapsack sprayer that has not been used for applying herbicides. Seedlings grown from seeds treated prior to sowing by soaking in metalaxyl fungicide may need to

be sprayed with metalaxyl (10g of product per litre water) at about six weeks of age for continued seedling blight control. After six weeks, the lower leaves of the seedlings have hardened and outbreaks of seedling blight should be rare. If blight does occur after metalaxyl treatment, the affected plants should be removed from the nursery and burnt. **Rhizoctonia**: If seedlings are showing symptoms of disease from the base of the stem up, the pathogen is more likely to be Rhizoctonia. This is another fungus. It can be controlled with an application of a benomyl or oxyquinoline based soil fungicide.

Insect Pests of Cocoa Seedlings

Treat any significant pest problems using the control measures outlined in Chapter 9 of this publication and PNG-CCRI Information Bulletins 01 and 43-58. The nursery should be monitored for insect infestations on a daily basis, so that any problem can be treated early and quickly. If leaf feeding insect pests such as caterpillars or psyllids become a problem, a spray of 40g

Orthene 75 and 2ml surfactant in 10 litres of water may be needed for control. If snails or slugs are a problem, spread snail pellets or dried tobacco leaves around the seedling beds. Be careful when using snail pellets that non-target species are not poisoned.

More details on controlling the insects that are most likely to be pests in cocoa nurseries are presented below.

Grey Weevils

Damage

Grey Weevil adults damage young cocoa by chewing off the half-hardened bark of the cocoa shoots as well as the leaf stem. They also sometimes feed on and damage the leaves, in which they make small 'shot-holes'. Damage by Grey Weevil can stunt or even kill cocoa seedlings. There are many different kinds of Grey Weevils in different parts of PNG, and they feed on many different host plants. Other host plants include: Aibika, Apple, Avocado, Bananas, Broom stick plant, Brussels sprouts, Cabbage, Capsicum, Carrot,Celery, Choko, Citrus-Mandarin, Citrus, Coffee, Cocoa, Celery, Dahlia, *Desmodium*, Europeanpotato, French bean, *Gliricidia*, Guava, *Hibiscus*, Hollyhock, Lima bean, Macadamia, Maize, Monstera", Mulberry, Onion, Orchid, Passionfruit, Pawpaw, Pepper, Pumpkin, Rhubarb, Russian comfrey, Strawberry, Sunflower, Soya bean, Silver beet, Strawberry, Thistles, Tea, Wing bean.

Chemical Control

Grey Weevil adults can be controlled by insecticides. Up to six spray rounds at two-weekly intervals may be necessary to control a severe infestation. Both cocoa and *Gliricidia*, if present, must be treated. It may only be possible to spray *Gliricidia* trees if they have not grown too high. Repetitive treatments are required to kill adults emerging from the ground over a period of three months.

Sometimes it may also be necessary to blanket spray insecticides on weeds in a block recently planted with young cocoa seedlings.

Pyrethroid insecticides such as the following can be used:

1. Karate (L-Cyhalothrin)
2. Decis (Decamethrin).
3. Fastac (Alpha-cypermethrin)

To prepare 10 litres of spray, mix together: 28ml of one of the three pyrethroid insecticides listed above ("Decis", "Karate" or "Fastac"), 2ml of surfactant, 50ml of sticker and 10 litres of water. The same quantities and reagents are used when mixing up any of the three insecticides. These three insecticides have good residual activity (*spray stays on plant longer*). Insecticides should be applied with a knapsack pressure sprayer using a nozzle with a flow rate of about 230ml per minute. Spray the tree evenly but not to "run off" as this is a waste of chemical. Each seedling should be sprayed for up to 15 seconds.

Cultural Control

Locating the nursery at least 100 metres from the nearest cocoa trees will help minimise the number of weevils that move from the field into the nursery. Control by hand any weeds that grow after the seedling has emerged. Weeds are a food source and habitat for weevils. Therefore control any weeds that grow in or near the nursery by hand or very careful applications of a herbicide. Hand picking of adult weevils does not reduce weevil populations significantly and is not recommended.

Biological Control

There are few natural enemies of Grey Weevils - populations seem to be regulated mainly by weather and habitat. Although Crazy Ants effectively control some pests of cocoa, such as Mirids and *Pantorhytes*, and give some control of Grey Weevils in the field, they are of little use for controlling weevils in a nursery.

Cocoa Root Chafer

Damage

Cocoa Root Chafer is a serious pest of young cocoa throughout Papua New Guinea. The larvae of these beetles feed on cocoa roots. When a larva chews the tap root of a young seedling, the plant dies. There are a number of different species of Root Chafer that attack cocoa in Papua New Guinea. Each kind is found in a different part of the country, although some areas may have more than one kind.

The main species we know about are as follows:

1. Dermolepidauniforme,
2. Dermolepidameeki,
3. Dermolepidaundatum,
4. Dermolepidanoxium,
5. Dermolepidanigrum

Cultural Control

Old food gardens should be removed and especially those crops which grubs like to feed on such as taro. This has to be done some months before planting cocoa. All Chafer larvae, pupae or adults found in the area should be destroyed.

Biological Control

A Scoliid wasp (*Campsomeris sp.*) has been seen parasitising the larvae. No other information is available on this parasite. Other natural enemies of Root Chafer are fungal diseases, nematodes and birds.

Chemical Control

Young cocoa seedlings can be protected from the larvae using an easily applied granular insecticide called "Chlorpyrephos". It can be applied inside the poly bag first before the seedling is planted or applied inside the hole before planting the seedling. This insecticide gives good control for a long time. The application rate is 2 grams of Chlorpyrephos (Suscon Blue) granules for one plant. Mix it in the soil in the poly bag before sowing or sprinkle it inside the hole before planting the seedling in the field.

Mealy Bugs

Damage

Mealybug adults and nymphs feed on cocoa shoots, pods, and flower cushions. Severe damage to the shoots of young seedlings can deform or kill them. On mature cocoa, damage to pods or flowers can reduce yields.

Chemical control

Mealybugs need to be controlled only if they are present on cocoa seedling shoots in large numbers. They can be controlled by spraying with Malathion and White Oil in the following mixture:

1. 30ml Malathion 50, (0.15%)
2. 100ml White oil,
3. 2ml Surfactant,
4. 50ml Sticker,
5. 10L Water

Apply the mixture with a knapsack pressure sprayer using a nozzle with a flow rate of 230ml per minute. Spot spray only those seedlings that are infested with the pest. Apply the chemical evenly, but not to "run off", as this is a waste of chemical.

Other Aspects of Nursery Management

1. Selecting Seedlings for Planting Out

You will need to look after your seedlings for about 3-4 months in the nursery before they are ready for planting out in the field. At 3-4 months they should be about 0.5 of a meter tall, or as high as a man's knee and about the diameter of a pencil at their base. When the seedlings are big enough choose **only the best** of them for planting out on the block. Throw the others away. This may seem like a waste, but is a lot less of a waste than the money lost by having unproductive trees taking up space in the block.

2. Nursery Records

Setting up and running a nursery is an important part of establishing a block and a significant expense. Costs of nursery construction and operations need to be properly recorded so that the block can be run well and managed as a profitable enterprise. The farmer must know how much the nursery operation is costing to help determine if he/she is making any profit. Records of the following nursery activities need to be kept:

1. Costs of materials (keep receipts) and any hired labour used to build the nursery. This should include the cost of transporting the construction materials from the shop to the nursery site.
2. Costs and an inventory of the equipment used for the day to day operation of the nursery such as watering cans, wheelbarrows etc.
3. Recurrent costs and inventories of consumables such as pesticide chemicals, poly bags, seeds, and energy costs of running the irrigation system and if collected off site, soil.
4. The dates of each activity/management operation such as when seeds are planted into planting bags.
5. A monthly stock takes of seedlings in the nursery.
6. How many seeds are ordered and delivered for each planting.
7. The number of seedlings planted out or dispatched to customers.

Teaching Strategies

Introduction/Motivation

1. Teacher to connect or link the sub-unit on nursery establishment with the sub-unit on nursery management. Using the link on a nurse have set up the nursery in the hospital to look after the infant that is premature, discuss what are the management skills needed to raise the premature infant:

2. Get student into groups to discuss the requirement of nursery management and report back to class for a summary.
    a. Put student into equal groups with a gender equal numbers
    b. Appoint a leader to chair the discussion
    c. Appoint a recorder
    d. Conduct the discussion
    e. Group recorder to represent the summary of discussions

Body/Content/Subject Matter

1. Teacher to set up the groups and supervise the group discussion
2. Upon completion of group activity the teacher should coordinate the summary on the board
3. Teacher to ensure the content in the sub-unit are covered in the summary

Closure/Conclusion

1. Teacher should give time to students to copy the summary note
2. Dismiss the class when the notes have been copied

Student Activities

Complete the table by searching the definitions to the terms listed

Terms	Definitions
Shade	
Water Requirements	
Fertilizing	
Weed Control	
Disease Control	
Seedling Blight	
Chemical Control	
Cultural Control	
Biological Control	
Seed selection	
Nursery Records	
Cocoa Rot Chafer	
Mealy Bugs	
Grey weevil	

UNIT 7: COCOA BUD WOOD GARDENS

Introduction

Most of the cocoa currently being grown in Papua New Guinea is hybrid material grown from seeds. The new hybrid clones are produced by either juvenile budding or conventional bud grafting, using buds from selected clones. These buds are taken from young shoots, usually called bud wood or bud sticks, from trees grown specifically for the purpose in a small block of cocoa known as a bud wood garden. The establishment and maintenance of a bud wood garden is basically the same as for any other block of cocoa, but attention needs to be paid to some matters, to ensure that the bud wood garden meets its objectives. The major difference between a bud wood garden and a normal block of cocoa is that the "crop" is sticks of bud wood, not beans from pods. This means that the bud wood garden has to be managed differently. These differences are discussed in the section on cocoa bud wood garden maintenance (Section 4.4.1 on the next page).

Learning Outcomes

At the end of the unit, the students can:

A. Plan a bud wood garden
B. Plant the Bud wood garden
C. Describe management requirements of a bud wood garden

Content

Planning the Bud Wood Garden

1. Timing of operations

The timetable for planting a bud wood garden is the same as it is for any block of cocoa. Temporary and possibly also permanent shade must be planted, the planting points for the cocoa must be lined and the planting holes dug just prior to planting. All these matters are covered in other parts of the manual. The budded seedlings that will be planted in the garden will be in the nursery for two weeks longer than seedlings if the juvenile budding technique is used, or for three months longer if conventional budding is used.

2. The size of the bud wood garden

The size that the bud wood garden needs to be will depend on how much bud wood it will have to supply each year. Harvesting of bud wood can start in the third year after planting. At this age, about 20 sticks of bud wood, each

containing five to eight buds, can be taken from the trees every three months, giving a total of 80 sticks per tree per year. A good budder can obtain a success rate of over 90 percent, but for planning purposes a figure of 80 percent should be used, so that an extra 20 % of buds must be provided to produce the required number of budded plants. Hybrid clone varieties – Big, Intermediate and Small – consist of four or five clones each. When a farmer requests a certain hybrid clone variety, he **must** be given equal numbers of plants or bud sticks from each of the clones for that variety that are recommended for his area. A bud wood garden must contain all the clones of all varieties that are recommended for that area.

It is very important that the different clones are clearly labelled at all stages, from collection of bud sticks to the nursery and to the bud wood garden itself. It is also important that the bud sticks are not mixed when they are being harvested; one way to minimize this risk is to plant the different clones in rows that run across the whole width of the block. This reduces the risk of the person accidentally harvesting bud sticks from different clones as he walks through the block.

3. Planting the Bud Wood Garden

The budded seedlings for the bud wood garden can be planted in exactly the same way that other hybrid clones are planted. Refer to Section 5.3.3 on page 5-6. All the clones, Big, Intermediate and Small, can be planted at a spacing of 4 m x 2 m; that is, 4 metres between rows and 2 metres between plants within rows. This is because the regular pruning to maintain the production of young shoots and harvesting of bud sticks effectively reduces the inherent differences in plant size and competition. One additional and extremely important point to remember is the crucial importance of being able to correctly identify every single plant, so that plants from different clones are not mixed up during planting. It is worth labelling every plant with the hybrid clone variety and clone number as soon as it has been budded, with a label that will last until after the plants have been planted in the bud wood garden. A plan of the bud wood garden should be drawn, showing the position of each clone. One copy of the plan will be kept by the person responsible for running the bud wood garden and copies will also be sent to the provincial, regional and national headquarters of CCEA.

4. Maintaining the Bud Wood Garden

Maintenance of the bud wood garden can be considered under a number of headings: drainage shade control, weed control, pruning, and fertilizer. The techniques for each of these operations are described in other sections of this manual. This section contains additional points that refer specifically to bud wood garden.

Drainage

Adequate drainage is essential for healthy growth of the trees in the bud wood garden and drains that were dug when the block was being developed must be maintained. Any additional drains that become necessary in low-lying areas should be dug as soon as the need for them becomes apparent. Refer to Section 8.6 on page 8.6-1of this manual.

Shade Control

Shade control can be a major expense, but it is essential that shade is maintained at a suitable level for the age of the cocoa trees, so that they develop well. Over-shading will result in the trees having an etiolated, spindly growth habit, with inadequate ramification. Refer to Section 8.5of this manual for information about the appropriate timing for the pruning of permanent shade and the removal of temporary shade.

Weed Control

Weeds compete with the cocoa trees for nutrients and water and even for light, resulting in weaker growth. Research has shown that good weed control during immaturity results in higher yield when the cocoa trees start producing pods. Although the trees in the bud wood garden are being grown for bud sticks rather than pods, the same principle, of enabling them to grow strongly when young without competition from weeds, still applies. Refer to Section 8.1of this manual.

Pruning Trees in the Bud Wood Garden

The pruning methods for clones in the bud wood garden are different to the ones used for trees in normal block that are being grown to produce pods. This is because the bud wood garden trees must be maintained in a state of vegetative growth, to supply bud sticks continuously, whereas normal trees must have mature wood that produces flowers.

Formation and Immature Pruning

Pruning of trees in the bud wood garden during the first two years after planting, the formation and immature pruning, is the same as it is for a normal block of cocoa. Refer to Section 8.4.2of this manual for information about formation and immature pruning.

Mature pruning and harvesting bud wood

Harvesting of bud wood can start in the third year after planting. Pruning the trees so that bud sticks will always be available requires more severe pruning than would be used for cocoa trees producing pods. In the third year after planting, the trees should be pruned quite severely every four months, i.e. three rounds per year. This will ensure that the trees are always producing new shoots that can be harvested for bud wood. The type of pruning required to achieve this will need four men to prune one hectare in one day, or 0.25 man-days per hectare. The sort of pruning that is needed to maintain production of green bud wood will severely reduce the ability of the tree to produce pods. This does not matter in a bud wood garden, where the primary product is bud wood. If the trees in the bud wood garden are producing as many pods as trees in nearby blocks of normal cocoa, it means that they are not being pruned severely enough and the severity of pruning needs to be increased. Some trees in the bud wood garden will still produce a few pods, even with the severe pruning. This does not matter Production of small numbers of pods does notreduce production of new shoots for bud wood. So the few pods that are produced by trees in the bud wood garden can be allowed to mature and be harvested to provide a small amount of supplementary income.

Fertilizer

Depending on the natural fertility of the soil, the cocoa trees in the bud wood garden may need fertiliser when harvesting of bud sticks starts, or from when they are planted. The growing tree immobilises nutrients in itself and, in contrast to a normal cocoa block in which all pruned branches are left to decompose in the block, bud sticks are regularly removed from the bud wood garden. Unless specific nutrient deficiencies are apparent, either a compound fertiliser such as 12:12:17:2 or a mixture of straights (urea or sulphate of ammonia, triple super phosphate, muriate of potash and kieserite) should be applied. When the trees are three years old, NPK (Mg) 12:12:17:2, or its equivalent in a combination of straight fertilisers, can be applied at 80 grammes per tree every three months. If the bud wood garden is in an area where fertiliser is applied during the immature

period, the immature schedule should be applied. Refer to Section 8.7.2 of this manual for more information about fertilisers and cocoa nutrition.

Other aspects of maintenance

Pest and disease control measures should also be applied in the bud wood garden as needed. Refer to the relevant sections of this manual for further information about pest and disease control.

Teaching Strategies

A. Introduction/Motivation

1. Teacher to introduce the topic of bud wood garden
2. Why have a bud wood garden
3. Discuss in genetic/breeding terms the relevance of a bud wood garden

B. Body/Content/Subject Matter

1. Plan a Bud wood garden
2. Explain the need for a bud wood garden
3. Describe the establishment requirement of a bud wood garden

C. Closure/Conclusion

a. Orally ask students to:
   i. Orally report on
   ii. Show vegetative propagation
b. Write a paragraph as a homework on the good plan of the bud wood garden

Student Activities

Students are to explain the following phrases and complete the table in Bud Wood Garden Management

Phrase	Definitions
Timing of operations	
Size of Bud wood Garden	
Planting the Bud wood Garden	
Drainage	
Shade Control	
Weed Control	
Pruning Trees	
Formation and Immature Pruning	
Mature Pruning and Harvesting Bud wood	
Fertilizer	
Other Aspects of Maintenance	

Activities

This should done as Practical Assessment where a list of Activities and Criteria is drawn up and assessed by the teacher

1. Plan a bud wood garden

2. Construction of a bud wood garden

UNIT 8: CONTROLLING INSECT PESTS

G) Introduction

More than 300 kinds of insects feed on cocoa in PNG. Ten regularly cause a lot of damage to cocoa. Not all insects are pests. Insect pests are usually controlled by application of insecticides. Routine applications of broad- spectrum insecticides should not be carried out because:

1. Are expensive
2. Not healthy to human and beneficial insects
3. Contaminated local environment
4. Contaminated cocoa with levels of chemicals residues that make them unsaleable
5. Can create resistance to the chemical in the target species of insects
6. Reduce population of useful predator species, e.g. crazy ants controlling Pantorhytes

Hand operated pneumatic knapsack sprayers should be used on young trees. Motorized knapsack mist blowers for plantations and extension lances on knapsack sprayers for small blocks

All spraying should be done in fine weather when rain is not expected for several hours. The following outcomes would have been achieved at the end of the unit by discussing briefly the following of the insect pests:

- Economic importance
- Controls measures
- Chemical controls
- Cultural/ physical controls

Learning Outcomes

End the end of this unit, the students can:

A. State the Insect pests in order of economic importance to PNG cocoa industry
B. Discuss the life cycle of the insect
C. Describe and demonstrate the damages control techniques
D. Carry out chemical control techniques when using chemicals
E. Demonstrate the importance of Safety when handling chemicals

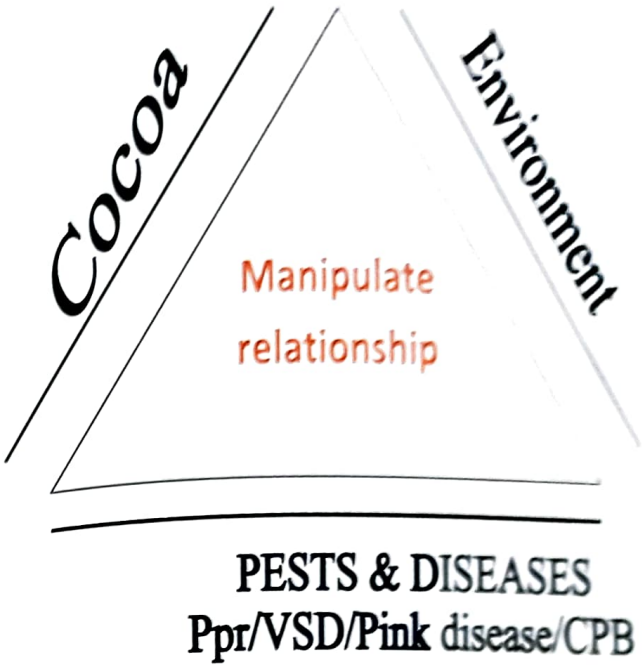


Figure 8.1: Host-Insect-Environment Triangle

To enhance realization of maximum potential

1. Disrupt Pest & Disease cycle at weakest link
2. Environment discriminately favourable for cocoa.
3. Build plant health through removal of stress factors
4. Enable cocoa trees both in time & space to withstand pest & disease pressure

Table 8.1: Insect pests in order of economic importance

Group	Insect Pest	Type of Damage
1	**Cocoa pod borer** (*Conopomorphacramerella*)	Larva feeds on the placenta

2	Defoliating Caterpillars (Lepidoptera GemetridaeLimacodidae, Noctuidae	Larva eat both young and mature leaves
	Longicorns (Coleoptera: Cerambycidae)	Larvae bore into wood of trunk and main branches
	Mirids (Hemiptera: Miridae)	Adults and nymphs suck sap from pods and shoots
	Pantorhytes (Coleoptera: Curculionidae)	Larvae bore into wood of trunk and main branches
3	Grey Weevils (Coleoptera: Curculionidae)	Adults chew bark of young cocoa shoots
	Pansepta. (Lepidoptera: Xylorictidae)	Larvae bore in branches of larger trees
	Termites (Isoptera: Kaiotermitidae)	Adults and nymphs chew wood inside the tree
4	Amblypelta (Hemiptera: Coreidae)	Adults and nymphs suck sap from pods
	Chafers (Coleoptera: Melolonthinae)	Larvae chew roots of young trees
	Oxymagis (Coleoptera: Cerambycidae)	Larvae bore into terminal branches
	Husk Borers; Cryptophlebia (Lepidoptera: Tortricidae) Olethreutes (Lepidoptera: Olethreutidae)	Larvae bore into husk of pods
	Rhyparida (Coleoptera:	Adults eat leaves

Chrysomelidae)	
Zeuzera (Lepidoptera: Cossidae)	Larvae bore into wood of trunk and main branches
Miscellaneous Pests	More than 300 species which eat leaves, pods and wood of the cocoa tree

1. **The Most Serious cocoa pest now present in Papua New Guinea**

   Cocoa pod borer (*Conopomorphacramerella*)

2. **Second important group is made up of caterpillars, which eat leaves**

   a) Pantorhytes weevils
   b) Longicorns Beetles, the grubs (larvae) bore into the wood and
   c) Mirids suck sap from pods and shoots

3. **Third group is made up of**

   a) Grey Weevils, which chew the bark of young shoots
   b) Pansepta moths, the grubs bore into branches
   c) Termites which eat wood inside the trees

4. **Fourth group is made up of**

   a) Rhyparid beetles which eat leaves, some moth larvae which bore into pods
   b) Larvae of Zeuzera moths which boreza into the main truck and branches
   c) Root chafers which chew roots
   d) Oxymagis beetles which bore into branches
   e) Amblypelta pod suckers
   f) Mealy bugs which feed on shoots pods and flowers

5. Fifth group is made up of more than 300 pests of lesser importance

Control techniques

Inter-related- factors is called the Host Insect Environment triangle, refer to figure 9.1). The host is the cocoa tree. For damage to occur, the insect has to be present on a susceptible tree in an environment that suits the insect. Control techniques aims to break one or more of this links

Management/ culture control of insects

Management/ culture control reduces the trees' susceptibility to attack. Where trees are well managed and healthy will be strong enough not to be seriously affected by insects pests. Also involves removing of host plants and tree species the insects like

Biological control of insects

Certain fungi kill some insect pest. Fungal disease only kills a small portion of an insect population and only where the target species behaves in a congregative manner

Pest control with crazy ants (Anoplolepislongipes) is most effective and easily managed biological control. Good control, especially Pantorhytes weevils and mirids. Feed on eggs and interfere with feeding and egg lying of adult insects. It is called crazy ants because the worker ants run around quickly when disturbed. It is usually seen outside their nest collecting food. Males are smaller, darker and thinner than the workers. Have long wings. Queens are much bigger than the workers. Usually stay inside the nest and lay eggs. At the beginning of the wet season, some ants emerge from their cocoons as males or queens. Males die soon after mating. Live on the ground, beneath or inside anything that will give them shelter. Also feed on honeydew, sweet liquid extracted by homopteran insects (sap sucking bugs). Main hompterans that give honeydew to crazy ants are Mealy Bugs (Planococcuspacificus), Scales (Coccusviridus), Membracids (Maurya spp.), and Aphids (Toxopteraaurantl). The anrs protect homopterans from some of their enemies

How to introduce crazy ants to a block

Should not be done during very wet or dry times of the year

Steps:

1. Cut sections of giant bamboo so that the node seals one end and the other end is open
2. Ants will use these tubes as nests
3. Place large dry cocoa leaves inside tube to increase the surface area inside the nest and cuts down the amount of light getting into the tube
4. Place tubes on the ground where there are many crazy ants. Put them one meter apart on a slope making sure the open ends are facing down wards
5. Ants will soon move into the tubes. Will usually build one nest in each tube. Collect and tie a piece of plastic nag or banana leaf over the open of the tube to stop ants escaping

6. Cover the tube with banana leaves to keep them cool and carry the tubes to the cocoa block
7. The best place to put the crazy ants is in an open, sunny and well drained place
8. Put the crazy ants where the insect pests are mostly likely to come into the block or whereabouts on the block. Make sure open ends of tubes point downwards to stop rainwater getting in
9. Other types of ants such as Pheidole, Iridiomirmex, Crematogaster and Oecophylla are enemies and will drive the crazy ants away. Kill them before crazy ants are introduced with poison ant bait
10. When ants have built their nets, do not cut grass too close as may disturb the nests. File mulch or off cuts to slow grass growth and give good places for nest
11. Takes time to increase crazy ant numbers to control Pantorhytes and mirids. During this phase, spot spraying of trees being attack by pests can be done. Unlikely too many crazy will be killed

Herbicides and fungicides will not kill crazy ants

Some disadvantage of crazy ants

1. May not stay in the block long. When they go into a new area their number will increase until they have eaten most of insects and honeydew then move on.
2. Mealy bugs which give the crazy ants honeydew, may become a pest on shoots of young cocoa seedlings
3. coconut pest such as Tirathaba, Amblypelta can be a problem in a block because ants drive away Kurukum ant (Oecophyllasmaragdina) that feeds on these pest
4. blocks very close to the house, crazy ants can be a nuisance

Chemical control techniques

Chemical concentration

The strength (concentration of active ingredient or a.i.) of chemicals sold in didistoa may vary

Spraying

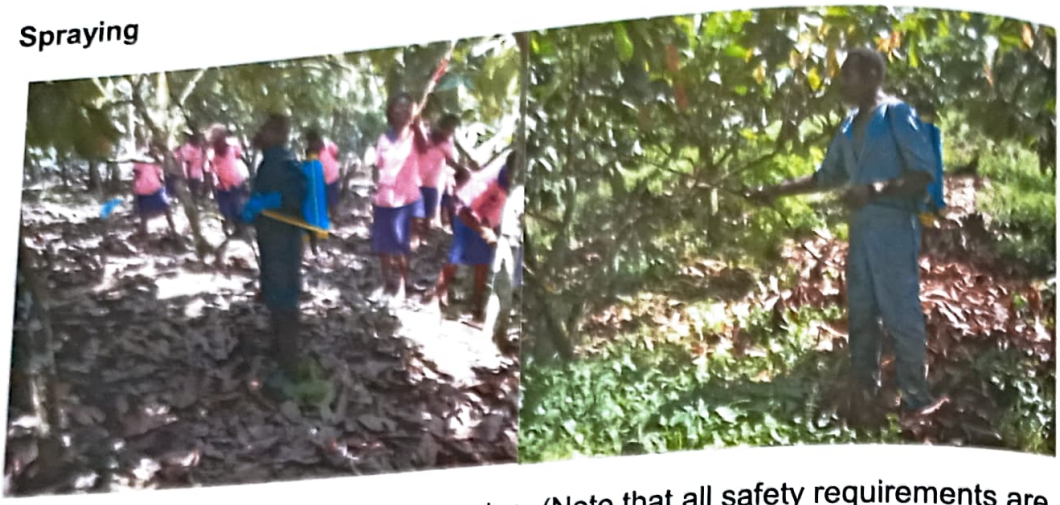


Figure 8.2: Demonstrating spot spraying. (Note that all safety requirements are not met).

Always 'spot' spray in the areas with pest. Do not spray regularly but regularly checked for pests.

Table 8.2: Flow rate and conversion factors for insecticide spray nozzles

Nozzle	Flow rate: ml per minute	Application rate litres/ha (625 trees)	Amount of chemical in 10 litre tank R=recommended rate	No. of mature cocoa trees covered by a 10 litre tank
SA-04-392	800	375	R x 0.3	17
02-13	270	125	R x 0.9	50
02-23	430	200	R x 0.6	34
TX2	140	65	R x1.7	95
TX4	230	110	Recommended rate	56
TX8	460?	210	R x 0.5	28

Table 8.3: Summary of insecticide treatments for insect pests of cocoa

	Pests	Rate of Application
1	Caterpillars	28 ml Decis or Karate 2.5% EC + 2 ml surfactant + 50ml sticker + 10 L water Or 75g Septene 80 EC + 3ml surfactant + 50 ml sticker + 10 L water Or 40g Orthene 75 WP + 2 ml surfactant + 50 ml sticker + 10 L water
2	Rhyparids	28 ml Decis or Karate 2.5% E + 2 ml surfactant + 50 ml sticker + 10 L water Or Septene 80 EC + 3 ml surfactant + 50 ml sticker + 10 L water Or 40g Orthene 75 WP + 2ml surfactant + 50 ml sticker + 10 L water
3	Grey Weevils	28 ml Decis or Karate 2.5% EC + 2 ml surfactant + 50 ml sticker + 10 L water Or Furadan 2.5 g/tree @ planting, 5 g/tree @ 3 months, 10 g/tree, @ 3-6 months, granules sprinkled drip circle
4	Mealy Bugs	30 ml Malathion 50 EC + 100 ml white oil + 2 ml surfactant + 50 ml sticker +10 L water
5	Termites	28 ml Decis or Karate 2.5% EC + 2 ml surfactant + 10 L water Or 25 ml Lorsban + 2 ml surfactant + 10 L water
6	Longicorns & Coffee Stem Borer	30 ml Nuvan 50 EC + 250 ml white oil + 15 g RidomilPlus + 700 ml water Or as above but replace Nuvan 50 EC with Vapona 50 Both mixture for channel painting

7	Pansepta Web Worm	Swab: 70 ml Rogor 30 EC + 2 ml surfactant + 50ml sticker + 10 L water Spray: 210 ml Rogor 30 EC + 2 ml surfactant + 50 ml sticker + 10 L water
8	Pantorhytes	30 ml Nuvan 50 EC + 250 ml white oil + 15 g Ridomil Plus + 700 ml water for channel painting larvae 28 ml Decis or Karate 2.5% EC + 2 ml surfactant + 50 ml sticker + 10 L water for spraying adults
9	Mirids	28 ml Karate 2.5% EC + 2 ml surfactant + 50 ml sticker + 10 L water 45 ml Decis or Cymbush 2.5% EC + 2 ml surfactant + 50 ml sticker +10 L water 45 ml Unden 50 WP + 2 ml surfactant + 50 ml sticker + 10 L water
10	Amblypelta	28 ml Karate 2.5% EC + 2 ml surfactant + 50 ml sticker + 10 L water 45 ml Decis or Cymbush 2.5% EC + 2 ml surfactant + 50 ml sticker + 10 L water

Table 8.4: Insecticide application times on the basis of tree age

Age of cocoa tree (years)	2	3	4	5t
Spray time per tree (seconds)	15	25	35	45

Figure 8.3: Mist Blower

Mist blowers

These are made for a flow rate of 230 ml/minute

Surfactants

Reduces the surface tension of the mixture to increase the area that an amount of mixture can cover. That makes a tank load of mixture go further and so makes the operation cheaper

Stickers

Increase the adhesiveness of the mixture so that it stays on the surface it has been sprayed onto. Sticker is necessary because of frequent heavy rain showers

Safety

All safety precautions that apply to herbicides also apply to using insecticides

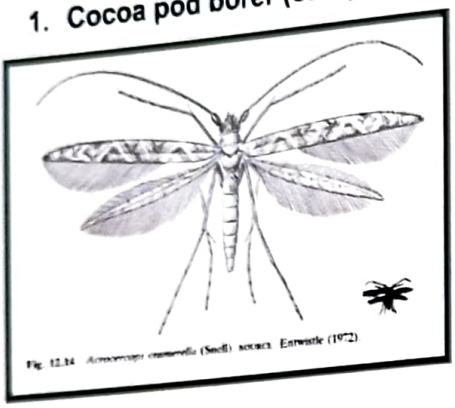
A few more precautions because most insecticides are more toxic to human than herbicides

1. When applying the mixture always wear a facemask, rubber boots and overall
2. These should be washed regularly
3. If feel sick after spraying see a doctor

The main Insect Pest and specific Management recommendations

Serious cocoa pests now present in Papua New Guinea

1. Cocoa pod borer (Conopomorphacramerella) Life cycle



An adult Moth Cocoa Pod Borer (Drawn) and An adult Moth Cocoa Pod Borer (Life)

Figure 8.4: An adult Moth Cocoa Pod Borer

Morphotypes of Pod Borers

1. From the 3 morphotypes, the Morphotype 1 is highly likely to be the aggressive type that is attacking cocoa.
2. However, it may express itself in two forms based on its feeding habitat. The form in the forest is feeding on an unknown fruit tree while the form in the cocoa farming area feeds on cocoa pods even though they are morphologically identical.
3. If that is the case it is highly likely that they have been around for sometime feeding on some other unknown host plants

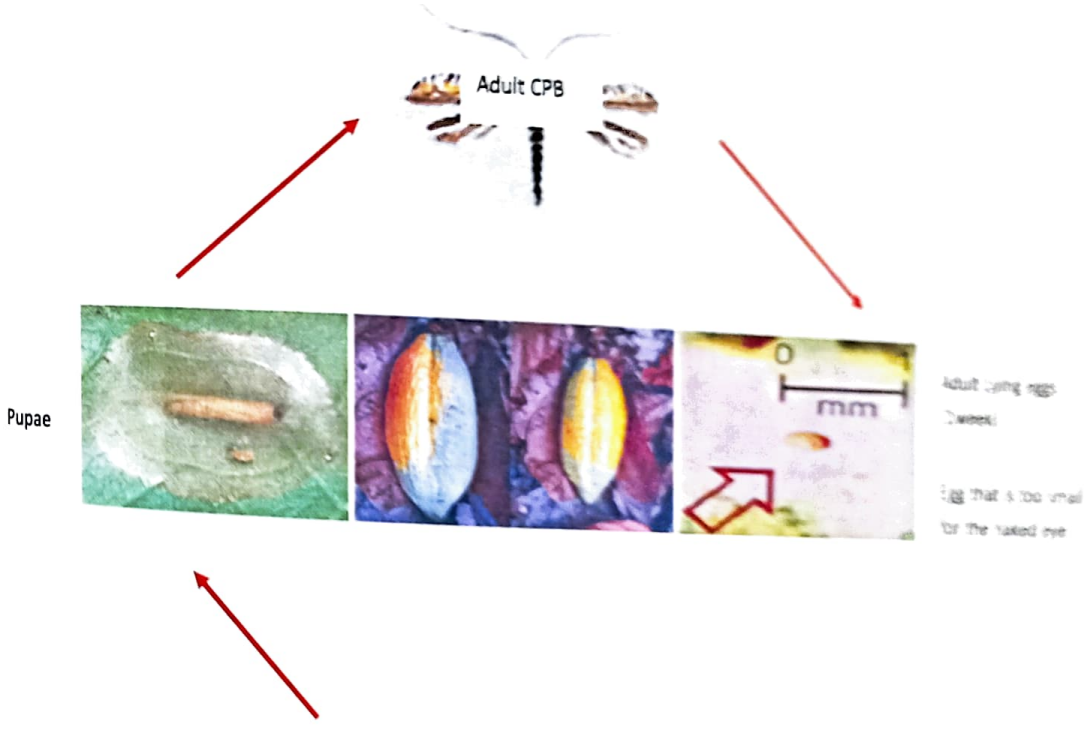
Ecology of CPB

1. CPB hibernate in shady conditions.

2. The adult moth flies around at night, and lay eggs on the surface of cocoa pods, and also on lateral branches
3. The adult is a weak flier about the size of a mosquito that is active at night and rests in dark cool places during the day
4. The adult can only fly for some 200 metres during its life span and die

Mode of Transmitting the Pest

1. CPB is transmitted through planting materials like cocoa pods and seedlings
2. Movement of people can also transport the pest through its adult and egg. The adult can sit on man clothes and lay eggs that if unattended to properly, the egg pupate on any leave, and then later change into adult.
3. The other host plants for CPB are rambutan, taun and namnam. Movement of these planting materials will also transmit the pest.
4. Natural conditions like strong winds can also transport the adult pest from one location to another.
5. Possibility that the local type had mutated to become aggressive, and adapted to feed on cocoa pods and this must have resulted from global changes in weather patterns and the environmental conditions.
6. Changes in the environment such as continuing volcanic activity, and or transformation in climatic conditions that have favoured CPB or disadvantaged its predators.



Larvae (2 weeks)

Figure 8.5: Showing CPB adult moth and infested cocoa pods

1. The adult lives for 3-7 days.
2. It laid eggs on pod surface and the eggs remained on pod surface for 2-7 days before hatching into larvae
3. An adult female moth lays 6- 8 eggs per night.
4. For its life span, can lay around 200 eggs

Symptoms of infestation

Below are six symptoms that would indicate that CPB is present in the cocoa block.

1) Uneven yellowing or premature ripening of cocoa pods.
2) Presence of exit holes of larvae on pod husks.
3) Characteristics CPB tunnels within pods
4) Clumping and Cemented cocoa beans
5) Pupae on pods and on debris/leaf litter on the ground.
6) Adult moth resting on underside of horizontal branches of cocoa.

Symptoms of CPB

Plate 8.6: Symptoms of CPB infested Pod showing uneven ripening

Plate 8.7: Placenta of cocoa pod heavily infested by CPB larvae and beans are

Economic importance

Status of cocoa in PNG economy

1. PNG cocoa is an exportable cash crop that is ranked as third to oil palm and coffee, in terms of its contribution to the National Gross Domestic Product (GDP).
2. It fetches an annual export earnings of between K200 – K300 million
3. It contributes to employment, directly and indirectly
4. The presence of CPB threatens the industry, and therefore farmers and all stakeholders in the industry must play their roles to maintain, and increase production in the presence of CPB.
5. The negative perspectives of CPB must be transformed into positive strategies by way of adoption of improved farming practices to reduce CPB population, and increase cocoa yield

Cocoa pod borer (CPB) is the most serious pest of cocoa to have emerged in PNG in the last 10 years. It was found in the ENBP in 2006 with much of it located in the Gazzelle area. CPB has almost singlehandedly destroyed the cocoa industry in the ENBP. For example, prior to CPB invasion, the ENBP was the largest producer of cocoa in PNG. Production figures indicate that before the CPB arrival the ENBP was producing between 15, 000 to 23, 000 tons per year but after the CPB incursion into ENBP in 2009 production dropped significantly to about K8, 000 tons per year. Comparatively, the ESP production steadily increased cocoa production to over 16, 000 in 2008 to be the second largest producer behind Bougainville which leads by producing about 17, 000 tons per annum . It therefore implies that CPB is the single most important economic pests and all effort must be made to reduce its impact on the economic life of the coastal rural people that rely on cocoa for a cash income.

Controls measures

Plate 8.8: Spray Infested Trees

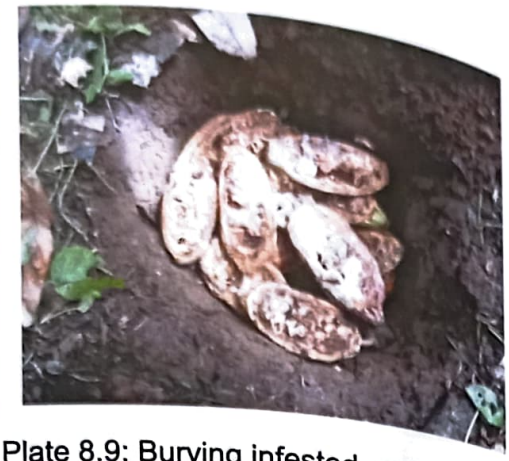


Plate 8.9: Burying infested pod husks

Five rules to contain CPB

1. Clear weeds and Reduction of Shade
2. Cocoa pruning
3. Weekly harvesting
4. Pod husk burial
5. Target spot spraying

2. The Cocoa Weevil

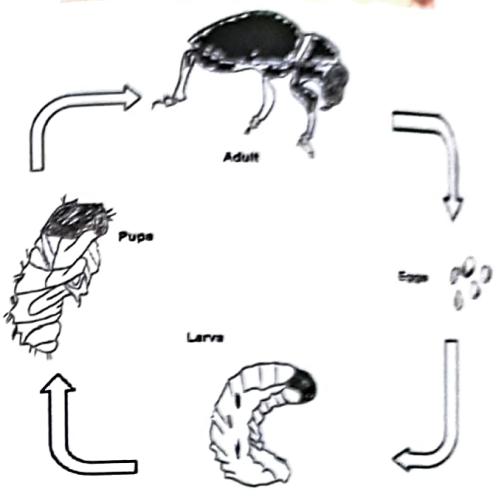


Figure 8.10: COCOA WEEVILS *(Pantorhytes batesi)* Figure 8.11: The Weevil Life cycle(adult and feeding damage on a cocoa pod)

Figure 8.12: *Pantorhytes plutus*adult, larval channel (cut open) andassociated bark canker

Damage and Economic importance

Larva hatches from eggs and straight away chews into the wood of the trunk or the main branches making a tunnel under the bark

The adult feeds on the young shoots and sometimes on pod husk
Damage affect the canopy, branches may be ring- barked and die, when attacked near the jorquette
Larger numbers can kill most trees in the area

One reason for cocoa business collapsed in some parts of P.N.G in the 1960s and 1970s

Pantorhytes szentvanyi is found in Oro Province *Pantorhytes plutus is* found in New Britain and New Ireland Province *Pantorhytes batesi is* found in Morobe Province *Pantorhytes proximus is* found in Central Province*Pantorhytes stanleyanus is* found in Central and Milne Bay Provinces *Pantorhytes pseudocarbonarius is* found in the Sepik and Madang Provinces

Controls Measures

1. Mannual/ Hand picking of adults can be done
2. Cultural control
   Not a big problem in cocoa inter-planted with coconut as Kurukum ant that lives in coconut palm attacks Pantorhytes adult and eats their eggs
3. Removal of alternative plant hosts
4. Biological control Cray ants and other ants
5. Chemical control.
   Note: For all the boxes below: the chemical is stated and how much to mix, what to add before spraying

15% a.i. Dichlorvos

i.	30ml "Nuvan" 50 EC
ii.	250 ml white oil
iii.	15g metalaxyl (a fungicide also known as Ridomil)
iv.	700ml water

0.007% Pyrethroid

i. 28 ml "Decis/Karate" 2.5% EC

ii. 2 ml surfactant

iii 50 ml sticker

v. 10 L water

Various insecticides used at specific stages of its life cycle

Some Important Points

a) For Manual, Cultural, Alternative Host and Biological Control is quiet similar for all insect Pests

b) Much easier and cheaper to prevent Pantorhytes from entering newly planted cocoa blocks than to control them when they have entered

c) **3. Trunk Longicorns**

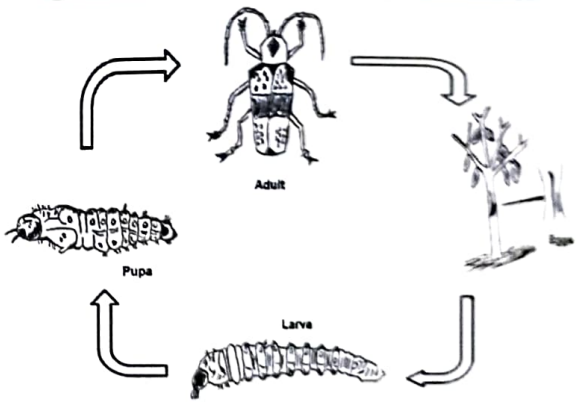


Figure 8.13: *Gleneaaluensls*adult Figure 8.14: Trunk Longicorn (*Gleneaaluensls) Life cycle*

*Gleneaaluensis*is found on the Islands Region of PNG.

Glenealefebueri is found on the P.N.G mainland and Irian Jaya

Longicorn damagesymptoms on a cocoa tree trunk

Figure 8.15: *Gleneaaluensis* Longicorn larva channelexposed to show the larva

Damage and Economic importance

After the larvae hatch out of the eggs, they bore into the tree and make tunnels while feeling on the young wood under the bark

A single larva can cause considerable damage to a tree by totally orpartially ring barking ring barking the trunk or a main branch

Weakened branches may break.

Channels are a major entry points for the bark canker fungus which cause widespread crop loss and tree deaths

Controls measures

Chemical controls

1.5% a.i.Dichlorvos

i. 30 ml Nuvan 50 EC

ii. 250 ml white oil

iii. 15 g metalaxyl (Ridomil)

iv. 700 ml water

All trees be inspected and larval channels with fresh frass be treated every six weeks until pest numbers are reduced to an acceptably low level

Cultural/ physical controls

Proper pruning of shade trees and cocoa to maintain low shade levels, thus reduce incidences of longicorns

2.3: Mirids or pod suckers

a. *Pseudodoniellatypica* adult
b. *Helopeltisclavifer*

Figure 8.16: *Helopeltisclavifer*adult

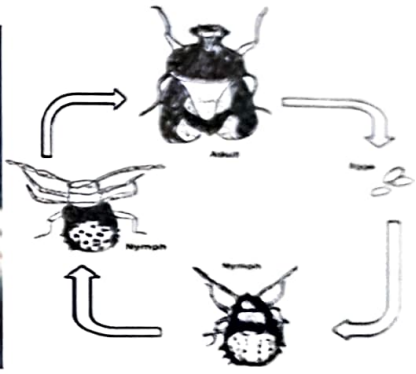


Figure 8.17: Life cycle of Mirid

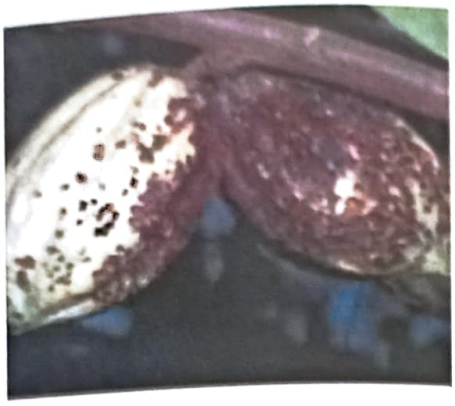


Figure 8.18: Severe mired damage on cocoa pods

Damage and Economic Importance

a) Can cause extensive crop losses in all areas of Papua New Guinea
b) Feed the sap of cocoa pods/ chelles and shoots/stems. Can cause crop losses of up to 80%
c) When damage is more than one-fifth of a cherelle, it dies
d) Damaged pods may die or become deformed and young become stunted from severe tip "dieback"

Controls measures

Biological Control

Use of Dense crazy ant (Anoplolepislongipes), population to drive out both kinds of mirid

Chemical controls

8 g a.i./ha lambda cyhalothrin	12 g a.i./ha decamethrin	250 g a.i./ha propoxur (Unden)
45 ml "Decis/ Cymbush 2.5% EC 2 ml surfactant 50ml sticker 10 L water	45 g "Unden" 50WP 2 ml surfactant 50 ml sticker 10 L water	28 ml "Karate" 2.5% EC 2 ml surfactant 50 ml sticker 10 L water

2.4: Leaf- eating caterpillars

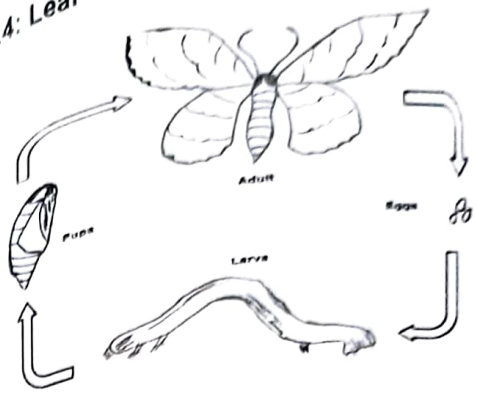


Figure 8.19: life cycle of caterpillar

Figure 8.20: Looper Caterpillar damage

Figure 8.21: Bagworms and damage Figure 8.22: Leaf roller damage

Damage and Economic Importance

Most caterpillars are important pests of cocoa through Papua New Guinea.

They eat soft, flush leaves and shoots or sometimes hardened leaves

Severe defoliation by caterpillars slows/retards growth or malformation or death on young trees and causes yield decline on mature trees

If there is pest outbreak, it is isolated and short- lived, not be necessarily or economical to apply control measures

Controls measures

Chemical controls

Acephate (0.3%) 350g a.i./ha
a.i./ha

0.6% Carbaryl at 650g

40 g "Orthene 75"
2 ml surfactant
50 ml sticker
10 L water

75 ml "Septene" 80
2 ml surfactant
50 ml sticker
10 L water

0.007% Pyrethroid at 8g a.i./ha
330 g a.i./ha

0.3% Pirimiphos-methyi at

28 ml "Decis"/ "Karate" 2.5% EC
2 ml surfactant
50 ml sticker
10 L water

60 ml "Actellic"
2 ml surfactant
50 ml sticker
10 L water

Cultural control

Outbreaks are associated with some types of shade trees,
Leucaenaleucocephale is often associated with severe caterpillar problems in the country

Third Economical Group of Pests

3.1: Grey weevils

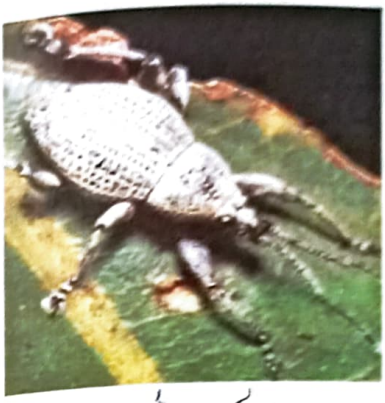


Figure 8.23: A grey weevil adult

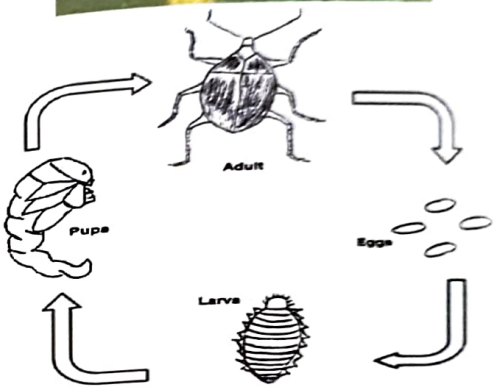


Figure 8.24: Life cycle of Grey Weevil

Damage and Economic Importance

Important pest of young cocoa in Papua New Guinea

Adult chew on growing stems, petioles and leaves of cocoa and Gliricidia shade

Damage stunts or even kills cocoa seedlings and Gliricidia shade trees

Does most damage in dry weather on blocks that have poor soils and lots of weeds and not much shade

Cultural control

Increase shade, weeding and mulching

Biological

The use of crazy ants

Controls measures

Chemical controls

0.007% a.i. Pyrethroid

28 ml Decis/ Karate/Cymbush 2.5% EC

2 ml surfactant

50 ml sticker

10 L water

Carbofuran (10%)

2.5 Gm "Furadan" 10% granules at field planting

5 gm "Furadan" 10% granules at 3 months after planting

10 gm "Furadan" 10% granules at 6 months after planting

3.2: Pansepta webworm

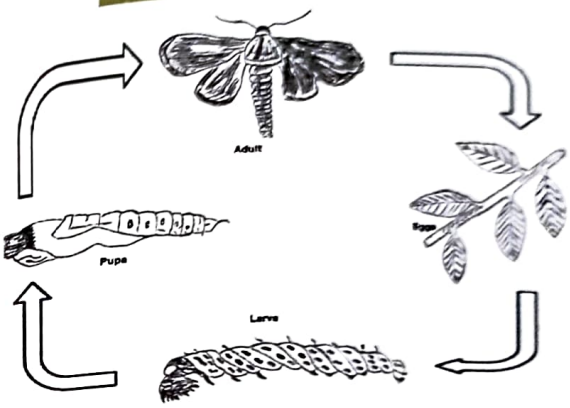


Figure 8.25: *Pansepta* adult moth

Figure 8.26: Life Cycle of Pansepta

Figure 8.27: *Pansepta* damagesymptoms Figure8.28: Cocoa branch splitopen to show *Pansepta*andchanneland webs on a cocoabranch

Damage and Economical Importance

Larvae bores into the bark of main branches of young cocoa and terminal branches of mature cocoa to feed on the wood which turn to grow poorly. If the branch is ring barked, it will die back from the tip to the location of damage

On young trees, ring barking around jorquette region or main branches can cause the loss of the main pod bearing branches, or even tree death. Damage can cause severe tip dieback, spoiling the canopy. Damaged cocoa trees will produced fewer pods. Main branches and sometimes truck of young trees can be killed

Biological control

Cray ant (Anoplolepislongipes) population living in the cocoa will control webworms

Cultural Control

Have enough Shade and never leave young cocoa trees without shade

Controls measures

Chemical controls

Dimethoate (0.2%)

70 ml "Rogor" 30 EC

Or 50 ml "Rogor" 40 EC?

2 ml surfactant

50 ml sticker

10 L water

Dimethoate (0.6%)

210 ml "Rogor" 30 EC

Or 150 ml "Rogor" 40 EC?

2 ml surfactant

50 ml sticker

10 L water

3.3: Termites

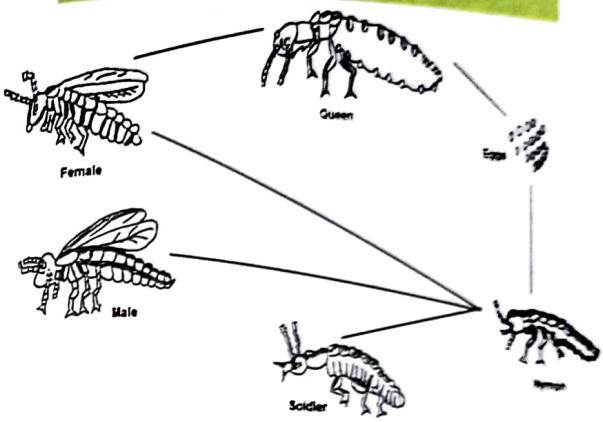


Figure 8.29: Giant Cocoa Termites Figure 8.30: Life cycle of Termites

Figure 8.31: Cocoa tree trunk cut open to show Giant Termite damage

A termite colony consists of one reproductive queen, a male, eggs, nymphs, and many soldiers.

Damage and economic Importance

Termites feed on living wood inside the truck and main branches of the cocoa trees. It is a minor economic pest

Cultural Control

Prune and remove dead wood. Coconut most suitable shade

Controls measures

Chemical controls

Decamethrin (0.007%)
(0.007%)

28 ml Decis 2.5% EC
2 ml surfactant
10 L water

L. Cyhalothrin

28 ml Karate 2.5% EC
2 ml surfactant
10 L water

Cypermethrin (0.007%)

28 ml Cymbush 2.5% EC
2 ml surfactant
10 ml water

Chlorpyrephos(0.5%

25 ml Lorsban 50 % EC
2 ml surfactant
10 ml water

Fourth Group of Economical Pest

4.1: Longicorn tip borer

Figure 8.32: *Oxymagis*adult

Figure 8.33: *Oxymagis*larva

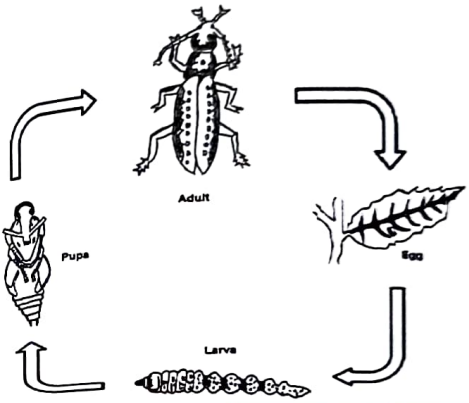


Figure 8.34: Longicorn Tip Borer Figure 8.35: Symptoms and exit hole
Figure 8.36: Cocoa branch cut open to show *Oxymagis*larva and channel

Damage and Economical Importance

Larvae bore into the thin outer branches of cocoa trees to feed on the pith and sap wood. It is a minor pest

Cultural Control

Prune off infected branches to a point 30cm below the lowest exist hole. Pruned be burned to kill larvae, pupae and emerged adults resting inside the pruning. Combined with other management practices

4.2: Rhyparid beetle or shot hole beetle

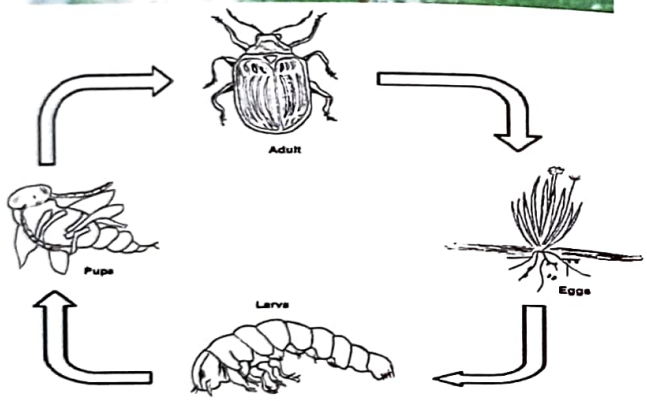


Figure 8.37: Rhyparidadult Figure8.38: Life cycle of Rhyparid

Figure 8.39: Rhyparid "shot hole" damage on young cocoa leaves

Damage and Economic Importance

It is the most common leaf-eating beetle pest of cocoa. Adults chew small, round holes in flush leaves. Repeated feeding damage produces a "peppered" effect on the leaf where leaves can be covered with holes. Excessive feeding damage can slow growth and reduce yield mostly on young cocoa less than three years. Very large number in cocoa, causing considerable damage to flush leaves. Found to be worse during periods of prolonged dry weather, which favours larval development. On young up to about three years old, heavy and repeated defoliation can slow growth and reduce yield. Both young and mature trees can withstand some defoliation before yield is affected.

Cultural Control

A number of Trinitario cocoa clones show some resistance

Leaves of these clones probably have a taste that Rhyparids do not like

Biological Control

It is control by Cray ants (Anoplolepislongipes)

Chemical controls

0.6% Carbaryl at 650 g a.i./ha
380 g a.i./ha

40 g "Orthene 75"
2 ml surfactant
50 ml sticker

0.3% Acephate at

75 ml "Septene 80"
2 ml surfactant
50 ml sticker

0.007% Pyrethroid at 8 g a.i./ha
methyl at 330 g a.i./ha

28 ml "Decis" or "Karate" 2.5 % EC
2 ml surfactant
50 ml sticker

0.3% Pirimiphos-

60 ml "Actellic
2 ml surfactant
50 ml sticker

4.3: Husk borer

Fusariumsolani, Fusariumdecemcellulare, Gliocladiumroseum.

Figure 8.40: Cocoa pod showing damage caused.

Damage and Economic Importance

The larvae tunnel inside the cocoa pods to feed on the outer layer of the husk. This damage enables fungal diseases to invade the pod and rot the beans. Yield losses can be as high as 50% of the crop. Crop loss is worst during wet weather

Economic losses occur only when the fungal diseases are present

Biological Control

Cray ants (Anoplolepisfongipes) is used

Controls measures

Chemical controls

Lambda-cyhalothrin (0.007%) 8 g a.i/ha

(0.01%) 12 g a.i./ha

45 ml "Decis/Cymbush" 2.5% EC
2 ml surfactant
50 ml sticker 10 L water

Deltamethrin/Sypermethrin

28 ml "Karate" 2.5 % EC
2 ml surfactant
50 ml sticker 10 L water

Propoxur (o.2%) 250 g a.i./ha

45 ml "Unden" 50 WP
2 ml surfactant
50 ml sticker
10 L waters

4.4: Root chafer pests

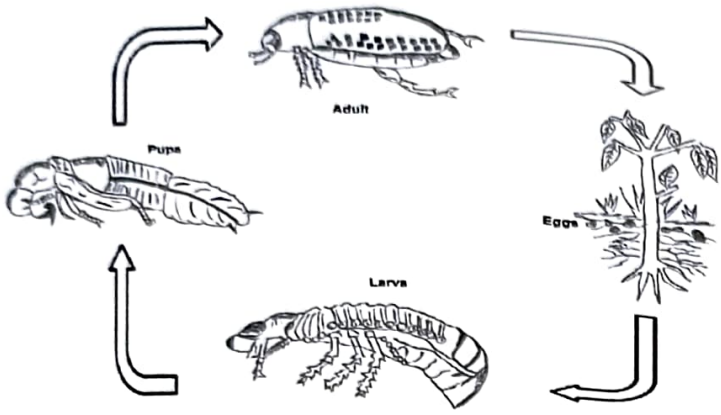


Figure 8.41: Life cycle of Root Chafer Figure 8.42: Cocoa seedling roots damaged by larvae

Damage and Economic Importance

It is an important pest of young cocoa plants in Papua New Guinea. Larvae feed on roots of cocoa tree of any size. When the grub chews and ring bark the taproot of a young seedling, the plant dies. Enough root chafers present, can kill every seedling in a newly planted cocoa block. It is often bad when cocoa is planted on or near the site of an old food garden.

4.5: Coffee stem borer (Zeuzeracoffeae)

It appears to have wings. That is why it is sometimes called a Leopard Moth. The larvae grow to about 40mm long

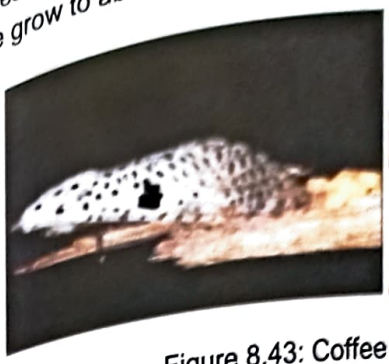


Figure 8.43: Coffee stem borer adult

Figure 8.44 Coffee stem borer larva and channel

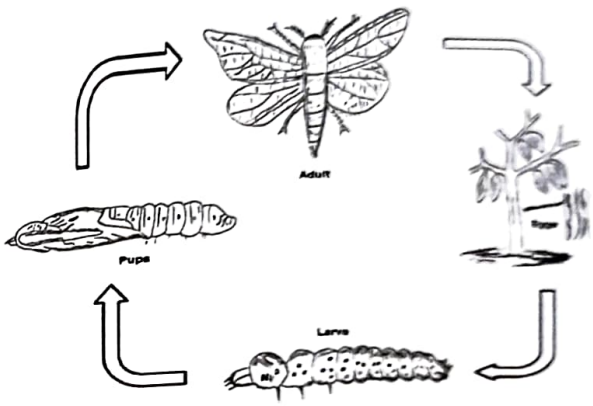


Figure8.45: Life cycle of Coffee Stem Borer

Damage and Economic Importance

It is a serious pest of cocoa in Papua New Guinea. Larvae cause damage by boring into the trunk and main branches of young cocoa trees to feed on the wood. Damage branches may grow poorly, die back from the tip, or break.

If bores into the truck of a seedling that is less than one year old, stopping it from growing properly the part of the tree above the damage, may die. Causes extensive damage on cocoa trees

Controls measures

Recommended control

Through prune damaged branch off about 30cm below the lowest outlet hole and burn it to kill the grubs and pupae

If tree is damaged, the tree should be stumped (cut off) about 20 cm above the ground

Chemical controls

1.5% a.i. Dichlorvos

30 ml "Nuvan 50"
2 ml surfactant
1 L water

4.6: Mealy Bug Pests of Cocoa

Figure 8.46: Mealy bugs feeding on apod Figure 8.47: Mealy bugs feeding on a seedling

The mealy bug, *Planococcuspacificus (Hemiptera: Pseudococcidae),* is a minor pest of cocoa in Papua New Guinea. Adults and nymphs feed on cocoa shoots, pods, and flower cushions,

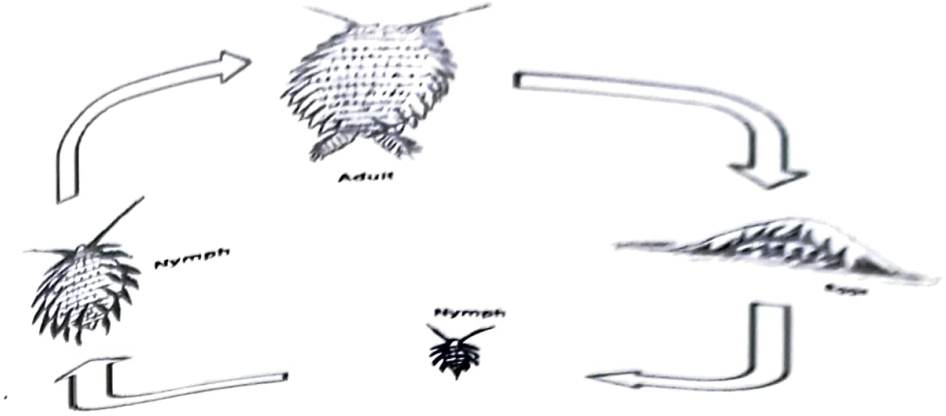


Figure 8.48: Life cycle of Mealy bug

Damage and Economic Importance

It is a minor pest. Adults and nymphs feed on cocoa shoot which become deformed or stunted or die, pods and flower cushions

It can do a lot of damage on cocoa seedlings in the nursery. When in large numbers, can attack young pods, pods become deformed or ripen too early. In dry weather the numbers can increase significantly and cause damage

Controls measures

Chemical controls

Malathion (0.15%)

30 ml Malathion 50
100 ml white oil
2 ml surfactant
50 ml sticker
10 L water

4.7: Thrips

Figure 8.49: Thrips damage to cocoa

Damage and Economic Importance

It is a minor pest in Papua New Guinea. Activities mainly during dry weather, not enough shade and growing in poor-nutrient deficient soils with high weed competition. Adults and nymphs suck from the Leaves of young cocoa seedlings

Severe prolong damage causes the leaves to turn yellow and fall off can slow growth or kill a young seedling. Tree over 9 to 12 months old rarely suffer economic damage

Controls measures

Shade levels, soil fertility and weed control. Wet weather reduces pest numbers

Chemical controls

Acephate (0.3%)

40 g Orthene 75
2 ml surfactant
50 ml sticker
10 L water

Malathion (0.15%)

30 ml Malathion 50
2 ml surfactant
50 ml sticker
10 L water

Deltamethrin (0.007%) Lambda-cyhalothrin (0.007%)

28 ml Decis	28 ml Karate
2 ml surfactant	2 ml surfactant
50 ml sticker	50 ml sticker
10L water	10 L water

Fifth Economical group

5 Vertebrate pests

- Damage from rats, flying foxes and parrots can occasionally be severe

TEACHING STRATEGIES

1. Introduction/Motivation

1. Do you know some economic and some common pests in PNG?
2. What do you know happened to the cocoa industry in the ENBP?
3. Do you know wan insect caused the traumatic drop Cocoa Production in the ENBP?
4. Which Province is now the largest Cocoa Producer?
5. Which Province is the Second Largest Cocoa Producer
6. Name the most serious threat to the cocoa industry in PNG?

2. Body/Content/Subject Matter

1. Teacher to introduce the idea of an economic pest
2. Definite the term pest!
3. Study five most important pest of cocoa in PNG
4. Students to be grouped and each study a pest as a project and present to the class (Use pictures of pest, its damage, life cycle, control measures, and discuss its economic significance to the cocoa industry in PNG)
5. Get students in groups to conduct economic survey and analysis

3. Closure

1. Student presentations using available media and discuss presentations
2. Use the presentation charts, tables and illustration for display in the class.
3. Award marks to best groups and display

Student Activities

a) State five Insect pests in order of economic importance

b) Describe and demonstrate the Control techniques

c) Demonstrate and get students to carry out chemical control techniques

d) Demonstrate the importance of Safety by using appropriate protective procedures

e) Draw the life cycle of the Cocoa Pod Borer Pest and label each part

f) The main insect pest and specific management recommendation

Pests (Five Pests)	Control	Marks

g) Practical – Insect Collection Activity

Introduction

Disease is one of main reasons for losses in cocoa production. Most serious and widespread cocoa diseases in PNG are Black Pod and Stem Canker. Both these diseases are caused by the fungus Phytophthora. Vascular Streak Dieback (VSD) is caused by another fungus Oncobasidiumtheobromae. There are other diseases that regularly destroy up to 40% of cocoa crop. To be able to control diseases, growers need to able to recognize disease the disease causal organism, the symptoms, understand the life cycle and how the diseases organisms can be best controlled and managed. This an area where the students will appreciate the importance of controlling diseases for better yield in cocoa production

Learning Outcomes

At the end of the unit, the students can:

A. Identify the disease
B. Describe the lifecycle
C. Explain the usefulness of the Pathogen – Host- Environment Interaction
D. Describe the four methods used to prevent disease developing and/or controlling them if they do get established
E. List and describe the most important diseases of cocoa in PNG are caused by fungus/fungi.
F. Demonstrate the control measures of the disease

Content

Pathogen – Host- Environment Interaction Useful model Disease Triangle

Integrated Pest & Disease Management

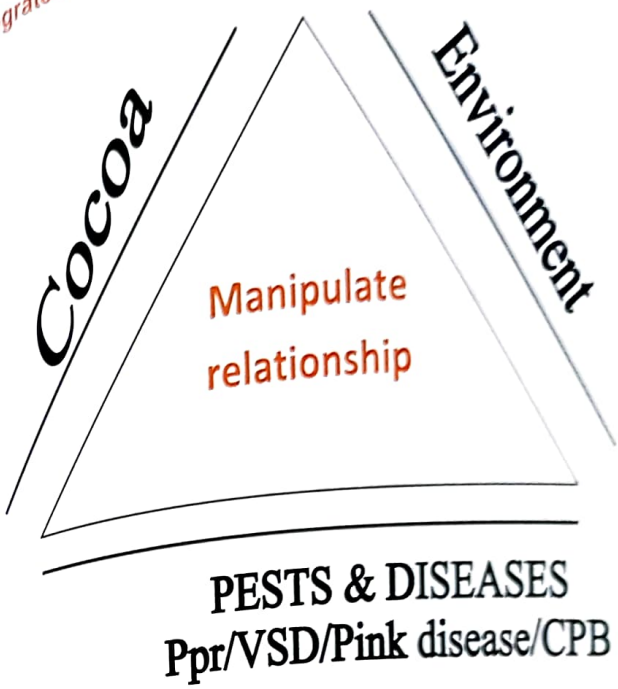


Figure 9.1: Pathogen-Host-Environment Disease Triangle

Important Points

1. Disrupt Pest & Disease cycle at weakest link
2. Environment discriminately favourable for cocoa.
3. Build plant health through removal of stress factors
4. Enable cocoa trees both in time & space to withstand pest & disease pressure to enhance realization of maximum potential

For disease to occur, all three components must be present. A pathogen needs a host organism to feed on and it needs an environment that suits its life cycle. Pathogens often depend on the environment to provide a vector (another organism such as an insect or some factor such as wind or rainfall) to carry to their host

Factors interacting between host, pathogen and environment determine how serious a disease is:

1. Population of the pathogen inhabiting a single host
2. Aggressiveness of the pathogen-the pathogen's ability to make a healthy host sick
3. Host susceptibility-ability of host to resist or tolerate the presence of the pathogen
4. Suitability of the environment for the pathogen
5. Suitability of the environment for the host

Crop Loss

Figure 9.2: Number of cherelles lost

Figure 9.3: Pods lost through diseases

Figure 9.4: Cocoa plants not producing to maximum potential

Crop loss at different Stage:

Stage 1: Flower stage

Figure 9.5: Flower stage-
From flower formation,

1. 50 ++ flowers produced per cushion, only 5% are pollinated. Only about 1-2% develop to pods
2. Losses are due to:

- failed pollination
- Natural elimination
- Weather changes
- Pests & diseases

Stage 2: Cherelle

About 70% of cherelle are lost
Losses are due to;
- failed pollination
- Natural elimination
- Weather changes
- Pests & diseases

Figure 9.6: Cherelle

Stage 3: Immature pod stage

10 % of losses occurred.
Suitable stage for CPB egg laying
- Natural elimination
- Pests and diseases

Figure 9.7: Immature pod stage: very young pods 9-16 weeks old. Immature

Stage 4: Mature Pod

19% reaches maturity
- Most losses due to
Pests & diseases
CPB 80 – 90%
Ppr 1.2%
* On 16.48 % of the initial flowering reaches ripening

Figures 9.8 &9.9: Pods between 17 t0 26 weeks old- mature beans

Four methods used to prevent disease developing and/or controlling them if they do get established

Methods are:

1. ***Regulatory***
   - Measures (enforceable by law) to prevent material contaminated with a pathogen begin transported from one area that already has a particular disease to another area which does not-called Quarantine

2. **Cultural a broad approach to control disease involving:**
   a) Preventing pathogen coming into contact with and infecting cocoa trees by managing the block so the environment is unfavourable for the pathogen
   b) Eradicating the pathogen
   c) Reducing susceptibility of cocoa by selecting resistant planting material
   d) Managing block so needs of the block of trees are more fully met
   e) Managing the block so environment favours micro-organism antagonistic to pathogen

3. **Biological**
   a) Reducing susceptibility of the cocoa plant to the pathogen
   b) Directly introducing other micro-organism that are enemies of the pathogen
   c) Use different genotypes pest that are less susceptible to the pathogen

4. **Chemical**
   a) Seek to remove pathogen from the 'disease triangle'.
   b) Are toxic to the pathogen

It is useful to have an understanding of epidemiology (process of how a disease spreads through a population of host organism) to decide which control methods to use for each particular disease

Most important diseases of cocoa in PNG are caused by fungus/fungi

Fungi thrive in dark and damp conditions

Important to keep inoculum levels (the source of new infections) as low as possible.

Can be achieved by:

1. Ensuring correct cocoa density by using the appropriate spacing
2. Managing shade density to achieve a maximum of 75%- 85% sunlight penetration by regular pruning of cocoa and shade trees
3. Ongoing control of weeds
4. Regular attention to sanitation practices such as hooking diseased pods and pruning of disease branches

Specific Diseases of Cocoa in PNG

Seedling and Budding Blight Diseases

Introduction

The main disease risk young cocoa trees face in the nursery is seedling and budding blight caused by Phytophthora

The same pathogen causes black pod, canker, chupon blight and probably some Cherella Wilt. Seedling blight can cause very serious losses, particularly in wet season when environmental conditions suit this disease

How seedling Blight Spreads. The fungal spores (seeds) are splashed up from contaminated soil to fill sowing bags

Risk of infection depends on the source of soil used to fill bags and the amount of rainfall

Seedling Blight (Phytophthora palmivora) in a nursery

Figure 9.10: Seedling Blight - dark brown spots spread quickly

Seedling blight disease symptoms

Young plants are highly susceptible to the pathogen as its tissues are soft and provide an easy medium for fungal hyphae (fungus roots) to grow into. The disease often affects the young leaves and green stems of cocoa seedlings (see figure 10.10). Usually, brown spots appear on the diseased parts of the seedling and quickly spread to the growing point. Finally, dry wilting appears and the plant dies.

Controlling seedling blight

1- **Using fungicides for preventative control**
Metalaxyl fungicide

'Ridomil Plus 72' or 'Laxyl Copper' 1% - low and moderate areas or 2% for high risk areas

2. **Using fungicides for treatment control**
As above

Current control recommendation for blight seed soaking

a. Seed soaking
To make 1% metalaxyl solution:

i. Add 2 L water to container

ii. Add 40g of metalaxyl powder to 2 litre water

iii. mix well well with a stirring stick
iv. Soak for five minutes then sow

b. Foliar spraying of seedlings
-A 0.5% metalaxyl solution is made by adding 50 gm of metalaxyl to 10 litre of water for 1500 seedlings

-fine spray during the 2nd to 4th leaf stages and protected for 3 to 4 weeks where by the lower leaves should hardened off

-plants showing symptoms be removed and burnt

Warning: Safety considerations when handling fungicides

Vascular Streak Dieback (VSD)

Introduction

A fungal disease caused by caused by Oncobasidiumtheobromae

Infects young growth and grows back into older tissue clogging up phoem and xylem with its hyphae

This block the tree's nutrient and moisture supply vessels, killing the affected tree

Figure 9.11: VSD Infected seedling

How VSD spreads

White patches of fungus that grow out onto the bark of diseased stems are called fruiting bodies

It produces fungal 'seeds' called basidiospores. They are very small

Fruiting bodies and spore production only occur in wet and humid conditions such as wet season

Spores carried from one plant to another by wind

Ultra violet light of the sun kills the spore, so only stay viable at night

VSD disease symptoms

VSD - Fruiting bodies and rough bark

Figure 9.12: VSD - Three black patches on the leaf scar

Figure 9.13: VSD - Leaf turns yellow with green spots

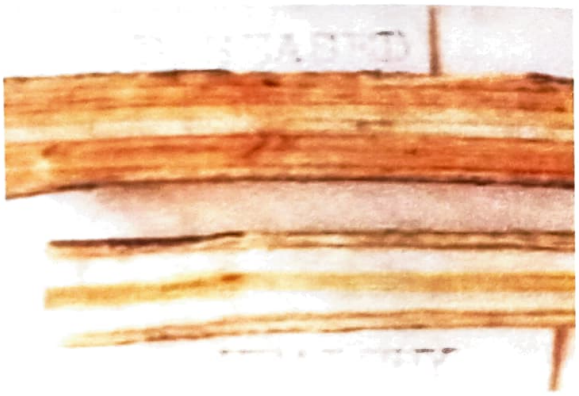


Figure 9.14: VSD - Split stems

The top one infected with VSD showing brown steaks and a healthy stem below

Controlling VSD

1. Appropriate location of nurseries and the use of Poly house or plastic covers
2. The use of resistant and tolerant planting material
3. Appropriate sitting of new plantings in areas that are badly affected by VSD
4. Consistent management of shade to maintain low shade levels
5. Use of appropriate planting densities
6. Canopy management and sanitary pruning

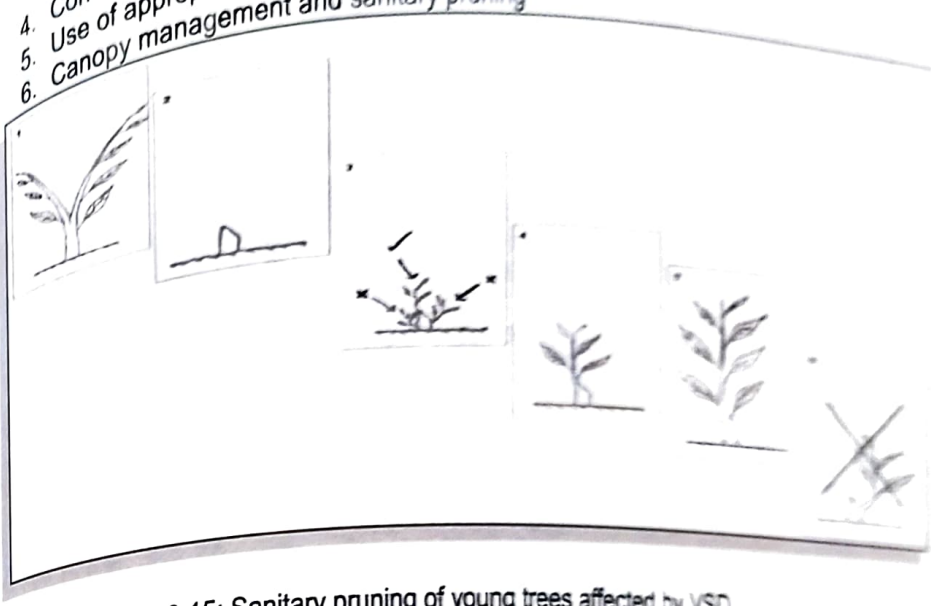


Figure 9.15: Sanitary pruning of young trees affected by VSD

1. Split the plant down the middle to see how far down the brown streaks go down.

2. Cut the seedling off at an angle (so any rainwater will run off the cut) at least 30 cm below the end of the brown streak and at least20 cm above the ground and paint with a solution of red or green copper to prevent entry of root rot.

3. After some shoots have grown out to about 10 – 20 cm choose the top shoot on the high side of the cut. Cut off the other shoots with a clean sharp tool.

4. This will make sure the new shoot grows quickly over the cut.

5. In a few months the join will be healed..6. If a shoot on the low side of the cut is chosen, the cut will not heal quickly and

Current control recommendations for VSD:

Warning:

Pruning out too much wood is not recommended. This will further stress the trees

Main aim is to help the tree grow well so are more tolerant to disease

Control strategies: control of shade levels, cocoa planting densities and canopy pruning will also reduce risks of other disease, such as Phytopthora Pod Rot and Pink Disease

Pink disease of cocoa

Introduction

The fungus Corticiumsalmoni color causes Pink disease

Can be very serious for cocoa tree in the field between the ages of 18 months and 5 years

How pink disease spreads

Apart from cocoa, occurs on a wide range of other trees such as rubber, coffee, citrus, jackfruit, avocado, leucaena

Like disease first transferred to cocoa from some of these hosts

Pink disease symptoms

Practical activity

Controlling pink diseases

1. Cultural control

Figure 9.16: Third stage of Pink disease

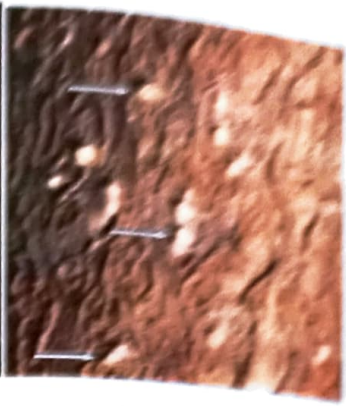


Figure 9.17: Second stage of Pink disease

-Pink/Orange or pink/white crush

pink/white pustules (arrowed)

Figure 9.18: Final stage of Pink disease -damage and death of branches

2. Chemical control

Currently there is no chemical strongly recommended for controlling pink disease in cocoa trees. Current control recommendations for pink disease

Small holders

Farmers musts prune branch off 30 cm beyond where the fungus can be seen growing. Cut branches should be burnt

Large branches, jorquette and stem-apply the fungicidal paint Macuprax (10%) over the affected area and 30 cm beyond its visible edges

Large areas/ plantations

Preventative sprays should be applied all over each tree every 4 to 6 weeks during the wet season

One of the following 2% copper-based fungicides sprays can be used:

a) 2% cuprous oxide ('Copper Sandoz')
b) 2% copper oxychloride (it is important to only use high grade material)
c) Ready-activated Bordeaux mixture such as 'Macuprax 2%'
d) Freshly made 'Bordeaux mixture'. 1.6 kg copper sulphate, 1.6 kg quicklime (or 2.4 kg slaked lime), 200 litres of water as the following recipe:

Steps:

1. First dissolve the copper sulphate in 50 litres of water
2. Mix the line in with the other 150 litres of water
3. This will produce a suspension that is then strained through a fine sieve
4. Add the copper sulphate solution to the lime mixture, stirring vigorously. This mixture should be used as soon as possible

Phytophthora pod rot disease

Phythophthora fungus is the main cause of Black Pod Disease of cocoa throughout the world

There are several species of Phytophthra. Most serious disease of cocoa in PNG with losses ranging from 15-40% or higher if rainfall is high

Infection:

First appears as a brown spot on the pod. It continues to extend over the whole pod within a week. Pods can be infected at all stages of the development

Figure 9.19: Phytophthora Pod Rot

Phytophthora Pod Rot Symptoms

Under the wet and humid conditions that suit the fungus, pods can be infected at any stage of their development although losses may be partially replaced by additional flower setting. *Phytophthora* infection of Cherelles can be told apart from physiological Cherelles wilt only during the few days it takes for the Cherelles to completely turn black. With physiological wilt, there is a general yellowing or a yellow band in front of the brown margin before the Cherelles become generally necrotic, while with the **Figure 10.19 Comparison of physiologi-**fungal infection, there is no yellowing. Sometimes this **calwilt** (top **row) and black pod (bottom** can be due to another fungus *Colletotrichum*. This differ-**row) symptoms on immature podsence** is shown in **Figure 10.19** – the top row are cherelles aborted due to physiological wilt and the bottom row are immature pods infected with Black Pod.

How Spore spreads

Spores can be from any part of an infected tree, i.e. pods, stem cankers, flower cushion or young leaves and shoots.

Soil is the initial and main source of Phytophthora inoculum

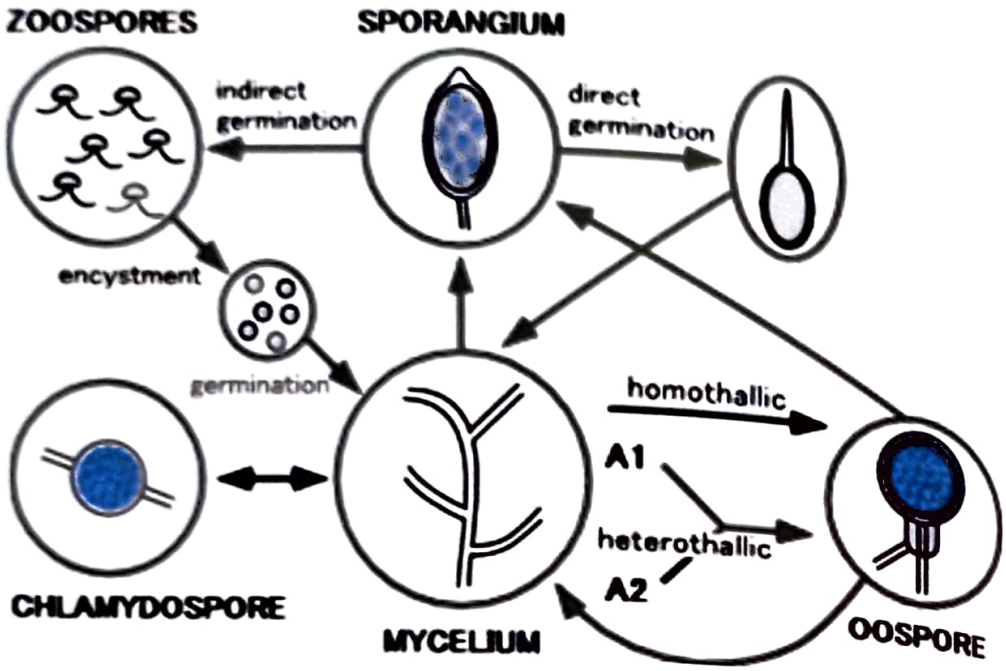


Figure 9.20: C.i. Phytophthora life cycle: at cellular level

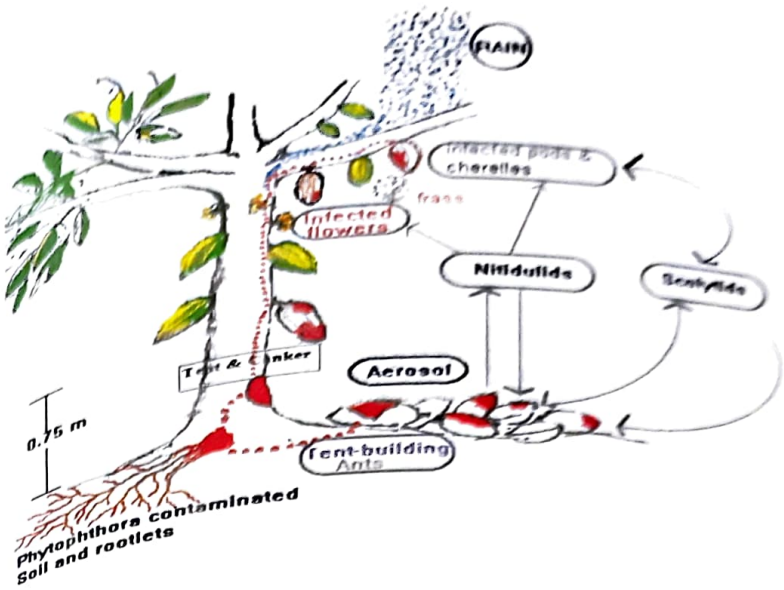


Figure 9.21: Factors governing initiation & epidemics are relative similar for all diseases and pests:

Science well advanced in PNG: Yet knowledge is not used by growers in PNG!

Figure 9.22: *Phytophthora* causing chupon blight

1.**The use of resistant planting material:** Using resistant planting material is an important component in the overall strategy for controlling Black Pod. Some varieties of cocoa have some resistance to black pod. Since the release of theSG2 hybrid in the 1990s all the budding that come from CCRI are relatively resistant, as are the parent trees used to produce hybrid seeds. However, the earlier SG1 hybrid cocoa has little resistance to Black Pod. It was produced from nine crosses between Tinitario (male) and Amazonian (female) parents selected mainly for resistance to VSD. SG2 material was selected from 16 crosses.

Parents were selected from the same VSD resistant population as the SG1 parents, but selection emphasised the combination of VSD resistance (Trinitario parent) and Phytophthora pod rot resistance (Amazonian parent).

Controlling phytophthora pod rot

As management strategies for controlling other fungal diseases

Cultural control

1. Use of resistant planting material
2. Shade management
3. Appropriate planting densities
4. Canopy management and pruning warning. Avoid severe pruning during flush, flowing or early pod development as it may reduce yield a lot
5. Sanitation

Chemical control

Used only as a last resort

Knapsack sprayers

Pressure Sprayers are more cost effective than motorized knapsack mist blowers as lower rate of chemicals used and spray directed more accurately at pods and cherelles

Current control recommendation for Ppr

Fungicide: Two kinds recommended for the control of Black Pod:

1. 0.3% metalacyl (Ridomil plus 72 or Laxly Copper)
   Mix 30 grams of metalaxyl fungicide and 5ml* of sticker in 10 L water

(Treating bark cankers with a paint of metalaxyl mixed at a rate of 200g in 10 litres of water helps control Black Pod too).

2. 2% cuprous oxide. ('Copper Nordox' or Copper Sandoz')
   Mix 200 g of cuprous oxide fungicide and 5ml* of sticker in 10 L of water

Warning:

Fungicides are poisonous so care must be taken. Wear rubber gloves, a dust mask and an eye-shield. If mixture gets on your skin, wash it off immediately with soap and water

When to spray

Used only during the wetter months

Nozzles: TX 4 usually recommended as it has a low volume application rate. TX nozzles have spray angle of 80 degrees. For more acute angle, TY nozzles with 60 degrees can be used

Table 9.1: spraying time for different tree ages

Tree age (years)	Spraying time per tree (seconds)
2-3	15
3-4	25
4-5	30
5-6	40
6-7	50
7-8	60

Volume application rate depends on how many trees per hectare and age of trees, i.e. how long to be sprayed

Other control measures

Introduce crazy ants to drive tent-building ants away

Bark canker

Is an infectious fungal disease of cocoa trees caused by Phytophthora palmivora (also causes black pod). Can infect and kill cocoa trees of any age, mainly trees over 10 years.

Bark canker symptoms

Figure 9.23: A bark canker from Phytopthora infection Figure9.24: The same canker after scraping

How trees get bark canker

1. Mechanical damage
2. Infected chupons
3. Black pods
4. Insect damage
5. Apparently undamaged bark

Control measures

1. Control by improved management
2. Chemical control
3. Resistance- planting material- some SG2 hybrid clones do have reasonable resistance

Root rot disease

Caused by different types of fungi

It can attack many types of trees including Leucaena and Gliricidia- shade trees. Most important root diseases in PNG are White Root Rot caused by the Rigidoporuslignosus fungus and Brown Root Rot caused by the Phellinusnoxius fungus

Symptoms

Figure 9.25: Brown Root Rot (*Phellinusnoxius*) showing an affected root collar
Figure 9.26: Root Rot disease - leaves on an infected tree. Figure 8.3.21 White Root Rot *(Rigodoporuslignosus)* showing fruiting bodies

Brown Root Rot: The roots are covered with a hard, brittle crust of soil held by dried fluid that seeps

Figure 9.27: White Root Rot, (Rigodoporuslignosus) showing fruiting bodies

How root rot disease spread

Spores are carried in air currents released by fruiting bodies of the fungus. As the spores lands on freshly cut surface of a host tree, grows slowly down the stump into roots, feeding on the wood. For replanted blocks refer to the figure 9.28 below for a replanted block

Bark canker symptoms

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Figure9.24: The same canker after scraping

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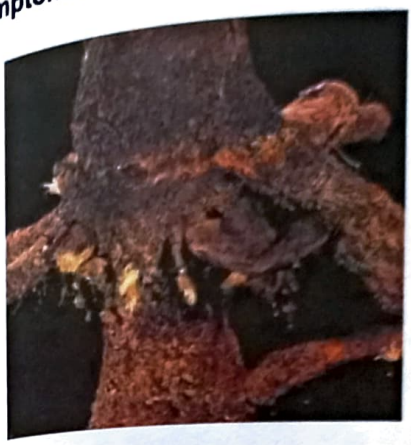

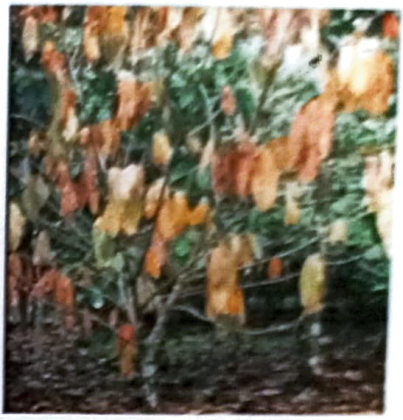

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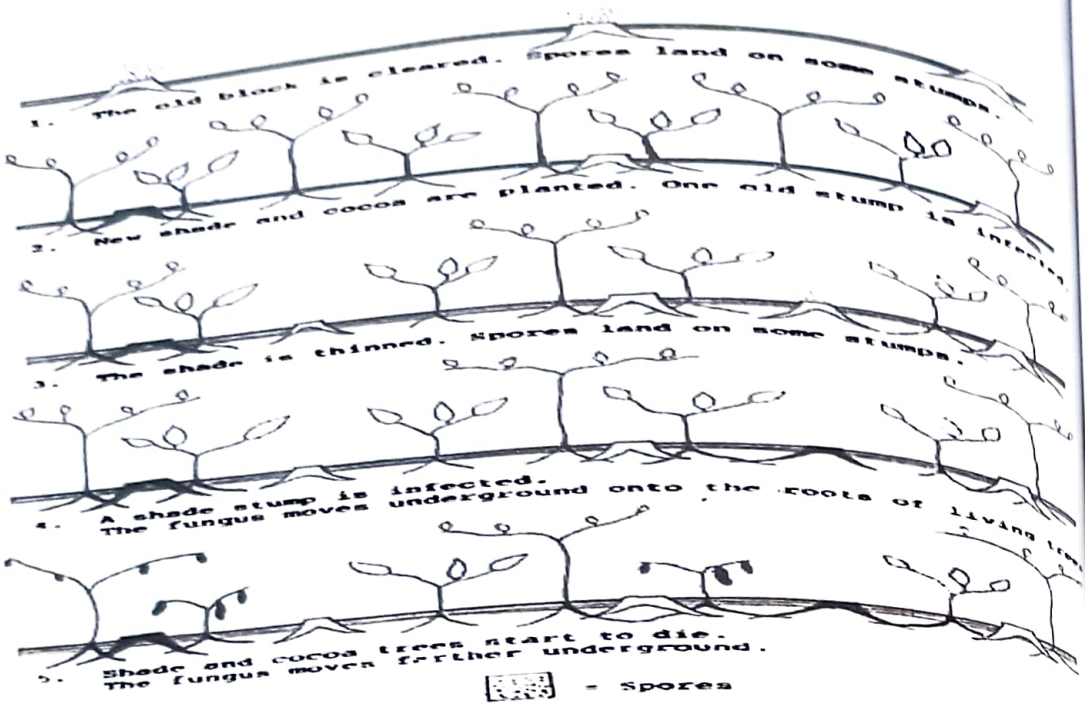


Figure 9.28: Spread of Root Rot Disease in a replanted cocoa block

Disease control

Disease tree is dug out straight away. Get out all main roots plus any old stump nearby and be burnt

Painting the cut surfaces with one of the following mixtures:

- Mix one part of Garlon with 60 parts of diesel fuel. Add three parts of red copper ('Sandoz') or green copper ('Cuprox' or other brand) to 100 parts of the Garlon/ diesel fuel mixture
- Mix red or green copper with diesel fuel or old engine oil. Add three parts of copper to 100 parts of diesel fuel or engine oil

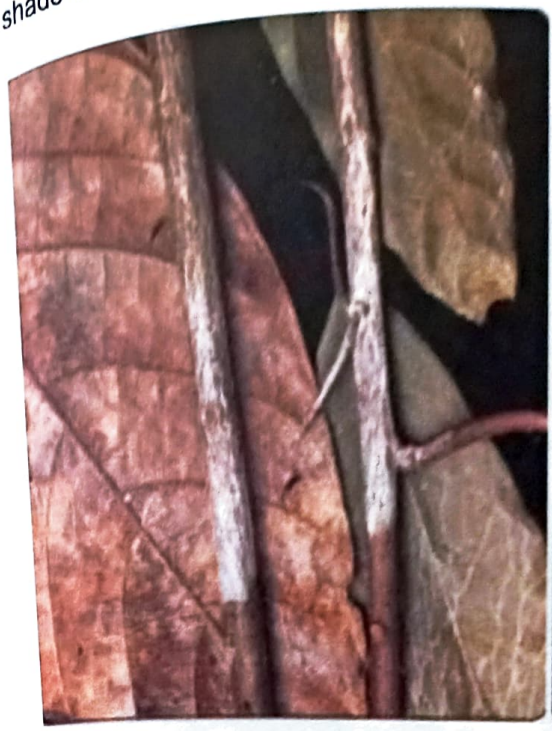
Warning: Care must be taken. Wear rubber gloves, a dust mask and an eye-shield. If mixture gets on your skin, wash it off immediately with soap and water

Thread blight disease

Is a disease often seen in older, poorly managed cocoa with too much shade. There are two types thread blight disease attack cocoa in PNG:

1. White Thread Blight caused by fungus Mrasmiusscandens
2. Horse Hair Blight caused by fungus Marasmiusequicrinus

Not a serious thread but indicates the block is not well management, especially shade management



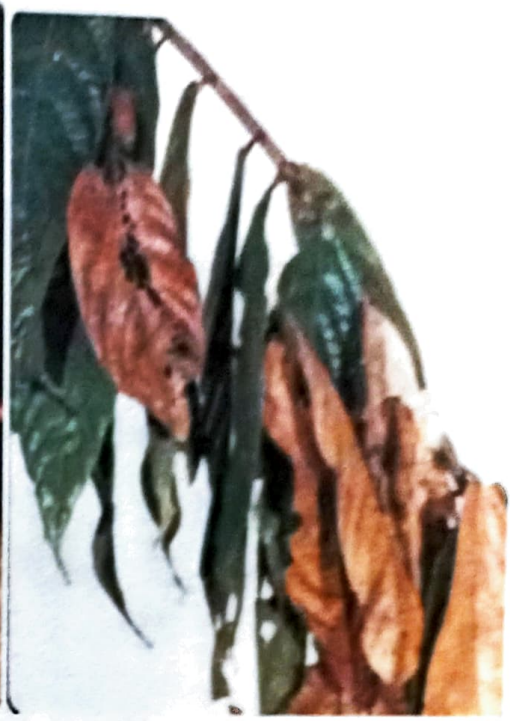


Figure 9.29: White Thread Blight (*Marasmiusscandens*) Figure 9.30: Horse Hair Blight (*Marasmiusequicrinus*)

Symptoms

A typical symptom of both pests is the thread like structures growing over infected tree plants.

White Thread Blight is characterized by white mycelia (thread-like structures of the fungus) spreading over leaves, petioles and branches as shown in Figure10.30. It leads to the death of the leaves which remain hanging from the branches by the threads

Horse Hair Blight forms a black tangle of threads through the cocoa canopy, but does not kill the leave

How thread blight spreads

Found in blocks with thick, un-pruned canopies where cocoa branches interlock and the trees are heavily over-shaded

Control

Regular pruning and reduction of shade levels to reduce humidity

Warning: Care must be taken. Wear rubber gloves, a dust mask and an eye-shield. If mixture gets on your skin, wash it off immediately with soap and water

Serious cocoa disease not present in Papua New Guinea

Figure 9.31 Swollen Shoot Virus.

Figure 9.32: Frosty pod rot Moniliasis

Fruiting body of the Witches' Broom fungus, Bolivia. Photo H. Evans © CABI Bioscience

Figure 9.33: Cocoa witches room

Virus disease

Wide spread in West Africa. Occurs in Trinidad, Sri Lanka and Sabah

Carried from tree to tree by mealy bugs

Witches broom disease (Crinipellisperniciosa)

Comes from Amazon basin and spread to many South American, Central American and West Indies countries

Moniliophthora pod rot (Moniliophthoraroreri)

Sometimes known as 'Moniliaroreri' or Monilia Pod Rot or Frosty Pod Rot

Occurs in the north western region of South America and southern part of Central America

Irregular dark brown spots develop on the pods which eventually join up to cover the whole surface

Teaching Strategies

A) Introduction/Motivation

a) Do you know some economic and some common diseases in PNG?
b) Name the most serious threat of disease to cocoa industry in PNG?
c) Bring to the class samples of some disease found on the cocoa tree from the school and examine them with students

B) Body/Content/Subject Matter

a. Teacher to introduce the idea of an economic diseases of PNG cocoa industry
b. Discuss, what do you know about the term disease!
c. Discuss cocoa disease as a parasite!
d. Study five most important diseases of cocoa in PNG
e. Students to be grouped and each study a significant disease as a project and present to the class (Use pictures of major disease, its damage, life cycle, control measures, and discuss its economic significance to the cocoa industry in PNG)
f. Get students in groups to conduct economic survey of cocoa disease and analysis their impact on the industry

C) Closure

a. Student presentations using available media and discuss presentations
b. Use the presentation charts, tables and illustration for display in the class.
c. Award marks to best groups and display

Student Activities

1. State five cocoa diseases in order of economic importance in PNG

2. Describe and demonstrate the environmentally friendly control techniques

3. Demonstrate and get students to carry out chemical control techniques (i.e. Correct mixing, spraying and safety procedures

4. Demonstrate the importance of Safety by using appropriate protective clothes and procedures

5. Discuss one of the major diseases of cocoa and provide illustrations and graphics to show their significance to the cocoa industry in PNG

6. The main insect pest and specific management recommendation

Major Diseases\	Control	Marks

7. Practical – Do a disease collection Activity


17/05/2013

Introduction

The main aim of cocoa block management is to maximize

1. Early growth to obtain high early yields
2. Sustained peak yields with good management and good soil conditions

The agronomy of cocoa is more complex than of some other crops like oil palm. There is very strong interaction between nutrition and other agronomic factors. Example, the use of nutrients by cocoa trees decreases with increasing overhead shade. Nutrition should not be a limiting factor for achieving high yield. Fertilizer use is important for maximizing yields in many cocoa growing areas in Papua New Guinea

Environments that are suitable for cocoa growing in Papua New Guinea has been categorized into 29 agro- ecological zones (AEZ) based on:

1. Land form
2. Soil drainage
3. Slope gradient
4. Inundation (flooding)
5. Water retention
6. Annual rainfall (see Hanson, et al 1998).

Classifications are on a national scale and are not sensitive enough to identity small pockets of land in which cocoa may grow well. This unit covers practices where students can realized the importance of soil management

Learning Outcomes

At the completion of the unit, the students can:

A. State what is involved in Soil management
B. List and describe Types of erosion
C. Explain causes of erosion
D. Describe soil conservation methods
E. List types of fertilizers and their uses

Content

Soil management

1. Land under undisturbed forest or grass is protected from the impact of rainfall
2. Good structure of the topsoil and the presence of leaf litter allow most rainfall. To infiltrate (soak into) the soil, so that there is little run off

Soil Erosion

Clearing and cultivating land expose the soil to battering effect of raindrops. which break down soil aggregates and seal soil surface. The movement of rainwater into the soil is reduced and run off increased leading to erosion

Types of erosion

Figure 10.1: Types of Erosion

1. Starts with the movement of water over the soil surface
2. Can end with creation of deep gullies or collapse of river banks
3. Different types represent successive stages in a process rather than separate events

Types of Erosion

1. Sheet Erosion or Splash Erosion

The first damage implies the uniform removal of soil particles by the even flow of a thin sheet of water. Much erosion, the result of the run off that is not moving fast enough to transport soil particles. This has the ability to transport soil that comes from turbulence produced by the impact of large raindrops. This effect of raindrops and importance in breaking down soil aggregates into smaller particles, some refer to as splash erosion

2. Rill or Shoe String Erosion

As sheet/ splash erosion proceeds, small channels appear. Run off concentrate in these channels giving rise to rill or shoe string erosion

Gully Erosion

If the amount and speed of water is large enough to deepen and widen these channels which leads to what is known as **Gully erosion**. Gullies also develop from naturally occurring channels or from the channels caused by ploughing up and down the slope, wheel nuts, cattle tracks or footpaths.

3. Head Erosion

When water begins to deepen a gully, a small water fall forms at its upper end this leads to water flowing with increased speed causing **head erosion**. It results in the gully gradually eating its way up to the top of the slope. The deepening of the bed of the gully may lead to undercutting and curving in of banks. The material that falls is quickly washed away, leaving vertical banks to be undercut by the next floods. Flow of water over small depressions at the top of the banks may lead to further head erosion and development of branches of gully. Once started, gullies can become greatly enlarged very quickly

4. **Stream bank erosion**

Stream erosion is undermining and collapsing of banks due to river flow. It can also result from surface run-off over edges of banks. When the land is cultivated right up to the edge of rivers or streams stream erosion occurs. Agriculture

projects are required to leave a strip of vegetation undisturbed 30 meters wide each side of the rivers/ streams to prevent stream erosion from occurring.

Cause of erosion

Important factors affecting soil erosion caused by water are: the amount, distribution and intensity of rainfall. The higher the intensity of rainfall, the more rainfall per minute, the greater volume (amount) of runoff water per unit time, the higher the speed of run-off. Experiment in Africa, protecting the bare soil with two layers of fly wire reduced soil erosion more than dense permanent grass infrequent storms of high intensity can cause a higher proportion of soil erosion Erosion is usually worst in regions that have alternating wet and dry seasons than more evenly distributed rainfall where soil is usually moist

First rain after a period of dry weather is likely to cause much erosion. The major factor is the frequency of high intensity storms: It also depends on:

1. The slope and nature of land surface
2. The vegetation cover
3. The type and fertility of the soil
4. The land use and farming practice

Prevention and control

Methods of prevention and control

Effective control of erosion requires use and treatment of various types of land over the whole catchment area

The three major components are:

1. Suitable land use: Each type of land should only be used for a purpose for which it is suited without undue risk of erosion
2. Appropriate soil: Conserving methods of husbandry must be used on each type of land. E.g. when ploughing is done plant along contours and use cover crops when feasible
3. Where necessary, use suitable mechanical conservation measures, such as silt pits or narrow-based ridge terraces

1. Physical survey and classification of land

This is done with the objective of preparing an overall land-use plan in which soil conservation is the major component.

The mapping of three land characteristics needed for soil conservation purposes:

a) Soil Slope
b) Degree of erosion.
c) Existing vegetation or land use can be mapped, necessary where considerable erosion has already occurred and control require reorganization and re-planning of land use
d) Establish and map land –capability classes, based on information obtained in the survey and knowledge of local climate and agriculture. Land –capability class will indicate suitability of an area for certain types of crop and type of agronomic and mechanical conservation measures needed

Further advice can be obtained from the Land Utilization Branch of the Department of Agriculture and Livestock if needed.

2. Mechanical measures for soil conservation

Consist mostly of earth banks with channels above them, constructed at suitable intervals across the slope. These earth works break up the slope, catch the run-off before it move with too much speed and divert water down safe grades to suitable discharge points

1) Hillside ditch: The simplest form of conservation work
2) Narrow-based ridge terrace or contour ridge: A ridge of earth built along a contour or slight grade (slope) with a channel on the lower side. Suitable for fairly deep soils on moderate slopes of 10% to 20%
3) Broad-based terrace ridge: A much larger, but relatively lower ridge and a shallow channel above it. Used mostly on arable land with moderate slope and deep soils
4) Bench terrace: Oldest, consists of a series of steps cut into slope on the contour with forward edges never cultivated. Used on very steep slopes and water conservation and irrigation on less steeply sloping land
5) Modified bench terraces: Used in contour cultivation of tree crops on relatively steep slope

6) Individual bench terraces: Known as platforms, short lengths of modified bench terrace. Can be prepared along contour lines before planting and joined up to form continuous terrace. Not usually very effective
7) Storm drains/ diversion ditches: May be needed in addition to terraces to protect the terraced area from run-off from higher land. Relatively wide and shallow channels, with excavated earth placed on the lower side to make a substantial embankment. Both channel and bank are best protected by grass cover
8) Outlets: must be provided so that water discharged will not cause erosion elsewhere
9) Other mechanical measures:
   a) Logs can be placed at an angle across the slope to prevent water from running straight downhill
   b) A series of logs, placed so that water runs from the end of one a short distance down to the next
   c) Dig holes in the ground to act as silt traps at intervals to slow water flow. Can be lined with old metal drums to prevent sides collapsing

3. Agronomic measures for soil conservation

Mature cocoa is as good as undisturbed rainforest in protecting soil from heavy rain and run-off

Reasons for prevention and control:

a) Loss topsoil and the decline in fertility accompanying erosion reduce crop yields
b) Can also reduce the productivity of flatter land below the land that the eroded soil came from, as the result of floods depositing large amount of coarse sand or gravel
c) Water supplies can get worse as the result of soil erosion
d) Floodwater from streams resulting from run-off can damage water supplies, roads, bridges, hydroelectric power installations and other property over large areas.

Cocoa nutrient requirements

Reasons for applying fertilizer:

1. The amount of shade is important that a relationship exist between shade and nutrient requirements.
2. The more shade, the lower the metabolic rate of the tree and thus the lower the rate at which the tree will draw nutrients from the soil.
3. The need to apply fertilizer will vary according to shade levels.
4. In heavier shade a cocoa tree needs less fertilizer and vice versa

5. The standard of management (pest and disease, weed control, shade control) also affects the response to applied fertilizer
6. Fertilizers are a complement to good management, not a substitute for it

Cocoa is grown in PNG on a wide variety of soils of widely varying suitability

General guide to cocoa soil requirements

1. Soil depth of at 1.5m so cocoa can develop a good root system and obtain sufficient water and nutrients during the dry season
2. Soil texture is able to hold adequate moisture and be free draining. Suitability of soils varies with climate and hence heavier soils are desirable where there is a strong dry season
3. Optimum soil pH is about 6.5, but a range from 4.5 to 7.5 can be tolerated by cocoa
4. Minimum soil nutrient levels should be:
    1) Nitrogen > 0.2%
    2) Phosphorus > 10 ppm
    3) Base exchange capacity = 12.0 m.e/100 g soil
    4) Calcium = 8.0 m.e/100 g soil
    5) Magnesium = 2.0 m.e/100 g soi
    6) Potassium = 0.24 m.e/100g soil

Possibility of Nutrient Deficiencies

Nitrogen

1. In high light conditions
2. Induced by an interaction between nitrogen and phosphorous
3. Water logging

Phosphorous

1. Rarely a limiting factor
2. Level in leaves of adult cocoa trees gives a good indication of soil phosphorous levels

Potassium

1. Natural deficiency in parts of New Ireland, New Britain and where soils are derived from coralline material
2. Affected by soil pH
3. Low levels usually shown in leaves

Other Nutrients like:

1. Sulphur
2. Zinc
3. Iron are detected by foliar symptoms or leaf analysis

Important considerations:

1. Inorganic fertilizers are quite expensive and cost of applying it is high
2. Soil suitability should be assessed through soil surveys, soil sampling and chemical analysis to determine nutrients status of the soil
3. Fertilizer input should be based on soil analysis, crop yields, shade regime and age of cocoa tree

Sampling for nutrient analysis
Soil sampling

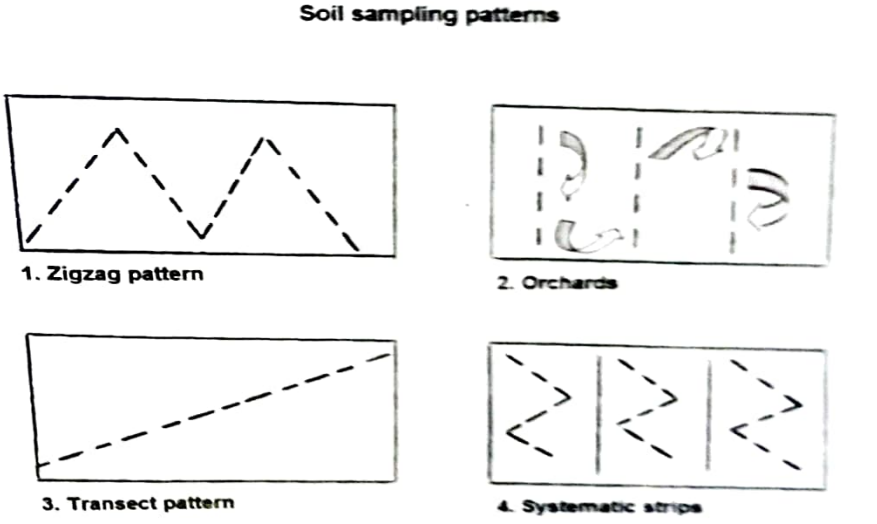
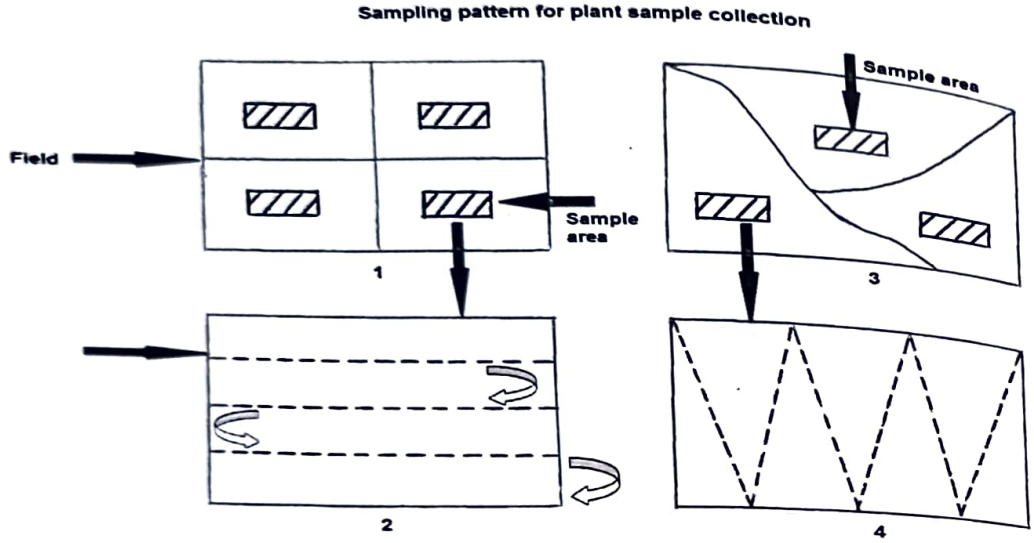


Figure 10.2: Soil sampling patterns

In well-managed plantations and small-holders blocks, it takes 6 months after field plating. When no serious nutritional deficiencies, excesses or imbalances, a second sample should be taken 3 years later and then every third year

Sites where nutritional problems are identified, frequent sampling and sought advice from an expert soil chemist is necessary.

Leaf Tissue Sampling



Source: Reuter & Robinson, 1999

Figure 10.3: Sampling pattern for plant sample collection

Leaf samples may be taken from trees that are 5 years old and older

Foliar analysis is most useful where there are unexplained growth or productivity problems

Accuracy of leaf analysis depends on following standard method of collecting samples as chemical content of leaves changes with ages and with degree of exposure to sunlight

PNG Analytical Laboratories Ltd require the following procedures

1. Leaf sample must be representative of an area uniform in tree age, variety, cultural treatments soil type and appearance
2. A single composite sample should not represent an area greater than 2 ha
3. Samples should be taken from suspected problem area and nearest good area for comparison

4. If inter planted with coconuts, samples should be taken from both crops

Steps:

To take samples,

1. Select the third leaf on a branch where a new flush is about to emerge
2. Leaves will be completely hardened, exposed rather than non-vigorous under canopy
3. Branches selected and petioles should be removed
4. At least 40 trees should be sampled to give 40 to 80 leaves

Types of fertilizer

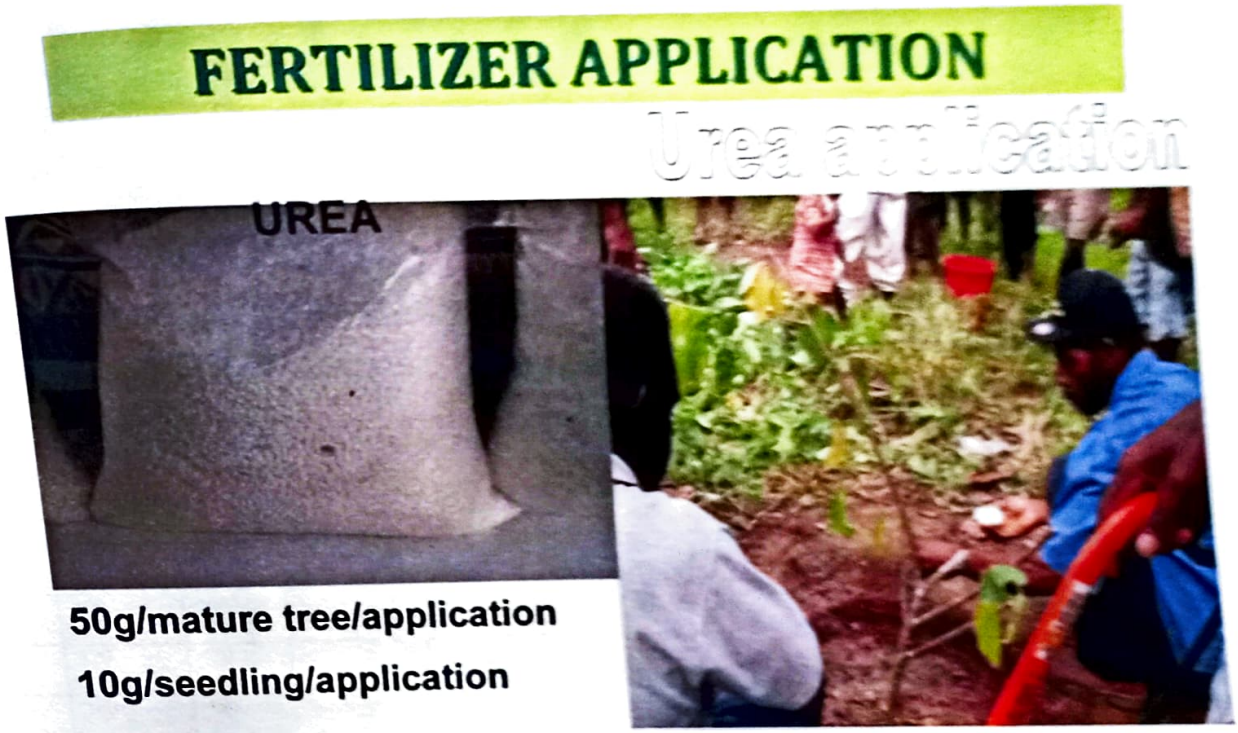


Figure 10.4: Urea fertilizer and application

Figure 10.5: NPK fertilizer and application

1. Nitrogen
2. Potassium
3. Trace Element Deficiencies

Timing of fertilizer application

Depends on weather patterns and the types of nutrients/fertilizers applied in the Nursery

Only foliar feeds can be used to stimulate nursery growth

Young cocoa in the field is aided by well shaded establishment and properly reduced

Table 10.1: Recommended Fertilizer Application per tree for cocoa in the first 12 months after field planting with very good or good management

Option	Period after field planting (months)			
	0 month	3 months	6 month	9 month
1	50g NPKMg	50g NPKMg	50g NPKMg	50 NPKMg
2	150g rock PB + 15g ureaD or 30g AS	15g urea or 30g AS	15g urea	15g urea or 30g AS
3	30g triple PB + 15g Urea or 30g AS	+ 15g Urea or 30g AS	30g triple P + 15g Urea or 30g AS	+ 15g Urea or 30g AS
4	0g DAPB	30g DAP	30g DAP	30g DAP

Table 10.2: Fertilizer Recommendations for hybrid cocoa planted on 4 meter

	Volcanic ash soils, sandy loams				Alluvial, clay loam				Clay loam over limestone			
	Urea OR:	Ammonium sulphate	NPK 15:15:15	Muriate Of potash	Urea OR:	Ammonium sulphate	NPK 15:15:15	Muriate Of potash	Urea OR:	Ammonium sulphate	NPK 15:15:15	Muriate Of potash
	30	60	60	-	30	60	60	200	30	60	60	200
	40	80	80	-	40	80	80	-	40	80	80	-
	50	100	100	-	50	100	100	-	50	100	100	-
	60	120	120	-	60	120	120	-	60	120	120	-
	80	160	160	-	80	160	160	-	80	160	160	-
	100	200	200	-	100	200	200	-	100	200	200	-
	120	240	240	-	120	240	240	-	120	240	240	-
	120	240	240	-	120	240	240	-	120	240	240	-
nature	120 every 3 months	240 every 3 months	240every 3 months	-	120 every 3 months	240 every 3 months	240every 3 months	400 annually	120 every 3 months	240 every 3 months	240every 3 months	400 annually

squares (grams per tree)

Table 10.3: Nutrient removal (kg nutrient per ha) for each tone of dry bean yield

	Nitrogen	Phosphorus	Potassium	Magnesium	Calcium
Husks	10	0.5	46	4	5
Beans	21	4.2	11	1	3
Immobilized in trees	4	2.0	8	--	--
Total	35	6.7	65	5	8

Bearing trees (25 months and older) At this stage, the table is showing estimates of how much of the various nutrients are removed in a cocoa crop of mature bearing trees **Placement of fertilizers**

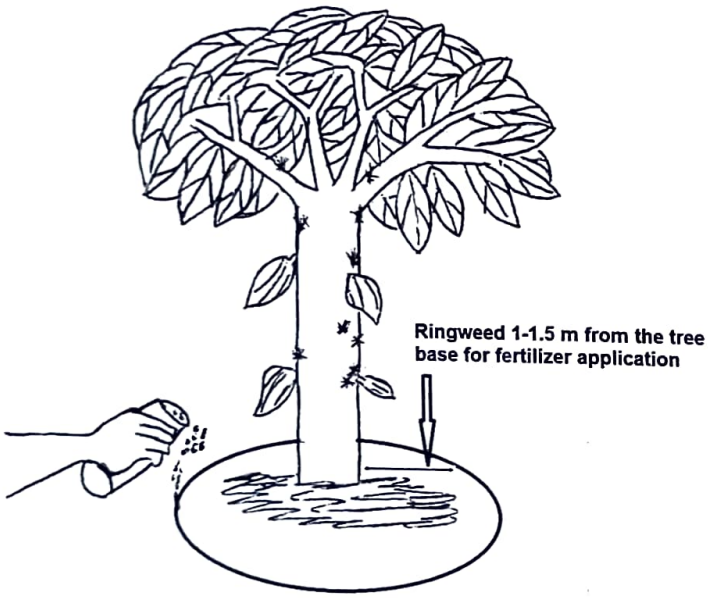


Figure 10.6: Placement of fertilizer

Standard fertilizer Recommendations by Tree Age

Table 10.4: Fertilizer placement by age

Age of cocoa (months)	Distance from base of tree
0-6	30
7-12	80
13-18	120
19-24	150
>24	Broadcast

Teaching Strategies

A) Introduction/Motivation

Pose questions like:

1. What do you know about soils?
2. Does Soils get lost and what does that mean?
3. What are the causes of soil loss
4. How can we prevent soil loss?
5. How does your farmer controls soil loss

B) Body/Content/Subject Matter

1. Show pictures and explain types of erosion
2. Use notes and field trip/visit to describe and explain erosion types
3. Use notes to summaries control measures of erosion

C) Closure/Conclusion

Orally ask students to:

1. Name each types of erosion
2. Describe how erosion occur
3. Discuss erosion control measures

Written questions and exchange papers to mark

1. Name each types of erosion
2. Describe how erosion occur
3. Discuss erosion control measures

Student Activities

State what in involved in Soil management

List and describe Types of erosion

Explain Causes of erosion-

Describe soil conservation methods

List types of fertilizers and their uses

Prevention and control	Marks

Students Research Activities

Key to deficiency symptom in cocoa by symptoms

Symptoms	Deficiency in What mineral
A. Plants markedly chlorotic	
B. Chlorotic mottling between veins	
C. Leaves chloritic	
D. New leaves deformed	
E. Absence of chlorosis, necrosis or leaf deformities	

Key to deficiency symptoms in cocoa by nutrients

Grouped generally on the whole tree,

- More prominent on older leaves
- More prominent on young leaves

Nutrient deficiency	Symptoms
Nitrogen	
Sulphur	
Phosphorus	
Boron toxicity	

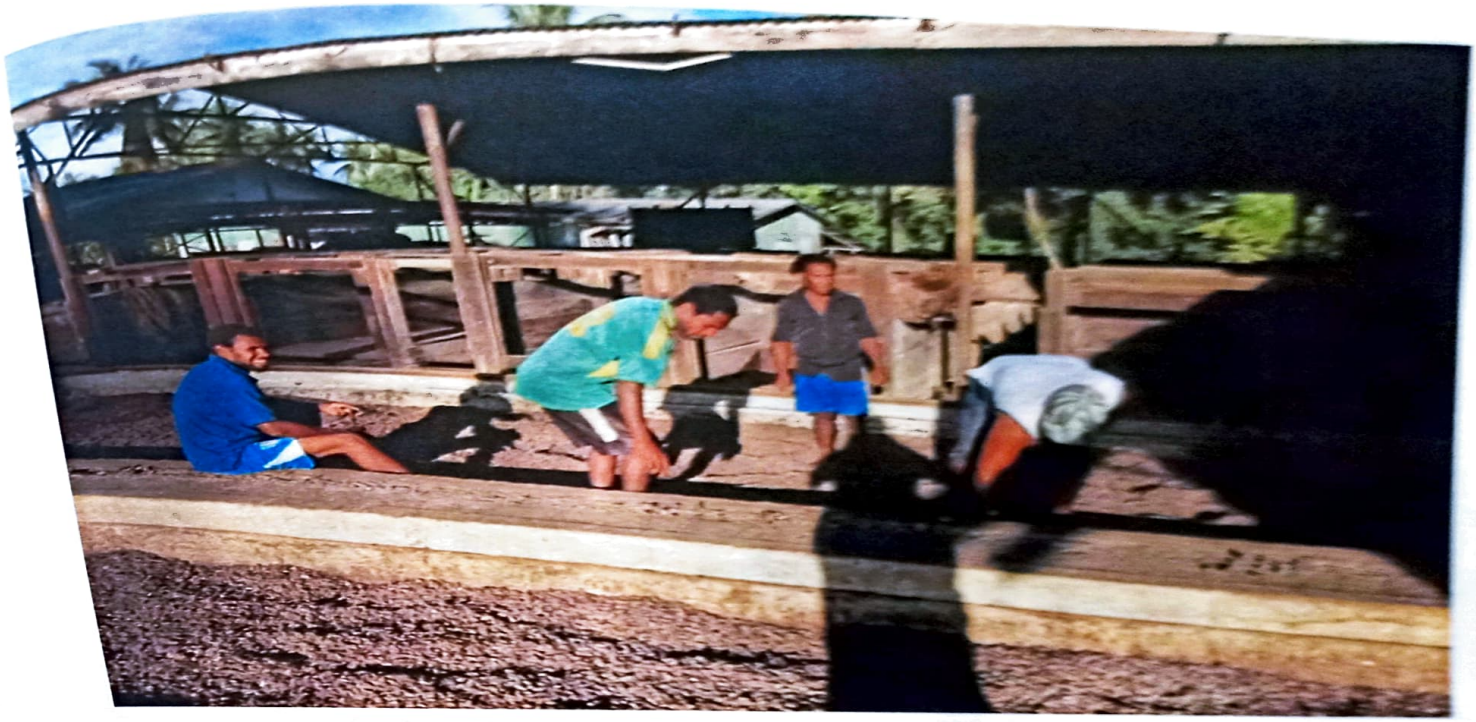
Symptoms more pronounced on mature leaves

Nutrient deficiency	Symptoms
Potassium	
Calcium	
Magnesium	
Iron toxicity	

Symptoms more pronounced on young leaves

Nutrient deficiency	Symptoms
Iron	
Boron	
Zinc	
Magnesium	
Manganese toxicity	
Zinc toxicity	

UNIT 11: PROCESSING



Introduction

Cocoa beans of commerce are seeds. Seeds must undergo many changes before of any value as an export commodity. The reason for the cocoa's popularity as food substance in many parts of the world lies in its unique chocolate flavour. The flavour developed only by means of curing (fermentation and drying) and manufacturing (roasting)

The seeds (beans) from ripe fruits (pods) put through the first stage of curing process- fermentation immediately after harvesting. The second stage of drying a week a week later processes brings changes within cocoa beans responsible for the development of flavour. Fermentation 1- aid mucilaginous bulb removal 2- allow biochemical reactions within the beans necessary to the formation of flavour potential

Unfermented beans do not develop any chocolate flavour when roasted. It produces excessively bitter and astringent and is unacceptable to manufacturers

Drying reduces moisture content of beans necessary for storage and shipment

Drying completes fermentation stage in developing the desirable flavour

It is importance student understand the key issues in this unit as it affects the quality of production

Learning Outcomes

At the end of the unit, the student can:

A) Discuss proper pod breaking
B) Take correct weighting
C) Describe Fermentation process
D) Demonstrate proper Drying and show

1. Turning
2. Testing
3. Sorting
4. Bagging
5. Storage

Content

Pod breaking

Breaking the pod

It is done straight after a pile of cocoa is hooked. Delays lead to losses from disease expected

Can brought to own fermentry or

Sell as wet beans to licensed cocoa board dealer

Figure 11.1: Breaking pods and removal of cocoa beans

Some important rules

1. Do not use knife as cuts beans
2. Avoid rain as it washes mucilage for good fermenting. Remove beans from pod and placenta
3. Put in a plastic or a bag
4. Remove hard, black, germinated or flat beans
5. Leave husk in the block as it attract midges to help pollinate cocoa
6. Taken straight to the fermentry, not delayed

Weighing

It is useful to weigh wet beans before putting into the fermenting box. This will give the conversion rate from wet beans to dry beans of 40% and a range of 35% to 45%. This depends on how fresh the beans are and when put into the box

Dealer's has a limited adjustment of 2% and calculated on a wet to dry conversion and work out the price to pay

Fermentation

The process is considered on the main parts of seeds:

1. Seed coat or testa with surrounding pulp
2. The cotyledon focus on the nib used in manufacture of chocolate

The mucilaginous pulp spongy material containing juices chemical composition is:

a. Water 84.5%
b. Pentosan 2.7%
c. Sucrose 0.7%
d. Glucose/ fructose 10.0%
e. Protein 0.6%
f. Acids 0.7%
g. Inorganic salts 0.8%

Pod composition

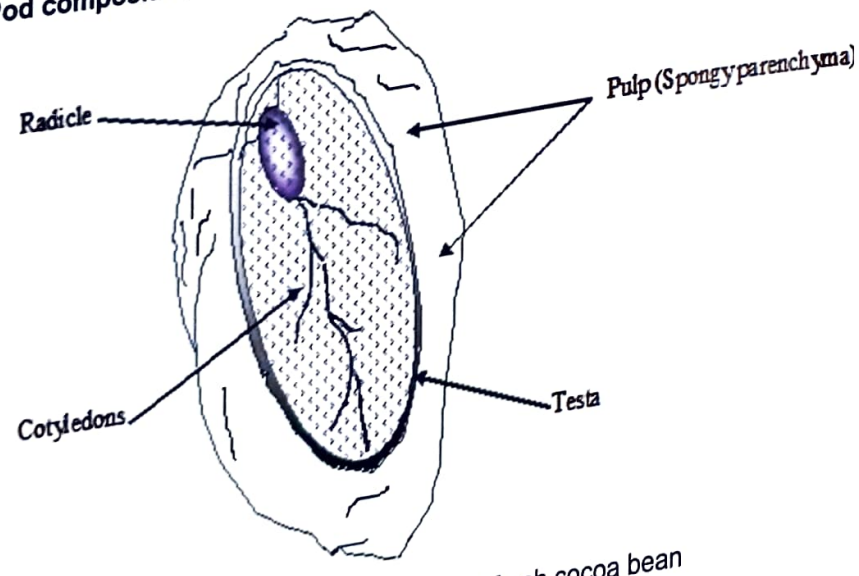


Figure 11.2: Composition of fresh cocoa bean

Essentials for proper fermentation to break down the pulp material surrounding the seeds

It is impossible for manufacturers to produce chocolate from cocoa beans, which have not been fermented or have been badly fermented. This means fermentary operators must always take care when processing cocoa as dealing with something that is food

When producing poor cocoa, will not sell their beans and Papua New Guinea cocoa will get a bad name with the chocolate manufactures. Therefore it is essential for proper fermentation

0perators need

1. **A weather proof building**
2. **Approved fermentary boxes**

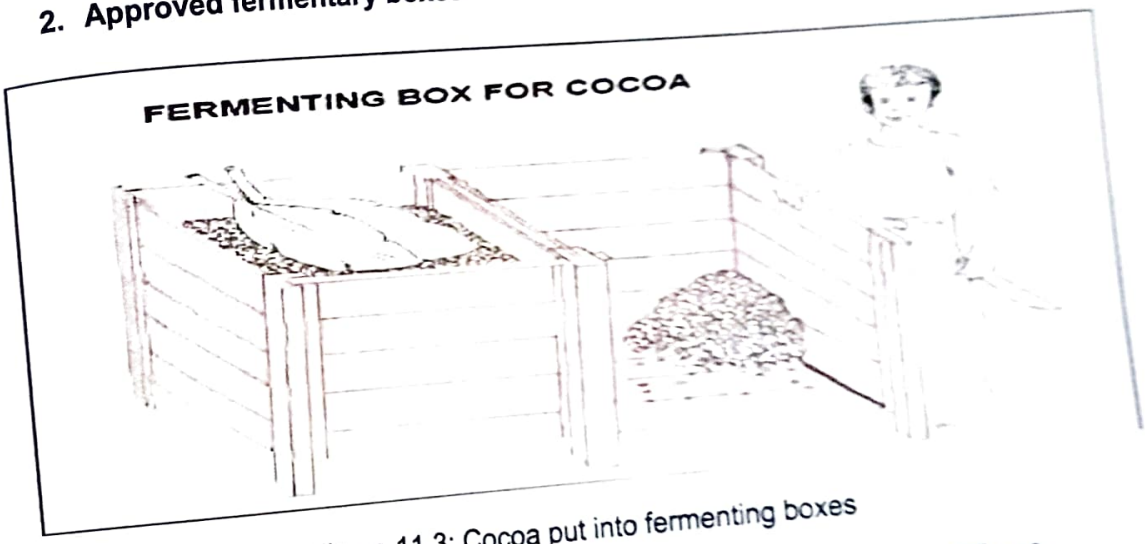


Figure 11.3: Cocoa put into fermenting boxes

Constructed in pairs/ compartments separated by removable partition. Fill one compartment leaving one empty for next day when turning. It is made of 15cm x 2,5cm (6 inch x 1 inch) planks. It is raised above 15 cm for small operators and 1m off the ground for large operators. This enables excess moisture to drain away, air to enter and space for rubbish clearing.

The slots are to be 3-5mm wide and easier to clean. The compartment to be at least 900mm wide, 900mm deep and 1200mm long as approved by the cocoa board

3. **Shovel**

For turning and made from aluminium or stainless steel/ plastic and or wood. Steel shovel is not good and can contaminate beans to go black

The edge to be blunt and rounded as when sharp can cut or bruise beans and provides a point of disease entry

4. **Small, sharp knife**

   To keep cutting a few beans and checking the progress of the fermenting and drying

5. **Patience**

   Be patient and not rush work as this may cause low quality work

6. **Dealer will require a good quality set of scales with hook**

Important Points:

1. The wet beans go into fermenting boxes
2. Only fresh wet beans from sound, ripe pods
3. Should be put in the fermenting boxes
4. Wet beans must go into fermenting boxes within 24 hours after breaking the pods

Turning the beans

The fermenting beans must be turned once every day

Figure11.4: Turning cocoa beans in the fermenting boxes

Turning is very important

1. Ensures even heating of beans
2. Air enters the ferment
3. Lumps get broken up
4. Mould will not form on the beans

If not turned regularly, the beans will be mouldy and bad-smelling and will not ferment properly

Length of ferment

- Cocoa beans should be fermented for five to seven full days

What happens in ferment?

Chemical reactions take place that cause certain changes to cocoa beans

Operators can judge their ferments by observing three main physical changes that occur:

1. Colour
2. Temperature
3. Smell

Cleaning up after each ferment

CHECKING IF BEANS ARE PROPERLY FERMENTED

1. **Over-fermented** beans are nearly black on the outside and brown-black inside.
2. **Under-fermented** beans are sometimes deep purple inside. Sometimes the inside is white and "cheesy".
3. Beans that are **slightly under-fermented** are a light purple colour inside.
4. Beans that did **not ferment at all** are **slaty** (a grey colour inside).
5. **Beans that are PROPERLY FERMENTED are brown on the outside and either a Choco-late-brown (Forastero) or light brown (Criollo) colour on the inside. They have brown liquid inside, and they are brown on the inside of the skin. These beans are ready for drying.**

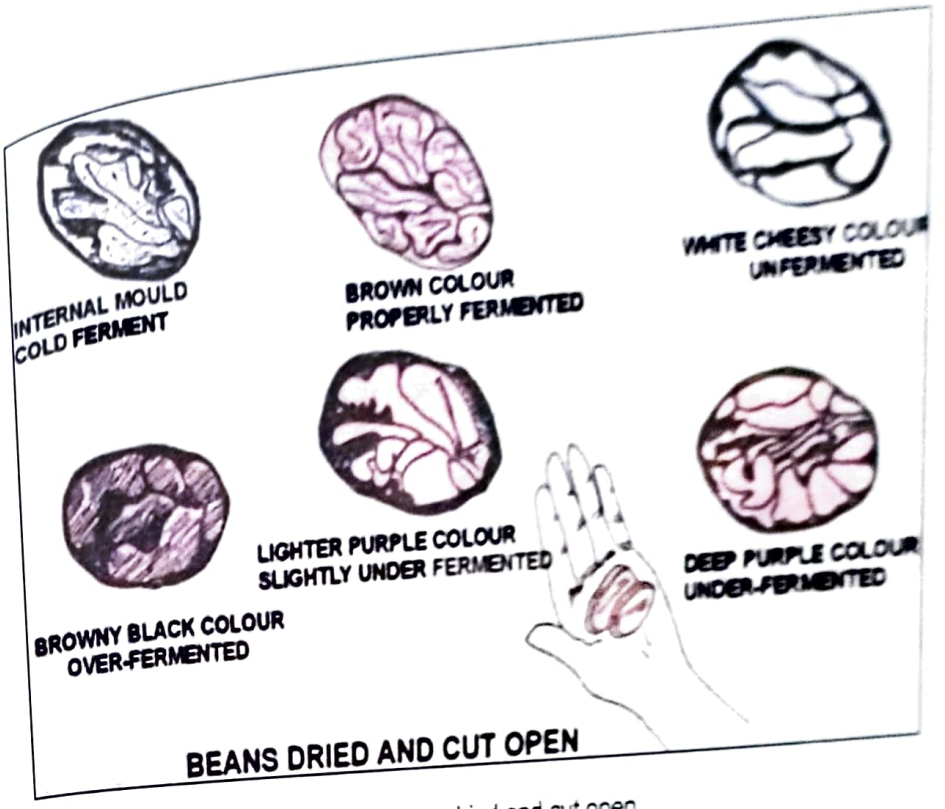


Figure 11.5: Beans dried and cut open

Drying

After fermenting, cocoa beans must be dried on special cocoa driers

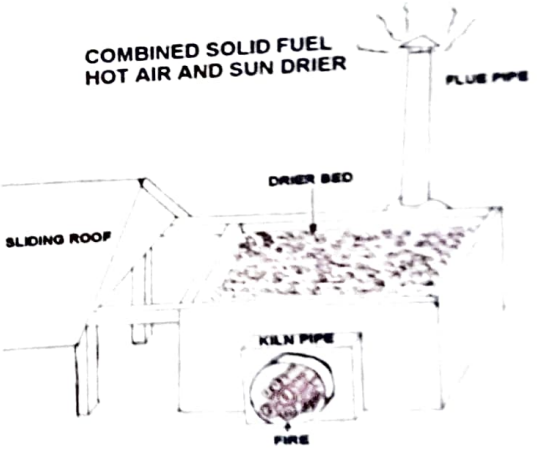


Figure 11.6: A Combined Solid Fuel Hot Air and Sun Drier

Steps in drying

1. Beans dried by sun or kiln pipe heat until the skins are just dry
2. As soon as the skin are just dry, should be left for 12 hours
3. After the rest, beans should be dried during the day only. Use sun or kiln pipes for no more than 6-8 hours each day. Allow beans to rest overnight
4. Have the beans dry in three to four days and not more
5. Over fermented beans should be dried in no more than two days

Turning cocoa while drying

Beans need to be turned regularly so that they are dried evenly. Beans stuck together be separated. Rubbish as placenta or rope must be removed

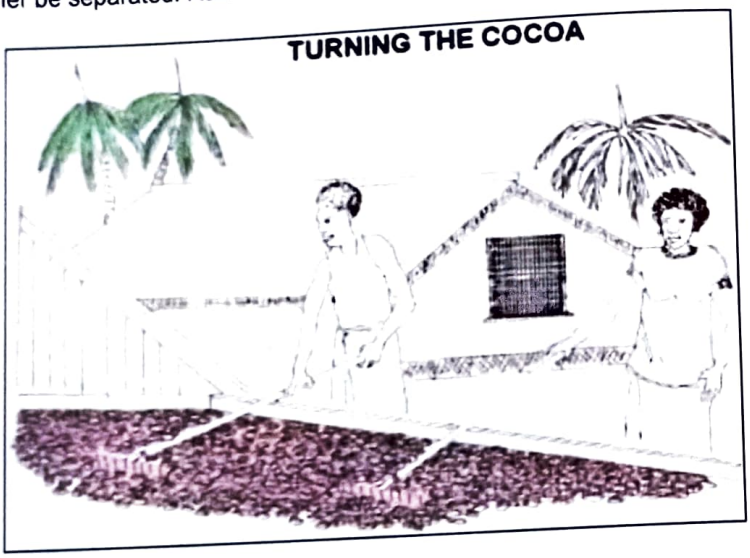


Figure 11.7: Turning Cocoa Beans while Drying

Common mistakes in cocoa drying

1. Not letting the cocoa beans have resting times
2. Running drier at too high temperature for too long
3. Allow cocoa to be spoiled by smells from smoke or diesel fumes
4. Uneven drying because of cold spots on the drying bed

Overcome by:

1. Make sure drying beds are cleaned well, inside and outside, before putting fermented beans on

2. Make sure all kiln and flue (chimney) pipes are sealed and there are no smoke leaks

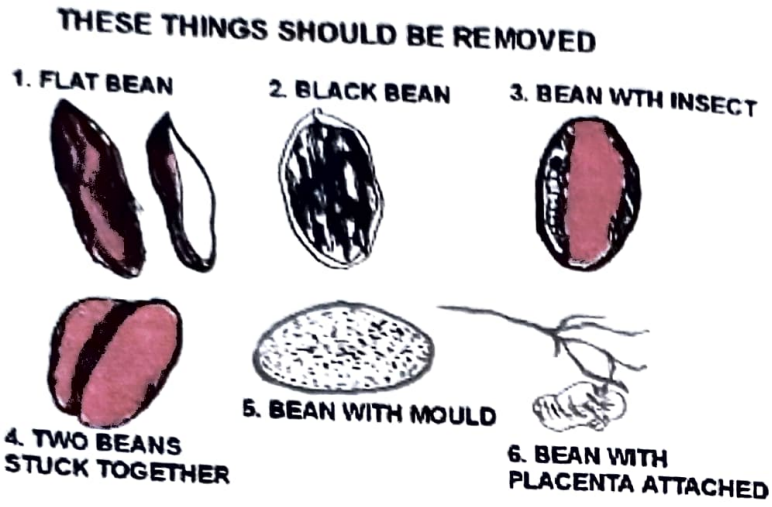
Testing the dried beans

1. One way is crush some dried beans between our fingers and thumb
2. If dried properly, the inside of the beans break into pieces but
3. The skin of the beans does not break so much
4. Another way is after a resting time. Pick up a handful of cooled beans and squeeze them, when there is cracking noise, means are dry

Sorting the dried beans

Before bagging, beans are allowed to cool

Remove flat beans, shrivelled beans, black beans, mouldy beans, small beans, double beans, insect damage beans, bits of broken bean, placentas or rope, stones and other rubbish



Many more small bits of broken bean fall through the drying beds. All the bits of of broken bean are kept together and later sold as nibs.

The good cocoa beans, with no rubbish, are now ready to be bagged.

Figure 11.8: Things to be removed when drying and bagging

Bagging

1. Dry cocoa beans must be put in new, clean sacks
2. Filled and weighed to 63.5 kilograms. Sack 1 kilogram and cocoa beans 62.5 kilograms. (i.e. 16 bags are needed for one tonne of dried bean)
3. After filling and weighing the up opening must be stitched with a bagging needle and twine, starting with a knot inside the lip of the bag
4. Each bag marked on one side with the words "PNG COCOA BEANS" over fermentry name and registration number
5. Bags of dried cocoa beans put in s storage shed

Storage

1. Essential to ensure the processed cocoa stays good
2. Sheds must be weather proof and free from damp, insect and animal pest, as weevils and rats, away from smoke and other smell
3. Must be clean all times
4. Cocoa must not be stored for more than three weeks before taken to the exporter

Teaching Strategies

1. Introduce unit/Motivational tool

Describe processing

2. Body/Content/Subject Matter

a) List steps and explain correct methods of cocoa processing

b) Use notes and field trip/visit/exposure, describe and explain

3. Closure

Orally ask students to:

Give correct steps

- Show correct fermentation method

Student Activities

Explain the process of Cocoa Pod breaking

Describe Weighing

Describe the process of Fermentation

Why is fermentation is important

Why must the cocoa bean be turned when drying

Describe the process of Drying

Activity

Summary of cocoa harvesting/ processing

Quality checks	Mark
Appear for work on time	
Daily turning of cocoa in fermenting box	
Cover tight and well placed in fermenting box	
Right cover material changed daily	
Vacant fermenting box washed and changed	
Make fire during the day when cocoa is on the drier	
Regularly turn cocoa on drier	
Remove rubbish and nibs from drier cocoa	
Right packing bagging and storage	
Remove placenta from wet/dry bean	
Clean inside and outside the building	
Weighing using scales of dry and wet	
Remove beans fire ashes from inside drum	
Wet and or dry beans not contact with water	
Cocoa beans have no bruises	
Calculation of prices per KG WT	
Wet beans free from foreign matters	
Immediately transportation to fermenting box	

UNIT 12: QUALITY, QUARANTINE AND MARKETING

Introduction

At the farmer's end of line in cocoa production, the farmer has to sell his/her cocoa. The cocoa beans must be marketable after it has gone through growing, harvesting and process before the farmers gets the reward after which the cocoa leaves our shores for overseas market.

To improve quality of cocoa beans, the conditions and restrictions introduced in the Cocoa Act and Regulation must be complied by all involved in the industry. This is to set quality standards and when implemented will ensure exported cocoa beans meet the chocolate manufacturers' requirements and improve the price paid to growers. Price manufacturers pay will depend partly on world market prices and partly on our cocoa quality

At the end of the unit, the student should appreciate the process as in cocoa growing areas the crop plays a very vital role in their house hold.

Outcomes

At the end of the unit, the students can:

A. Explain flavour in cocoa production
B. Describe purity in cocoa production
C. Explain consistency in cocoa production
D. State what is Yield of edible material of cocoa
E. Who is responsible for these factors in cocoa production
F. List activities involved in marketing and quality control in cocoa production
G. Describe briefly quality management system in cocoa production

Content

Cocoa must taste good and should be of good quality to attract a good price. The issue of quality is dictated by the consumers and so the market conditions determine the criteria in which cocoa has to be produced. Producers have to comply with market requirements or they will lose the market to other producers who are prepared to meet market conditions.

The four factors

1 **Flavour**
It is not good if the cocoa tastes:

a) Mouldy flavour is caused by mould inside the beans
b) Smoky flavour is caused by smoke on the beans
c) Too bitter flavour caused by poor fermentation

d) Acidic flavour is caused by poor fermentation
e) Chemical flavour is caused by using pesticides which have not passed what we call taint tests
f) Copra flavour is caused by using cocoa drier for copra or storing near copra
g) Can be also contaminated by other products stored nearby, as beans absorb other flavours

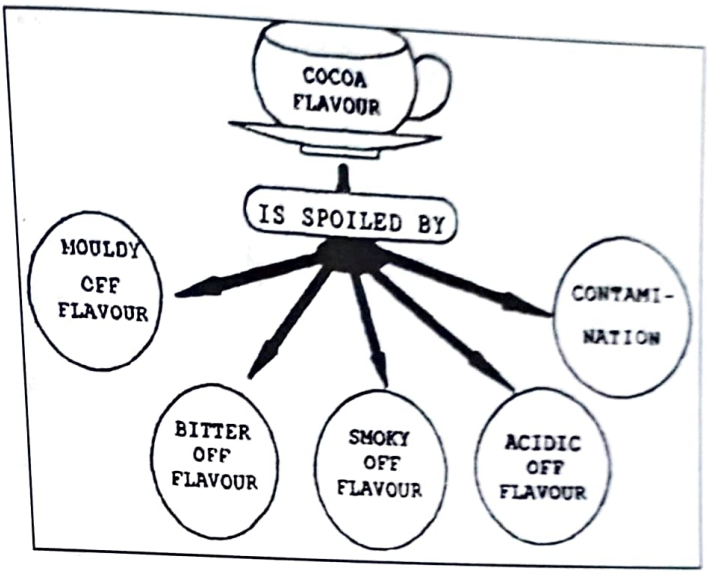


Figure 12.1: Cocoa flavour chain

2. Purity

Purity means cocoa must be clean. The cocoa is not clean, if:

a) Some pesticides are safe and Food and Agriculture Organization (FAO) recommends that only these should be used near cocoa. These change from time to time. CCI and NARI will have the latest information on this recommendations
b) High levels of bacteria on cocoa beans increase the risk of contamination
c) All rubbish (foreign particles) should be taken out of the cocoa before it is bagged
d) Insects, rats, and other pests should be kept away from stored cocoa

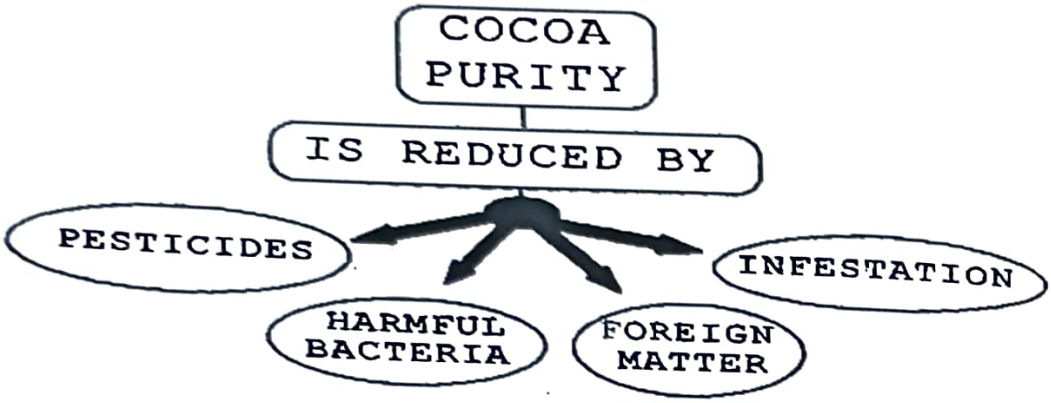


Figure 12.2: Cocoa purity chain

3. Consistency

Consistency means the quality of the cocoa from one producer must be the same all the time. It must not change:

a) Manufacturers who buy cocoa aim to make chocolate of consistent quality
b) Prefer to buy cocoa from a fermentry which they can rely on to supply beans of consistent quality

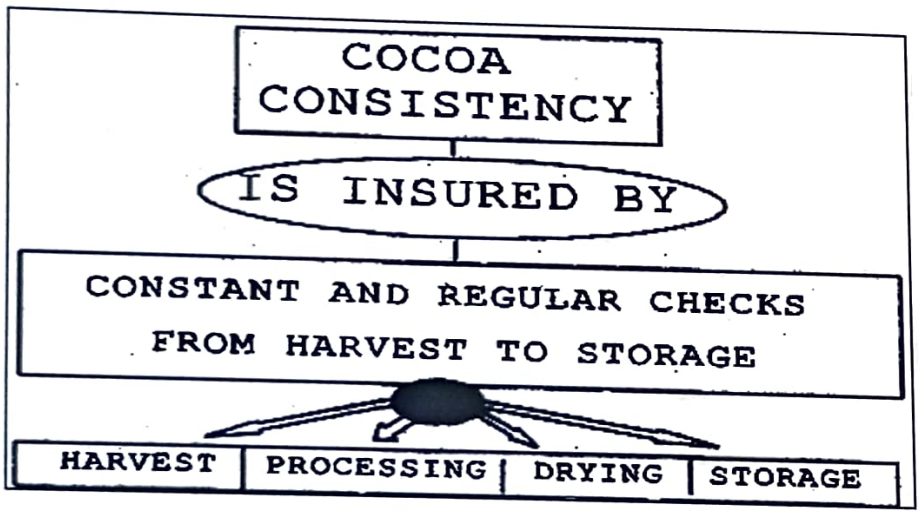


Figure 12.3: Cocoa consistency chain

4. Yield of edible material

Yield of edible material means how much of the cocoa beans in a bag are useful for making chocolate or cocoa powder.

This depends on many things such as:

a) Each bean should weigh at least 1 gram. Smaller beans have too shell. Not enough fat. Beans should be about the same size, so that it is easy to clean and roast them in machines
b) A flat or shrivelled bean does not contain much nib- that is the useful part of the bean
c) If a bean is damaged by insect, it is useless and should be discarded
d) Manufacturers like a moisture content of 6-7%, if above 8%, the beans could go mouldy or can breed bacteria
e) Shell on beans should be loose, but strong enough not to break during normal handling. If the shell breaks, the nib is lost. The shell should not have dry pulp stuck to it
f) Any rubbish (such as placenta) reduces the amount of useful material in a bag of beans

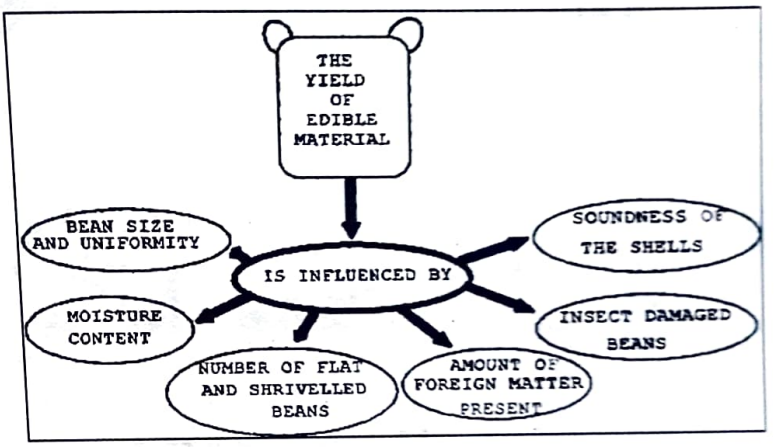


Figure 12.4: Yield of edible material chain

Who is responsible for cocoa quality marketing and quality control?

Many people share the responsibility for PNG's cocoa quality. They include:

1. The researchers
2. The growers
3. The processors
4. The wet bean dealers
5. The exporters
6. The National Department of Agriculture and livestock (DAL)

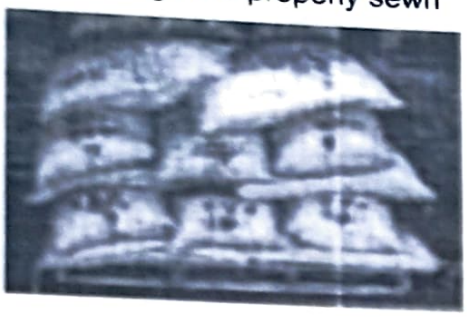
7. The Provincial Departments of Primary Industry (DPI)
8. The PNG Cocoa Board
9. The Cocoa Quality Improvement Project

Summary of the quality assurance process that PNG cocoa is put through in preparation for export

Cocoa to Exporter's Sheds

Checks:

1. Weight of each bag- 63.5 kg
2. Bags are clean, undamaged, insect-free
3. Bags have correct marks
4. Bags are properly sewn



A. Each bag of cocoa should weigh 63.5 kg

B. Sampling cocoa beans using a stabber

C. Carrying out the "cut" test

D. Sniffing a ground up sample of beans to detect foul odours

E. Checking the contents of a bag for foreign materials (e.g. stones)

G. If the cocoa meets PNG standards, the bags are sealed with a metal tag and marked with a red triangular stamp

Figure 12.5: The quality testing process

Sampling Screening

1 Collect sample of several bags flow sampler)
2 Odour test
3 Cut test (100 beans): count of beans that are *slaty *mouldy *insect-damaged *germinated *double *broken *flat (Slaty beans: not more than 1% by count. Flat, double, broken or germinated beans: not more than 5% by count. Internal mould or insect infestation: not more than 5% by count.)
4 Check for foreign matter: not more than 1% by weight
5 Check moisture content: between 5.5% and 7.5%
6 Check average weigh of beans: not more than 1000 per kg
7 Write out quality assessor's report

Approach NAQIA for Export Assessment

NAQIA Assessment

1. collect samples and do same test as QA
2. accept export quality cocoa: triangular red stamp affixed just below mouth of bag, bag sealed with metal tag
3. reject non-export quality: green stripe painted across mouth of bag
4. non-export quality to be stored away from export quality
5. temporary rejection of cocoa that can be upgraded: bags not marked
6. write out Export Assessment Report
7. NAQIA may override QA report: Exporter can appeals committee
8. Producers may appeal to committee against QA Assessment
9. Appeals Committee's decision may be argued b NAQIA

Note

1. 16 bags of cocoa = 1 tonne
2. 100 cocoa beans cut for grading
3. Overweight: more than 63.5 kg
4. Fumigation of cocoa: 24 hours

Marketing and Quality Control

The exporter and export standards

Bags of processed cocoa beans are taken to a Cocoa Board approved and licensed cocoa exported. It is the

Exporters job to:

1. Make contact with people in other countries who buy cocoa beans
2. Finds out how much they need
3. What they are prepared to pay
4. Uses this to set the D.I.S. (Delivered-in-store) price he/she can offer, then buys cocoa to satisfy the needs of his buyers

The cocoa must be of export quality. Must meet export standards, Papua New Guinea standard. To meet PNG Export Standard, the cocoa should be:

1. Properly fermented and dried
2. Be free of foreign odours
3. Contain less than 1% by count of slaty beans or less than 5% by count of flat, double, broken or germinated beans and Less than 5% by count of mouldy or insect-damaged beans or less than 1% by weight of foreign matter
4. Be evenly dried
5. Have a moisture content of 5.5% to 7.5% by weight
6. Have not more than 1000 cocoa beans per kilogram

All cocoa must be inspected before being sold to an exporter. These should be inspected twice

1. By the exporter's own Cocoa Quality Assessors Inspection by cocoa quality assessors,
   Agriculture Quarantine Officers from DAL Agriculture Protection Division or be Inspected by agricultural quarantine officers
2. Making sure the quality standards for exported cocoa are met and maintained

Permanent rejection

1. Is when cocoa does not meet PNG Export Standard, and beans be unsound they will be marked with a green stripe along the top of the bag. Must sell as "Non-Export Standard"
2. Faults that cannot be fixed are insects in cocoa, smoky beans, salty beans, bad-smelling beans, moldy beans and under-fermented/over-fermented beans
3. Such fermentries will have the registration cancelled if this happens more than two months

Temporary rejection

1. This is when cocoa does not meet PNG Export Standard, and beans are sound will not be marked
2. Upon advice, the processor can take the bag back and bring the beans up to standard
3. Faults that can be fixed are overweight/underweight bags, under-dried, too much rubbish in the bags, wrong sewing of bags and wrong marking of bags
4. Faults are written down, and a Cocoa Board inspector advises processor how to correct faults. If continue to produce non-export quality cocoa may lose license

Acceptance

When beans meet PNG Export Standard, is marked with a red triangular stamp and sealed with a metal tag with the name "PNG" on it. The AQO then issues an inspection certificate in quadruplicate.

1. Original and one copy to seller
2. One copy to cocoa board
3. When beans are sold, the seller surrenders the original and
4. One copy to the exporter

Fumigation

1. Before the cocoa can be shipped overseas, it must be fumigated to kill insects.
2. Done at exporter's shed for overseas export
3. Shipment is covered with a tarpaulin
4. Cocoa is fumigated by means of Methyl Bromide sprayed under the tarpaulin and left under tarpaulin for 24 hours
5. Fumigation service company issue Fumigation Certificate and confirm by AQO that fumigation is done
6. AQO issue a Phytosanitary Certificate in quadruplicate
7. One copy attached to export statistics form for the Bureau of Customs, which later goes to Cocoa board

Quality management system

The operation of the quality management system involves:

1. DPI Extension Officers
2. Cocoa Board Inspectors
3. Exporters' assessors and
4. DAL Quarantine Officers

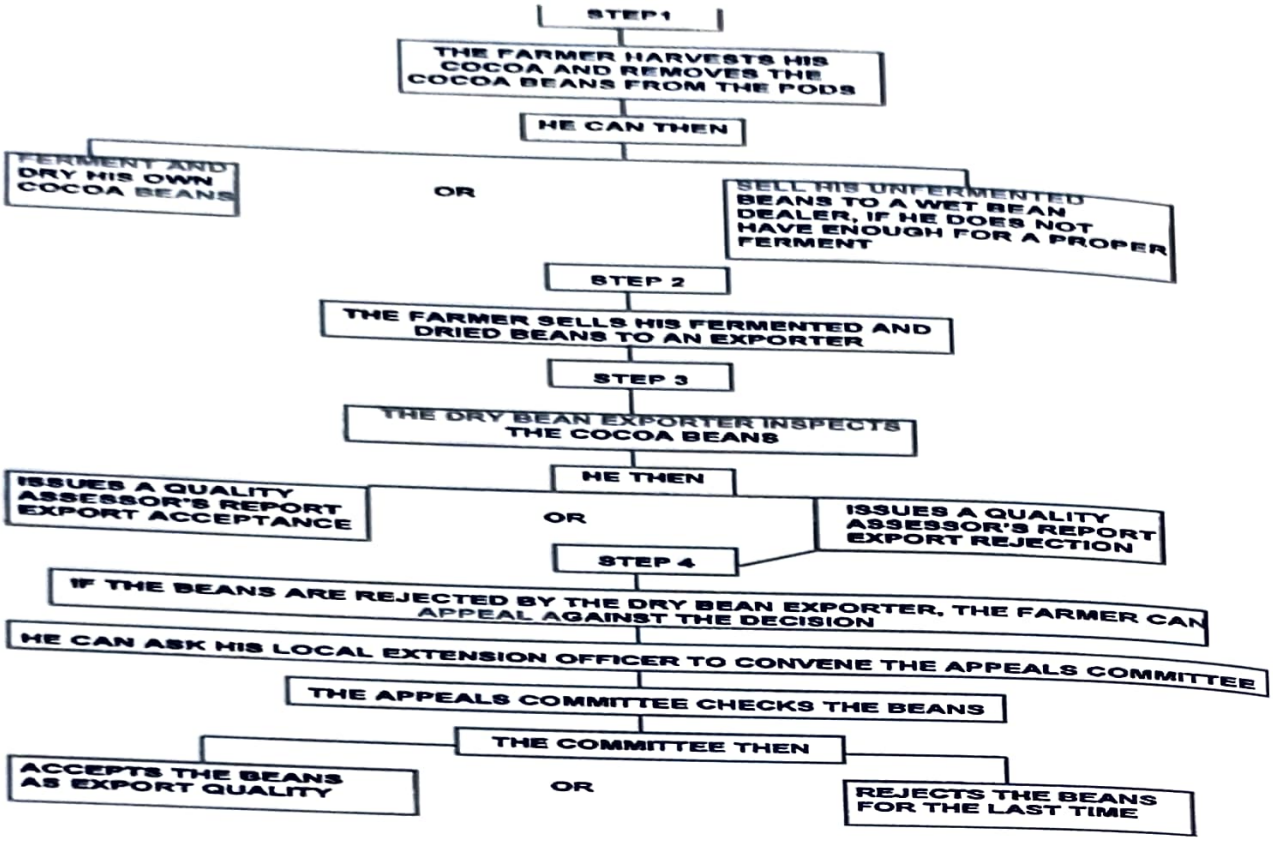


Figure 12.6: Steps in the Quality Management System

Teaching Strategies

A) Introduction

1. Show sample of good and bad quality cocoa and have students examine and provide feedback
2. Explain quality standard
3. Show features of good standard
4. Discuss smoke as a feature of quality cocoa

B) Body

1. Describe function of Quarantine
2. Describe process marketing
3. Use notes and field trip/visit/exposure to describe and explain quality standard

C) Closure

1. Get students to summary what features constitute quality cocoa
2. Discuss how PNG cocoa quality can be improved
3. How can you as a producer of cocoa help improve cocoa quality?
4. Does the farmer control cocoa prices, if so how?

1. **Student Activities**

Explain Flavour in cocoa production

Describe Purity in cocoa production

Explain Consistency in cocoa production

State what is Yield of edible material of cocoa

Who Responsibility for these factors in cocoa production

List activities involved in Marketing and Quality Control in cocoa production

Describe briefly Quality management system in cocoa production

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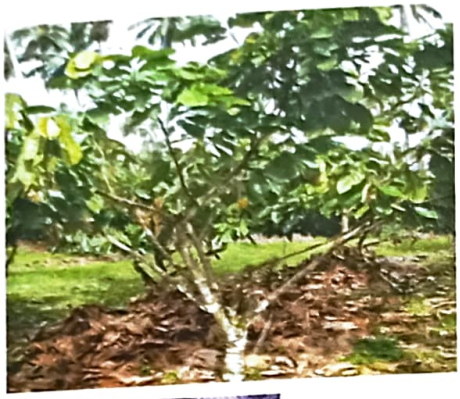
Cocoa is an Entrepreneurial crop

The cocoa units of MAL provide the prerequisite knowledge, skills and attitude for cocoa farming as an experiential and entrepreneurial activity. Cocoa as an entrepreneurial crop means that it has to be farmed as a business adopting business principle and attitude necessary to make money to support the cocoa farming communities.
The secondary coffee units build on the learning from the MAL unit. It introduces important and higher levels skills and what it takes to grow cocoa as a commercial crop. It presents production, management processing and marketing knowledge, skills and attitude necessary for coca farming, and in the process, helps student live positively in the communities after they leave school.
Cocoa has to be grown as a commercial cash crop so that much needed rural income is generated whole as the same time, bring in foreign exchange for the country. It is vital that the crop as a business is well understood and promoted. The schools and teachers have the land, knowledge and skills to plan, teach and assess it impact under the business model. The aspects of farm investment and banking as an investment are also important skills to be taught at the secondary schools. Such skills make learning of the cocoa units especially relevant.


Kabaira Vocational Students as the School Cocoa & CPB Infested Pod
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