GUIDELINES FOR

Establishing Coffee-Agroforestry Systems





Endri Martini, Riyandoko, James M. Roshetko

2017

World Agroforestry Centre

WORLD AGROFORESTRY CENTRE

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This guidelines was developed based on the experiences of the World Agroforestry Centre (ICRAF) in helping to improve smallholder's in establishing and managing coffee-agroforestry farms in Indonesia. Information and graphics in this book was obtained from compilation of booklets that was produced based on agroforestry farmer field schools activities that was conducted by ICRAF and partners under AgFor project funded by Global Affairs Canada. Indonesian national research institutes that were involved in the implementation of agroforestry farmer field schools were includes Indonesian Research Institute for Medicinal plants and Spices (Balittro), IPB Centre of Tropical Horticulture Study IPB, and Indonesian Coffee and Cocoa Research Center (Puslitkoka). Other information was obtained from technical guidances developed by Indonesia research institutes, i.e. Palma Plants Research Institute (Balitpalma) for areca nut, and Indonesia Agricultural Research Institute for bird eye chili. This booklet was developed in collaboration between World Agroforestry Center (ICRAF) and Hanns R. Neumann Stiftung (HRNS) to support the implementation of farmer field school on coffee agroforestry in Ogan Komering Ulu (OKU) Selatan District, South Sumatra province on 9 to 14 October 2017.

CONTENTS

WHAT IS AGROFORESTRY?

- Agroforestry originates from the word "agriculture" and "forestry".
- In simple terms, agroforestry is any land-use system that integrates trees with agriculture crops.
- Agroforestry is also known as "mixed tree farming".
- Based on the components, there are two types of agroforestry:
  a) Simple agroforestry: contains 2 to 5 tree species besides the main dominant agricultural crops. Besides yielding products (fruit, timber, spice, etc), the trees usually serve as shade for companion crops and form a single layer of canopy.
  b) Complex agroforestry: contains more than 5 tree species besides the main dominant agricultural crops. Besides yielding products (fruit, timber, spice, etc), the trees usually serve as shade for companion crops and form a multiple layers of canopy.

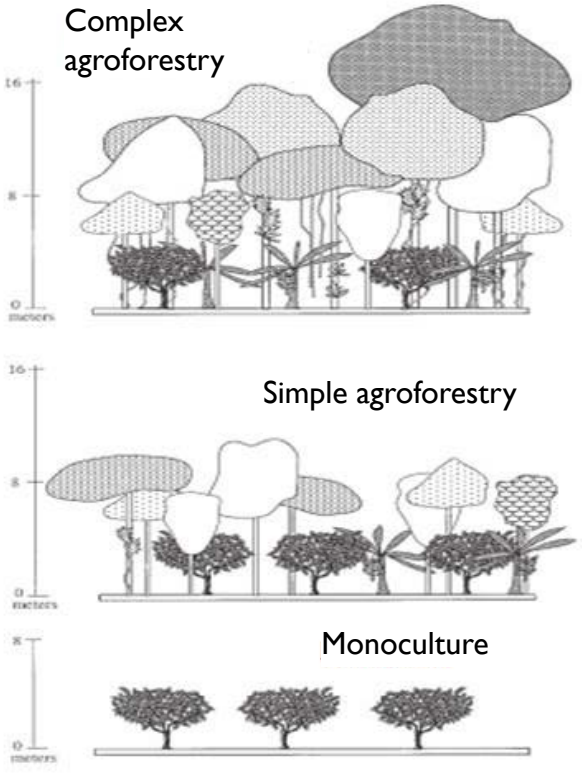


Figure: modified from Rice and Greenberg (2000)

EXAMPLE OF SIMPLE AGROFORESTRY

- Spacing between individual plants usually regular.
- The expected benefits from the system are focused on economic aspects.

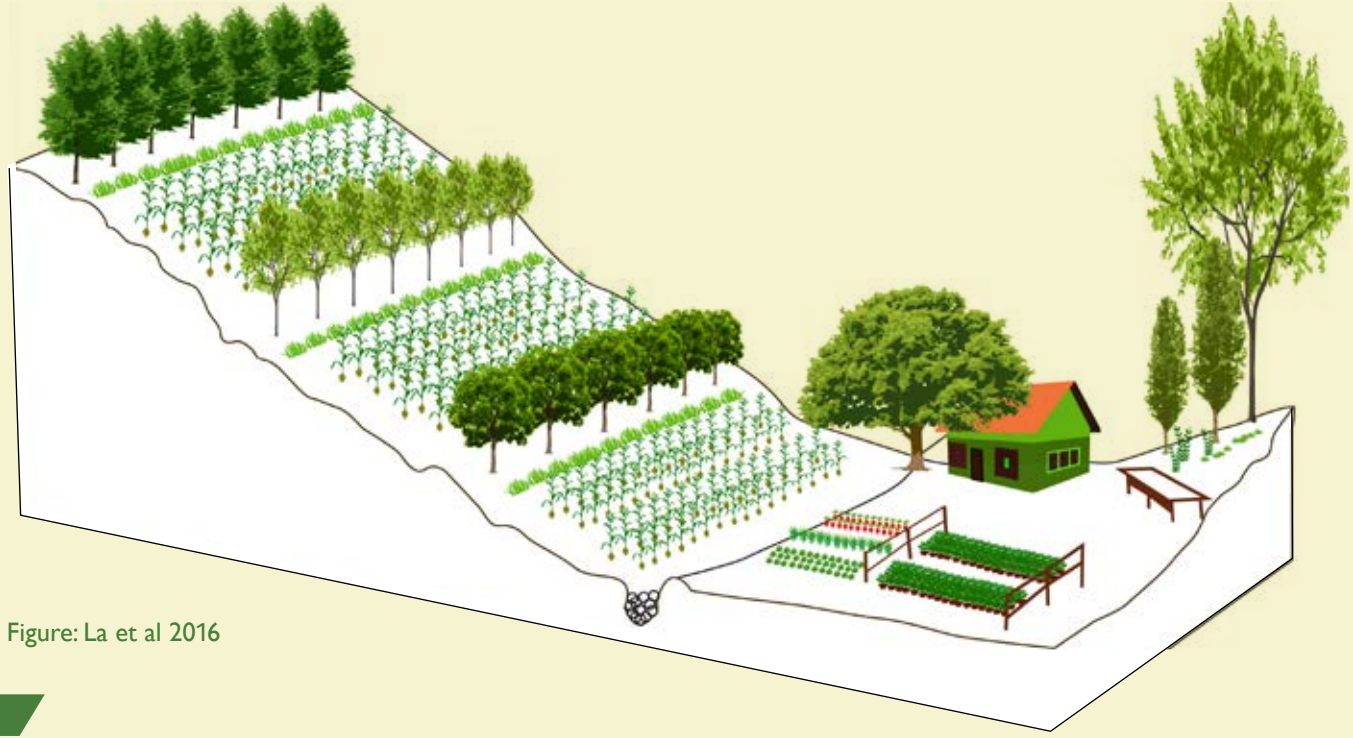


Figure: La et al 2016

EXAMPLE OF COMPLEX AGROFORESTRY

- Spacing between individual plants is usually irregular, and management of the system is usually extensive.
- The benefits are economic (tangible products) and ecosystem services (carbon sequestration, water regulation, prevention of soil erosion and landslides, and habitat for endemic animals and plants).

WHY AGROFORESTRY?

- Agroforestry benefits smallholder with 0.25–2 ha of landholding size.
- Agroforestry produces numerous commodities that provide income security for smallholder.
- A diverse plant species in the agroforestry system helps to regulate water, prevent erosion, maintain soil fertility and decrease pest and diseases.
- Agroforestry can mitigate the negative impact of extremes climate (e.g. heavy rainfall events, prolonged drought, and storm) on plant growth and production.

WEAKNESSES AND OPPORTUNITIES OF AGROFORESTRY

Based on ICRAF observation in farmer demonstration trials, regular pruning and fertilizing of arabica coffee trees, increased production by 5 times more than farms with no pruning and fertilizing.

- Weakness: lower production of one commodity if compared to the same commodity that are planted in a monocultural system. This is because the number of individual plants in a monocultural system is higher than in an agroforestry system.
- Opportunity: production from agroforestry can be maximized by enhancing the productivity of individual plants through regular spacing and intensive management.

COMMON COFFEE-AGROFORESTRY SYSTEMS IN INDONESIA

In Indonesia, the main system used by smallholders for coffee is simple agroforestry. This is because under complex agroforestry system, coffee trees only receive at least 25% of light, which is not enough for producing fruits. In a simple agroforestry system, the light received is around 25-50% which is optimum for fruit production.

Simple coffee-agroforestry system with regular spacing

Simple coffee-agroforestry system with irregular spacing

MANAGEMENT ISSUES IN COFFEE AGROFORESTRY

- Low productivity owing to poor management of spacing between individual plants, lack of a process to select superior varieties, and poor management of soil fertility.
- Occurences of pests and diseases due to too dense shade or too open, and overdosing of pesticide.
- Extreme climate events with negative impact on coffee trees (see table below).

Extreme climate events	Impacts to coffee trees
High temperature	Temperature > 23°C leads to acceleration of fruit ripening, leading to progressive quality loss; Temperature > 25°C reduces photosynthetic rate; Temperature >30°C tree growth is depressed, abnormalities and abortion of leaves, stems and flowers, pests and diseases incidences are increased.
Heavy rainfall/storms	Damages trees, increases flower and fruit fall, soil erosion, landslides.
Prolonged drought (dry month > 4 mo)	Weakens trees, increases wilting, increases mortality of young trees. Stressed trees more susceptible to some pests and diseases. Production can fall 30-60%.
Prolonged rainfall	Reduces flowering, affects fruit set, lowers photosynthesis, increases humidity that favour some fungal diseases, Increase mortality of some insects pests such as Coffee Berry Borer (CBB).

Reference: Coffee and Climate 2015

AGROFORESTRY ROLES IN FARM RESILIENCE TO CLIMATE CHANGE AND PRICE VOLATILITY

- Shade trees in an agroforestry system maintain the microclimate of the farm and its surrounding. In coffee agroforestry systems, shade trees protect the coffee trees from increased air temperatures. Coffee trees under shade experience less stress than those with no shade.
- Litter leaves of shade trees in coffee agroforestry systems provide additional nutrition for the soil and maintain soil humidity, particularly, during prolonged drought and when air temperature increase.
- A range of different plants with diverse responses to extreme climate events buffers the risk for smallholders of reduced income owing to failure of a single crop.
- Numerous commodities in agroforestry systems buffer the risk of decreased smallholder household income when the price of the main commodity drops.

PRINCIPLES FOR ESTABLISHING COFFEE AGROFORESTRY

1. Provide appropriate shade trees species

Shade tree should be planted one year before the coffee. Coffee trees need 25% of shade. Management of shade trees need to consider optimum temperature for various species: Robusta 21-24°C, Arabica 15-25°C, Liberica 21-30°C.

Under shade trees, coffee production tends to be better. Although care needs to be taken to select appropriate shade trees.

Age of coffee plants (year)	Coffee productivity without shade tree (kg/ha)	Coffee productivity under shade tree (kg/ha)		
		Gliricidia	Erythrina	Magnolia
3	465,3	463,3	389,9	557,5
4	1352,4	1637,4	1595,0	1446,1
5	1290,5	1431,1	1573,2	1364,4
15	683,5	805,6	987,5	534,5
16	598,8	839,2	935,5	489,8

Note: Spacing between coffee is 2 x 2 m, spacing between shade trees is 4 x 4 m.
Source: Evizal et al (2012) study in Sumberjaya, Lampung

Leaves of arabica coffee grown with no shade tend to have a yellowish colour compared with trees under shade.

2. Select species and integrate into the system

- Select plant species that are suitable for the biophysical condition of the farm, have good market potential, and have different responses to extreme climate events.
- In areas that are frequently affected by strong winds, windbreak plants (e.g. candlenut, toona, jackfruit) can be planted on the borders of the farm.
- The level of economical benefits received from a coffee agroforestry system will depend greatly on the species selected to be integrated in the system.

System	Non-coffee species	Location	NPV (per ha)	References
Agroforestry	cacao, banana, clove, coconut	Bali	Rp 34.500.951	Hariyati (2013)
Agroforestry	avocado, durian, clove dan short term crops	Bondowoso, East Jawa	Rp 21.483.580	Hariyati (2013)
Agroforestry	cacao, hisbiscus, erythrina, cinnamon, coconut	Pasawaran, Lampung	Rp 10.122.577	Asmi et al (2013)
Monoculture		Bogor	Rp 13.594.616	Rachman (2011)

3. Use high quality planting materials.

4. Management of spacing between plants is critical, both horizontal and vertical.

5. Land preparation and planting timing are important.

- Plants that are tolerant of light need to be planted before those that are tolerant of shade.
- Preparation of land needs take into consideration principles of soil and water conservation, e.g. terracing sloping land.

6. Routinely monitor and maintain.

- Monitoring is necessary to prevent and control pests and diseases.
- Soil fertility needs to be maintained through routine application of organic fertilizers.
- Pesticides should be applied wisely based on recommended dosage.

STEPS IN ESTABLISHING AND MANAGING COFFEE AGROFORESTRY FARMS

- Select the species
- Establish nurseries for producing high quality seedlings
- Designing combinations of different species
- Prepare the land, spacing and planting
- Maintain the farm (fertilizing, pruning, thinning, controlling pests and diseases)
- Take precautions with harvesting and post-harvest handling
- Strategies in selling agroforestry products

SPECIES SELECTION

- Select species that have good market potential and can contribute to household income.
- Select species with planting materials (seeds or seedlings) that can easily be accessed from reliable source that can ensure the quality of the material.
- Select varieties that are resistant to extreme climate events for example Robusta clone BP409 is resistant to drought.
- Select varieties that are resistant to pests and diseases, for example: arabica variety S795 is resistant to leaf rust disease.
- Take into consideration whether the species is tolerant of shade or full sun.

Source: Hulupi and Martini 2013

Resistant coffee clones and varieties for various climatic zone

Arabica coffee (thicker and smaller leaves)

1. Dry climate, altitude 900 masl: **S795, Gayo1**.
2. Dry climate, altitude 1000 masl:

   S795, Gayo1, Andungsari 2K, Komasti.
3. Dry climate, altitude 1250 masl:

   S795, Gayo1, Gayo2, Andungsari 1, Andungsari 2K, Komasti
4. Humid climate, altitude 1000 masl:

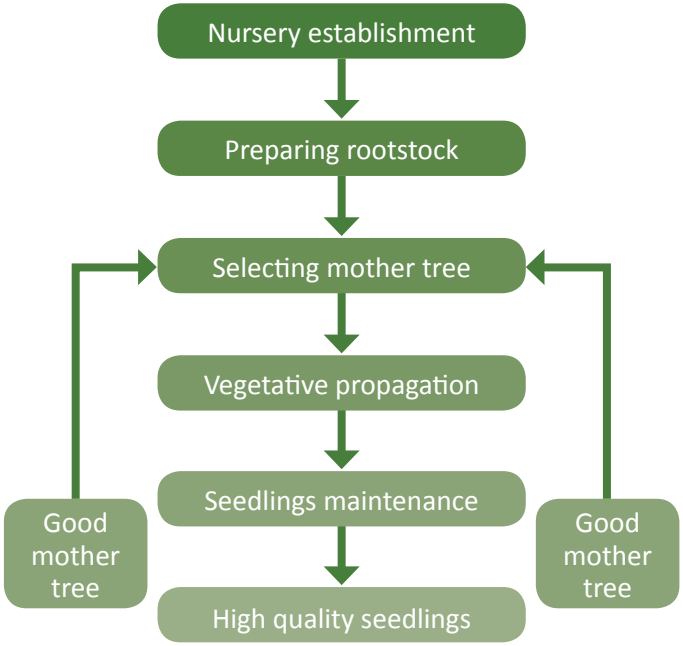
   Sigarar Utang, S795, Andungsari 1, Andungsari 2K, Komasti

Robusta coffee (thinner and wider leaves)

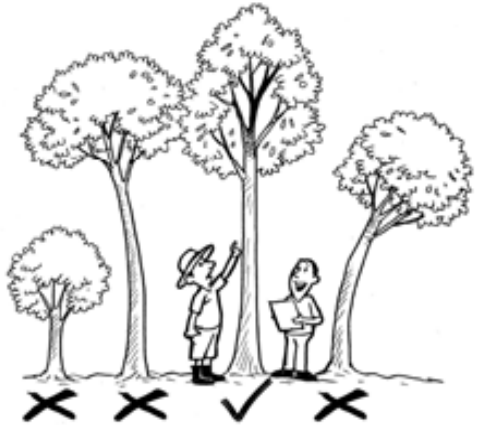
1. Dry climate, altitude 0-900 masl: **BP 936, BP 939, BP 409**
2. Humid climate, altitude 0-900 masl: **BP 436, BP 358, BP 936, BP 534**

ESTABLISH NURSERIES FOR PRODUCING HIGH-QUALITY SEEDLINGS

Steps to produce high-quality seedlings



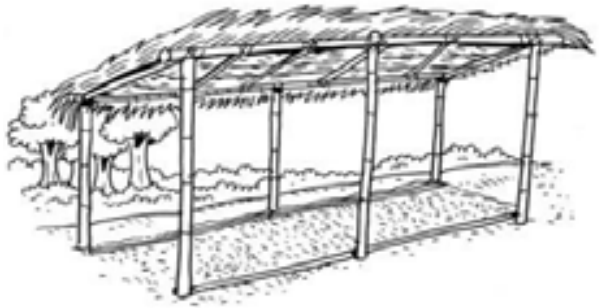
Source: Sobir and Martini 2014



Mother trees should meet several criteria:

- Normal physical attributes;
- Healthy and resistant to pests and diseases;
- Gone through at least two harvesting cycles to ensure that the trees are fruiting on time with high, quality production;
- Resistant to extreme climate events.

Select a location for the nursery



- Select a location that is flat, near water supply, protected from strong winds and livestock, and receive sufficient sunlight.
- Measure the nursery area and draw a sketch of the shade shelter and bed layout.
- Build a framework for the shade/ paranet with 60% light intensity, ensuring that it is 1.75 meter above ground.
- Prepare nursery beds with width 1–1.2 m and length adjusted based on needs.
- Record sources of mother trees, names of varieties or mother trees, number of seedlings and dates when the vegetative propagation was conducted.

Steps to collect and select seeds from high quality mother tree

- When collecting seeds, make sure they are from 30 mother trees to maintain genetic diversity. This particularly valid for timber trees species.
- Pick the seeds directly from the trees. If you do have to pick fallen seeds, do so from under the canopy not from further away from the mother trees (at least under the radius of the width of mother tree canopy).
- Choose seeds that are fresh and have uniform large size.
- If you bought seeds, only choose certified seeds or those that have clear information about their mother trees.
- For orthodox seeds (seeds with hard, water proof shells), clean the seeds and have it air-dried for 1–3 days if they are to be stored.
- For recalcitrant seeds, such as seeds of fruit species, these are best cleaned and then directly sown.

Maintenance of seedlings

Source: Sobir and Martini 2014

- Water regularly to ensure consistent humidity of the planting media.
- Weed regularly.
- Fertilize as needed.
- Pests and diseases need to monitored regularly and necessary steps taken to control them.
- Separate seedlings that are infected by disease or have low growth rate.
- Eliminate unproductive buds or shoots that grow on the rootstock.
- Move large seedlings from crowded polybags to bigger polybag if needed.
- Group the seedlings based on size.

DESIGN COMBINATIONS OF DIFFERENT SPECIES

Designing the integration of different species in an agroforestry farm needs to consider site-specific, biophysical characteristics of the plants as well as socio-economic factors.

Biophysical considerations

- Potential competition between species for water, light and nutrition.
- Different species' responses to extreme climate events and resistance to pests and diseases:
  - Don't mix species that have the same response to a specific climate event.
  - Don't mix species that share susceptibility to the same pests and diseases or have similar levels of resistance to particular pests or diseases.

Low production during drought	Low production during heavy rainfall
Vegetables	Clove
Coconut	Fruits (avocado, lansium, durian, parkia, mangosteen, archidendron)
Birdeye chili	Birdeye chili
Ginger	Robusta coffee
Rubber	Rubber
	Pepper

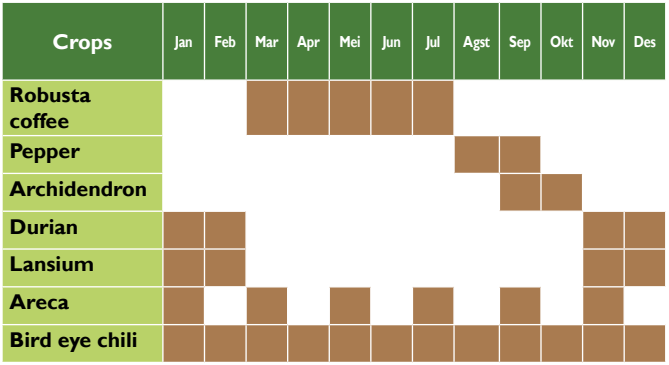
Source: Discussion with farmers in Ogan Komering Ulu Selatan District, April 2017

Socio-economic factors

- **Price volatility of different crops**
  - Don't combine species that have the same price volatility rate, e.g. in the table below, a good combination is to mix bird's eye chili with areca.

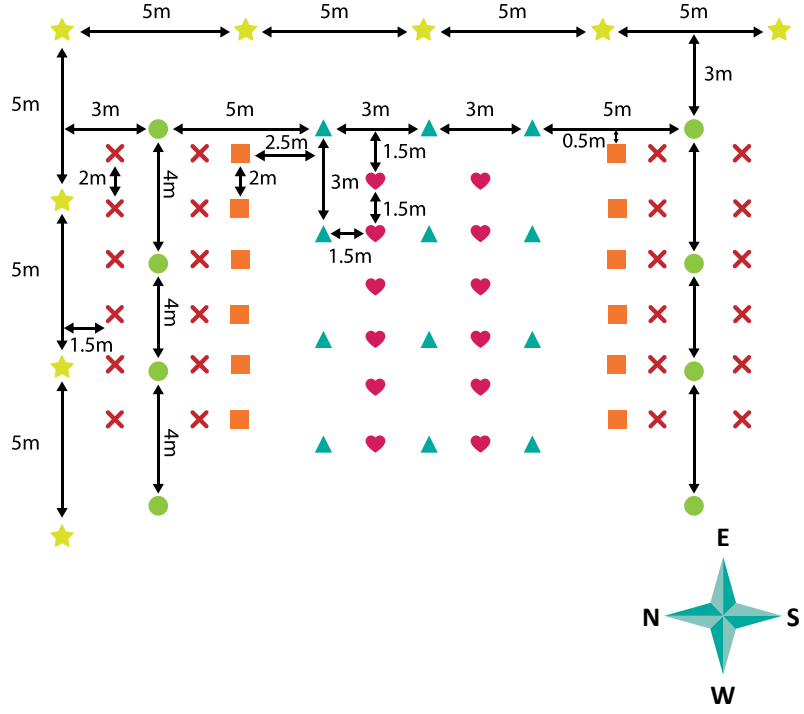
- **Link harvesting times to income security throughout the year**
  - Combine species that have different harvesting times to spread income and risk.

Crops	Lowest price received by farmers (IDR/kg)	Highest price received by farmers (IDR/kg)	Difference between highest and lowest price (%)
Bird's eye chili	10.000	115.000	91%
Ginger	1.800	3.200	75%
Cacao	15.000	25.000	40%
Pepper	60.000	85.000	29%
Clove	80.000	95.000	16%
Areca	9.000	10.000	10%



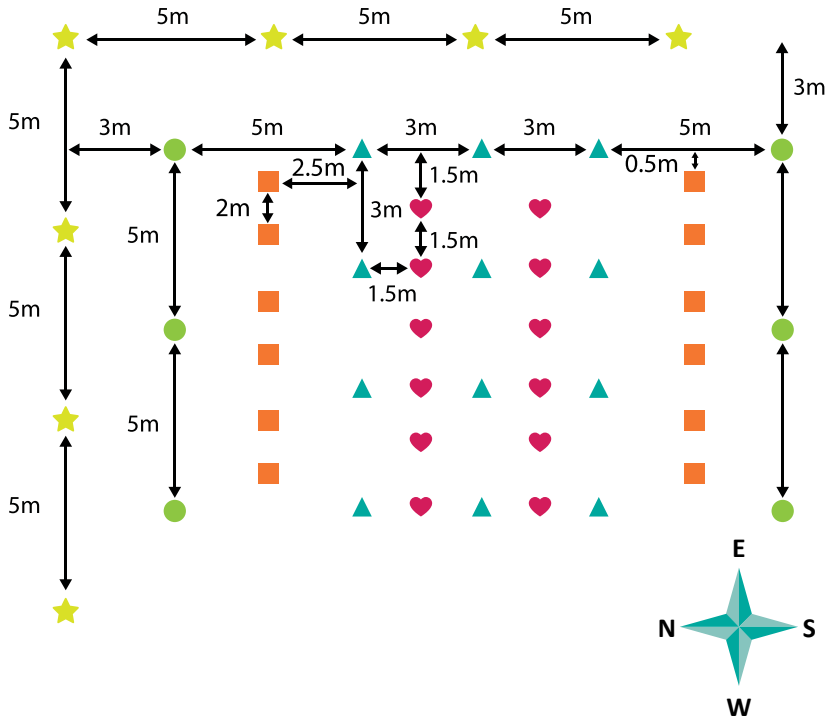
Source: Discussions with farmers and extension officers in Ogan Komering Ulu Selatan District, April 2017

Example of agroforestry design in the first four years, for location with elevation above 700 masl in Ogan Komering Ulu Selatan.



Note: Note: Coffee (triangle) n=625/ha, Areca (circle) n= 150/ha, Pepper with Gliricidia (rectangle) n=600/ha; Star symbol is for candlenut (35/ha), Jackfruit (20/ha), Timber trees (25/ha); Heart symbol is for chili (400/ha), vegetables (400/ha); Cardamom (cross) n=600/ha. The numbers of trees per hectare are for the first 4 years; the number can decrease as the system ages. Chili and cardamom are grown in years 1–3 before the coffee and pepper produces. Soil conditions need to be fertile and farmers can apply fertilizer to enhance production. In the case of poorer soil fertility and farmers not applying fertilizer, the spacing between species and trees needs to be wider.

Example of agroforestry design in the first four years for location with elevation below 700 masl in Ogan Komering Ulu Selatan.



Note: Coffee (triangle) n=625/ha; Durian grafted (circle) n=120/ha; Pepper with Gliricidia (rectangle) n=600/ha; Star symbol is for jackfruit (20/ha), timber trees(25/ha), banana (35/ha); Heart symbol is for chili (400/ha) and vegetables (400/ha). The numbers of trees per hectare are for the first 4 years; the number can decrease as the system ages. Chili and vegetables are grown in years 1–3 before the coffee and pepper produces. Soil conditions need to be fertile and farmers can apply fertilizer to enhance production. In the case of poorer soil fertility and farmers not applying fertilizer, the spacing between species and trees needs to be wider.

PREPARE THE LAND, SPACING AND PLANTING

1a) Preparation: on flat land, make individual bench terraces

1b) Preparation: on sloping land, make terraces or plant natural vegetative strips, following the contours

http://teca.fao.org/technology/natural-vegetative-strips

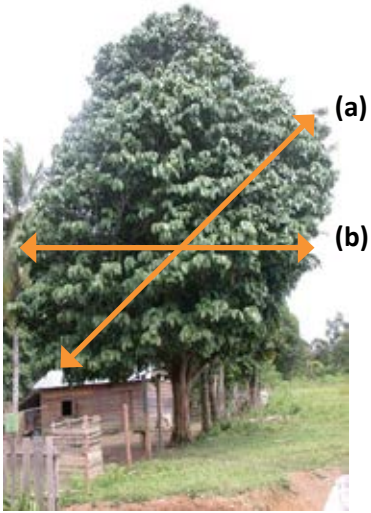
Note: Information in this section refers to Hulupi and Martini (2013).

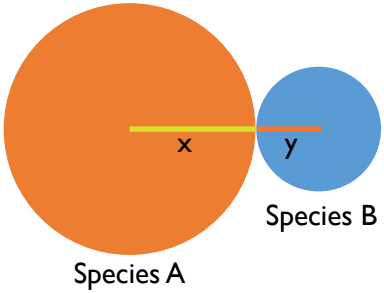
2) Regulating spacing between individual plants

- Spacing needs to be regulated horizontally between plants and vertically between the coffee canopy and the shade-tree canopy.

Horizontal spacing

- Standard dimensions for horizontal spacing can be obtained from extension officers or research institutes on agriculture and forestry.
- When there is no known standard spacing, it can be estimated using these steps:
  1. Find mature, productive trees that grow in a relatively open area.
  2. Estimating spacing distance between individuals of the same species (see photo): measure the crown width or canopy width to find the spacing size (a). Repeat the crown width measurement in a different direction to obtain the other spacing size (b). The spacing size between trees of the same species will be (a) x (b).
  3. Estimating spacing distances for different species: spacing distance with other species is half of the average canopy width of Species A (x) + half of the average canopy width of species B (y).
- For new species, information on planting distances can be found online, in libraries or from extension officers or related research agencies.





Vertical spacing

Maintain a distance between the coffee canopy and the shade canopy of at least 2 m for young coffee plants and 5 m for productive coffee plants.

Source: https://rampages.us/policeofthemind/2015/12/01/4/

Young plants (below 4 years-old)

Source: https://www.flickr.com/photos/scotnelson/8284185925

Productive plants (above 4 years-old)

3) Planting shade trees before coffee trees

Orange and vegetables in coffee agroforestry

Don't mix coffee trees with:

- Plants that have the same root depth as coffee trees (e.g. coconut and cacao).
- Plants that are hosts for nematodes, e.g. banana.
- *Eucalyptus* and *Casuarina*. However, if selected the distance between the coffee and Eucalyptus or *Casuarina* needs to be more than 10 m.

Permanent shade trees:

- Lamtoro (*Leucaena*), Gamal/ *Gliricidia*, Dadap/*Erythrina*.
- Timber trees (to be planted on the border of the farm): *Paraserianthes*, *Toona*, Mahagony, Teak.

Other crop or tree species:

- Fruit trees: mango, jackfruit, orange, durian, areca.
- Vegetables (chili, tomato, long bean) and maize can be planted until the coffee trees reach 2 years-old.

4) Planting hole should dug 3–6 months before planting with the size is 60 x 60 x 60 cm. In agroforestry system, potential spacing distance between coffee trees is 5 x 2.5 m.

5) Put organic fertilizer in the holes one month before planting the coffee trees.

FERTILIZING

- Application of a combination of chemical and organic fertilizers is recommended for optimum production.
- Organic fertilizers can be applied at the end of the wet season and the end of the dry season while chemical fertilizers can be applied at the start of the wet season.

	Chemical fertilizers	Organic fertilizers
Strengths	• Nutrients are quickly absorbed by plants. • Provide standard dosage of particular nutrients.	• Improve soil fertility and structure. • Cheap and easily available.
Weaknesses	• Expensive and limited stock. • Excessive dosage is dangerous: can kill the plants and destroy soil fertility. • There are many fakes on the market.	• Nutrients are slowly absorbed by plants. • Information on the standard dosage of particular nutrients is limited.

Macro-nutrients in fertilizers

Nutrient	Functions for plants	Chemical fertilizer	Symptoms of lacking of nutrient	Symptoms of overdose of nutrient
Nitrogen (N)	Involved in creating food for the plant through photosynthesis in the leaf	Urea; ZA	Chlorosis (yellowing leaves, pale colour of leaf veins)	The colour of the leaves is dark green or bluish green.
Phosporous (P)	• Involved in plant metabolic processes in transferring energy within the plant • Critical for root development and flowering	SP36	Leaves shrink and easily fall	There is no clear physical symptoms.
Potassium (K)	• Regulates plant metabolism and affects water pressure regulation inside and outside of plant cells • Important for good root development • Potassium is critical for plants' stress tolerance	KCl, ZK	Flowers or young fruits easily fallen.	Plant growth inhibited.

- In productive plants, nitrogen or NPK fertilizer is applied after harvesting
- When the plant is fruiting, don't apply Urea/ZA or NPK because the nitrogen may cause shedding of flowers and fruit

Livestock integration maintains sources of manure for organic fertilizer

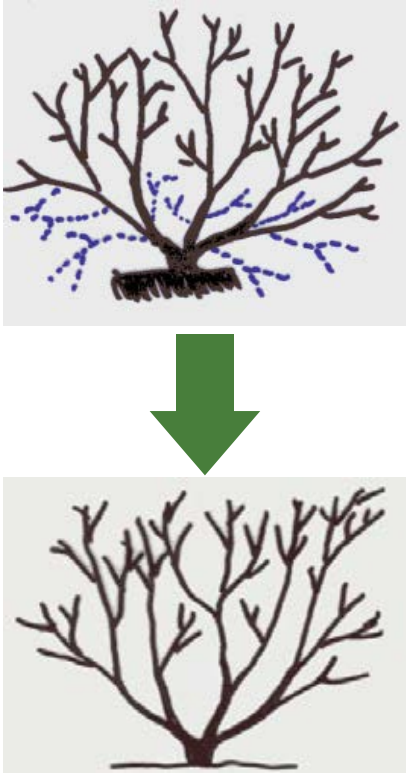
- To support the sustainable production of organic fertilizer, keep livestock as a source of both liquid and solid material
- Plant fodder crops, such as *Arachis pintoi* and *Gliricidia*
- Objectives of using organic fertilizer:
  1. To maintain humidity of soil around the plant's rooting zones
  2. To improve air circulation around the rooting zones
  3. To stimulate the formation of new roots near the soil surface

Maintaining soil humidity during prolonged drought

- Mulch can maintain soil humidity during prolonged drought. Recommended mulch thickness is 10–15 cm of rice straw, grass or litter leaves
- "Rorak" technique can be used to maintain soil humidity and stimulate the growth of new plant roots. Rorak is a 75–100 x 30–40 x 40–60 cm pit dug 60–100 cm from the plant. The pit is filled with organic fertilizer. Number of rorak per hectare is 50% of the total number of coffee trees

Source: Hulupi and Martini, 2013

PRUNING



General objectives of pruning: (i) Form tree crown; (ii) Eliminate plant parts that are infected by pests and diseases; (iii) Eliminate unproductive shoots or branches; and (iv) Increase plant air circulation.

Pruning of young plants is done with the objectives of improving growth and potential production.

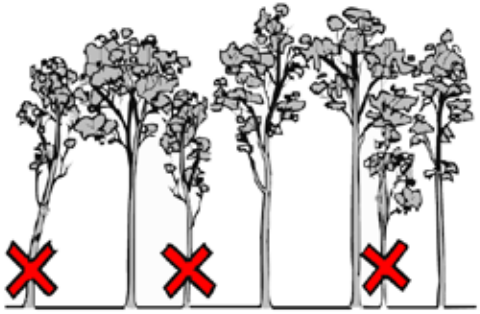
Pruning of productive trees is done a minimum of once a year, with the objectives of

- Stimulating the process of flower sprouting and pollination;
- Providing branches for fruit for the next harvest; and
- Ease of harvesting.

Pruning of shade trees is necessary to increase the production of crops growing beneath, such as pepper, coffee and cacao.

THINNING

- Tree thinning removes unproductive trees to reduce water, light and nutrition competition. Thinning is done if the crown between individual trees overlap owing to spacing distances that are too close. Trees to be removed will have low growth rates and abnormal shape.
- Fruit thinning usually done to enhance fruit quality by limiting the number of fruits per branch so as to allow remaining fruits to receive sufficient nutrition for growth. In application, fruit thinning needs to consider the estimation of maximum number of fruits that can be supported by the branch, for example, to grow one durian a branch needs at least 100 leaves. Fruits to be removed will be those of smaller size and abnormal shape.



Source: Pramono et al 2009

Too dense. Number of fruits needs to be reduced

Source: Sobir and Martini 2014

PRINCIPLES OF CONTROLLING PESTS AND DISEASES

- Pests are animals that attack crops or livestock, inhibiting growth and decreasing yields.
- Diseases are plants, fungi, bacteria or viruses that attack crops or livestock, inhibiting growth and decreasing yields.
- Potential causes of outbreaks of pests and diseases are 1) no predator of the pest or disease; 2) favourable environment and sufficient food sources for the pest or disease to increase in population.
- Preventing pests and diseases can be done by providing sufficient nutrition for the crops or livestock and maintaining sanitation of the farm.
- Activities to control pests and diseases
    1. Identify and increase the population of the natural enemies of the pest or disease. To prevent insect pests, planting cover crops with white or yellow flowers can increase the number of natural enemy agents.
    2. Apply biopesticides.
    3. Burn or remove the infected plants or animals.
    4. If the population of the pest or disease is unmanageably high, change the plants or animals with other commodities for 1–2 harvest cycles.
    5. Chemical pesticide is the last option. Make sure to follow the instructions carefully.

TAKE PRECAUTIONS WITH HARVESTING AND POST-HARVEST HANDLING

Precautions in harvesting

- Harvesting should be done based on standards of sustainable harvesting techniques that are recommended by research institutes.
- For fruit plants, harvesting techniques should not destroy parts where flowers will set in the next harvest period.
- For plants that are harvested for their bark exudate, such as rubber, harvesting techniques should not destroy the trunk up to its cambium.
- For timber trees or others that are harvested by cutting (e.g. cinnamon), harvesting techniques should minimalize potential destruction of other nearby plants.

Precautions in post-harvest handling

- Don't dry harvested products directly on soil, instead use drying beds.
- For over-produced fruit, fresh products can be converted to semi-processed or processed products.

Coffee drying beds

CREATE STRATEGIES FOR SELLING AGROFORESTRY PRODUCTS

- Grade the product based on its quality. Products with high quality will be valued higher than products with lower quality.
- Storing products can be part of the strategy if the market price is dropping owing to over production. Products can be sold when the price is better. Good storing techniques need to be considered for preventing the decreasing quality of the products over time.
- Processing fresh products into semi-processed or processed products will increase the product value.
- Processed products, such as roasted coffee beans or ground coffee, need to be packed in a hygienic and interesting package.
- Collective selling is important for strengthening bargaining positions when negotiating prices with buyers.

TECHNICAL AGRICULTURAL GUIDELINES OF MOST IMPORTANT NON COFFEE CROPS IN OKU SELATAN

- Commodities that contributed to annual income
  - Pepper
  - Durian
- Commodity that contributed to monthly income
  - Areca
- Commodity that contributed to weekly income
  - Bird eye chili

Guidelines for
Cultivation of Coffee

Authors:
Retno Hulupi and Endri Martini

This chapter was compiled from a field guide on coffee cultivation based on research results from Pusat Penelitian Kopi dan Kakao (Indonesian Coffee and Cacao Research Institute). The field guide complemented agroforestry farmers' field schools conducted in October 2013 as part of the Agroforestry and Forestry in Sulawesi: Linking Action to Knowledge project. Dr Retno Hulupi, a researcher from the Centre, and Endri Martini from ICRAF provided their skills and knowledge in the schools.

IMPORTANT FACTORS THAT INFLUENCE COFFEE PRODUCTION AND QUALITY

1. Superior varieties or clones from reliable sources.
2. Altitude: arabica coffee will have best quality if planted at elevations above 1000 masl while robusta will have best quality if planted in the range 40 to 900 masl.
3. Garden maintenance and management
   - Provide sufficient number of shade trees.
   - Provide sufficient fertilizer (chemical and organic).
   - Routinely prune the coffee and shade trees.
4. Good harvesting techniques, e.g. picking red fruit and sorting the fruit.
5. Good post-harvest handling, e.g. depulping, drying and storing.

COMMON COFFEE SPECIES PLANTED IN INDONESIA

ARABICA: small and thick leaves, best planted at elevations ranging 1000 to 1500 masl.

ROBUSTA: large and thin leaves, best planted at elevations ranging 40 to 900 masl.

LIBERICA/EXCELSA: large and thick leaves, generally planted in peatland.

Generally, coffee trees are best planted in areas with annual precipitation rates from 1500 to 3500 mm, with a maximum of 3 dry months (precipitation less than 60 mm per month).

RECOMMENDED CLONE:

ROBUSTA BP42

- **This is an old clone released by the Indonesian Coffee and Cacao Research Institute (ICCRI).**
- **It is best grafted with rootstock from Robusta Clone BP308.**

SUPERIORITY:

- Resistant to rust leaf disease.
- Can be planted at any elevation from 40 to 900 masl and has Climate Class B to D based on Schmidt-Ferguson Classification.
- Big bean size.
- High productivity (0.7–1 kg/tree).

WEAKNESSES:

- Intolerant to dry climate.
- Susceptible to nematode.

RECOMMENDED CLONE:

ROBUSTA BP358

- **This clone is appropriate for wet areas, such as in Sumatra.**
- **It is best grafted with rootstock from Robuta Clone BP308.**

SUPERIORITY:

- Resistant to rust leaf disease.
- Big bean size.

WEAKNESSES:

- Intolerant to dry climate.
- Susceptible to nematode.

RECOMMENDED CLONE:

ROBUSTA BP409

This clone is appropriate for dry areas, such as in Sulawesi.

SUPERIORITY:

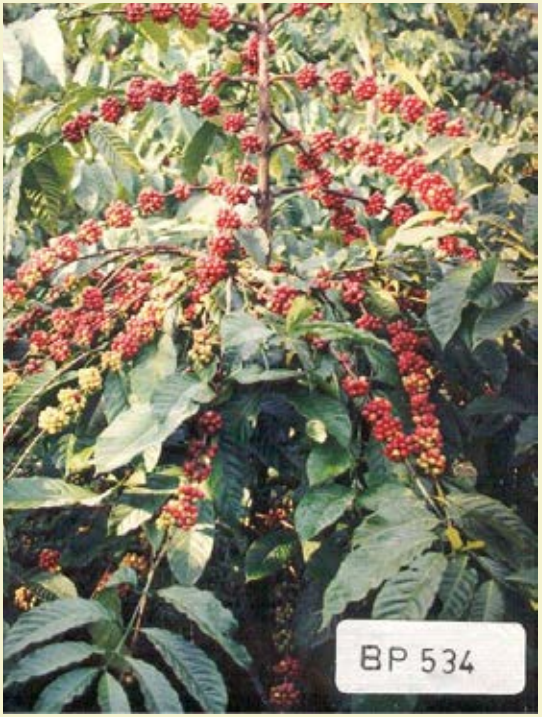
- Big bean size.
- High productivity (1 kg/tree).

WEAKNESSES:

- The tree will not fruit but only produce leaves if planted in wet areas.

RECOMMENDED CLONE:

ROBUSTA BP534



- Best planted at any elevation with a wet climate (category A, B or C according to Schmidt Ferguson classification).
- Good for side grafting.

SUPERIORITY:

- Big fruit size and dense berries per fruit cluster.
- High productivity (1–1.5 kg/tree).

WEAKNESSES:

- Susceptible to branch borer.

RECOMMENDED CLONE:
ROBUSTA BP936



- Recommended for elevations above 400 masl.
- Fruit shape is rounded, big, with smooth surface and a light-green colour.
- Fruit ripening is relatively uniform.
- Fruit location is behind the leaves.
- Bean size is medium to large.

RECOMMENDED CLONE:
ROBUSTA BP939

- Appropriate for dry areas.
- Best to be planted in lowlands (from 40 masl).
- Bean size is medium except if the trees receive insufficient nutrition in which case the bean size will be small.

SUPERIORITY:

- Dense berries per fruit cluster.
- High productivity (1–1.25 kg/tree).

RECOMMENDED CLONE:
ROBUSTA SA203

- Tree crown shape is big and wide.
- Fruit size is medium to small, with dense berries per fruit cluster and long fruit branches.
- Bean size is small to medium.

SUPERIORITY:

- Dense berries per fruit cluster.
- High productivity (1.5 kg/tree).

WEAKNESSES:

- Bitter coffee aftertaste.

RECOMMENDED CLONE:
ROBUSTA BP308

- THIS CLONE IS ONLY FOR ROOTSTOCK. IT IS NOT RECOMMENDED FOR SOURCES OF SCIONS OR FOR PRODUCTION.

SUPERIORITY:

- Tolerant of dry conditions.
- Tolerant of marginal soil.
- Resistant to nematode.

PROPAGATION OF COFFEE TREES

Propagation can be done in two ways.

1. Generative propagation by planting seeds. This is best for arabica.
2. Vegetative propagation via cuttings and grafting. This is best for robusta.

VEGETATIVE PROPAGATION BY GRAFTING CUTTING MATERIAL

1

Preparing rootstock for cuttings from Robusta Clone BP308.

2

Prepare scion from cutting of superior recommended robusta clone. Sharpen the end part of the scion to be grafted to the rootstock and secure with a plastic tie.

3A

Prepare planting beds for direct planting without polybags. Covered the planting beds with a plastic cover. Open the plastic cover when watering the planted cuttings.

3B

Prepare planting beds for planting with polybags. Cover the planting beds with plastic cover. Open the plastic cover when watering the planted cuttings.

Plant the cuttings. This can be done by three people: two to plant the grafted cuttings and one to close the plastic cover.

5 Water the cuttings every day. Do not water the cuttings directly: spray the plastic cover. Spray cuttings with pesticide once a week and apply fertilizer once a month.

6 The cuttings are successful if the scion part is still green two weeks after being planted.

7

When new shoots emerge, open the plastic cover two hours per day, in the mornings. After more shoots appear, open it four hours a day, in the mornings. When 4–6 leaves have emerged, open the plastic cover and transplant into the polybags.

Guidelines for

Cultivation of Black Pepper

Authors:
Dyah Manohara and Dono Wahyuno

This chapter was compiled from a field guide on pepper cultivation based on research results from Balai Penelitian Tanaman Rempah dan Obat (Herbs and Medicinal Plants Research Agency). The field guide complemented agroforestry farmers' field schools held from April to May 2013 as part of the Agroforestry and Forestry in Sulawesi: Linking Action to Knowledge project. The authors are researchers with the Agency and provided their skills and knowledge for the schools.

I. SITE-SPECIFIC REQUIREMENTS FOR PEPPER

- Altitudes between 0–1000 masl
- Shade with 50–75% light interception
- Dry season not more than 3 months per year

Examples of tree species used as 'living standards' for the black-pepper plants → { *Gliricidia*, *Erythrina*, *Ceiba*, teak etc }

Requirements for living standards
- Can be pruned
- The bark can support attachment of the pepper root

Growing pepper on dead standards and without groundcover crop is not recommended.

Growing pepper on living standards with groundcover crop is recommended.

II. TYPES OF BLACK-PEPPER SHOOTS

Primary climbing shoots

Lateral fruit shoots

If the primary climbing shoots don't attach to the standard, problems can occur

Hanging shoots

Not recommended as planting material

Runner shoots

Recommended as planting material

PRIMARY CLIMBING SHOOTS OF BLACK PEPPER FOR PLANTING MATERIAL

- Primary climbing shoots for planting material should be taken from healthy plants.
- Choose shoots that are neither too mature nor too young.

Technique to harvest the climbing shoots as cutting material.

The wound should be covered with wax, vaseline or insecticide.

Cuttings from 1 node and 1 leaf

III. VEGETATIVE PROPAGATION

A. LONG CUTTINGS TECHNIQUE FOR BLACK PEPPER


1


2


3


4

Long cuttings consist of several different parts used for cultivation. They have 5 to 7 nodes per cutting (1). Some of the leaves that are attached to the cutting can be cut in half (2) then buried up to the node to produce roots (3). Cover the cuttings with banana leaves (4) to maintain optimum humidity for 10 to 14 days or until roots emerge from the nodes.

B. SHORT CUTTING TECHNIQUE FOR BLACK-PEPPER (1 NODE AND 1 LEAF)


1

Cut the long cuttings into several short cuttings of 1 node with 1 leaf. Soak the short cuttings for 1 hour in a solution of 1 tablespoon of sugar in 5 litres of water.


2

Prepare polybags with a mix of soil, manure and sand (ratio of 2:1:1 or 1:1:1). When weeds begin to grow in the polybags they are ready to be used.


3

Plant the short cuttings in the polybags after soaking for 1 hour in the sugar solution.

4

Cover the cuttings with plastic for 3–6 weeks until new shoots emerge.

5

When 2–3 new leaves have emerged, add a bamboo stick to each polybag as standards for the seedlings.

6

Seedlings are ready to be planted in the field after 5–7 leaves have emerged.

C. CUTTINGS FOR PRODUCING BUSHY BLACK-PEPPER PLANTS

There are two type of shoots that can be used:

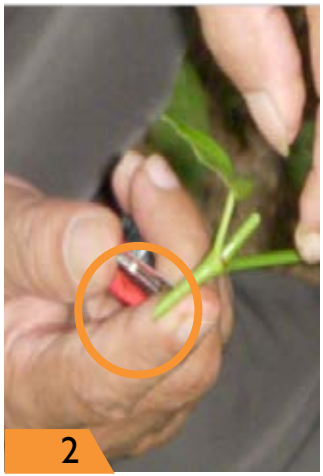
1) Lateral fruit shoots

2) Terminal part of climbing shoots

1) Cuttings from lateral fruit shoots of black pepper

1–3) Wound the end part of the cuttings to stimulate the growth of roots.

4) Soak the cuttings in sugar solution for 0.5–1 hour.



Cuttings from lateral fruit shoots ready to be planted in polybags

2) Cuttings from terminal part of climbing shoots of black pepper


1


2


3


Cuttings from terminal climbing roots ready to be planted in polybags
4

After the terminal part of the climbing shoot is cut, soak it in sugar solution for 0.5–1 hour.

5

Plant the cuttings in the polybags filled with mixture of soils and manure.

6

Close the plastic cover.

7

Bushy black-pepper seedling ready to be planted in the field (minimum 7–10 leaves).

IV. LAND PREPARATION AND PLANTING TECHNIQUES FOR PEPPER

- Don't use land that has been contaminated with diseases that attack pepper.
- On slopes, establish terracing or use other soil-conservation techniques. Plant the land with cover crops.
- Dig drainage channels around the farm with the size of 30 cm deep and 40 cm wide.

Spacing: 2.5 x 2.5 m or 3 x 3 m

- Prepare cuttings of living standards 2 m long with diameters of 5 cm.
- Plant the living standards at least one year before planting the pepper.
- Plant the living standards on the western sides of the planting holes.

Sharpen the tips of the living standards

PREPARING PLANTING HOLES FOR PEPPER

1. Size of the planting hole is 45 x 45 x 45cm.
2. Open the planting hole at least 1 month before planting time.
3. Mix the soil with manure and, if available, add *Trichoderma harzianum*. Apply dolomite if needed.
4. Dig raised beds for individual plants 90 cm long, 60 cm wide, and 25–30 cm high.

PLANTING TECHNIQUE FOR ROOTED LONG CUTTINGS (5 TO 7 NODES) OF PEPPER

Put the cutting in the planting hole, with at least 3 nodes underground.

Close the planting hole with fertile soil and make sure the cutting stands steadily.

Provide shade to protect the plant.

PLANTING TECHNIQUE FOR PEPPER SEEDLING IN A POLYBAG

Carefully open the polybag

Put 3-4 nodes in the hole

Fill the hole with soil

Ensure the plant stands steady

Bind the seedling to the living standard

Provide shade to protect the seedling

PLANTING TECHNIQUE FOR BUSHY BLACK PEPPER

Intercropping bushy black pepper with coconut

V. PRUNING YOUNG PEPPER PLANTS (0–2 YEARS)

First pruning at tree age of 5–6 months

Second pruning at tree age of 13–14 months

Third pruning at tree age of 21–22 months

VI. PRUNING PRODUCTIVE PEPPER AND SHADE TREES

Prune or eliminate the hanging shoots

Prune or eliminate the runner shoots

Pruning of shade trees is done before applying fertilizer to pepper trees so as to

- Reduce competition for nutrients.
- Optimize the microclimate for pepper.

VII. MAINTAINING PEPPER PLANTS

1. Maintain the cover crop (*Arachis pintoi* or legumes) between the pepper plants.
2. Only weed the area around the pepper

3. Maintain live fencing surrounding the farm.

Jatropha

Guinea grass

FERTILIZATION

Fertilization of young pepper plants with chemical fertilizer NPKMg (1:2:3:4)

		First fertilization	Second fertilization	Third fertilization	Fourth fertilization
Application period (within a year)		Start of wet season	Three months from the first fertilization	Three months from the second fertilization	Three months from the third fertilization
Recommended pruning of living standards		Prune all branches on shade trees	Prune a few of the branches	Leave 2–3 branches on the tree	Prune a few of the branches
Dosages for plants with age of	**Less than 12 months**	20 g and manure	40 g	60 g	80 g
	Between 13 and 24 months	40 g and manure	80 g	120 g	160 g

Note: 1 Tablespoon = 20–30 g

FERTILIZATION FOR PRODUCTIVE BLACK-PEPPER PLANTS

Use 1600 g of NPKMg (12:12:17:2) per year per plant, applied 3 to 4 times per year

	First fertilization	Second fertilization	Third fertilization	Fourth fertilization (dry season)
Application period (within a year)	Start of wet season	30–40 days from the first fertilization	30–40 days from the second fertilization	30–40 days from the third fertilization
Recommended pruning of living standards	Prune all branches on shade tree	Prune a few of the branches	Prune a few of the branches	Leave 2–3 branches on the trees
Dosage	640 g	480 g	320 g	160 g and 5–10 kg of manure

Note: 1 Tablespoon = 20–30 g

FERTILIZING TECHNIQUE FOR BLACK PEPPER

Scrape the surface of the soil within the boundary of the canopy of the tree. Pour the fertilizer and dig it into the scraped soil.

IX. PESTS AND DISEASES OF BLACK PEPPER

TRUNK BORER PESTS

Symptoms: 1) Wilting trees, 2) Black spot on the trunk nodes




Natural enemies

Fungus: *Beauveria bassiana*

Insect: *Spathius piperis*

MAJOR DISEASES IN BLACK PEPPER

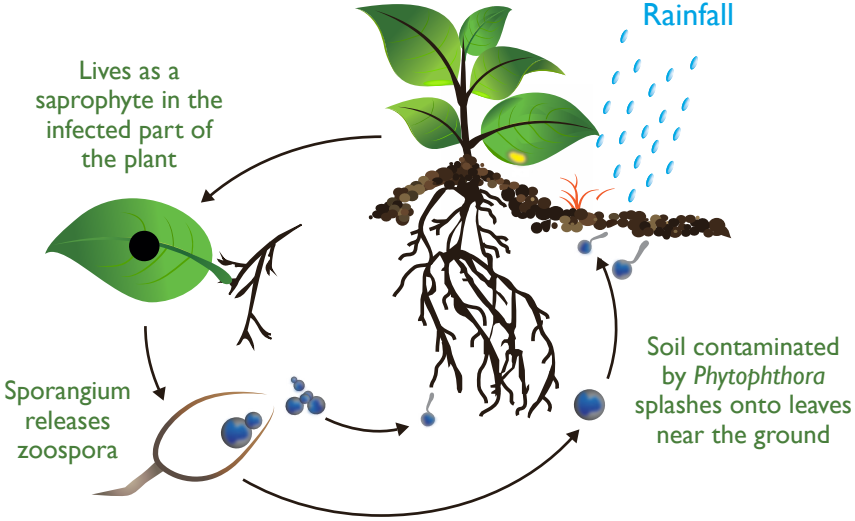
Root rot (*Phytophthora capsici*)

Yellow (*R. similis, M. incognita, Fusarium oxysporum*, infertile soil)

Stunt (virus)

1) Root rot of black pepper

Symptoms: Leaves yellowing and wilting; black spots on the leaves and mycelium appears on the root.



LIFE CYCLE OF *PHYTOPHTHORA CAPSICI*, THE FUNGUS THAT CAUSES ROOT ROT

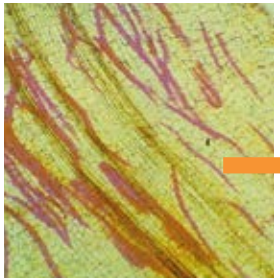
Biological control of root rot of black pepper

Dispersion of root rot can be inhibited by the presence of a groundcover crop.

Allium tuberosum can prevent the infection of *P. capsici* in black-pepper roots through the *Trichoderma* attached to *Allium* roots.

Application of clove oil or powder can prevent infection.

2) Yellow disease in black pepper



Symptoms:

1) Swollen roots

2) Nematode in the root tissue

Vectors: a) nematodes (*Radopholus similis*, *Meloidogyne incognita*); b) fungus (*Fusarium oxysporum*); and c) infertile soils
Prevention: apply fertilizer to infertile soils
Handling: infected plants should be burnt in place

3) Stunt disease

Caused: Cucumber mosaic virus (CMV), turnip yellow mosaic virus (TYMV)
Symptoms: Stunted plant growth and curly leaves
Prevention: Do not obtain planting materials from where stunt disease commonly occurs
Handling: Burn the infected plants in place




Stunt disease is spreaded by

- Agricultural equipment
- Planting material
- Insects, such as *Ferrisia virgata*, *Planococcus minor, Aphis* sp

X. HANDLING PESTS AND DISEASES

1) Use good agricultural practices

- Select varieties that are resistant to root-rot disease, e.g. Natar 1 (for producing only black pepper owing to smaller seed size compared to other varieties).
- Plant cover crops and don't use herbicide for weeding. Weed only in areas near the pepper plants.
- Fertilize the plants regularly with appropriate dosage, method and timing.
- Prune the living standards if too dense.
- Establish drainage lines around the farm.
- Establish fencing around the farm.
- Remove from the farm, or burn, infected parts of the plants.

2) Biological control:

- *Pasteuria penetrans* (formulated) + organic materials, mulch
- *Trichoderma harzianum* + organic materials
- *Beauveria bassiana*
- Biopesticides → extract of clove powder and seeds of mexican turnip

3) Wise use of chemical pesticides:

a) When a pest population is difficult to control.
b) When a pest or disease increases rapidly in a very short period.

Chemical insecticides
Active ingredients: Methidathion, Dimethoate, Fenthion, Carbaryl, or granules insecticides that can be applied to the soil such as Carbofuran.

Chemical fungicides
Active ingredients: Metalaxyl-Mancozeb, Copper oxychloride, Potassium phosphonate, fosetyl-aluminium, Fosfit acid, systemic fungicides, Bourdeaux mixture.

MATERIALS AND METHOD FOR PREPARING BORDEAUX MIXTURE

Materials:
100 g copper sulfate ($CuSO_4$) dissolved in 5 litres of water

100 g slaked lime ($Ca(OH)_2$) dissolved with 5 litres of water

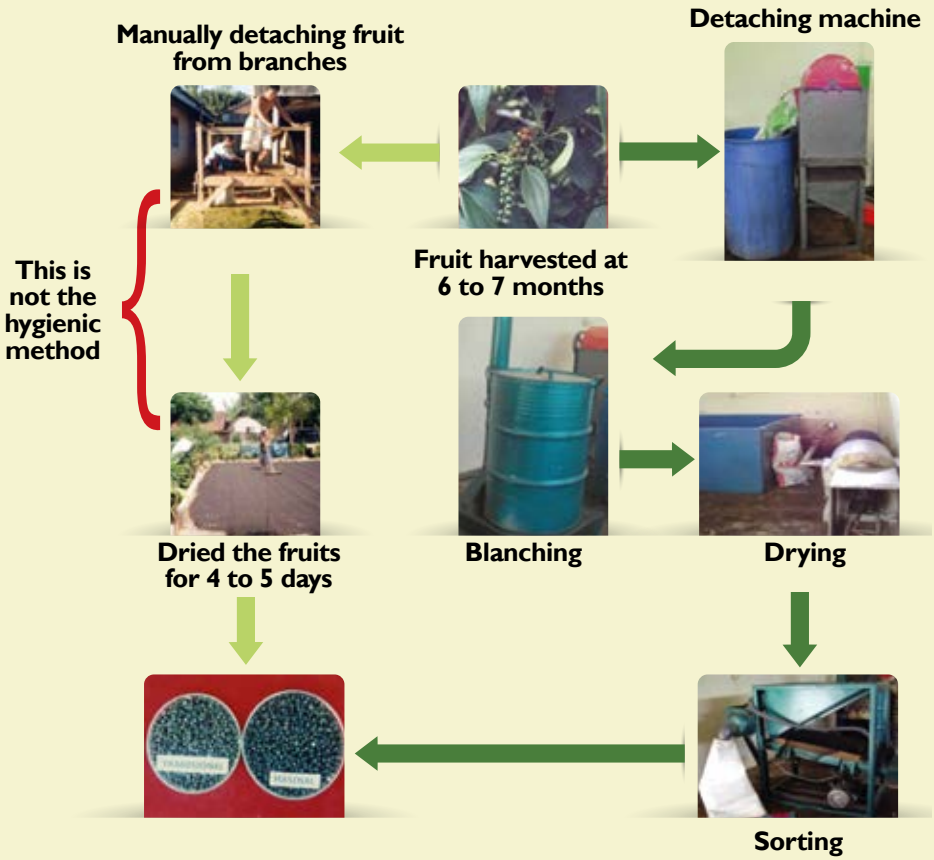
Method

- Pour the copper sulfate solution into the slaked lime solution and mix together.
- The Bordeaux mixture should be used as soon as it is made.

Application

- Apply to soil where the *Phytophthora* fungus occurs.
- The mixture can also be used to sanitize equipment used with infected plants.

HARVEST AND POST-HARVEST OF BLACK PEPPER



HARVEST AND POST-HARVEST OF WHITE PEPPER PRODUCT

Harvest when fruit is yellow or red (8 to 9 months)

Detach the fruit from branches

Detached pepper fruit

Soak the fruit in water for 3 to 5 days

Depulp the fruit

Dry the depulped fruit under sun for 3 days

Sortation

White pepper product

Guidelines for
Cultivation of Durian

Authors:
Sobir and Endri Martini

This chapter was compiled from a field guide on durian cultivation based on research results from Pusat Kajian Hortikultura Tropika (Centre for the Study of Tropical Horticulture) at the Bogor Agricultural University. The guide complemented agroforestry farmers' field schools in February 2014 conducted as part of the Agroforestry and Forestry in Sulawesi: Linking Knowledge to Action project. Dr Sobir, one of the authors, is a researcher at Pusat Kajian Hortikultura Tropika.

I. GENERAL INFORMATION ABOUT DURIAN

- Durian is originated from Indonesia, mostly from Borneo island.
- Durian is often called the king of tropical fruit because its season begins before other fruits.
- There are several species of durian that can be consumed.

Durian (*Durio zibethinus*)

Lai (*Durio kutejensis*)

Lahung (*Durio dulcis*)

Kerantungan *(Durio oxleyanus)*

CHARACTERISTICS OF SUPERIOR DURIAN FRUIT

- Fruit flesh is dry and not sticky.
- The thickness of the flesh is more than 2 cm, the seeds are small, more than 20% of the flesh in each carpel can be eaten.
- The smell of the fruit is not too strong.
- The colour of the flesh is more orange.
- The taste is sweet and not too bitter.
- Septum part of the fruit is thin.
- Fruit can be artificially ripened without decreasing its quality.

SUPERIOR FRUIT

NOT SUPERIOR FRUIT

CHARACTERISTICS OF SUPERIOR DURIAN FRUIT IN INDONESIA

Durian varieties	Resistance to root rot disease	Resistance to fruit borer	Size of the fruit (kg)	Maximum production per tree per year
Otong/ Monthong	Susceptible	Susceptible	2–4	20–50
Matahari	Resistant	Resistant	2–3.5	50–200
Kani	Susceptible	Susceptible	2–4	15–20
Lalong	Not known	Not known	1.7–2.6	100–300
Tamalatea	Resistant	Resistant	1–2	150–200
Petruk	Resistant	Susceptible	1–4	15–150
Hepe	Resistant	Resistant	1.5–2	150–250

Source: Trubus online, Durian Enak Nusantara

II. SELECTION OF SUPERIOR DURIAN VARIETIES

Durian tends to not self-pollinate, thus, to obtain superior varieties durian needs to be planted with different varieties.

The advantages of diverse varieties in a farm

- There will be more fruit developed (> 25%)
- The taste will be sweeter
- Size of the fruit will be bigger

Examples of pollination partnering of different varieties

- Monthong with monthong: fruit of superior quality is only 1 to 3% of total
- Monthong with chanee: fruit with superior quality is 14 to 17% of total
- Monthong with kradumthong: fruit with superior quality is 23 to 27% of total

III. VEGETATIVE PROPAGATION OF DURIAN

Propagating durian from seeds is not recommended because the fruit quality cannot be assured and the time to the first fruiting year is longer than with seedlings produced by vegetative propagation. From seeds, durian trees will only begin producing after more than eight years.

First-fruiting years from different types of vegetation propagation techniques

Top-working (2–3 years after top working)

Bud grafting (4–6 years after planting)

Shoot grafting (4–5 years after planting)

PREPARING DURIAN ROOTSTOCK

1. Collect the seeds from healthy mother trees.
2. Select seeds that are healthy and mature.
3. Do not collect fallen seeds on the ground.
4. Clean the fruit flesh from the seeds with sawdust or paper.
5. Germinate the seeds directly in polybags filled with soil and organic matter or sawdust.
6. Water the polybags every 2–3 days or when dry.
7. Weed and fertilize the germinated seeds.

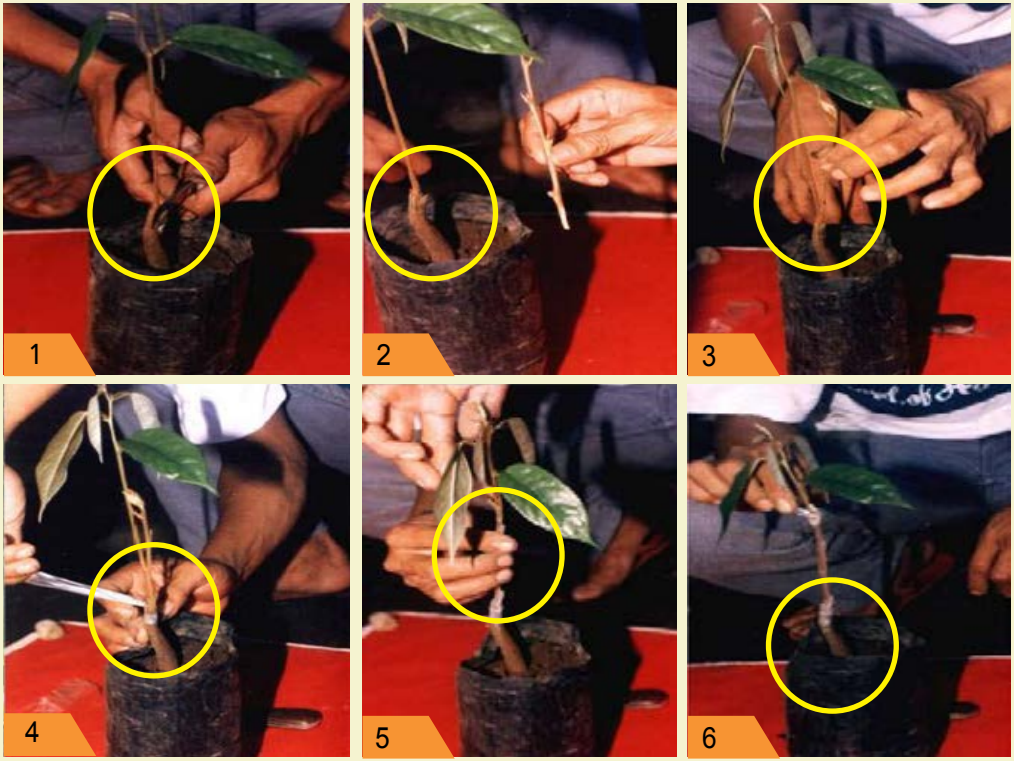
PREPARING DURIAN SCIONS

1. Collect scions from superior mother trees that have been registered or certified.
2. Collect scions at the end of the dry season for a higher success rate.
3. Select scions that have 6–8 leaves 15–20 cm long.
4. Transport to a nursery the scions enclosed in a humid container.

A. SHOOT GRAFTING

1. Select healthy rootstock 3 to 4 months old.
2. Cut the rootstock 20 to 30 cm from the base of the trunk. At the tip of the cut rootstock, cut the trunk 5 cm from the tip of the cut rootstock into two of equal size.
3. Prepare a scion at least 5 cm long from the terminal shoot. The branch or trunk diameter of the scion and the rootstock needs to be the same.
4. Put the scion in the cut part of the rootstock so that it can be joined well. Wrap the grafted part with an elastic plastic wrapper.
5. Remove the plastic wrapper after new leaves have developed on the scion.

Grafting technique at the *hypocotil** of the durian rootstock



* Hypocotil is the part of the stem of an embryo plant beneath the stalks of the seed leaves or cotyledons and directly above the root.

Impact of uneven size of rootstock and scion

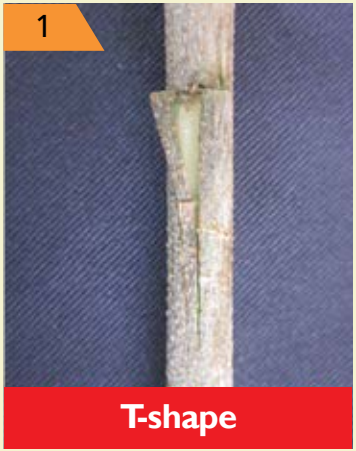
If the rootstock is smaller than the scion, then

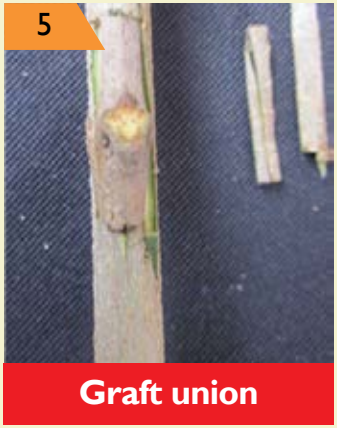
- Nutrition and water supply in the plant will be inhibited owing to underdeveloped food channels inside the trunk.
- Plant growth will be slower.
- During prolonged drought, there will be a higher chance of fallen flowers and fruit owing to limited water supply from the roots to fruit parts.

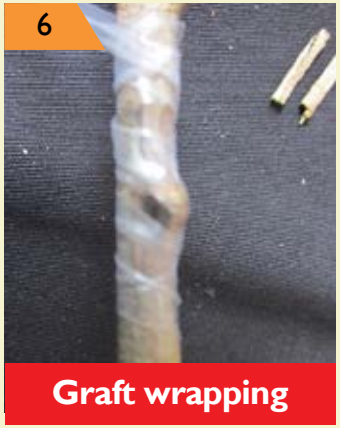
B. BUD GRAFTING

1. Select healthy rootstock with 1 to 2 cm diameter,
2. At a height of 20 to 25 cm from the trunk base, cut the bark of the seedling with a T-shape cut. Peel the bark up 2 cm and cut it so that it is only 0.5 cm attached to the seedling,
3. Prepare the scion by detaching the scion from its source (of the size that matches the size of the cutting window on the rootstock),
4. Put the scion in the cutting window and tie it with an elastic plastic wrapper. The wrapping should start from the base of the grafted part to prevent water penetrating the grafted area,
5. Remove the plastic 3 to 4 weeks after grafting,

Steps in bud grafting







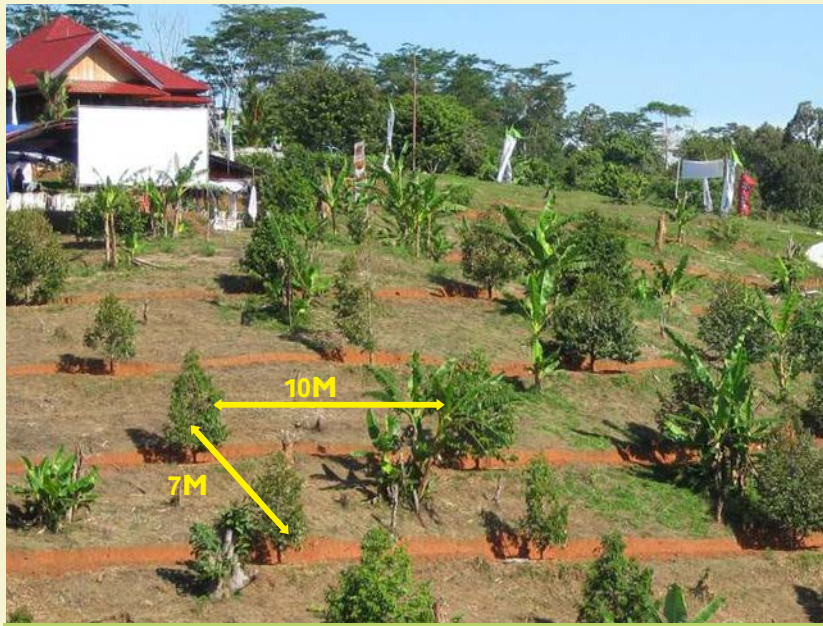
CHARACTERISTICS OF SUPERIOR DURIAN SEEDLINGS

Origin	: Clear, recorded or certified
Propagation	: Grafting
Height of the grafting	: 20 to 25 cm
Height of the bud grafting	: 15 to 20 cm
Number of leaves	: 8
Height of the grafted part	: minimum 40 cm
Age of the seedling	: 6 months after grafting
Seedling condition	: Vigourous, healthy, free from root rot disease

IV. LAND PREPARATION AND PLANTING FOR DURIAN

Spacing management

- Do spacing at the end of the dry season.
- Prepare sticks to mark the spacing distances.
- For plain landscapes, the spacing distance is 8 x 8 m with a total 156 trees per hectare.
- Clear weeds and debris from the planting area.



On sloping landscapes, spacing distance is 10 x 7 m

Preparing planting holes

- The size of a planting hole should be 70 x 70 x 70 cm.
- Dig the hole, placing the surface soil to the right of the hole and the deeper soil to the left of the hole.
- Leave the hole open for 2 to 4 weeks. This will allow sunlight to paralyze any fungi in the soil.
- After 1 month, mix the soils with at least 10 kg of manure and, if necessary, add 0.5 kg of dolomite. Put the mixture into the planting hole. The hole is ready to be planted.

Planting techniques

- Planting is best done at the beginning of the wet season.
- Open the seedling's polybag by first cutting the bottom part of the polybag then the side part.
- Plant the seedling in an upright position.
- Plant the seedling up to 5 cm above from the base of the trunk.
- Position a stick next to the seedling and bind the seedling to it in an upright position.
- Durian seedlings are better planted under shade trees, such as banana.
- Soil humidity should be maintained with mulch made from organic material.

V. PRUNING DURIAN TREES

Pruning young trees (1 year after planting)

The objective of pruning young plants is to optimize their growth and potential production.

Pruning technique for young durian trees with height of 70 to 100 cm from the ground:

- Eliminate young shoots branches 20 to 30 cm from the trunk.
- Form the tree crown shape by adjusting the direction of the primary branches in a balanced direction.

Pruning productive durian trees

- The aim of this technique is to provide space where potential flowers may grow on the lateral branches.

Pruning technique for productive trees

- Prune all branches growing 1–2 m from soil surface.
- Maintain the crown height at 4 to 6 metres above the soil.
- Eliminating unproductive branches for regulating air circulation and sun penetration will reduce the incidences of fungi (*Phytophthora*).
- Maintain the tree with only one trunk. It is not recommended to maintain two trunks of one durian tree.

VI. THINNING DURIAN FRUIT

The objective of fruit thinning is to prevent the durian trees from dying after harvest.

Techniques for fruit thinning

- Remove fruit that is infected by pests or diseases or which has an abnormal shape.
- Every 1 kg of durian needs at least 100 leaves to support fruit growth.
- Thin the fruit 40 days after the fruit has developed.
- Mature fruit needs to be protected from pests and diseases.

Too many fruits. Need thinning.

VII. FERTILIZATION OF DURIAN TREES

- Fertilizer dosage depends on soil characteristics and condition.
- When the tree is flowering or beginning to fruit, do not apply nitrogen fertilizers to avoid shedding of flowers and young fruit.
- Chemical fertilizers should be dug in at the projection of the crown boundary on the ground.
- Organic fertilizers should be applied at the end of both wet and dry seasons.

Fertilizer dosages for individual productive durian trees

Apply fertilizer twice a year, i.e. after harvesting and at the end of the dry season.

Number of fruits	Weight of total fruits/tree (kg)	Urea (g/tree/year)	SP36 (g/tree/year)	KCl (g/tree/year)
25	50	206	143	308
30	60	247	172	370
35	70	288	200	431
40	80	330	229	493
45	90	371	257	554
50	100	412	286	616
100	200	824	572	1232
200	400	1648	1144	2464

Note: 1 tablespoon = 20 to 30 gram

Guidelines for
Cultivation of Areca

Authors:
Endri Martini and Riyandoko

This chapter was compiled from references, particularly from Balai Penelitian Tanaman Palma (Balitpalma):

Miftahorrachman, Matana YR, Salim. 2015. Teknologi budi daya dan pasca panen pinang. Cultivation and post-harvest technology for areca nut. Manado, Indonesia: Balai Penelitian Tanaman Palma.

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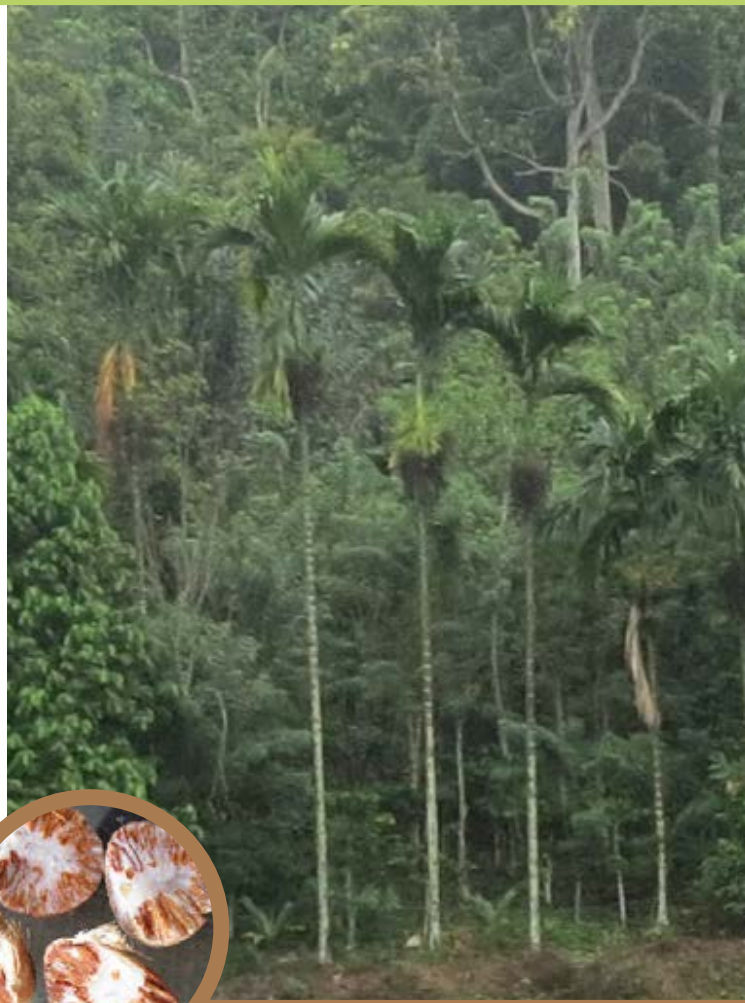


I. SUPERIOR ARECA NUT VARIETIES IN INDONESIA

Betara areca nut, originates from Betara Sub-district, Tanjung Jabung Barat District, Jambi Province

- Produces 131 seeds per fruit stalk.
- The colour of the young fruit is green and mature fruit is orange.

Mongkonai areca nut, originates from Kotamobagu, North Sulawesi Province

- Tanin content 13.2%.
- The colour of young fruit is light green and mature fruit is yellow.

Source: Balitpalma 2015

Source: Balitpalma 2015

II. SITE REQUIREMENTS

- Altitude 0 to 1000 masl, optimum growth at altitudes between 0 and 600 masl
- Soil type: lateric, red clay, alluvial
- Porous soil, deep solum
- Soil acidity (pH) 4 to 8
- Slope degree 10%
- Annual precipitation rate 1250 to 4500 mm
- *Areca needs sunlight 6 to 8 hours per day*

III. PLANT PROPAGATION

Source:
Balitpalma 2015

Criteria of superior areca mother trees

- Trunk is vigorous and straight, leaves tend toward a horizontal direction and width of leaves is relatively uniform.
- Trunk diameter of 45 cm at 1 m from the ground.
- Early flowering (minimum 6 years).
- Distance between leaf scars on trunk is narrow (less than 10 cm)
- Minimum number of leaves is 7.
- Minimum production per year is four inflorescences with number of seeds per inflorescences above 50 .
- Age of the tree is between 10 to 25 years.

Criteria of superior fruit for planting material

- Fruit weight is around 35 g with equal or uniform size and which floats vertically in water.
- Age of fruit is 10 to 12 months, when the fruit has orange or yellow-orange colour.
- Healthy (no pests or diseases).

STAGES IN GERMINATING ARECA SEEDS

- Make sowing beds 1 m wide with length adjusted based on needs (1 m for 500 seeds).
- Sow the areca fruit immediately after it is harvested from the tree.
- Place the fruit in a horizontal position.
- Cover the fruit with a mixture of soil and sand 0.5 cm thick.
- Provide shade to maintain humidity. Avoid direct sunlight the beds.
- Watering should be done every morning and afternoon.
- Fence around the beds to avoid disturbance by livestock.
- Seeds will start to germinate after 1.5 to 3 months.
- To accelerate the germination process, provide 75% shade and remove the exo- and mesocarp of the fruit then scarify the endocarp of the seed.

Source: Permentan 2014

TRANSFERING GERMINATED SEEDS INTO POLYBAG

After the seeds are germinated, they are grown in two stages

Stage 1 (2 to 5 months): germinated seeds are transfered to polybags 25 x 25 cm that have been filled with a mixture of soil and compost. Provide shade from a height of 1.75 to 2.5 m. After two months, decrease the shade gradually to no shade at 3 months.

Source: Permentan 2014

Stage 2 (5 to 12 months): the 5-month-old seedlings should be transfered to polybags of 40 x 50 cm that have been filled with a mixture of soil and compost. The seedlings are ready to be planted on farm after they are 12 to 18 months-old.

CHARACTERISTICS OF SUPERIOR ARECA SEEDLINGS

Source: Permentan 2014

- Age: 12 to 18 months.
- Number of leaves is 5 with horizontal direction of the leaves.
- Seedling height is 60 to 75 cm with vigorous trunk.
- Healthy (no occurence of pests and diseases).

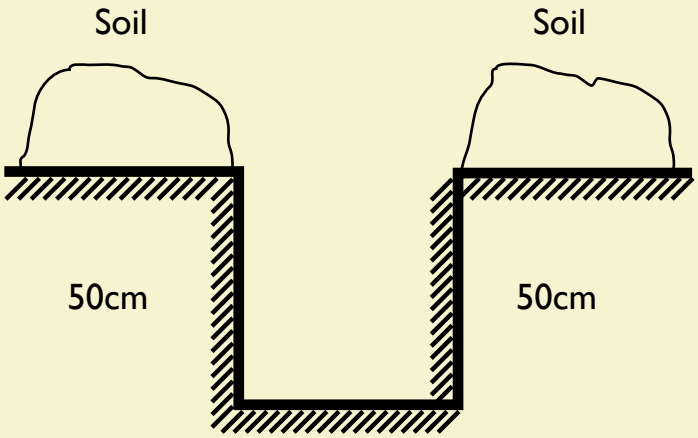
IV. LAND PREPARATION FOR ARECA

Spacing distance

- Spacing distance between individual trees depends on soil depth and fertility. The recommended distance between areca trees in a monocultural system is 3 x 3 m.
- At the age of 1 to 4 years, based on areca rooting system, the minimum distance between individual areca trees or other tree species is 1 m.
- When areca trees are mixed with other species, the distance between the other plants needs to be widened, for example, if areca is planted with banana the distance between areca and banana is 4–5 x 2–2.5 m.

Planting holes

- Recommended planting hole size is 50 x 50 x 50 cm. Deeper planting holes (90 cm) can strengthen the rooting systems of areca plants.
- Planting holes need to be established at least one month before planting. Just before planting, filled the soil with mixture of surface soil, compost and 1 kg of manure.



Source: Permentan 2014

V. PLANTING TECHNIQUES FOR ARECA

1. Planting is done at the beginning of the wet season.
2. Before planting the seedlings, carefully tear open the polybags. Make sure the planting process does not destroy the rooting system of the seedlings.
3. Make sure that soil is still attached in the rooting system.
4. Make sure to fill the planting holes with a mixture of soil and compost at least one month before planting.
5. Put the seedlings in the planting holes with the trunk base position parallel with the soil surface.
6. The soil around the seedlings should be compacted.
7. After the seedlings are planted on the farm, protect them from direct sunlight for at least six months.

VI. FERTILIZING AND WEEDING

- Apply fertilizer twice a year, i.e. at the start and end of the wet season.

Plant age	Fertilizer and dosage per tree per year			
	Urea (g)	TSP (g)	KCl (g)	Manure (kg)
1–3 years	55	40	180	0
More than 4 years	220	80	240	6

- Remove weeds within a radius of 0.5 to 2 m from the areca trunk. Weed three times per year or more depending on how quickly weeds regrow.

VII. PEST AND DISEASE HANDLING FOR ARECA

- Select varieties that are resistant to pests and diseases.
- Select healthy planting material (seeds or seedlings).
- Treat planting material with recommended pesticides.
- Regulate standard spacing distance between individual plants.
- Apply mulch or organic fertilizer to enhance soil fertility and health.
- Combine the application of chemical and organic fertilizers.
- Regulate watering if necessary.
- Replace areca with other species if pests and diseases cannot be handled.

YELLOW LEAVES ON ARECA

Cause of the disease: *mycoplasm-like organism (MLO)*

Effect to plant: decreases production up to 50%

Source: Balitpalma 2015

Symptoms

- Yellowing of leaves, starting from the tips of the leaflets of the outer leaves gradually extending along the margin to the middle of the lamina.
- The affected leaves often develop necrosis from their tips.
- In advanced stages, the leaves become smaller, stiff and pointed
- The crown reduces and the palm is stunted, giving very few or no nuts at all.
- Root tips become dark and gradually rot.
- Kernel of affected nuts shows discoloration and later turns blackish.

Prevention and integrated controlling

- Routinely fertilize the plant with appropriate dosages.
- Apply fungicide with active ingredient: 2 g of phorate granula per tree.
- Sanitize the plot, improve drainage and grow cowpea or cover crops between the trees.

VIII. HARVESTING ARECA

Source: Permentan 2014

Harvesting the ripe fruit

- The colour of ripe fruit is light yellow or orange.
- On 1 hectare, harvesting can be done every month with production of 400–450 kg of dry seeds.

Harvesting young fruit

- Fruit age is 3–4 months. The endosperm will still be tender and can be chewed.
- Boil and dry the young fruit if to be stored for a long period of time.

Source: Balitpalma 2015

IX. POST-HARVEST HANDLING

Source: Balitpalma 2015

Cut the fruit into two pieces to accelerate the drying process. The seeds are extracted from the fruit and dried for 50 hours. Normally, the drying process takes four days.

Guidelines for

Cultivation of Bird's Eye Chili

Authors:

Endri Martini and Riyandoko

This chapter was compiled from various references.

Bidang Pengembangan Produksi Hortikultura. 2014. Standar Operasional Prosedur (SOP) budidaya cabai rawit. Standard Operating Procedure (SOP) for cultivation of bird's eye chili. Palangka Raya, Indonesia: Dinas Pertanian dan Peternakan Provinsi Kalimantan Tengah, Republik Indonesia.

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Source: rickysetiawan96

I. SUPERIOR VARIETIES OF BIRD'S EYE CHILI

- The registered superior variety of Kathur bird's eye chili (SK No. 343/Kpts/TP.240/6/2003) is appropriate for planting at elevations of 5–600 masl. The strengths of this variety are good growth, can be harvested 60 days after planting, can be stored for long periods, and productivity is 12–13.5 tonne per hectare.
- The registered superior variety of Dewata hybrid bird's eye chili (SK No. 345/Kpts/SR.120/9/2005) can be planted at elevations of 0–1300 masl. The strengths of the variety are high productivity (14 tonne per hectare), can be harvested 65 days after planting, fruit shape is rounded and long with an orange-red colour.
- The superior variety of Prima Agrihorti has a potential productivity of 20–25 tonne per hectare.
- The superior variety of Rabani Agrihorti has a potential productivity of 13–14 tonnes per hectare.


Kathur


Dewata F1

II. SITE REQUIREMENTS FOR BIRD'S EYE CHILI

- Bird's eye chili is best planted at elevations of 0–500 masl. When planted in the range 500–1500 masl, the time of first harvest is longer than when planted below 500 masl.
- Fertile soil rich in organic material.
- Bird's eye chili grows well with soil pH of 6 to 7 but can also grow in soil with pH 4.3 to 9.7.
- The plant needs to be exposed to sunlight for at least 6 hours per day.
- Temperature is an important factor that affect the plant's growth and flowering. The optimum temperature is 20–30 °C. Low humidity and high temperature will cause the shedding of chili flowers and fruit.
- Optimum annual rainfall for chili is 600–1200 mm. Higher annual rainfall will cause the leaves to shed and fruit to rot while low annual rainfall, as in the dry season, can cause stunted growth of seedlings and shedding of flowers and fruit, thus, watering is necessary.

III. PROPAGATION OF BIRD'S EYE CHILI

Select superior varieties released by reliable institutions, such as government agricultural agencies. The characteristics of superior varieties are germination rates above 80%, well adapted to local conditiosn, vigorous, healthy, and with good market potential. Do not use expired seeds.

Techniques to produce bird's eye chili seeds for planting

- Obtain seeds from fruit that was harvested in the 4th to 6th harvesting cycle.
- Obtain fruit from healthy and vigorous plants.
- Select mature superior fruit that is healthy, has a perfect shape, bright-red colour, vigorous and no wrinkles on its surface, and the fruit stalk has a fresh green colour. Let the fruit mature and dry on the plant.
- From mature superior fruit select seeds that are located in the mid part of the fruit.
- Soak the seeds in clean water and remove floating seeds. Select seeds that are not floating and dry them for three days before planting.

GERMINATION PROCESS OF BIRD'S EYE CHILI

- The germination process is best done January–February, June–July or September–October.
- Provide 50% shade in a nursery for germinating the seeds.
- For 1 hectare, 100–125 g of chili seeds is needed.
- Germination beds should be aligned north–south.
- Germination media is a mixture of soil and compost at 1:1 proportions.
- Soak the seeds in cool water for 6 hours.
- Sow the seeds in the germination beds and thinly cover with soil. Water the beds and cover with banana leaves. Gradually remove the banana leaves after a few days.
- Seven days after sowing, transfer the germinated seeds to 5 x 10 cm polybags with planting media mixture of soil and compost with 1:1 proportions.
- Water twice a day in early morning and afternoon. Use sprayer to avoid water destroying the young chili plants.
- Seedlings are ready to be planted on farm after 3–4 weeks when the seedlings have 4–6 leaves and 8–10 cm height.

IV. LAND PREPARATION AND PLANTING OF BIRD'S EYE CHILI

- Select a location that has never previously been planted with other Solanaceae, such as tomato, eggplant, melon, and tobacco, or at least was not planted in the past planting cycle.
- Select location that previously was planted with Graminae, such as rice, maize, sugarcane, or from Liliaceae, such as shallot and onion.
- Dig the soil to 25–30 cm depth and apply manure. For acid soils, apply calcium on the soil surface 2 to 3 weeks before planting.
- Establish planting beds of 1 to 1.2 m width, 40 to 50 cm height, with length adjusted based on need. Distance between planting beds can also be adjusted based on need.
- Spacing distance between individual chili plants should be 70 x 70 cm. When planted in an agroforestry system, the minimum spacing distance with other species is 1 to 2 m, depending on the characteristic of the other species.
- Size of planting hole should be 15–20 cm deep and 20–25 cm wide. Leave the planting hole open for 1 day before planting.
- For planting on farm, select seedlings that have 8–10 cm height, at least four leaves, straight trunks and good rooting systems.
- Planting is best done in the early morning or afternoon, to avoid wilting owing to overexposure to direct sunlight.

V. PRUNING BIRD'S EYE CHILI

- The objective is to stimulate flowering and fruiting.
- Pruning is done by removing leaves from the Y area (see illustration).
- First pruning is conducted 8–12 days (lowlands) or 15–20 days after planting (highlands).
- Second pruning is conducted 75 days (lowlands) or 90 days after planting (highlands).

Source: Food and Agriculture Organization of the United Nations and Ministry of Agriculture (n.d.)

VI. MAINTENANCE OF BIRD'S EYE CHILI

- Replanting of dead plants should be done two weeks after initial planting.
- Watering the soil during the dry season. Do not water the plant parts.
- In the wet season, provide drainage channels to avoid plants being flooded.
- Weeding should be done one month after planting.
- Fertilization should be done one month after planting
  - » Fertilize once every one or two weeks depending on soil condition. The more fertile the soil, the less intensive the fertilization. For hybrid plants, fertilization is done at 15, 28 and 42 days after planting with additional fertilization for non-hybrid plants at 60 and 80 days after planting.
  - » Dosage of fertilizers should be adjusted based on local conditions.
  - » Deconcentrated 125 mg NPK with 10 L of water or deconcentrated liquid organic fertilizer can be used to fertilize 40 plants (250 mL per plant). Add calcium (Ca) to stimulate the fruiting process.

VII. TECHNIQUES FOR PRODUCING LIQUID ORGANIC FERTILIZER

MATERIALS

Producing 50 litre of liquid organic fertilizer	Producing 200 litre of liquid organic fertilizer
12.5 kg manure	50 kg manure
1.25 kg gliricidia leaves	5 kg gliricidia leaves
1.25 kg vegetable and fruit residues	5 kg vegetable and fruit residues
0.5–1 kg paddy straws	2–3 kg rice straw
37.5 L of water	150 L of water
0.25 L EM4	1 L EM4
1 kg palm sugar	4 kg palm sugar

EQUIPMENT

200 L drum

Measuring cup

Bucket

Machetes

Plastic sheets and rubber ties

Filter with 1MESH

1.5 L plastic bottle

Water hose 1.5 m long with 1 cm diameter

Shovel

Mask

Two stirring sticks: one long and one short

STEPS FOR PRODUCING LIQUID ORGANIC FERTILIZER

1. Put 25 kg manure into the drum.
2. Add 20 L of water to the drum and stir.
3. Chop gliricidia leaves, vegetable and fruit residue, and add to the drum.
4. Add another 20 L of water and stir.
5. Add rice husk powder and another 20 L of water and stir.
6. Add a mixture of 2 kg sugar with 15 L of water and stir.
7. Add 500 ml EM4 and stir.

STEPS FOR PRODUCING LIQUID ORGANIC FERTILIZER (CONTINUED)

8. Make sure there is room for air to circulate by keeping the level of the mixture 20 cm from the top of the drum.
9. Close the drum with plastic sheeting and rubber ties to ensure an anaerobic process.
10. Make a hole in the plastic sheet that fits the diameter of the water hose and place one end of the hose into the drum and the other end into a plastic bottle filled with water. This will allow the gas in the drum to be released.

STEPS FOR PRODUCING LIQUID ORGANIC FERTILIZER (CONTINUED)

11. After one week, carefully open the plastic sheeting. Wear a mask when doing so.
12. Stir the mixture. If the mixture is too condensed, add more water and stir.
13. Tightly re-close the drum.
14. After another three weeks (one month after making the mixture), open the drum again.
15. Filter to separate the liquid from the residues of decaying material.
16. The liquid organic fertilizer is ready to be used.
17. The residues can be air dried and used as compost.

CHARACTERISTICS OF LIQUID ORGANIC FERTILIZERS AND CAUTION WITH APPLICATION

Characteristics of liquid organic fertilizers ready for use

- All the materials have decayed and blend well with the liquid.
- The liquid has an alcoholic fermentation smell.

Caution with the application of liquid organic fertilizers

- Liquid organic fertilizer needs to be stored in a closed container under shade. Avoid direct sunlight.
- **Liquid organic fertilizer needs to be deconcentrated before application.** If applied without deconcentration, it can burn and poison the plants.

Liquid organic fertilizer concentrate	Water to be added
1 L from decaying leaves and fruit	3 L
1 L from decaying manure	5 L
1 L from decaying manure, leaves and fruit	10 L

VIII. HANDLING OF PESTS AND DISEASES OF BIRD'S EYE CHILI

THRIPS

- Thrips are vectors for mozaic and curly virus in chili.
- In the dry season, thrip populations increase dramatically.

Prevention:

- Plant cover crop with yellow flowers, such as 'kenikir kuning' (*Cosmos caudatus*).
- Cut and remove leaves or plant parts infected by thrips.
- Install 40 yellow traps per hectare two weeks after planting.


Source: Surahmat, 2011


Kenikir kuning

WHITE FLY

- White fly (*Bemisia tabaci*) is dangerous because it can transmit 60 types of virus, such as Gemini, Clostero, Nepo, Carla, Poty and Rod-shape DNA.

Prevention and control

- Plant chili in mixed systems with maize or tagetes.
- Use rotation planting with other non-*Solanaceae* species, such as potato and cucumber.
- Use selective pesticides as a last alternative, e.g. Permethrin, Amitraz, Fenoxycarb, Imidacloprid, Bifenthrin, Deltamethrin, Buprofezin, Endosulphan or Asefat.

WILTING *FUSARIUM*

Symptoms: Leaves are yellowing and wilting starts from the base to the tip.

Control:

- Sanitize the plot by removing and destroying the infected plants.
- Use antigony agents, such as *Trichoderma* spp and *Gliocladium* spp, as a mixture in base fertilizer in the planting holes.
- Chemical fungicide can be used as a last alternative.

FRUIT ANTHRACNOSE

- This disease is particularly active during the wet season when humidity is high and optimum temperature ranges 20 to 24 °C. The disease spreads through water.
- Heavy infection of the disease can cause the fruit to wrinkle and dry out with the colour of the fruit surface becoming that of rice husks.

Source: Meilin, 2014

Prevention and control:

- Prevention can be conducted by sanitizing the land and removing the infected plants.
- Use superior varieties that are resistant to this disease, as this disease can be transmitted through seeds.
- Use healthy seeds and remove and destroy the infected fruits.
- Do planting rotation to cut the disease cycle.
- Pesticide application is recommended as the final alternative. Do not use sprayer to apply pesticide, or make sure the sprayer is clean before used.

GEMINI VIRUS OR YELLOW DISEASE

- Yellow disease is caused by the gemini virus through grafting. It is transmitted by white bugs.
- Heavy infection of gemini virus causes the leaves to dwarf, with bright yellow colour, stunted plants and no fruit developed.

Source: Meilin, 2014

Prevention and control:

- Additional fertilization is necessary to increase plant imunity while infected with the virus and to stimulate the fruiting process in the infected plants.
- Control the population of white bugs by planting maize or tagetes around the border of the plot or in between planting beds.
- Plant chili varieties that are resistant to gemini virus, such as hot chili.
- Use plastic mulch to control the population of the host and limit the development of the virus.
- Sanitize the plot from infected plants.

BIOPESTICIDE FOR PESTS AND DISEASES IN BIRD'S EYE CHILI

1. Biopesticide to control thrips and aphids

Material: 50–100 soursop leaves, 15 g detergent, 5 L water

Process:

- Pound the soursop leaves and mix with 5 L water. Ferment the mixture for 24 hours and then filter the leaves from the water.
- Deconcentrate 1 L of fermented mixture with 10–15 L of water that has been mixed with detergent.
- Spray onto infected plants and other plants nearby.

2. Biopesticide to control anthracnose

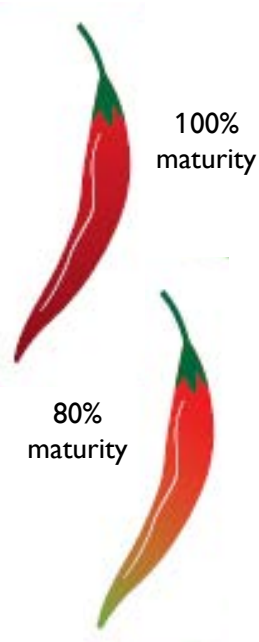
Material: 1 kg galangal, 2 L water

Process:

- Slice galanga into thin slices. Dry the slices. Chop into small pieces.
- Add 2 L water to distillation pan, heat it, and add dried galanga. Pour the distilled galangal water into a beaker glass.
- Deconcentrate 1 L of the distilled galanga water with 7 L of water and apply to infected plants. It is best to spray in the afternoon.

IX. HARVESTING

- Stop spraying pesticides two weeks before harvesting.
- Harvesting is best done in the morning, picking the fruit along with its stalk.
- Harvest fruits with 80–90% level of maturity. Don't harvest fruit that is overripe.
- First harvest is conducted 60–75 days after planting.
- After first harvest, fruit can be harvested every 3–7 days.
- Chili can be harvested for 24 months, 15–18 times with production of at least 30 kg per harvest.
- The sorting process of chili is better done on farm to avoid the transfer of pests and diseases to the storage places.



Source: Food and Agriculture Organization of the United Nations and Ministry of Agriculture (n.d.)

X. POST-HARVEST HANDLING

Drying

- To produce dry chili, dry for 3 to 4 days depending on weather and level of water content in the chili, which needs to be at least 7.5 to 8%.
- Don't dry chili directly on soil surface but on drying beds.
- Don't dry chili in open places, to avoid rain or sunburn.

Sorting

- For effiency, sorting can be done while drying.
- Separate high-quality chili and store on lowest shelves for 2–3 days.

Storing and packing

- Don't store chili inside plastic bags. Use gunny bags or bamboo baskets.
- Store products in clean and dry places.
- Chili fruit needs to be packed in bags that have holes for air circulation.

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These guidelines aim to improve smallholders' ability to establish and manage coffee-agroforestry farms in Indonesia. The information herein includes results from national research partners, such as the Indonesian Research Institute for Medicinal Plants and Spices, Centre of Tropical Horticultural Study at Bogor Agricultural University, Indonesian Coffee and Cocoa Research Center, Palm Plants Research Institute and Indonesian Agricultural Research Institute. This booklet was developed in collaboration between the World Agroforestry Centre and Hanns R. Neumann Stiftung.

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