Smallholder Oil Palm Handbook
Module 3: Plantation Maintenance

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Module 3: Plantation Maintenance

**GOAL: To manage the plantation effectively, efficiently, and sustainably**

After this section, farmers should:

- Be able to identify the different parts of the oil palm
- Be able to discern beneficial and noxious weeds
- Know how to remove noxious weeds effectively
- Be able to create an efficient plantation layout including clean harvesting paths and circles
- Know how to prune the palms and how to stack the pruned fronds
- Know how to implement basic soil conservation measures

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1. **IMPORTANT TERMS**

In **Figure 1** the following parts of the oil palm are indicated:

- The **trunk**
- The **crown**: all the leaves of the palm
- The **leaves**, also known as ‘fronds’ in the case of oil palm
- The **young leaves**: these appear from the growing point in the centre of the top of the trunk
- The **old leaves**: these are found at the bottom of the crown
In Figure 2 the following parts of the oil palm are indicated:

- The **trunk**
- The **base**: the part of the trunk that is closest to the ground. The roots grow from the bottom of the trunk base.
- The **frond butts**: these are pieces of leaves that remain behind after the leaves are cut during pruning or harvesting. When the palm grows older, the frond butts usually detach from the trunk, but this can take 10 to 15 years.
In Figure 3 the following parts of the oil palm are indicated:

- The developing fruit bunches, also known as 'black bunches'
- The oldest leaves
- The youngest leaves
- The petiole: the bottom part of the leaves, which has spines but no leaflets
Figure 4 shows a close-up of an oil palm leaf. The leaf is composed of a central **rachis** with **leaflets**, also known as ‘**pinnae**’, on either side. When collecting leaf samples (**Appendix 1**), usually both the rachis and the leaflets are collected. Note that some of the leaflets point a bit more upwards and others a bit more downwards. This is what gives oil palm leaves a ‘messy’ appearance, compared with for example coconut palm leaves, where the leaflets are all set in one single plane.
Figure 5 shows a male inflorescence (left) and female (right) inflorescence.
Figure 6 shows the most efficient plantation layout. The plantation is divided into the following areas:

- The weeded circle, 1.5-2 meters in diameter, around the palm trunk
- The harvesting path, every other row
- The frond stack, in a U-shape around the palm, every other row alternating with the harvesting path
- The interrow, which includes all the areas outside the weeded circle and the harvesting path
2. GENERAL NOTES ON STORING AND SPRAYING CHEMICALS

**Warning!** Herbicides, pesticides and other chemicals are often toxic to humans, animals and palms, and should be used sparingly and with care.

- Application of chemicals should always be carried out wearing full protective clothing (see Figure 7) including:
  - Rubber gloves
  - Boots
  - Gas mask or mouth cover
  - Safety glasses
  - Rubber apron
- It is recommended that spraying is carried out only by workers who have followed a training session
- Spray equipment should be kept clean and in good shape
- Label every chemical container to say what is inside it (e.g. herbicide (with name), pesticide (with name), etc.)
- When preparing chemicals carefully follow the instructions on the package

Never store food in containers that were used for chemicals or fertilisers.

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### Using knapsack sprayers [1, 2]

The most commonly used knapsack sprayers are the so-called ‘lever-operated knapsack sprayers’ (see Figure 8). When using a knapsack sprayer, be sure to follow these steps:

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1.</td>
<td>Read the manual carefully before using the sprayer.</td>
</tr>
<tr>
<td>Step 2.</td>
<td>Before herbicide application, test with water to make sure the knapsack sprayer is functioning properly and has no leaks.</td>
</tr>
<tr>
<td>Step 3.</td>
<td>Select the right nozzle. The nozzle is the part from which the herbicide spray comes out. The type of nozzle determines how much spray comes out and what the size of the spray is.</td>
</tr>
<tr>
<td>Step 4.</td>
<td>Calibrate the sprayer once every 3 months using clean water and a bucket.</td>
</tr>
</tbody>
</table>
Spraying herbicides

Herbicides can be sold as liquids or as powder. Liquid herbicides are often mixed at 0.5, 1 or 2 percent, which means 5, 10 or 20 ml per liter of water.

Always prepare herbicide solution according to the instructions on the package. Ask others for help if you are not sure how to do it. Before getting
started, make sure that the sprayer is properly calibrated so that it is clear how much water comes out of the sprayer every minute.

Prepare the sprayer and do the spraying following these steps (see Figure 9):

| Step 1. | Fill the knapsack sprayer with water (e.g. 10 L). |
| Step 2. | Add the herbicide (e.g. 100 or 200 ml). |
| **Note:** | Always use gloves while adding the herbicide! |
| Step 3. | Close the lid and shake well. |
| Step 4. | Fill the sprayer up with more water (e.g. another 5 L) until it is full. |
| Step 5. | Spray the weeds with the herbicide solution. Per hectare it is normal to spray 50-200 L of solution (0.5 to 2 L of herbicide) depending on the number of weeds. When doing clear-weeding (not normally a good idea!) more herbicide will be needed (e.g. up to 300 L/ha). |
| Step 6. | Keep clear records of when you have sprayed, and how much. |
| Step 7. | If it rains less than 4 hours after spraying, repeat the treatment (but not if spraying Gramoxone). |

*Figure 9: Overview of how to spray herbicides*
Common herbicides in oil palm

Mode of action of common herbicides

Herbicides are often divided into two groups: contact herbicides and systemic herbicides. These groups differ in their mode of action (see Figure 10). Contact herbicides are toxic to the plant where they touch it. The most well-known contact herbicide is paraquat. Systemic herbicides move into the plant and are transported to the stem, roots, and other leaves. The most well-known systemic herbicide is glyphosate. For an overview of the most common herbicides used in oil palm plantations, see Table 1. Glyphosate, paraquat and triclopyr are discussed in more detail below.

Table 1: Some contact and systemic herbicides and their common brand names

<table>
<thead>
<tr>
<th>Contact herbicides</th>
<th>Brand:</th>
<th>Systemic herbicides</th>
<th>Brand:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Herbicide:</td>
<td></td>
<td>Herbicide:</td>
<td></td>
</tr>
<tr>
<td>Paraquat</td>
<td>Gramoxone</td>
<td>Glyphosate</td>
<td>RoundUp</td>
</tr>
<tr>
<td>Glufosinate</td>
<td>Basta</td>
<td>Metsulfuron methyl</td>
<td>Ally</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Triclopyr</td>
<td>Garlon</td>
</tr>
</tbody>
</table>

Figure 10: The mode of action of contact herbicides (left) and systemic herbicides (right). A contact herbicide kills the leaves it covers but is not transported into the stem or roots. Systemic herbicides are transported into the stem and roots and kill the entire plant.
Glyphosate [3]

The most well-known trade name of glyphosate is ‘Roundup’. Glyphosate can be used to kill a wide range of weeds. It is a ‘systemic herbicide’ so it is taken up through the leaves of the weeds and transported through the plant (see Figure 10). Glyphosate becomes inactive in the soil, so it is not taken up through the roots. It is rain fast within 1–4 hours after spraying.

Glyphosate should be handled with care:
- It is slightly toxic to humans and animals
- It is harmful for the eyes

Always wear proper protective clothing including safety glasses when mixing and spraying glyphosate, and make sure all body parts apart from the head are fully covered.

Glyphosate will not damage the palms unless sprayed directly onto the leaves or used carelessly and in excessive quantities.

Figure 11: Glyphosate of a local Indonesian brand
Gramoxone [4]

The active ingredient of gramoxone is paraquat. Paraquat can be used to kill many different types of weeds, including grasses. It is a ‘contact herbicide’: it works through direct contact with the leaves of the weeds and is not taken up into the plant. Paraquat becomes inactive in the soil. It is rain fast within half an hour after spraying.

Paraquat should be handled with great care:
- It is highly toxic to humans and animals
- Undiluted paraquat is deadly when swallowed
- It is toxic when inhaled
- It is harmful for the eyes
- It can also irritate the skin

When mixing and spraying paraquat use full protective clothing including face mask, safety glasses and rubber gloves, and make sure that all body parts apart from the head are fully covered. Undiluted paraquat should be handled with extra care.

Paraquat will not damage the palms unless sprayed directly onto the leaves or used carelessly or in too large quantities

For the control of woody weeds: Garlon, Release, or similar [5, 6]

The active ingredient of these herbicides is triclopyr [6]. The most commonly used brand in oil palm plantations is ‘Garlon’ (see Figure 12). Herbicides with triclopyr kill woody weeds and most other weeds, but not grasses such as Imperata cylindrica (alang-alang). Triclopyr is a ‘systemic herbicide’: it is taken up through the leaves or through wounds in the bark. It becomes inactive in the soil and it is rainfast within 2-4 hours after spraying.

Herbicides with triclopyr should be handled with care:
- Triclopyr is slightly toxic to humans and animals
- It is harmful for the eyes
- It can irritate the skin
- It is highly toxic to fish and should never be sprayed in or next to waterways

When mixing and spraying triclopyr always wear proper protective clothing. Make sure all body parts apart from the head are fully covered.

Triclopyr is expensive, so use it only when necessary, and with care. Triclopyr will not damage the palms unless it is sprayed directly onto the leaves or used carelessly or in excessive quantities.
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Figure 12: Garlon
3. COMMON NOXIOUS WEEDS IN OIL PALM

Melastoma malabathricum

Clidemia hirta

Chromolaena odorata

Mimosa pudica

Lantana camara

Dicranopteris linearis
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Stenochleana palustris

Mikania spp

Asystasia gangetica

Imperata cylindrica
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<table>
<thead>
<tr>
<th>TABLE 2: COMMON NOXIOUS WEEDS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scientific name</strong>:</td>
</tr>
<tr>
<td>--------------------------------</td>
</tr>
<tr>
<td><em>Ischaemum muticum</em>;</td>
</tr>
<tr>
<td><em>Paspalum conjugatum</em></td>
</tr>
<tr>
<td><em>Imperata cylindrica</em></td>
</tr>
<tr>
<td><em>Asystasia gangetica</em></td>
</tr>
<tr>
<td><em>Mikania spp.</em></td>
</tr>
<tr>
<td><em>Chromolaena odorata</em></td>
</tr>
<tr>
<td><em>Lantana camara</em></td>
</tr>
<tr>
<td><em>Mimosa pudica</em></td>
</tr>
<tr>
<td><em>Clidemia hirta</em></td>
</tr>
<tr>
<td><em>Melastoma malabathricum</em></td>
</tr>
</tbody>
</table>

Properties:
- Soft grasses: used as forage species; palatable in mixed stands; used with oil palm.
- Slow grasses: predominant in pre-plantation phase; not palatable; sensitive to shading.
- Woody weeds and shrubs: allelopathic; used as forage species; palatable in mixed stands; used with oil palm.
- Herbs and creeping vines: allelopathic; used as forage species; palatable in mixed stands; used with oil palm.

Control:
- Grazing: burning; spraying or wiping with glyphosate.
- Uprooting: triclopyr.
- Spraying: glyphosate application.
- Grazing: burning; spraying; uprooting; glyphosate application.
- Uprooting: triclopyr.
- Spraying: glyphosate application.
4. REMOVING NOXIOUS AND WOODY WEEDS

**Background**

Noxious weeds are weeds that are unwanted in a plantation. Weeds can be noxious because they:
- Grow and/or spread very fast
- Are difficult to control
- Take up a lot of fertilisers
- Produce poisons in their roots to reduce the growth of other plants (allelopathy)
- Have spines or are dangerous in other ways

For an overview of common weeds in oil palm plantations, see Section 3. All woody weeds are considered noxious weeds. If woody weeds or noxious weeds are allowed to grow, the weeding will take much time and there may be negative effects on the growth and productivity of the oil palms. Also, more fertilisers may be needed and harvesting will take longer and becomes less efficient, so the plantation becomes less profitable.

**Goal**

- Remove woody and noxious weeds from the plantation
- Make weeding easier and less time-consuming in the future

**Standard**

- Plantations are free of woody and noxious weeds
- A dense vegetation of soft weeds (legumes and *Nephrolepis* ferns) is maintained in the interrow

**Timing**

- In the beginning and at the end of the rainy season
- Shortly before applying fertilisers
- Shortly before the peak season (so that harvesting can be done more efficiently)
- When no rain is expected that day (otherwise the herbicide will be washed away)

**Frequency**

- Every 3-4 months until all woody/noxious weeds are gone
- Then every 6 months if woody or noxious weeds have returned
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Labour time required

- Manual inter-row weeding: 0.5 to 2 days per hectare, depending on the type and number of weeds
- Chemical weeding: 1 day per 3 hectares (when noxious weeds are still present) [7]

Equipment and materials

- Manual weeding:
  - Chisel/spade
  - Bush knife
- Chemical weeding:
  - Bush knife
  - Knapsack sprayer
  - Protective clothing
  - Measuring cup (50-200 ml)
  - Clean water (50-100 L/ha)
  - Herbicide (glyphosate/gramoxone and Triclopyr, 0.5-2 L/ha)
  - Diesel
  - Paint brush (for applying herbicides to woody stumps)
Who

- Farmers and their families or hired labourers

How

Manual weeding

Manual weeding is an effective way to kill woody weeds. When weeding manually, no herbicides are used, so it is good for the other weeds and for the environment. However, manual weeding is labour-intensive, especially if the weeds have not been managed properly before.

Figure 13: This plantation needs to be weeded!

 Woody weeds and other noxious weeds can be removed manually as follows:

**Step 1.** Pull out as many of the noxious and woody weeds as possible. Make sure that most of the roots are also pulled out; if the weeds just ‘break off’ above the ground they will usually come back very fast.

**Step 2.** Cut the roots of the weeds that cannot be pulled out below ground
level using a chisel or spade. Remove the weed and the roots from the ground.

**Step 3.** Large bushes or trees should be dug out completely.

**Chemical weeding: herbaceous (i.e. non-woody) weeds**

See Section 2 for notes on how to spray herbicides correctly. Herbaceous weeds can be removed using chemicals as follows:

**Step 1.** Identify the noxious weed species that need to be removed using TError! Reference source not found.. Do not simply spray all the weeds; this is bad practice, the soil will be degraded, it is a waste of herbicide and it is bad for the environment.

**Step 2.** Spray the noxious weeds with glyphosate or gramoxone:
- Select a nozzle with a narrow cone to prevent spraying on soft weeds or the oil palms
- Spray the herbicide over the leaves of the weeds from above
- Remember that most herbicides work directly on the leaf and are not taken up through the roots. For the best result, try to get some herbicide on most of the leaves when spraying.
- The right amount of spraying is when the leaves are wet but the water is not dripping off (then, it is too much!).
- Do not spray all inter-row weeds but only the noxious ones

**Step 3.** If there are only a few *Imperata cylindrica* plants between the good weeds, they can be wiped with glyphosate solution instead of sprayed, using a sponge or piece of cloth.

**Chemical weeding: woody weeds**

**All woody weeds are noxious weeds and should be removed from the plantation.** Woody weeds often cannot be killed with normal herbicides. If they keep coming back, try the following:

For small woody weeds (no thick stems):

**Step 1.** After reading the label and putting on all necessary protective clothing, prepare the following solution:
- 1% Triclopyr or a similar herbicide (= 100 mL per 10 L water)
- 5% diesel (= 500 mL per 10 L water)
Prepare the solution by first mixing the triclopyr in diesel and then mixing the diesel with water. Note that the diesel may degrade the
rubber components of the sprayer, so these need to be checked for leaks regularly, and a spare set is useful. Put a nozzle on the sprayer that produces a narrow conical spray.

**Step 2.** Spray the woody weeds with the herbicide solution. If the woody weeds are all through the plantation, expect to spray about 3 L of Triclopyr per hectare. Usually it will be less (0.5-1 L). Note that Triclopyr is poisonous to humans and animals; use it with care and remember to wear gloves and other protective clothing.

**Step 3.** Spray the remaining noxious weeds (e.g. alang-alang) with glyphosate. Use Triclopyr only for woody weeds, as it is quite expensive.

**Step 4.** After one month, repeat the spraying with Triclopyr on the young shoots of the woody weeds that are still alive.

For large woody weeds (thick stems):

**Option 1**

**Step 1.** For each woody weed, scratch off some of the bark with a knife (an area of a few square centimetres is enough).

**Step 2.** Wipe/brush the scratched surface with a solution of 5% Triclopyr herbicide in diesel (no water is added, for example: 50 mL Triclopyr in 1 L diesel).

**Step 3.** If any young shoots appear on the trunks that were treated, repeat the treatment for these trunks after one month.

**Option 2**

**Step 1.** Cut the stems close to the ground. Make sure that fresh cuts are made on all woody stems.

**Step 2.** Apply a solution of 5% Triclopyr herbicide in diesel directly to the cut part of the stem (especially on the area just inside the bark). Make sure you apply the triclopyr less than 4 hours after cutting.

**Step 3.** If any young shoots appear on the trunks that were treated, repeat the treatment for these trunks after one month.

**Data recording**

Every weeding activity should be recorded in a log book as shown in the example below.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
<th>Activity</th>
<th>Input type</th>
<th>Input amount</th>
<th>Input costs</th>
<th>Labour input</th>
<th>Labour costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/01/13</td>
<td></td>
<td>Field 3</td>
<td>Removing woody weeds</td>
<td>Triclopyr Diesel</td>
<td>1 L 5 L 3 L</td>
<td>180000 35000</td>
<td>1 4</td>
<td>40000</td>
</tr>
</tbody>
</table>
5. **ESTABLISHING A COVER OF SOFT WEEDS**

**Goal**

Create a closed cover of soft weeds in the plantation to:
- Prevent soil erosion
- Keep the moisture in the soil
- Prevent loss of soil organic matter
- Attract as many natural enemies of pests as possible
- Make access into the plantation easy
- Make weeding fast and easy

**Standard**

- Good cover of soft weeds everywhere in the inter-row
- Legumes established where possible
- Inter-row weeds slashed at knee height
- No noxious or woody weeds in the plantation

**Timing**

- At planting, or at the start of the rehabilitation process, after the noxious weeds have been removed
- **Not** during very strong rain or during the dry period

**Frequency**

- Establishment of legume cover crop: once in the plantation lifetime
- Maintenance of weed cover: every six months

**Labour time required**

- Corrective phosphate application: 1 day per hectare
- Sowing legume cover crops or introducing soft weeds: 1-4 hours per hectare, depending on the extent of bare soil
- Slashing of inter-row vegetation: half a day per hectare

**Equipment and materials**

- Phosphate fertiliser: 500-1000 kg/ha
- Fertiliser measuring cup/bucket
- Bush knife
• Cover plant seeds: usually 1-2 gram per 10 square meters (1-2 kg per hectare)
  o *Calopogonium caeruleum*: 1-1.5 kg per hectare [8]
  o *Calopogonium mucunoides*: 1-3 kg per hectare [9]
  o *Pueraria phaseoloides* (also known as *Pueraria javanica*): 3-4 kg per hectare [10]
  o *Mucuna bracteata*: 200-300 g per hectare [11]

**Who**

• Farmers and their families or hired labourers

**How**

*Figure 14: Mature plantation with a vigorous cover of Calopogonium caeruleum*

**Application of phosphate fertilisers**

If there are many noxious weeds in the plantation (alang-alang, *melastoma*, *dicranopteris*) the soil is likely to be phosphorus-deficient. Beneficial weeds such as ferns and legumes grow better in phosphorus-rich soils.

To help the good weeds grow and reduce the growth of noxious weeds it is useful to apply phosphate fertilisers as follows:
• 500 kg/ha soluble P fertilisers (TSP, SP-36)
• 500-1000 kg/ha reactive rock phosphate

Spread the P fertiliser evenly throughout the plantation, mostly in the inter-row and over the frond stack.

Establishing legume cover plants or other soft weeds

**Table 3: List of the most common legume cover crops and some of their properties [12].**

<table>
<thead>
<tr>
<th>Name</th>
<th>Shade tolerance</th>
<th>Sowing practices</th>
<th>Other properties</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Calopogonium caeruleum</em></td>
<td>Very tolerant</td>
<td>Needs scarification</td>
<td>Very productive; tolerant of heavy shade; Figure 14</td>
</tr>
<tr>
<td><em>Mucuna bracteata</em></td>
<td>Tolerant</td>
<td>Needs to be sown in a seedbed and then planted; benefits from inoculation</td>
<td>Good N fixation; good soil cover; prevents soil erosion</td>
</tr>
<tr>
<td><em>Calopogonium mucunoides</em></td>
<td>Somewhat tolerant</td>
<td>Needs scarification</td>
<td>Pioneer species; short life span</td>
</tr>
<tr>
<td><em>Pueraria phaseloides</em></td>
<td>Somewhat tolerant</td>
<td>Needs scarification</td>
<td>Grows quickly; very palatable for livestock</td>
</tr>
</tbody>
</table>

Legume cover crops are best sown at the time of land preparation, when all the other weeds have been cleared. If there are many weeds, then the legumes may still grow, but selective weeding will become very difficult. In plantations where clear-weeding was a normal practice, legume cover crops can be sown directly after spraying. For sowing or planting legume cover crops, follow the steps below:

**Step 1.** Select the appropriate legume cover crop (see Table 3). They can also be mixed to increase the chances of successful establishment.

**Step 2.** Scarify the seeds, if necessary. Scarification is required to remove the hard outside of the seeds, so that the seeds can germinate faster and simultaneously. Scarification can be done mechanically (with sandpaper), by using 70% sulphuric acid or by using hot water [13]. The sulphuric acid method is the most common and the most effective one, but the acid may not be widely available and is a dangerous chemical, which is also difficult to dispose of after use. Therefore the mechanical scarification or the hot water treatment are recommended.

For mechanical scarification, use the following approach:
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- Place the seeds on a table between two pieces of sandpaper
- Make small rounds with the sandpaper, first one way and then the other
- There is no need to rub off the complete outside of the seeds; there just need to be some deep scratches for the water to enter

For scarification with hot water, try the following with a small batch of seeds [14]:

- Heat water to boiling in a pan
- Take the pan from the fire and let the water cool down to 75°C (check the temperature using a cooking thermometer)
- Add the seeds to the water and stir for 3 minutes
- Remove the seeds and rinse them with cold water, or leave the in the hot water to cool overnight
- Sow the seeds on the next day, or sun-dry them immediately to prevent rotting or germination
- The optimum temperature and soaking time vary from species to species; if the germination is not good, then it is recommended to try different temperatures and find out what works best

Step 3. Broadcast the seeds in the plantation, on bare soil or in an area that was recently weeded. Start with a small area to see if the legumes are able to establish effectively.

Apart from sowing legume cover crops, the population of *Nephrolepis* ferns can also be increased (Figure 15). To achieve this, pull the ferns from the trunks of the palms (roots and all) and throw them in the inter-row. Some of them may establish and start growing. The application of empty fruit bunches promotes the growth of *Nephrolepis* ferns.
Slashing inter-row vegetation at knee height

- Every six months slash all inter-row vegetation at knee height using a bush knife.
- Note: in some plantations it is considered a good practice to let the ferns in the frond stack area grow over 1 meter tall.

Data recording

Every weed management activity should be recorded in a log book as shown in the example below.

<table>
<thead>
<tr>
<th>Date</th>
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<th>Activity</th>
<th>Input type</th>
<th>Input amount</th>
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<th>Labour input</th>
<th>Labour costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/01/13</td>
<td></td>
<td>Field 3</td>
<td>P fertiliser application</td>
<td>Rock phosphate</td>
<td>1000 kg</td>
<td>1500000</td>
<td>2</td>
<td>80000</td>
</tr>
<tr>
<td>20/01/13</td>
<td></td>
<td>Field 3</td>
<td>Sowing legumes</td>
<td>Legume seed</td>
<td>2 kg</td>
<td>400000</td>
<td>2</td>
<td>80000</td>
</tr>
</tbody>
</table>
6. ACCESS AND HARVESTING PATHS

**Goal**

- Create good access into the plantation for all management activities
- Enable fast and easy harvesting

**Standard**

- Paths are between 50-75 cm wide
- Paths are completely free of weeds
- One path is present every other palm row (see Figure 16)
- Plantations are easy to access (e.g. footbridges over ditches and swamps, no steep slopes, etc.)
- Harvesters with heavy wheelbarrows can move around the plantation easily

![Figure 16: Good harvesting path, easily accessible plantation](image)

**Timing**

- At the beginning and end of the dry period, and;
- Shortly before the peak season (so harvesting can be done more efficiently)
Module 3: Plantation maintenance

- **Not** when rain is expected that day (otherwise the herbicide is washed away)
- Usually done together with circle weeding

**Frequency**

- Once every 3-4 months, or;
- Whenever the weeds on the path are above ankle height

**Labour time required**

- Manual weeding: 2 days per hectare
- Chemical weeding: together with circle weeding, 1 day per 2 hectares
- Bridges, ramps, etc.: depending on the condition of the plantation

**Equipment and materials**

- Manual weeding:
  - Chisel/spade
  - Bush knife
- Chemical weeding:
  - Knapsack sprayer
  - Protective clothing
  - Measuring cup (50-200 ml)
  - Clean water (50-100 L/ha)
  - Herbicide (0.5-2 L/ha)

**Who**

- Farmers and their families or hired labourers

**How**

**Manual weeding of paths**

To manually weed paths:

- Cut down all weeds on the path to ground level with a bush knife or scrape away all weeds using a spade
- If possible, pull out woody weeds with large roots. If they cannot be pulled out, dig out the stumps with a chisel or spade

**Chemical weeding of paths**
For tall weeds (more than 50 cm) start with one round of manual weeding and then spray the young re-growing weeds after one month or when the weeds are at ankle height using the following procedure:

**Step 1.** Make sure the sprayer is calibrated and working properly.

**Step 2.** Prepare the herbicide according to the instructions on the package (see also Section 2).

**Step 3.** Select a nozzle that gives a spray of about half a meter wide

**Step 4.** Spray the path using the following technique:
- Walk at a regular speed over the path and keep the nozzle steady and low above the ground
- Do not swing the nozzle left and right
- Never spray on palm leaves, otherwise the palm will be damaged

Per hectare, expect to spray 50 to 100 L of solution (0.5 to 2 L of herbicide), depending on the number of weeds and the instructions on the label. See Section 4 for information on how to kill woody weeds.

**Installing foot bridges and ramps**

- All harvesting paths should lead to a main path (or: ‘collection road’) which is accessible for a car, truck or heavily loaded motorbike
- If there are ditches or canals that need to be crossed install foot-bridges which are:
  - Strong and solid (will not collapse when a harvester with a full wheelbarrow walks over it)
  - At least 20 cm wide (best to use a wide plank or several planks attached together)
  - Well attached on both sides and not moving or wobbling (see Figure 17)
- If there are steep slopes:
  - Dig out a ramp where a harvester with a heavy wheelbarrow can pass easily
  - Put a wooden plank over the ramp to prevent it from getting too slippery
**Data recording**

Every weeding or maintenance activity should be recorded in a log book as shown in the example below.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
<th>Activity</th>
<th>Input type</th>
<th>Input amount</th>
<th>Input costs</th>
<th>Labour input</th>
<th>Labour costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/01/13</td>
<td></td>
<td>Field 3</td>
<td>Path and circle weeding</td>
<td>Round-Up</td>
<td>1 L</td>
<td>75000</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>
7. CIRCLE WEEDING

Goal

- Loose fruits on the ground are easy to spot and to collect (Figure 18)
- Harvesting can be carried out quickly and efficiently
- Efficient application and use of fertilisers

![Figure 18: Cleanly weeded circle](image)

Standard

- Palm circles (1.5–2.0 m from the trunk in mature plantations) are completely weed-free
- Palm circles are free of rubbish

Timing

- Shortly before the peak season (so that harvesting can be done more efficiently)
- At the same time as path weeding (if possible)
- Not when rain is expected that day (otherwise the herbicide will be washed away)
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Frequency

- Every 2–4 months depending on the season and weed growth

Labour time required

- Manual weeding: 4 days per hectare
- Chemical weeding: 1 day per 2 hectares (together with path weeding)

Equipment and materials

- Manual weeding:
  - Chisel/spade
  - Bush knife
  - Rake
- Chemical weeding:
  - Knapsack sprayer
  - Protective clothing
  - Measuring cup (50–200 ml)
  - Clean water (100–200 L/ha)
  - Herbicide (0.5–1 L)
  - Rake

Who

- Farmers and their families or hired labourers

How

Manual circle weeding

- Pull out all vegetation in the circle or cut vegetation to ground level with a bush knife, or alternatively scrape away all plants in the circle using a spade (see Figure 19)
- Rake weeds cut by a bush knife out of the circle
- Avoid ploughing or disturbing the soil in the circle because it can damage the palm roots
Chemical weeding

If the weeds are tall (more than 50 cm), it is best to start with one round of manual weeding and then to spray the young re-growing weeds after one month, or when the weeds are at ankle height using the following procedure:

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1.</strong></td>
<td>Make sure the sprayer is calibrated and working properly.</td>
</tr>
<tr>
<td><strong>Step 2.</strong></td>
<td>Prepare the herbicide according to the instructions on the package (see also Section 2).</td>
</tr>
<tr>
<td><strong>Step 3.</strong></td>
<td>Select a nozzle that gives a spray of about 1 meter wide.</td>
</tr>
</tbody>
</table>
| **Step 4.** | Spray the weed using the following technique:  
  - Walk at a regular speed around the palm  
  - Keep the nozzle steady and low above the ground  
  - Do not swing the nozzle left and right  
  - If the spray is not wide enough, walk two circles around the palm, one close to the trunk and one at 1–1.5 m from the trunk  
  
  Per hectare, expect to spray 100–200 L (0.5–2 L of herbicide), depending on the number of weeds. |
| **Step 5.** | Spray any re-growth one month after the first spraying to fully kill the weeds. |
Data recording

Every weeding activity should be recorded in a log book as shown in the example below.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
<th>Activity</th>
<th>Input type</th>
<th>Input amount</th>
<th>Input costs</th>
<th>Labour input</th>
<th>Labour costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/01/13</td>
<td></td>
<td>Field 3</td>
<td>Path and circle weeding</td>
<td>Round-Up</td>
<td>1 L</td>
<td>75000</td>
<td>1</td>
<td>8</td>
</tr>
</tbody>
</table>
8. PRUNING

Background

Good pruning is necessary for the most efficient use of fertilisers and to create an easily accessible plantation. Therefore the optimum number of leaves should be kept on the palms.

When pruning, remember:
- More fronds are better for production (palms can capture more sunlight)
- Dead or dying leaves hold nutrients which should be recycled
- If palms are tall it will be difficult to do good harvesting when there are many fronds

Pruned leaves decompose fastest when they are in touch with the soil and form an important source of food for palm roots. By stacking the fronds in a box shape, the nutrients and the organic matter are spread out, and the leaves decompose faster because the stacks are not too high. Stacking leaves also keeps them out of the harvester’s way, and helps to prevent soil erosion.

The appearance and organisation of oil palm leaves

Figure 21: Appearance and organisation of leaves in oil palm
The youngest leaves appear on the top and the older ones are at the bottom:

- The leaves grow in spirals of eight (see Figure 21)
- Leaf 1 is the youngest fully open leaf, on the top of the palm
- The leaf beneath Leaf 1 is Leaf 9 (1+8, because there are eight leaves on one spiral)
- The leaf below Leaf 9 is Leaf 17
- The leaf below Leaf 17 is Leaf 25, then Leaf 33, Leaf 41 and so on

About two new leaves appear per month. New leaves appear faster in young palms and slower in old palms. An ‘inflorescence’ (= a stalk with many flowers) is formed above each leaf, which can become male or female (Figure 5), or be aborted (no inflorescence at all). If the palm is stressed (e.g. by drought or lack of nutrients), more male inflorescences are formed and more inflorescences are aborted. Female inflorescences form bunches which are usually ripe about 16 months (32 leaves) after the supporting leaf has appeared and six months after the inflorescence has opened.

**Goal**

- Enable palms to capture the maximum amount of sunlight
- Ensure there is no waste of nutrients in unproductive fronds
- Enable fast, easy and complete harvesting
- Create a clean and efficiently organised plantation
- Conserve soil quality and nutrients
- Enable fast decomposition of pruned fronds

**Standard**

- Pruning only dead fronds in palms less than 4 years after planting
- Pruning down to 48-56 fronds per palm (or: 2-3 fronds below the last ripe bunch) for palms that are 5-7 years old
- Pruning down to 40-48 fronds per palm (or: 1-2 fronds below the last ripe bunch) for palms that are 8-15 years old
- Pruning down to ~40 fronds per palm (or: 1 frond below the last ripe bunch) for palms that are more than 15 years old
- Fronds butts are cut off close to the trunk
- Fronds are cut in two and stacked on the frond stack in a box-shape, with the bottom part behind the palms and the top part between the palms
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#### Figure 22: Over-pruning

<table>
<thead>
<tr>
<th>Timing</th>
</tr>
</thead>
</table>
| • Shortly before the peak production season (so that harvesting can be done more efficiently)  
• During the dry period (if possible) |

<table>
<thead>
<tr>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Twice per year</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Labour time required</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Corrective pruning: 2 days per hectare</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equipment and materials</th>
</tr>
</thead>
</table>
| • Chisel (for shorter palms)  
• Harvesting sickle (for tall palms)  
• Axe, chisel or bush knife (to cut the frond in two) |

<table>
<thead>
<tr>
<th>Who</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Farmers and their families or hired labourers</td>
</tr>
</tbody>
</table>
# How to Prune Oil Palms

To prune oil palms:

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 1.</strong></td>
<td>Cut off all dead and dying leaves</td>
</tr>
<tr>
<td><strong>Step 2.</strong></td>
<td>Count the number of remaining spirals and determine which leaves need to be cut off.</td>
</tr>
<tr>
<td><strong>Step 3.</strong></td>
<td>Cut the leaves as close to the trunk as possible, without damaging nearby bunches, fronds, or the palm trunk.</td>
</tr>
<tr>
<td><strong>Step 4.</strong></td>
<td>After pruning, cut each leaf into two halves, and throw the bottom half (thick stem part with sharp spikes) onto the frond stack behind the palm to prevent injuries.</td>
</tr>
<tr>
<td><strong>Step 5.</strong></td>
<td>Place the top half on the frond stack on the right or left side of the palm to make the so-called “box shape” (see Figure X)</td>
</tr>
</tbody>
</table>

*Figure 23: Frond stacking in box or U shape*
**Data recording**

Every pruning activity should be recorded in a log book as shown in the example below.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
<th>Activity</th>
<th>Input type</th>
<th>Input amount</th>
<th>Input costs</th>
<th>Labour input</th>
<th>Labour costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/01/13</td>
<td></td>
<td>Field 3</td>
<td>Pruning</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>16</td>
</tr>
</tbody>
</table>
9. **SOIL CONSERVATION**

**Background**

Soil erosion is the loss of fertile top soil. Soils in the tropics are often very sensitive to erosion, because there is much rainfall which washes the soil away from slopes. Once the soil is lost, it takes a long time to recover, and the fertility of eroded area will be reduced during this period. It is difficult to produce good yields on very eroded soils and soil erosion should therefore be prevented as much as possible. In addition to the loss of fertile top soil, erosion also usually results in the loss of fertilisers and organic material.

**Goal**

- Maintain good soil fertility
- Prevent erosion of the top soil
- Limit the loss of fertilisers
- Use water optimally

**Standard**

- 0-8% slope: No conservation measures needed
- 9-15% slope: Fronds are stacked along the contour line and silt pits are dug next to every other palm
- 16-25% slope: Individual palm platforms are constructed around each palm
- 26-40% slope: Terraces are installed during plantation establishment (see Figure 24)
- 40% slope or more: No oil palm is cultivated
- All soil conservation structures are correctly constructed and in good condition

**Timing**

- Fronds are stacked immediately after harvesting and after corrective pruning, or just before the rainy season
- Silt pits are constructed during the dry season
- Platforms are constructed during the dry season
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Figure 24: Terracing and legume cover crop establishment on steep slopes.

Frequency

- Fronds are stacked twice per year and after every harvesting round
- Silt pits are established once, at the start of the rehabilitation process, and maintained yearly
- Platforms are established once, at the start of the rehabilitation process, and maintained yearly

Labour time required

- Frond stacking is undertaken as a part of the pruning and harvesting activities
- Silt pits:
  - One hour for the establishment of each silt pit
  - 2 days per hectare for the maintenance of the silt pits
- Platforms:
  - One to four hours for the establishment of each platform
  - 3 days per hectare for maintenance of the platforms

Equipment and materials

- Frond stacking:
  - Same equipment and materials as for pruning
- Silt pits:
  - Excavator or spade
- Platforms:
  - Excavator or spade
  - Measuring tape (5 m)

**Who**

- Farmers and their families or hired labourers

**How**

**Frond stacking along the contour (9-15% slope)**

**Step 1.** Stack some of the pruned fronds between the palm rows, along the contour lines and parallel with the slope.

**Step 2.** Put some fronds between the palms in a straight angle from the contour stack, in a ‘box shape’ to increase water catchment and decrease run-off (see Figure 23).

**Silt pits (9-15% slope)**

Silt pits capture rain water flowing down the hill. Pits should be 1.5 m long, 0.5 m wide and 0.5 m deep.

**Step 1.** Dig one pit next to every other palm (in the middle between two palms) following the contour line (see Figure 25).

**Step 2.** Heap soil from the pit on the upslope side, about 0.5 meter above the pit.

**Step 3.** Stack fronds on the upper side of the soil heap to prevent destruction of the heap or the pit during heavy rain.
Platform construction (16-25% slope)

Individual platforms should be created around each palm. Platforms should have the following design characteristics:

- Platform diameter should be 4-5 m
- Platform surface should slope 5-10% in the opposite direction to the slope (see Figure 26)

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Dig soil from the upper part of the circle and place it on the lower part. Ensure the bottom (supporting) part of the platform is wider than the top.</td>
</tr>
<tr>
<td>Step 2</td>
<td>Compact the soil at the downhill edge of the platform to prevent washing away.</td>
</tr>
<tr>
<td>Step 3</td>
<td>Stack fronds just upslope from the platform to reduce water flows [15]</td>
</tr>
</tbody>
</table>
Every soil conservation construction or maintenance activity should be recorded in a log book as shown in the example below.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Location</th>
<th>Activity</th>
<th>Input type</th>
<th>Input amount</th>
<th>Input costs</th>
<th>Labour input</th>
<th>Labour costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/01/13</td>
<td></td>
<td>Field 3</td>
<td>Digging silt pits</td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>8</td>
</tr>
</tbody>
</table>
References and further reading

[12] Sime Darby, Leguminous Cover Crop Seeds, Sime Darby Agro-Bio Sdn Bhd, Subang Jaya, Malaysia,
**APPENDIX 1: PALM MARKING AND LEAF SAMPLING**

**PART 1: DRAWING A PLANTATION MAP**

**Background**

For keeping track of management and yield it is useful to have a good map of the plantation on which all palms are indicated. On this map, *dura* and *pisifera* palms and empty spots should also be marked. In addition, for pest patrols and leaf sample collection it is necessary to select and mark ‘sample palms’, because it is too much work to check or sample all palms. It takes some time to map the field and mark the sample palms, but in the end it will save a lot of time – even if no leaf sampling is done.

**Goal**

- Be able to monitor management and productivity efficiently;
- Be able to carry out pest patrolling efficiently;
- Be able to carry out leaf sampling effectively.

**Standard**

- A complete map of the plantation is available, indicating palms, empty spots, and field boundaries;
- A sample of 1-4 percent of the plantation palms is selected;
- Sample palms are healthy and representative of the plantation;
- Sample palms are spread equally throughout the plantation;
- Sample palms are clearly marked.

**Timing**

- Once, at the start of the rehabilitation process.

**Frequency**

- Once during the plantation lifetime.

**Note:** Each time sampling takes place (or once per year) check if the sample palms are still healthy and clearly marked. If not, select another palm and/or refresh the marking

**Labour time required**

- Drawing a plantation map: 2–3 hours for a field of two hectare.
Sample palm marking: 1–2 hours per two hectare.

**Equipment and materials**

- Paintbrush;
- Blue and yellow paint;
- Isometric or other paper (see Figure 27);
- Optional: measuring tape, GPS.

**Who**

- Farmers and their family or hired labourers.
- Best done together with extension workers or cooperative representatives.

**How**

**Drawing a plantation map**

Plantation maps are usually drawn on isometric paper (see Figure 27). Each palm should be indicated with a dot on the intersection of two lines (see Figure 28). If there is no palm, put a cross or leave the spot empty.

**Note:** If the field is not rectangular, drawing it can be more difficult. Isometric paper will only work when the palms are planted in the correct (triangular) spacing. For rectangular (square) spacing, use simple mathematical paper with squares. For other spacing, draw the plantation on white paper without lines.

To draw a plantation map follow these steps:

<table>
<thead>
<tr>
<th>Step 1.</th>
<th>Select the first field to be mapped.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2.</td>
<td>Determine the boundaries of the field (e.g. roads, other crops, rivers/streams, oil palm from someone else etc.).</td>
</tr>
<tr>
<td>Step 3.</td>
<td>Determine the direction of the palm rows:</td>
</tr>
<tr>
<td></td>
<td>• If the palms are planted in the correct (triangular) format, the rows can be seen in two directions.</td>
</tr>
<tr>
<td></td>
<td>• Selecting palms is easier when the directions are in line with the field borders.</td>
</tr>
<tr>
<td></td>
<td>• If the field is not rectangular, try to find the direction of the rows which makes them most easy to count.</td>
</tr>
<tr>
<td>Step 4.</td>
<td>Draw the palms next to the main road into the map and count the number of rows.</td>
</tr>
<tr>
<td>Step 5.</td>
<td>For each row, draw in the palms and count the number of palms per row.</td>
</tr>
</tbody>
</table>
Step 6.  Indicate streams, rivers, roads and other borders, trying to keep the size correct. **Note:** Usually a road is one palm row wide (sometimes two).

*Figure 27: Isometric paper*
Selecting and marking sample palms

To select and mark sample palms follow these steps:

**Step 1.** Select which road will be the main road

**Step 2.** Starting in one corner and moving along the road count five rows. At the 5th row:

- Stand on the side of the palm facing the road;
- Find a frond butt which has some flat area to write on;
- Paint the frond butt with white paint;
- When the paint is dry, write the row number at the top with blue paint (in this case: ‘5’);
- Below the row number, write the palm number with blue paint (in this case: ‘1’).

**Note:** all palm numbers at the roadside should be ‘1’.

**Step 3.** Find the direction of the row and follow the row from palm to palm until you get to palm 5. **Note:** Empty spots also count!

**Step 4.** At palm 5, check the following:

- Is the palm present?
- Does the palm look healthy?
- Is the palm more or less as tall as its neighbours?
- Is the palm in a representative location (for example not in a piece of swamp or on the very edge of a gully)?
- Are all the palms around that palm present (no empty
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<table>
<thead>
<tr>
<th>Step 5.</th>
<th>If the answer to one of the questions is 'no', move two palms further into the row and check again.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 6.</td>
<td>If the answer to all the questions is ‘yes’, mark that palm as described above (in this case: ‘5 over 5’) (see Figure 29).</td>
</tr>
<tr>
<td>Step 7.</td>
<td>Continue along the row, each time marking the 5th palm (or two palms farther along if the 5th palm doesn’t meet the conditions) until you are two palms from the other end of the field. The palms that are close to the edge of the field (one or two palms away) should not be sampled, because they are not representative (for example, they get more sunlight).</td>
</tr>
<tr>
<td>Step 8.</td>
<td>Move on to the field boundary</td>
</tr>
<tr>
<td>Step 9.</td>
<td>Move five rows further along the boundary at the other end. After 5 rows, mark the palm next to the boundary. This should be the 10th row after the start of the field, so the row number on this palm should be 10. The palm number is the number of the last palm in the row. <strong>Note:</strong> If the field is not rectangular, it may be necessary to walk back to the beginning of the row and count the number of palms to determine the palm number.</td>
</tr>
<tr>
<td>Step 11.</td>
<td>Continue until the entire field is done.</td>
</tr>
</tbody>
</table>

**Note:** The number of the palms to mark depends on the size of the field. In large fields (5-10 ha) it is better to take every 8th row and every 8th palm. In even larger fields (more than 10 ha) you can take every 10th row and every 10th palms. This is also what companies do.

If the field is not at all rectangular, try to select the palms as follows:
- One palm in 25 (or in 64 or 100 in larger plantations);
- Not the palms less than 2 lines from the boundary;
- At least 4 non-sample palms between the sample palms in each direction.
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Figure 29: How to mark sample palms
LEAF SAMPLE COLLECTION

Background

Leaf sampling is used to determine the nutrient content of palms in plantations. This helps to determine exactly how much fertiliser is required for the palms, and can help to track nutrient deficiencies.

Leaf sampling is quite complicated, and the analysis of the samples in the laboratory is expensive (~$30 per sample). Sampling should therefore be undertaken in discussion with extension officers or by a skilled worker.

In the Field Handbook – Mature (Rankine and Fairhurst, 1999), the protocol for leaf sampling is described in full detail [7]. The information below is a summary of that protocol, with some adaptations.

Goal

- Be able to identify the nutrient concentration in palm leaves;
- Be able to find nutrient deficiencies that had not been noticed before;
- Be able to decide about fertiliser requirements in the coming year;
- Be able to adapt the fertiliser programme specifically to the need of the palms.

Standard

- A representative sample of palm leaflets and rachis is collected.
- Samples are processed correctly and sent to the laboratory for nutrient content analysis.
- Sampling should be carried out by trained workers or extension agents, exactly according to protocol.

Timing

- Leaf sampling should be done once per year, more or less at the same time each year:
  - Not in very wet or very dry periods
  - At least 3 months after fertiliser application (if possible)

Note: Try to sample all fields as soon as possible after each other. That way, transporting costs can also be reduced because all samples can be sent to the laboratory at the same time.

Frequency

- Once per year.
Labour time requirement

- Sample collection: 5–10 minutes per palm
- Sample processing: 10–20 minutes per sample

Equipment and materials

- Clean harvesting tools
- Bush knife
- Sharp small knife
- Table or other clean cutting surface
- Clean plates
- Microwave
- Cloth bag
- Marker pen
- Notebook, pens
- Paper bags or envelopes
- Clean water
- Cardboard box

Who

- Trained workers, extension officers, or cooperative representatives

How

This protocol must be carried out cleanly and carefully. Training or experience is necessary.

To conduct leaf sampling follow these steps:

Step 1. Move to the first sample palm and check if it is healthy.
Step 2. Write down any nutrient deficiencies and damage to the palm that are observed.
Step 3. Determine if the spiral is going left or right by looking at the frond butts on the palm trunk (see Figure 30).
Step 4. Locate the last fully opened leaf in the centre of the palm crown. This is Leaf 1. In Leaf 1, the small ‘spines’ at the bottom of the leaf should already be visible, while in Leaf 0, the leaflets go all the way down into the centre of the leaf. It is easiest to look first for Leaf 0. Leaf 1 is located one-third round away from leaf 0, walking against the direction of the spiral.

Note: In order to learn how to recognise Leaf 0, 1, and 17, a field-training from an experienced professional is absolutely necessary!
Step 5. Follow the spiral of Leaf 1 downwards in the canopy:
- The frond below 1 on the same spiral is 8;
- The frond below 8 is 17.

**Note:** The spiral doesn’t run straight down but makes a curve (see Figure 31).

Step 6. Cut off Leaf 17 using clean harvesting tools.

Step 7. Place the frond on the weeds or on a plastic sheet. **It should never touch bare soil**, otherwise it can get contaminated with fertilisers.

Step 8. Find the point (a bit above the middle of the leaf) where the top of the rachis goes from flat to triangular (see Figure 32).

Step 9. Around two hands below this point, select six leaflets on the left side and six on the right side of the leaf. Of these leaflets, three should be in the upper rank and three should be in the lower rank (see Figure 32). The leaflets should not be split or damaged. Cut or pull the leaflets from the rachis.

Step 10. Cut off the top and the bottom part of the leaflets so that the middle 15-20 cm remains. Discard the top and the bottom part and put the middle part of the leaflets in a clearly marked paper envelope.

Step 11. Around the point where the leaflets were removed, cut out a piece of rachis of about 20 cm in length. Place it in the envelope with the leaflets.

Step 12. Proceed to the next sampling palm and repeat the steps above until all of the sampling palms have been done.

Step 13. Take the samples to a place where a table and cutting tools are available.

Step 14. For each leaflet, cut out and remove the middle vein. Cut the remaining pieces into small strips (about 0.5-1 cm each).

Step 15. Chop the pieces of rachis with a bush knife into small chips (about 1-2 cm each).

Step 16. Put the leaflets from one plantation together in a clean cloth bag. Place the bag in a microwave and dry as follows:
- 4 minutes at full power, remove, shake;
- 2 minutes at full power, remove, shake;
- 1 minute at full power, remove, shake;
- 1 minute at full power, remove, shake;
- 10-15 minutes cooling down at the table top.

The same protocol can be followed for the rachis.

Step 17. If no microwave is available:
- Put the samples in the sun for two days to sun-dry, or
- Air-dry in a room with low air humidity until the samples are dry enough to be sent to the lab without rotting along the way.

Step 18. Take two sub-samples:
- One 20–40 gram sample which is sent to the laboratory for
analysis;
- One 20–40 gram sample which is stored in a cool, dry place as a backup.

**Step 19.** If samples are sent regularly, then it is useful to make a large reference sample, of which a subsample is included each time, in order to check if the analysis is done correctly.

**Step 20.** Pack the sub-samples to be sent to the laboratory in a plastic bag with the sample code (for example a date and a field code), and then in a cardboard box.

**Step 21.** Send the samples to a good laboratory as soon as possible. To find a good laboratory, ask the extension workers or a nearby company.

**Step 22.** Put the backup samples in plastic bags and store them in a cool, dry place.

*Figure 30: Spiral going to the left (left) and to the right (right)*
Figure 31: Identifying leaf 17

Figure 32: The point where leaflets are sampled, two hands below the point where the rachis becomes triangular (indicated by a circle)
INTERPRETATION OF LEAF SAMPLING RESULTS

The table below can be used to determine if leaf nutrient concentrations are deficient, good, or excessive [7].

**Table 4: Nutrient concentrations in leaves of palms of more than six years after planting.**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Nutrient level</th>
<th>Deficient</th>
<th>Good</th>
<th>Excessive</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Macronutrients (N, P, K, Mg)</em>; nutrient concentration in % of dry leaf mass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen (N)</td>
<td></td>
<td>&lt; 2.30</td>
<td>2.40 – 2.80</td>
<td>&gt; 3.00</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td></td>
<td>&lt; 0.14</td>
<td>0.15 – 0.19</td>
<td>&gt; 0.25</td>
</tr>
<tr>
<td>Kalium (K)</td>
<td></td>
<td>&lt; 0.75</td>
<td>0.90 – 1.20</td>
<td>&gt; 1.60</td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
<td>&lt; 0.20</td>
<td>0.25 – 0.40</td>
<td>&gt; 0.70</td>
</tr>
<tr>
<td><em>Micronutrients (B, Cu, Zn)</em>; nutrient concentration in milligram per kilo dry leaf</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boron (B)</td>
<td></td>
<td>&lt; 8.0</td>
<td>15 – 25</td>
<td>&gt; 40</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td></td>
<td>&lt; 3.0</td>
<td>5.0 – 8.0</td>
<td>&gt; 15</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td></td>
<td>&lt; 10</td>
<td>12 – 18</td>
<td>&gt; 20</td>
</tr>
<tr>
<td><em>Other nutrients (Ca, S, Cl)</em>; nutrient concentration in % of dry leaf mass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td></td>
<td>&lt; 0.25</td>
<td>0.50 – 0.75</td>
<td>&gt; 1.0</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td></td>
<td>&lt; 0.20</td>
<td>0.25 – 0.35</td>
<td>&gt; 0.60</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td></td>
<td>&lt; 0.25</td>
<td>0.50 – 0.70</td>
<td>&gt; 1.0</td>
</tr>
</tbody>
</table>

**Table 5: Nutrient concentrations in leaves of palms of 1–6 years after planting.**

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Nutrient level</th>
<th>Deficient</th>
<th>Good</th>
<th>Excessive</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Macronutrients (N, P, K, Mg)</em>; nutrient concentration in % of dry leaf mass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nitrogen (N)</td>
<td></td>
<td>&lt; 2.50</td>
<td>2.60 – 2.90</td>
<td>&gt; 3.10</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td></td>
<td>&lt; 0.15</td>
<td>0.16 – 0.19</td>
<td>&gt; 0.25</td>
</tr>
<tr>
<td>Kalium (K)</td>
<td></td>
<td>&lt; 1.00</td>
<td>1.10 – 1.30</td>
<td>&gt; 1.80</td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
<td>&lt; 0.20</td>
<td>0.30 – 0.45</td>
<td>&gt; 0.70</td>
</tr>
<tr>
<td><em>Micronutrients (B, Cu, Zn)</em>; nutrient concentration in milligram per kilo dry leaf</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boron (B)</td>
<td></td>
<td>&lt; 8.0</td>
<td>15 – 25</td>
<td>&gt; 40</td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td></td>
<td>&lt; 3.0</td>
<td>5.0 – 8.0</td>
<td>&gt; 15</td>
</tr>
<tr>
<td>Zinc (Zn)</td>
<td></td>
<td>&lt; 10</td>
<td>12 – 18</td>
<td>&gt; 20</td>
</tr>
<tr>
<td><em>Other nutrients (Ca, S, Cl)</em>; nutrient concentration in % of dry leaf mass</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td></td>
<td>&lt; 0.30</td>
<td>0.50 – 0.70</td>
<td>&gt; 0.70</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td></td>
<td>&lt; 0.20</td>
<td>0.30 – 0.40</td>
<td>&gt; 0.60</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td></td>
<td>&lt; 0.25</td>
<td>0.50 – 0.70</td>
<td>&gt; 1.0</td>
</tr>
</tbody>
</table>
If concentrations are good, then the fertiliser application is good and should be continued.

If the concentrations are excessive, then too much fertiliser is applied; money spent on those fertilisers will not increase the yield.

- Excessive nutrient concentrations usually only occur when really large amounts of fertilisers are applied.
- Excessive N concentrations (and deficient K concentrations) can occur when NPK 15-15-15 or 16-16-16 fertilisers are applied (which are usually only suitable for immature plantings).
- If the leaf concentration of a specific nutrient is excessive, the application of this nutrient fertiliser should be reduced, and no negative effects on yields should be observed.
- In general, a reduction of applied quantities by a quarter or a third is recommended.
- In the next years, leaf nutrient concentration should be monitored closely, so that the best fertiliser quantity can be determined.

If concentrations are deficient, then too little fertiliser is applied, or the fertiliser does not reach the palm.

- The way of applying fertiliser should be checked – if fertilisers are applied at the wrong place or time, or if weeding is not done correctly, then it may be that fertilisers are lost.
- Extra fertiliser will be required to correct the nutrient deficiency.
- Module 4 gives suggestions for correct fertiliser quantities. If fertilisers are applied below the recommended quantities, the amount should be increased.
- For boron, copper and zinc, make sure that no more than the maximum quantities are applied (see Module 4, Table 3–6), because these fertilisers can be toxic when applied in excess.