APPENDIX: LEAF SAMPLING

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 [9]. 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:

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1</td>
<td>Move to the first sample palm and check if it is healthy.</td>
</tr>
<tr>
<td>Step 2</td>
<td>Write down any nutrient deficiencies and damage to the palm that are observed.</td>
</tr>
<tr>
<td>Step 3</td>
<td>Determine if the spiral is going left or right by looking at the frond butts on the palm trunk.</td>
</tr>
<tr>
<td>Step 4</td>
<td>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. <strong>Note:</strong> In order to learn how to recognise Leaf 0, 1, and 17, a field-training from an experienced professional is absolutely necessary!</td>
</tr>
</tbody>
</table>
| 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.

**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.

**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. 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.
Spiral going to the left (left) and to the right (right)

Identifying leaf 17
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.

## 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><strong>Macronutrients (N, P, K, Mg): nutrient concentration in % of dry leaf mass</strong></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 (Mg)</td>
<td></td>
<td>&lt; 0.20</td>
<td>0.25 – 0.40</td>
<td>&gt; 0.70</td>
</tr>
<tr>
<td><strong>Micronutrients (B, Cu, Zn): nutrient concentration in milligram per kilo dry leaf</strong></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><strong>Other nutrients (Ca, S, Cl): nutrient concentration in % of dry leaf mass</strong></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>
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## Nutrient Concentrations in Leaves of Palms of 1–6 Years After Planting

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<th>Good</th>
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<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>
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<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 (Mg)</td>
<td></td>
<td>&lt; 0.20</td>
<td>0.30 – 0.45</td>
<td>&gt; 0.70</td>
</tr>
<tr>
<td><strong>Micronutrients (B, Cu, Zn): nutrient concentration in milligram per kilo dry leaf</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
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<td></td>
<td>&lt; 8.0</td>
<td>15 – 25</td>
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<td>&lt; 0.25</td>
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</tr>
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</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.
- 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, because these fertilisers can be toxic when applied in excess.