Smallholder Oil Palm Handbook
Module 4: Fertiliser Application

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Module 4: Fertiliser Application

GOAL

To provide the right type of fertilisers, in the right amount, at the right time and in the right place, so that the plantation produces optimal yields with minimal damage to the environment.

After this section, farmers should:

- Know about the fertiliser requirements of oil palms at different developmental stages and for different soil types.
- Be able to recognise and interpret nutrient deficiency symptoms in palms.
- Be able to correctly apply the required quantities of fertiliser.
- Understand the benefits of organic fertilisers – especially empty fruit bunches.

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1. BACKGROUND

Oil palms require sufficient nutrients, in the right balance, to produce good yields and to stay healthy in the long term. While the soil provides some nutrients, it is often not in the right balance and there are generally not enough nutrients to sustain oil palm growth and productivity. Nutrients are also lost when the fruit is harvested and carried away (see Table 1), and immobilised in growing oil palm trunk and roots.

<table>
<thead>
<tr>
<th>Nutrient name</th>
<th>Compound</th>
<th>Nutrient removal (kg/ha/year) at two yield levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>N</td>
<td>80–110 [1]</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>P&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;5&lt;/sub&gt; (43.7% P)</td>
<td>30–37 [1]</td>
</tr>
<tr>
<td>Potassium</td>
<td>K&lt;sub&gt;2&lt;/sub&gt;O (83% K)</td>
<td>150–180 [1]</td>
</tr>
<tr>
<td>Magnesium</td>
<td>MgO (60% Mg)</td>
<td>20–30 [2]</td>
</tr>
<tr>
<td>Boron</td>
<td>B</td>
<td>Trace</td>
</tr>
</tbody>
</table>

To provide sufficient nutrients for good oil palm growth and fruit production, it is necessary to apply fertilisers. Some important things to understand in relation to oil palm production and the application of fertilisers are:

- Key nutrients which all oil palms need are nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg).
- Oil palms often also need small quantities of boron (B).
- On peat soils, it is usually necessary to fertilise with copper (Cu) and zinc (Zn).
- Other nutrients, such as calcium (Ca), sulfur (S), manganese (Mn), iron (F) and chlorine (Cl) are important but it is usually not necessary to supply them as fertiliser.
- If present in too large quantities, nutrients can poison the oil palm.
- Soil organic matter can be increased through good management, and is very important for soil quality and the efficient use of fertiliser (see Section 2).
- Fertilising oil palms is very expensive; it takes up about 60 percent of overall costs!
- If fertilising is done in the wrong way, up to 50 percent of the nutrients can be lost, which means a lot of money is spent on fertilisers that don’t reach the palms and don’t increase the yield.
- Fertilisers should be applied efficiently and effectively, according to the ‘4 R’ principle:
  - Right type
  - Right amount
  - Right place
  - Right time
• Palms of different ages need different amounts of fertiliser. The fertiliser needs of palms not only depend on the palm’s age, but also on:
  o Soil type (especially mineral or peat soils)
  o Soil fertility (nutrients and organic material in the soil)
  o Planting material
  o Current yields
• When deciding on how much fertiliser to apply, it is useful to get advice from one or more of the following:
  o Extension workers;
  o Cooperative experts;
  o Excellent farmers in the area;
  o Nearby plantation companies (while estate fertiliser rates may be very high, they can give a good idea of the ‘nutrient balance’ needed under the local conditions, which is the ratio between N, P, K and Mg. Companies may also be able to give information about the best type of fertilisers and the best timing of application);
  o Handbooks and other available materials;
  o By conducting your own experiment.

**Conducting your own experiment to assess fertiliser needs**

Yield increase after fertiliser application can be tested on small plots with at least 36 palms.

Early effects can usually be seen after six months to one year and should include:
• Larger bunches
• Different colour of ripe bunches
• Nutrient deficiency symptoms reduced/disappeared
• Denser canopy (larger leaves)

If the experiment is continued for 3 years, full effects can be seen which should include:
• Better yields
• More bunches
• Larger bunches
• Nutrient deficiency symptoms disappeared
• Denser canopy (larger leaves)
• Taller palms with bigger trunks at the top

It is necessary to keep good track of the fertiliser applications and the yield to decide if the experiment is successful! If the fertilisers are effective, they can be used in the entire plantation.
Before applying fertilisers it is necessary to make sure that the following plantation conditions are in order:

- Drainage and soil conservation are fully done;
- Maintenance is up to standard;
- Noxious weeds have been removed.

The information in this chapter will help you decide which type and what quantities of fertilisers you need to apply to your plantation and how to do it correctly.
2. CLAY, SANDY AND PEAT SOILS, AND SOIL ORGANIC MATTER

Background

Most normal soils (‘mineral soils’) consist of tiny particles of rock that have been broken into small pieces by such things as wind, water, plant roots, and ice (in colder regions).

- If the particles of rock are quite large, they are called ‘sand’;
- If the particles of rock are very small, they are called ‘clay’;
- If the particle size is somewhere in between, it is called ‘silt’.

The soil structure in a field is determined by the amount of sand, silt and clay particles, with:

- Sandy soils having mostly large sand particles;
- Clay soils having many small clay particles;
- Silt soils having mostly intermediate sized silt particles;
- Loamy soils having a mixture of sand, silt and clay particles.

In almost all mineral soils there is some organic material, called ‘soil organic matter’. Soil organic matter is the remains of dead plants, animals and microbes. It is usually dark brown or black in colour. Normal (mineral) soils contain between 1 and 6% organic matter, but peat soils contain >60% organic matter [3] (see Figure 1).

Because of all the organic matter, peat soils need to be managed in a special way.
How to recognise different types of soils

Sandy soils can be recognised as follows:

- You feel sand particles (pieces) grinding around if you roll a bit of soil between your fingers;
- It falls apart if you try to roll moist sandy soil into a ball or a sausage [4].

Clay soils can be recognised as follows:

- The particles are so small that if you roll the soil between your fingers, you don’t feel the particles but you feel a ‘paste’;
- You can take a handful of moist soil and roll it into a ball or sausage that doesn’t fall apart easily;
- Moist clay feels sticky if you touch it.

Silt soils can be recognised as follows:

- You cannot feel the particles easily when rolling the soil between your fingers;
• When moist, the soil has a soapy feeling [5];
• Moist silt soil leaves dirt on the fingers after you’ve held it.

Loam soils are difficult to recognise because they are a mix of the soils above. If a soil has some characteristics of each of the above types of soil, it is probably loam.

A peat soil can be recognised as follows:

• It is usually dark brown or black in colour;
• It is very spongy: you can feel your feet sink away if you step on it;
• Water drizzles out if you take a handful of wet peat and squeeze it;
• There are pieces of sticks, leaves and other organic materials in the peat;
• It is impossible to roll the peat into a ball or a sausage.

Figure 2: The flow of water through three different soil types. In the sandy soil, the water flows straight through. In the clay soil, the water stays on top. In the peat soil, the water flows in and is kept there like in a sponge.
Important properties of different soil types

Sandy soils

- Poor water holding capacity:
  - Because the particles are so big, the water quickly moves away from between them.
  - After rain, the water will quickly move down the soil.
  - Palms are more likely to suffer from drought because all the water has moved down.
  - Soluble nutrients (N, K, Mg) can easily be moved down by water, so these nutrients are quickly lost from the palm roots (leaching).
  - However, nutrients are less likely to be washed away from the soil surface because they move down into the soil more quickly.

- Small surface area of soil particles:
  - A few big particles have less surface area than a lot of small particles.
  - Nutrients stick to the surface of soil particles. In sandy soils, nutrients will not strongly stick to the soil particles which means the nutrients are easy for the palm to take up.
  - However, because the particles are big, the holes between the particles are also bigger and there are less of them, so the palm can make less fine roots.
  - Because of the above points, oil palms on sandy soils need relatively large amounts of fertiliser.

- Light structure:
  - Because of the big soil particles, the soil doesn’t stick together;
  - Digging holes or other soil management activities are therefore relatively easy;
  - There is also not much risk of soil compaction;
  - However, there is large risk of soil erosion from wind.
Clay soils

- Very good water holding capacity:
  - Because the particles are so small, the water is trapped between them.
  - After rain, the water moves into the soil slowly.
  - Palms are less likely to suffer from drought because the rain water is held in the soil.
  - However, flooding after heavy rains is more likely.
  - Nutrient leaching is not likely because the water moves down very slowly.
  - Nutrients can be washed away from the soil surface easily because the water stays on top of the soil and doesn’t move inside.

- Large surface of soil particles:
  - Small clay particles have a large surface area compared to sand particles.
  - Nutrients stick to clay soils more strongly.
  - Most clay soils are quite fertile and oil palms need relatively small amounts of fertiliser.

- Heavy structure:
  - Because of the tiny particles, the soil sticks together very easily (see Figure 3).
  - Digging holes or other soil management activities are difficult and should be carried out only on dry soils.
  - Soil compaction happens easily, especially when the soil is wet. Once compacted, the soil becomes very hard and the oil palm roots cannot grow well. Therefore, it is important to be careful with cattle grazing and with allowing machines such as trucks and excavators into the plantation, especially after rain.
Loam and silt soils

Loam and silt soils have a structure somewhere in between sand and clay soil and are usually the best soils for agriculture.

Peat soils

- High water table:
  - Peat soils form when the ground water table is very high, and can only be cultivated when they are drained first.
  - Unless drainage is done well, **peat soils often flood**.
  - If peat soils are drained too much, the **soil can dry out rapidly**.
  - Dried-out peat soils have a **large risk of burning** which can destroy a plantation.
  - **Water management is difficult on peat soils** and requires a lot of attention (see **Figure 4**).
  - Peat soils have a **good water holding capacity**, especially when compacted.

- Small surface of soil particles, strong acidity, binding of nutrients:
  - The soil particles in peat form less than 40 percent of the soil; the rest is organic material.
  - Often peat soil have a very low pH (<3.5-4.0).
  - Peat soils do not contain many nutrients apart from N which is in the organic matter.
  - Potassium (K) is not held by peat soil and so is easily leached and lost.
  - Because of acids in the peat soil, copper (Cu) and Zinc (Zn) are bound in the soil and are not available for uptake by the plant.

- Very light structure:
  - Because there are not many soil particles in peat soil the structure is very light, almost fluffy.
  - Palm roots don’t have anything to hold on to, so **palms tend to fall over**.
  - **Before planting, peat soils should be compacted** (by riding over it a few times with big machines) to make the soil more dense.

Due to the above issues, palms growing in peat soils require large amounts of K and the application of additional Cu and Zn fertilisers (see **Table 2**).
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### Table 2: Removal and immobilisation of nutrients on peat soils

<table>
<thead>
<tr>
<th>Nutrient name</th>
<th>Compound</th>
<th>Nutrient requirements (kg/ha/year) at two yield levels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>18–24 t/year FFB</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>P₂O₅ (43.7% P)</td>
<td>30–37</td>
</tr>
<tr>
<td>Magnesium</td>
<td>MgO (60% Mg)</td>
<td>0–20 [8]</td>
</tr>
<tr>
<td>Boron</td>
<td>B</td>
<td>Trace</td>
</tr>
<tr>
<td>Copper</td>
<td>Cu</td>
<td>Trace</td>
</tr>
</tbody>
</table>

---

**The importance of soil organic matter in mineral soils**

Soil organic matter is important because it improves the soil. Soil organic matter:

- Holds on to fertiliser nutrients;
- Holds water;
- Makes clay soils less dense and heavy;
• Makes sandy soils more sticky;
• Slowly releases nutrients while it is further broken down in the soil.

Soil organic matter content can be increased by:
• Recycling dead plant parts in the plantation (e.g. fronds, frond butts, male flowers etc., see Module 3);
• Adding organic waste materials from the mill (e.g. empty fruit bunches, palm oil mill effluent);
• Maintaining a good weed cover at around 50 cm height (see Module 3).

**Soil acidity**

It is useful to check the soil pH (level of acidity) before choosing which fertilisers to apply.

• The pH should be checked both within and outside the weeded circle, because acidification can be local and occurs mostly in the weeded circle.
• Checking the pH can be done very easily using a piece of pH paper and some moist soil.
• The moisture from the soil will cause the paper to change colour, depending on how acidic the soil is.
• If the acidity is below 5, then the soil is somewhat acid and the uptake of fertilisers can be slightly reduced.
• If the acidity is below 4, then the soil is very acid. Making the soil less acid will help to make fertilisers better available.
• Correct severely acidic soil by applying:
  o Rock phosphate (a phosphate fertiliser)
  o Dolomite (a magnesium fertiliser)
  o Lime (calcium carbonate)
  o Empty fruit bunches
  o Bunch ash (burned empty fruit bunches)
Figure 5: Rock phosphate application helps to reduce soil acidity
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3. FERTILISER TABLES

Background

Fertilisers can make up 60 percent of the total costs of producing palm oil so it is important to apply fertilisers efficiently.

Different fertilisers have different concentrations of nutrients. To know how much fertiliser to apply, it is necessary to know the nutrient concentration of the fertiliser (see Table 3).

**Table 3: Nutrient content of the most important fertilisers**

<table>
<thead>
<tr>
<th>Fertiliser</th>
<th>Nutrient content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td></td>
</tr>
<tr>
<td>- Urea</td>
<td>46</td>
</tr>
<tr>
<td>- Ammonium nitrate (AN)</td>
<td>34</td>
</tr>
<tr>
<td>- Sulphate of ammonium</td>
<td>20.6</td>
</tr>
<tr>
<td>Phosphorus (P₂O₅)</td>
<td></td>
</tr>
<tr>
<td>- Triple super phosphate (TSP)</td>
<td>45–47</td>
</tr>
<tr>
<td>- Rock phosphate (RP)</td>
<td>30–34</td>
</tr>
<tr>
<td>- Di-ammonium phosphate (DAP)</td>
<td>46</td>
</tr>
<tr>
<td>- SP-36 (Indonesia)</td>
<td>36</td>
</tr>
<tr>
<td>Potassium (K₂O)</td>
<td></td>
</tr>
<tr>
<td>- Muriate of potash (MOP, KCl)</td>
<td>60</td>
</tr>
<tr>
<td>Magnesium (MgO)</td>
<td></td>
</tr>
<tr>
<td>- Kieserite</td>
<td>26</td>
</tr>
<tr>
<td>- Dolomite</td>
<td>10–18</td>
</tr>
<tr>
<td>- Langbeinite</td>
<td>18</td>
</tr>
</tbody>
</table>

General fertiliser recommendations

In Table 4 to Table 7 general recommended fertiliser application rates are shown. Recommendations depend on palm age and current yields and include:

- Mature palms on mineral soils (see Table 4) [9];
- Mature palms on peat soils (see Table 5);
- Immature palms on mineral soils (see Table 6);
- Immature palms on peat soils (see Table 7) [10].

If you are not certain about how much fertiliser to apply, the tables below can be used as a guide. Recommended doses should give a good yield in most circumstances, but it is important to get local information and not to rely on the tables only!
### Table 4: Fertiliser recommendations for mature palms (> 3 years after planting) in mineral soils, in kilo per palm per year. FFB = Fresh Fruit Bunches.

<table>
<thead>
<tr>
<th>Fertiliser type</th>
<th>Recommendation (kilo per palm per year)</th>
<th>Yield: 18–24 t/year FFB</th>
<th>Yield: &gt;24 t/year FFB</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nitrogen</strong>* [%9]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Urea</td>
<td>1.2 – 1.5</td>
<td>1.5 – 2.0</td>
<td></td>
</tr>
<tr>
<td>- Ammonium nitrate</td>
<td>1.6 – 2.0</td>
<td>2.0 – 3.0</td>
<td></td>
</tr>
<tr>
<td>- Sulphate of ammonium</td>
<td>2.4 – 3.0</td>
<td>3.0 – 4.0</td>
<td></td>
</tr>
<tr>
<td><strong>Phosphorus</strong> [%9]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Triple super phosphate</td>
<td>0.5 – 0.8</td>
<td>0.8 – 1.2</td>
<td></td>
</tr>
<tr>
<td>- Rock phosphate</td>
<td>1.0 – 1.5</td>
<td>1.5 – 2.0</td>
<td></td>
</tr>
<tr>
<td>- Di-ammonium phosphate</td>
<td>0.5 – 0.8</td>
<td>0.8 – 1.2</td>
<td></td>
</tr>
<tr>
<td>- SP-36 (Indonesia)</td>
<td>0.6 – 1.0</td>
<td>1.0 – 1.5</td>
<td></td>
</tr>
<tr>
<td><strong>Potassium</strong> [%9]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Muriate of Potash (MOP, KCl)</td>
<td>1.8 – 2.5</td>
<td>2.5 – 3.0</td>
<td></td>
</tr>
<tr>
<td><strong>Magnesium</strong> [%2]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Kieserite</td>
<td>0.5 – 1.0</td>
<td>1.0 – 1.2</td>
<td></td>
</tr>
<tr>
<td>- Dolomite</td>
<td>1.0 – 1.5</td>
<td>1.5 – 2.0</td>
<td></td>
</tr>
<tr>
<td>- Langbeinite</td>
<td>1.0 – 1.5</td>
<td>1.5 – 2.0</td>
<td></td>
</tr>
<tr>
<td><strong>Boron</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Borax</td>
<td>0.05 – 0.1</td>
<td>0.05 – 0.1</td>
<td></td>
</tr>
</tbody>
</table>

* Young mature palms (4–6 years after planting) need 50–100 percent more N than the amounts given here, to develop a large and healthy canopy.

** Tropical soils are often very poor in P so the application of extra P is beneficial.
**Table 5: Fertiliser recommendations for mature palms (>3 years after planting) in peat soils, in Kilo per palm per year. FFB = Fresh Fruit Bunches.**

<table>
<thead>
<tr>
<th>Fertiliser type</th>
<th>Recommendation (kilo per palm per year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield: 18–24 t/year FFB</td>
</tr>
<tr>
<td>Nitrogen [6]</td>
<td></td>
</tr>
<tr>
<td>- Urea</td>
<td>1.2 – 1.5</td>
</tr>
<tr>
<td>- Ammonium nitrate</td>
<td>1.6 – 2.0</td>
</tr>
<tr>
<td>- Sulphate of ammonium</td>
<td>2.4 – 3.0</td>
</tr>
<tr>
<td>Phosphorus* [11]</td>
<td></td>
</tr>
<tr>
<td>- Rock phosphate</td>
<td>1.0 – 1.5</td>
</tr>
<tr>
<td>Potassium** [7]</td>
<td></td>
</tr>
<tr>
<td>- Muriate of Potash (MOP, KCl)</td>
<td>2.5 – 3.0</td>
</tr>
<tr>
<td>Magnesium*** [8]</td>
<td></td>
</tr>
<tr>
<td>- Kieserite</td>
<td>0 – 0.5</td>
</tr>
<tr>
<td>- Dolomite</td>
<td>0 – 1.0</td>
</tr>
<tr>
<td>- Langbeinite</td>
<td>0 – 0.8</td>
</tr>
<tr>
<td>Boron</td>
<td></td>
</tr>
<tr>
<td>- Borax</td>
<td>0.05 – 0.1</td>
</tr>
<tr>
<td>Copper</td>
<td></td>
</tr>
<tr>
<td>- Copper sulfate (CuSO₄)</td>
<td>0.1 – 0.2</td>
</tr>
<tr>
<td>Zinc</td>
<td></td>
</tr>
<tr>
<td>- Zinc sulfate (ZnSO₄)</td>
<td>0.1 – 0.2</td>
</tr>
</tbody>
</table>

* To reduce the soil acidity it is best to apply phosphorus as rock phosphate.
** On peat, a K to N ratio of >3 is needed, so it is best to apply three times more K₂O than N.
*** Mg application on peat is usually needed only when deficiency symptoms are observed.
<table>
<thead>
<tr>
<th>Fertiliser type</th>
<th>Recommendation (kilo per palm per year) [12]</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nitrogen</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Urea</td>
<td></td>
<td>0.6 – 1.0</td>
<td>1.3 – 1.7</td>
<td>1.3 – 2.2</td>
</tr>
<tr>
<td>- Ammonium nitrate</td>
<td></td>
<td>0.8 – 1.5</td>
<td>1.7 – 2.4</td>
<td>1.7 – 2.9</td>
</tr>
<tr>
<td>- Sulphate of ammonium</td>
<td></td>
<td>1.2 – 2.0</td>
<td>2.6 – 3.4</td>
<td>2.6 – 4.4</td>
</tr>
<tr>
<td><strong>Phosphorus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Triple super phosphate</td>
<td></td>
<td>0.6 – 1.1</td>
<td>0.8 – 1.3</td>
<td>1.0 – 1.5</td>
</tr>
<tr>
<td>- Rock phosphate</td>
<td></td>
<td>0.9 – 1.5</td>
<td>1.2 – 1.9</td>
<td>1.5 – 2.2</td>
</tr>
<tr>
<td>- Di-ammonium phosphate</td>
<td></td>
<td>0.6 – 1.1</td>
<td>0.8 – 1.3</td>
<td>1.0 – 1.5</td>
</tr>
<tr>
<td>- SP-36 (Indonesia)</td>
<td></td>
<td>0.8 – 1.4</td>
<td>1.0 – 1.6</td>
<td>1.3 – 1.8</td>
</tr>
<tr>
<td><strong>Potassium</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Muriate of Potash (MOP, KCl)</td>
<td></td>
<td>0.8 – 1.3*</td>
<td>2.5 – 3.5**</td>
<td>2.5 – 3.5</td>
</tr>
<tr>
<td><strong>Magnesium</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Kieserite</td>
<td></td>
<td>0.7 – 1.1***</td>
<td>0.7 – 1.5***</td>
<td>0.7 – 1.5</td>
</tr>
<tr>
<td>- Dolomite</td>
<td></td>
<td>1.4 – 2.1</td>
<td>1.4 – 2.8</td>
<td>1.4 – 2.8</td>
</tr>
<tr>
<td><strong>Boron</strong></td>
<td></td>
<td>0.05</td>
<td>0.10</td>
<td>0.10</td>
</tr>
</tbody>
</table>

* 0.5 kg/palm on coastal clays and K-rich volcanic soils.
** 2.0 kg/palm on coastal clays and K-rich volcanic soils.
*** No application needed on coastal clay soils.
TABLE 7: FERTILISER RECOMMENDATIONS FOR IMMATURE PALMS (1–3 YEARS AFTER PLANTING) IN PEAT SOILS, IN KILO PER PALM PER YEAR.

<table>
<thead>
<tr>
<th>Fertiliser type</th>
<th>Recommendation (kilo per palm per year) [12]</th>
<th>Years after planting:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Nitrogen</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Urea</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>- Ammonium nitrate</td>
<td>1.2</td>
<td>2.0</td>
</tr>
<tr>
<td>- Sulphate of ammonium</td>
<td>1.6</td>
<td>1.6</td>
</tr>
<tr>
<td><strong>Phosphorus</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Rock phosphate*</td>
<td>1.1</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Potassium</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Muriate of Potash (MOP, KCl)</td>
<td>1.6</td>
<td>2.5</td>
</tr>
<tr>
<td><strong>Magnesium</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Not needed</td>
<td>Not needed</td>
</tr>
<tr>
<td><strong>Boron</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Borax</td>
<td>0.05</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Copper</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- CuSO₄</td>
<td>0.1 – 0.2</td>
<td>0.05 – 0.1</td>
</tr>
<tr>
<td><strong>Zinc</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- ZnSO₄</td>
<td>0.1 – 0.2</td>
<td>0.05 – 0.1</td>
</tr>
</tbody>
</table>

* To reduce soil acidity it is best to apply phosphorus as rock phosphate.
Exceptionally rich soils

On almost all mineral soils found in Indonesia, the application of N and P is required. However, there are some special soils which are very rich in K and/or Mg, and in these soils the application of K and/or Mg fertilisers is not required, or only required in small quantities. There are no exceptionally rich peat soils.

If soil analysis has not been carried out, then the presence of exceptionally rich soils in the plantation needs to be deduced from other factors. The following steps can be followed:

<table>
<thead>
<tr>
<th>Step 1. Discuss with the farmers in the plantation area about their manuring practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2. Visit a number of plantations in the area which have been manured poorly and check for the presence of deficiency symptoms (Section 4) in the lower leaves:</td>
</tr>
<tr>
<td>• Potassium deficiencies are very commonly observed and indicate that sufficient application of K fertilisers is likely to be required on the soil type in the plantation area.</td>
</tr>
<tr>
<td>• Magnesium deficiencies are less commonly observed, but can still be found regularly in poorly manured plantations or in palms planted on eroded slopes. Presence of Mg deficiency symptoms indicates that Mg fertiliser application is likely to be required on the soil type in the plantation area.</td>
</tr>
<tr>
<td>• Boron deficiencies are commonly observed and the application of B fertilisers is usually required.</td>
</tr>
<tr>
<td>Step 3. In case of doubt, check the number of black bunches in the plantations, as well as the bunch size, and discuss the yields of the plantations with the farmers. The presence of leaf deficiency symptoms in combination with poor yields is a good indicator that application of sufficient fertiliser is required.</td>
</tr>
<tr>
<td>Step 4. The absence of deficiency symptoms combined with high productivity, even though certain nutrients were not applied or applied in small amounts during several years, may indicate that the soils are exceptionally rich in these particular nutrients. In such cases the application of these nutrients is not required. This can be temporary, as soils can get depleted after several years of high productivity.</td>
</tr>
</tbody>
</table>
Fertiliser application and lack of money

If not enough money is available to buy all the recommended fertilisers, do **not** leave out the more expensive fertilisers but follow these recommendations:

- Apply fertilisers correctly and in several rounds, so that losses are as small as possible.
- If there are any deficiency symptoms, give priority to applying the fertilisers which are needed to correct the deficiency.
- Do not save on potassium (K) and nitrogen (N) fertiliser, as these nutrients are most important for oil palm and do not stay in the soil for long.
- Magnesium (Mg) is important, but as long as there are no deficiency symptoms, you may decide to reduce application or apply the cheapest fertiliser type (e.g. dolomite).
- If enough phosphorus (P) was applied in the past, it is acceptable to apply less for one year, or to use a cheaper fertiliser type (e.g. rock phosphate).
- If the palms do not show deficiency symptoms, it is acceptable not to apply boron (B) for one year. However, in the next year application will be necessary again, especially in plantations with good production.
- Keep in mind that **if too little fertiliser is applied now, yield will go down two to three years later.** Fertilisers are a necessary investment and buying them should be a priority.
4. NUTRIENT DEFICIENCY SYMPTOMS

Background

A healthy oil palm leaf is dark green, strong and flexible. In fully mature palms (more than 10 years after planting) the leaf is 5–8 m long and has leaflets up to 1.20 m long (see Figure 6).

Nutrient deficiency symptoms in oil palms can occur as a result of the following:

- Not enough nutrients are applied;
- Nutrients are applied in the wrong way;
- Nutrients do not reach the palms because of the conditions in the plantation (e.g. waterlogging, soil erosion, or competition with weeds).

What follows is a description of the key types of nutrient deficiencies and their symptoms in oil palms.

Figure 6: Healthy oil palm leaf
Nitrogen (N) deficiency

- Leaflets turn an overall light green or yellow colour, starting in the older leaves (see Figure 7).
- In severe cases, leaflets may curl up and die, starting at the tip and edges.
- Also in severe cases, the rachis and the midribs of the leaflets turn bright yellow or orange [1, 9] (see Module 3 for an explanation of these terms). This type of yellowing often happens when palms are in low-lying areas or swamps that are flooded during part of the year and have a high water table.
- Weeds under the palms sometimes also show a pale green or yellow colour.

Figure 7: Immature palm with N deficiency symptoms
Phosphorus (P) deficiency

- P deficiency does not tend to show up clearly in oil palm leaves although in some cases the leaves may be shorter (‘stunted’) and bunches smaller.
- Trunks have a pyramid-shape (see Figure 8) which is wider at the bottom and much thinner at the top.
- P deficiency can show in the weeds by:
  - The presence of *Melastoma malabathricum* and/or *Dicranopteris linearis* (see Figure 9);
  - The presence of *Imperata cylindrica* with purple-coloured leaves;
  - Poor growth of legume cover crops [9] (which need a lot of phosphorus).

*Figure 8: Palms with tapered trunks*
Figure 9: Melastoma malabathricum growing under an oil palm
Potassium (K) deficiency

- Yellow or orange spots with irregular shapes appear on the leaves, starting in the older leaves. If the leaves are held up to the sun, the light shines through the spots (see Figure 10).
- Later, the spots turn orange and grow until they fuse together.
- In severe cases, K deficiency shows as an overall yellowing of the older leaves (especially on acid sands or peat soils) giving the appearance of the whole crown turning yellow.
- ‘White stripe’, a straight white line on both sides of the mid-ribs of the leaflet, sometimes is a sign of too much N and not enough K and B [1, 9] (see Figure 11), although this may also be genetic.

Figure 10: Potassium deficiency symptoms
Figure 11: White stripe
Magnesium (Mg) deficiency

- Leaflets on older leaves that are in direct sunlight get an even olive green to orange/yellow colour, starting at the tip of the leaflet;
- Typically only leaflets in full sunlight turn yellow, but not the shaded leaflets and young leaves (see Figure 12);
- In severe cases, the leaflets become bright yellow and die, starting at the edge and tip of the leaflets [1, 9].

Figure 12: Magnesium deficiency
Boron (B) deficiency

- Leaves are crinkled and dark green (see Figure 13);
- Leaflet tips sometimes fold sharply (see Figure 14);
- New fronds get shorter and shorter so the top of the palm crown appears flattened [9];
- Sometimes the tip of the leaf is completely missing (see Figure 15).

Figure 13: Boron deficiency – crinkled leaf
Figure 14: Boron deficiency – hooked leaf

Figure 15: Boron deficiency – blind leaf
Copper and zinc deficiency

Copper and zinc deficiencies are to be expected in peat soils only. It is very rare to find deficiencies in mineral soils.

- The youngest leaves become yellow at the tips of the leaflets, but the mid-ribs stay green;
- In severe cases, the leaflets die off from the tips inward (see Figure 16);
- New fronds become shorter and shorter.

*Figure 16: ‘Peat yellows’, a sign of copper or zinc deficiency*
5. TYPES OF FERTILISERS

WARNING: Fake fertilisers are a common problem in many countries. Be careful when buying fertilisers, especially from someone you don’t know.

When buying fertilisers, stick to the following guidelines:

- Buy from a trusted person;
- **Do not** buy fertilisers that are extremely cheap or from an unclear origin (these are likely to be fake);
- Check if the fertilisers are in good condition (i.e. dry, clean, correct colour);
- Check if the bags look good and have been closed correctly with a straight stitch and the same colour thread for all bags;
- Check if the soluble fertilisers (i.e. all fertilisers other than rock phosphate and dolomite) actually dissolve when a handful is thrown into a bucket of water. If the grains sink to the bottom and don’t dissolve after stirring the fertiliser is probably fake;
- If KCl (MOP) or urea is dissolved when put in water, the water temperature should go down, so the water should get colder;
- Check the smell of KCl - good quality KCl doesn’t have a particular smell.

Advantages and disadvantages of different types of fertilisers

The following tables provide an overview of the key advantages and disadvantages of different types of fertilisers on the market today [9] [13].

**Nitrogen fertiliser**

<table>
<thead>
<tr>
<th>Type</th>
<th>% N</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea</td>
<td>46</td>
<td>Cheap, easy to store</td>
<td>Loss through leaching and volatisation, acidifying</td>
</tr>
<tr>
<td>Ammonium nitrate (AN)</td>
<td>34</td>
<td>Little volatisation, non-acidifying</td>
<td>Expensive, difficult to store</td>
</tr>
<tr>
<td>Sulphate of ammonium (SA)</td>
<td>20.6</td>
<td>Easy to store</td>
<td>Expensive, very acidifying, induces Mg deficiency</td>
</tr>
</tbody>
</table>

**Phosphate fertiliser**

| Type                        | % P₂O₅ | Advantages | Disadvantages |
|-----------------------------|--------|------------|---------------|---------------|

### Fertiliser application

<table>
<thead>
<tr>
<th>Compound</th>
<th>% N, P₂O₅, K₂O, MgO</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-12-17-2</td>
<td>12-12-17-2 +</td>
<td>Easy to apply and</td>
<td>Expensive, less</td>
</tr>
</tbody>
</table>

### Potassium fertiliser

<table>
<thead>
<tr>
<th>Type</th>
<th>% K₂O</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muriate of Potash (MOP, KCl)</td>
<td>60</td>
<td>Relatively cheap, effective, also contains 35% Cl</td>
<td>Cannot be stored for long, difficult to obtain for smallholders</td>
</tr>
<tr>
<td>Bunch ash</td>
<td>20–40</td>
<td>Cheap, increased soil pH, effective</td>
<td></td>
</tr>
</tbody>
</table>

---

**Figure 17:** KCl, also known as potassium chloride or Muriate of Potash (MOP)
Module 4: Fertiliser application

+ micronutrients           micronutrients           easy to obtain, containing all required nutrients           suitable for mature plantations

Note: Compound (NPK) fertilisers are usually most suitable for application in nurseries and immature plantations (less than 3 years after planting). In mature plantations, the balance of N, P and K in the compound fertilisers is often not correct, and in most cases it is cheaper to apply single nutrient fertilisers unless the labour costs for application are high.

Figure 18: NPK fertiliser with magnesium and trace elements (12-12-17-2 + TE)

Magnesium fertiliser

<table>
<thead>
<tr>
<th>Type</th>
<th>% MgO</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kieserite</td>
<td>26</td>
<td>More soluble, also contains 23% S</td>
<td>Expensive</td>
</tr>
<tr>
<td>Langbeinite</td>
<td>18</td>
<td>More soluble, also contains 22% K₂O and 22% S</td>
<td></td>
</tr>
<tr>
<td>Dolomite</td>
<td>10–18</td>
<td>Reduces soil acidity, also contains ~ 30% CaO</td>
<td>Insoluble, only useful on very acid soils</td>
</tr>
</tbody>
</table>
### Boron fertiliser

<table>
<thead>
<tr>
<th>Type</th>
<th>% B</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borax</td>
<td>11</td>
<td>Effective</td>
<td>Expensive</td>
</tr>
<tr>
<td>Sodium tetraborate (48)</td>
<td>14</td>
<td>Effective</td>
<td>Expensive</td>
</tr>
</tbody>
</table>

### Copper and zinc fertiliser [14]

<table>
<thead>
<tr>
<th>Type</th>
<th>% Cu/Zn</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper sulfate</td>
<td>25</td>
<td>Also contains 13% S</td>
<td>Expensive, difficult to get</td>
</tr>
<tr>
<td>Zinc sulfate (ZnSO₄·H₂O)</td>
<td>36</td>
<td>Also contains S</td>
<td>Relatively expensive, difficult to get</td>
</tr>
<tr>
<td>Zinc sulfate (ZnSO₄·7H₂O)</td>
<td>22</td>
<td>Also contains S</td>
<td>Relatively expensive, difficult to get</td>
</tr>
</tbody>
</table>
6. APPLYING NITROGEN (N) FERTILISER

Goal

- Provide oil palms with sufficient nitrogen to produce optimum yields;
- Limit the loss of fertilisers to the environment.

Standard

Nitrogen fertiliser is applied according to the 4R principle: right type, right amount, right place, right time.

Timing

- After it rains, when the soil is still moist;
- Not when the soil is water-logged;
- Not in the dry season when no rain is expected;
- **Note:** For urea, apply in the morning of a day when rain is expected soon (in the afternoon or on the next day).

Frequency

At least 2 doses per year (once every 6 months) and optimally 3 doses (once every 4 months) because less nutrients are lost.

Labour time required

4–8 hours per hectare.

Equipment and materials

- Bucket, bag or wheelbarrow
- Kitchen scales
- Black marker pen
- Bowl (1.5–2 L)
- Fertiliser
Dosage

See: Table 4; Table 5; Table 6; Table 7.

Who

Farmers and their families or hired labourers.

How

Apply nitrogen fertiliser by following these steps:

- **Step 1.** Make sure the plantation is well maintained, noxious weeds have been removed and ground cover has been slashed to 50 cm height.
- **Step 2.** In a bowl or cup weigh the amount of fertiliser to be applied with kitchen scales.
- **Step 3.** Mark the bowl/cup at the right amount using a black marker pen.
- **Step 4.** Break up any clumps of fertiliser into small pieces before application.
- **Step 5.** Apply the N fertiliser in the following way:
  - For palms less than 10 years after planting, apply fertiliser in the weeded circle;
For palms greater than 10 years after planting, broadcast the fertiliser evenly in the circle or in the inter-row area, excluding harvesting paths (see Figure 19) [15]. If palms are located on the edge of a river, road or ditch, avoid applying fertilisers on the side of the palm closest to the edge.

**Note:** A good (and cheaper) way to provide part of the N is by sowing legume cover crops (see Module 3).

**Data recording**

Every fertiliser application 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>Fertiliser: N</td>
<td>Urea</td>
<td>150 kg</td>
<td>360000</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>
7. APPLYING PHOSPHORUS (P) FERTILISER

Goal

- Provide oil palms with sufficient phosphorus to produce optimum yields;
- Limit the loss of phosphorus to the environment.

Standard

Phosphorus fertiliser is applied according to the 4R principle: right type, right amount, right place, right time.

Timing

- When the soil is moist;
- **Not** during very strong rains or in the middle of the rainy season.

Frequency

1 or 2 doses per year (once per 6–12 months).

Labour time required

4–8 hours per hectare.

Equipment and materials

- Bucket, bag or wheelbarrow
- Kitchen scales
- Black marker
- Bowl of 1.5–2 L
- Fertiliser

Dosage

See: Table 4; Table 5; Table 6; Table 7.
Who

Farmers and their families or hired labourers.

How

Apply phosphorus fertiliser by following these steps:

**Step 1.** Before application, make sure that erosion control (i.e. terraces, dams) has been installed on sloping terrain because P fertiliser remains at the top of the soil for a long time and is therefore sensitive to loss by erosion or runoff.

**Step 2.** Make sure the plantation is well maintained, noxious weeds have been removed and ground cover has been slashed to 50 cm height.

**Step 3.** Weigh the amount of fertiliser to be applied in a bowl or cup, using kitchen scales.

**Step 4.** Mark the bowl/cup at the right amount using a black marker pen.

**Step 5.** Apply the fertiliser in the following way:

- For palms younger than 3 years after planting, P should be applied evenly in the weeded circle;
- For palms older than 4–10 years after planting, P should be applied in a band around the weeded circle;
- For palms more than 10 years after planting, P should be broadcast in the inter-row (excluding the harvesting paths), especially over the frond stack to prevent runoff.

If palms are on the edge of a river, road or ditch, avoid applying fertilisers on the side of the palm closest to the edge.

*Note:* For very acidic soils (pH < 4.0) and peat soils it is better to use rock phosphate than TSP (see Figure 20).

Data recording

Every fertiliser application 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>Fertiliser: P</td>
<td>TSP</td>
<td>300 kg</td>
<td>300000</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>
Figure 20: Rock phosphate application
8. APPLYING POTASSIUM (K) FERTILISER

Goal

- Provide oil palms with sufficient potassium to produce optimum yields;
- Limit the loss of potassium to the environment.

Standard

Potassium fertiliser is applied according to the 4R principle: right type, right amount, right place, right time.

Timing

Not during very wet periods.

Frequency

- Most soil types: 2–3 doses per year (once every 4–6 months);
- Very sandy soils and peat soils: 3–4 doses per year (once every 3–4 months).

Labour time required

4–8 hours per hectare.

Equipment and materials

- Bucket, bag or wheelbarrow
- Kitchen scales
- Black marker pen
- Bowl of 1.5–2 L
- Fertiliser

Dosage

See: Table 4; Table 5; Table 6; Table 7.
Who

Farmers and their families or hired labourers.

How

Apply potassium fertiliser by following these steps:

**Step 1.** Before application, remove noxious weeds and slash ground cover to 50 cm height.

**Step 2.** Weigh the amount of fertiliser to be applied in a bowl or cup, using kitchen scales.

**Step 3.** Mark the bowl/cup at the right amount using a black marker pen.

**Step 4.** Break up any fertiliser clumps into small pieces before application (see Figure 21).

**Step 5.** Apply the fertiliser in the following way:
- For palms younger than 7 years after planting, K should be applied evenly in the weeded circle;
- For palms 7–10 years after planting, K should be applied in a band around the weeded circle;
- For palms greater than 10 years after planting, K should be broadcast over the frond stack and in the inter-row, apart from the harvesting path;
- Apply bunch ash in the weeded circle [16].

If palms are on the edge of a river, road or ditch, avoid applying fertilisers on the side of the palm closest to the edge (if fertiliser is being broadcast).

Data recording

Every fertiliser application 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>Fertiliser: K</td>
<td>KCl</td>
<td>150 kg</td>
<td>840000</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>
Figure 21: This fertiliser should be spread better!
9. APPLYING MAGNESIUM (Mg) FERTILISER

**Goal**

- Provide oil palms with sufficient magnesium to produce optimum yields;
- Limit the loss of magnesium to the environment.

**Standard**

Magnesium fertiliser is applied according to the 4R principle: right type, right amount, right place, right time.

**Timing**

- **Not** during very wet periods because magnesium is sensitive to leaching.
- If magnesium is applied, then urea should **not** be applied shortly after because this will increase leaching of nitrogen.

**Frequency**

1–2 doses per year, depending on the total quantity of magnesium fertiliser applied [1].

**Labour time required**

4–8 hours per hectare.

**Equipment and materials**

- Bucket, bag or wheelbarrow
- Kitchen scales
- Black marker pen
- Bowl of 1.5–2 L
- Fertiliser
Dosage

See: Table 4; Table 5; Table 6; Table 7.

Who

Farmers and their families or hired labourers.

How

Apply magnesium fertiliser by following these steps:

Step 1. Before application, remove noxious weeds are and slash ground cover to 50 cm height.

Step 2. Weigh the amount to be applied in a bowl or cup, using kitchen scales.

Step 3. Mark the bowl/cup at the right amount using a black marker pen.

Step 4. Break up any clumps of fertiliser into small pieces before application.

Step 5. Dolomite is best applied as follows:
- For palms younger than 7 years after planting, dolomite should be applied in a band around the weeded circle;
- For palms older than 7 years after planting, dolomite should be broadcast over the frond stack and in the inter-row [1] (see Figure 22).

Kieserite is best applied as follows:
- For palms younger than 7 years after planting, kieserite should applied evenly in the weeded circle;
- For palms older than 7 years after planting, kieserite should be applied in a band around the weeded circle [1].

If palms are on the edge of a river, road or ditch, avoid applying fertilisers on the side of the palm closest to the edge.

Data recording

Every fertiliser application 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 amount</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>Fertiliser: Mg Dolomite</td>
<td>300 kg</td>
<td>300000</td>
<td>1</td>
<td>4</td>
<td>40000</td>
</tr>
</tbody>
</table>
Figure 22: This dolomite was applied in the circle, but should have been spread over the frond stack
10. APPLYING BORON (B) FERTILISER

Goal

- Provide oil palms with sufficient boron to produce optimum yields;
- Limit the loss of boron to the environment.

Standard

Boron fertiliser is applied according to the 4R principle: right type, right amount, right place, right time.

Timing

Not during very wet periods.

Frequency

Once per year.

Labour time required

2–4 hours per hectare.

Equipment and materials

- Bucket, bag or wheelbarrow
- Kitchen scales
- Black marker pen
- Cup or small bowl
- Fertiliser

Dosage

See: Table 4; Table 5; Table 6; Table 7.
Who

Farmers and their families or hired labourers.

How

Boron fertiliser is applied in small quantities and is toxic when applied in too large amounts.

Apply boron fertiliser by following these steps:

| Step 1. | Before application, remove all weeds from the weeded circle. |
| Step 2. | Weigh the amount to be applied in a bowl or cup, using kitchen scales. |
| Step 3. | Mark the bowl/cup at the right amount using a black marker pen. |
| Step 4. | Break any clumps into small pieces before application of fertiliser. |
| Step 5. | Apply boron fertiliser evenly in the weeded circle for palms of all ages. |

Note: Boron fertiliser is mildly toxic, so it is best not to eat, drink or smoke during application and to wash hands immediately after application.

Data recording

Every fertiliser application 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>Fertiliser: B</td>
<td>Borax</td>
<td>15 kg</td>
<td>200000</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>
11. APPLYING COPPER (Cu) AND ZINC (Zn) FERTILISER

Note: Copper and zinc fertiliser should be applied to peat soils only!

**Goal**

Correct copper or zinc deficiencies in oil palm plantations in peat soils in order to achieve optimum yields.

**Standard**

- Copper and zinc fertiliser are applied according to the 4R principle: right type, right amount, right place, right time.

**Timing**

- Usually when palms are still immature or young;
- **Not** during very wet periods.

**Frequency**

Once per year.

**Labour time required**

4–8 hours per hectare.

**Equipment and materials**

- Bucket, bag or wheelbarrow
- Kitchen scales
- Black marker pen
- Cup or small bowl
- Knapsack sprayer with long lance (for aerial application)
- Fertiliser
Dosage

See: Table 5; Table 7.

Who

Farmers and their families or hired labourers.

How

Application of copper and zinc fertilisers is usually necessary on peat soils only and not on mineral soils. When applying copper and zinc directly onto the soil, quite large amounts are needed because much of the fertiliser will be bound by the soil. An alternative in immature plantations is to apply copper and/or zinc fertilisers directly onto the leaves [7].

Copper / zinc application to the soil:

Step 1. Before application, remove all weeds from the weeded circle.
Step 2. Weigh the amount to be applied in a small bowl or cup, using kitchen scales.
Step 3. Mark the bowl/cup at the right amount using the black marker pen.
Step 4. Apply the fertiliser evenly in the weeded circle.

Copper / zinc application to the leaves:

Step 1. Make sure the knapsack sprayer is clean and works correctly.
Step 2. Fill the knapsack sprayer with water (4-5 L per palm).
Step 3. Weigh the amount to be applied in a small cup, using precise kitchen scales.
Step 4. Add the fertiliser to the sprayer and make sure it is dissolved well.
Step 5. Spray the palms with the fertiliser solution. Considerations when spraying fertiliser to the crown:
  - Much smaller quantities are needed;
  - Spraying is cheaper and the nutrients are taken up faster compared with applying to the soil because the soil cannot bind the nutrients;
  - However, copper and zinc can be toxic if applied in too large quantities, especially when sprayed onto the leaves;
  - It is a good idea to try out the spraying and the application on the soil with a few palms (at least four for
each treatment) to see if nutrient deficiency symptoms disappear. Symptoms should disappear in 3–12 months.

Note: If not enough potassium is applied, the palms will still be yellow because of potassium deficiency, even if the copper and the zinc are effective.

**Data recording**

Every fertiliser application 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 People</th>
<th>Labour input Hours</th>
<th>Labour costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>16/01/13</td>
<td></td>
<td>Field 3</td>
<td>Fertiliser: Cu</td>
<td>CuSO₄</td>
<td>25kg</td>
<td>700000</td>
<td>1</td>
<td>4</td>
<td>40000</td>
</tr>
</tbody>
</table>
12. APPLYING EMPTY FRUIT BUNCHES AS FERTILISER

Background

Empty fruit bunches (EFB) are what remains of the fresh fruit bunches after the fruit has been removed for oil pressing. Empty fruit bunches are a type of mill waste which is very valuable for farmers because:

- It provides nutrients;
- It increases the soil organic matter content of the soil.

Empty fruit bunches can replace fertilisers at the following rate:

1 tonne EFB = 3.8 kg Urea (N)  
            3.9 kg Rock Phosphate (P)  
            18.0 kg KCl (K)  
            9.2 kg kieserite (Mg) [17]

Empty fruit bunches can be bought at the mill, if available. The empty bunches can be transported to the field by the empty trucks that come back to pick up more harvested fresh fruit bunches.

Goal

- To provide the oil palms with nutrients;
- To reduce fertiliser costs;
- To increase organic matter content in the soil.

Standard

- Empty fruit bunches are applied at least once in every 5–8 years.
- Empty fruit bunches are applied in the right way and the right place.

Timing

Whenever empty fruit bunches become available.

Frequency
Every 5 years, if enough empty fruit bunches are available.

**Labour time required**

- Transport: depends on distance to the mill.
- Application: 2–3 days per hectare.

**Equipment and materials**

- Wheelbarrow
- Shovel
- Truck (returning empty from the mill)

Note: Empty fruit bunches can be purchased at the mill if they are not all bought up by large plantations. Availability may depend on the smallholder’s relation with the mill and/or competition with other buyers (large companies often get priority). It helps to purchase empty fruit bunches as a cooperative or farmers’ group.

**Dosage**

- Optimum rate: 30 to 40 t/ha.
- When EFB are applied at the optimum rate there it is enough to replace mineral K, P, Mg and B fertilisers for one year.
- It is recommended to keep applying N fertilisers, because the N in the EFB is mostly not available to the palm.
- **Note:** 25 tonne FFB produces 5 tonne EFB, so the amount of available EFB is limited [9].

**Who**

- Transport: Workers who normally transport the fresh fruit bunches to the mill.
- Application: Farmers and their families or hired labourers.

**How**

Apply empty fruit bunches as fertiliser by following these steps:

**Step 1.** Once the truck has delivered the empty fruit bunches to the
roadside, transport the empty fruit bunches into the plantation by wheelbarrow.

**Step 2.** Apply the empty fruit bunches as follows:
- In a band (line) next to the frond stack, or;
- In a patch of 2–4 square meters between the palms (see Figure 24).

In immature plantations, empty fruit bunches can be applied in the weeded circle. In mature plantations, empty fruit bunches should not be applied in or around the weeded circle, because this will make access into the plantation and collection of the loose fruits more difficult (see Figure 25).

**Note:** The layer of empty fruit bunches should always be **only one bunch thick** because it makes the decomposition go faster and also prevents rhinoceros beetles from using the empty fruit bunches as a breeding place.

**Step 3.** Check patches of empty fruit bunches regularly to see if there are any breeding rhinoceros beetles. This can be done by turning the empty fruit bunches upside down. Remove any rhinoceros beetle larvae that are found in, or under, the bunches and spread the bunches more widely if necessary. See Module 5 for more information about rhinoceros beetles.

*Figure 24: Correct application of empty fruit bunches in a patch*
Every fertiliser application 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>EFB application</td>
<td>EFB</td>
<td>40 tonne</td>
<td>3000000</td>
<td>6</td>
<td>480000</td>
</tr>
</tbody>
</table>

*Figure 25: Incorrect application of empty fruit bunches around the weeded circle*
Module 4: Fertiliser application

References and further reading

## APPENDIX 1: 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.
Module 4: Fertiliser application

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 26).

**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 27**).

**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 28**).

**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 28**). 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
### 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 26: Spiral going to the left (left) and to the right (right)*
Module 4: Fertiliser application

Figure 27: Identifying leaf 17

Figure 28: 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 [9].

**Table 8: 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>Macronutrients (N, P, K, Mg); 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>Micronutrients (B, Cu, Zn); 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>Other nutrients (Ca, S, Cl); 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 9: 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>Macronutrients (N, P, K, Mg); 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>Micronutrients (B, Cu, Zn); 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>Other nutrients (Ca, S, Cl); 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.
- Table 4–7 give 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 Table 4–7), because these fertilisers can be toxic when applied in excess.