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Fertiliser use efficiency

Matching fertiliser inputs to vegetable crop removal

Do you know how closely your rate of fertiliser application matches your crops needs? By calculating your fertiliser use efficiency, you can check how well you are currently doing this. Rising input costs and community concerns about off-farm nutrient losses are highlighting the need for sustainable nutrient management. While the nutrient of most interest is nitrogen and is the example used here, the process described in this fact sheet can be used for other nutrients such as phosphorus and potassium.

How to use this fact sheet

This fact sheet is divided into two parts:

- An overview of the information you need to calculate your fertiliser use efficiency
- Step by step instructions on how to sample and calculate your crop removal and fertiliser use efficiency.

An excel spreadsheet calculator has also been developed to do all the calculations for you.

What you need to calculate your fertiliser use efficiency

There are some tools that can help calculate crop nutrient removal particularly the US Department of Agriculture website <http://plants.usda.gov/npk/main>. However, this data should be used with caution as there can be major differences in values between Australian and US crops. Information on crop removal for some vegetable crops can also be found in Appendix 1 of the *Australian soil fertility manual* (2006).

The best option is to measure removal in your own crops and calculate your fertiliser use efficiency. You will need the following information to calculate your crops fertiliser use efficiency:

- how much and what type of fertiliser you applied
- crop yield
- how much nutrient your crop removed in harvested product
- how much nutrient was returned to the soil system as crop residues.

Fertiliser inputs

All fertilisers contain different percentages of nutrients and you need to know what types and how much you have applied to compare with what your crop removed.

Nutrient uptake and removal

This requires you to measure both your product yield and the amount of crop residue left in the field then sampling these for analysis of total nutrient content. Step by step instructions are on the following pages. Your agronomist may be able to help out with sampling.

Crop and residue yield

Why is this important? The nutrients removed by your crop are directly related to the yield of the crop so you need to accurately determine crop yield. You will also need to know how much residue your crop produces to work out how much nutrient is returned to your system.

Sampling of nutrient content in product and crop residues for removal

Knowing the nutrient content in your harvested product and crop residues allows you to calculate how much nutrient was removed in harvested product and what is also in the crop residues. This is important because the nutrient in the unharvested crop residue becomes available for following crops and should be considered in fertiliser rate decisions.

Interpreting your fertiliser use efficiency values

What does your fertiliser use efficiency value mean? Your fertiliser use efficiency will allow you to see how well your applied fertiliser matches what is removed by the crop. Ideally you should be aiming for a fertiliser use efficiency value as close as possible to 100%. This would suggest that the applied fertiliser matches that used by the crop and removed in harvested product. In practice this is difficult to achieve as some losses are unavoidable.

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Fertiliser use efficiency value	What does this mean?
Less than 100%	You are applying more nutrient than your crop is using and removing
About 100%	You are applying nutrient at rates that roughly matches crop use and removal
Greater than 100%	You are applying less nutrient than your crop is using and removing. Other nutrient sources are making up the shortfall

Step by step guide for calculating your fertiliser use efficiency

Step 1. Calculating fertiliser inputs

All fertilisers have different percentages of nutrients. You need to know how much you have applied to compare this with crop removal.

Keep a record of the amount of fertiliser applied to each crop including base fertiliser and in-crop applications.

Calculate the total kilograms of nutrient applied per hectare by multiplying the amount of fertiliser applied (kg/ha) by the percentage of nutrient in the fertiliser. This information is usually printed on the fertiliser packaging. Add up the nutrient applied in each fertiliser application.

Nutrient applied (kg/ha) = (% nutrient in fertiliser / 100) x rate of fertiliser applied per ha

Example 1. A typical lettuce example for nitrogen

Fertiliser	Nitrogen % in fertiliser	Fertiliser applied (kg per ha)	Calculation of nitrogen applied	Nitrogen applied in fertiliser (kg/ha)
Nitrophoska	12.0%	300	12.0 / 100 x 300	36.0
Calcium nitrate	17.1%	40	17.1 / 100 x 40	6.8
Potassium nitrate	13.8%	80	13.8 / 100 x 80	11.0
Ammonium sulphate	21.2%	100	21.2 / 100 x 100	21.2
Total units (kg) of nitrogen applied per ha				**75.0**

Step 2. Calculating nutrient uptake and removal

You need to do the following:

A. Calculate your plant population.
B. Collect a sample of both harvested product and crop residues.
C. Weigh the samples of product and crop residue.
D. Calculate the yield of harvested product and crop residues.
E. Take a smaller sample (0.5–1.0 kg) of produce and crop residues and send these to a laboratory for analysis of nutrient content.
F. Calculate product nutrient removal and crop residue nutrient content (kg nutrient per ha).

These are discussed in more detail below.

A. Calculate your plant population

Calculate your plant population in the field. Often target plant populations are not accurate for various reasons so it is best to get accurate measurements from the plant density in the field.

Count the number of plants in 15 metres of row then calculate the plant population using the following:

Plant population (plants/ha) = a / 15 x b / c x 10000

where:
a = plants in 15 m row
b = number plant rows per wheel spacing
c = wheel spacing (m)

Example 2. Calculating plant population

A grower measures 15 m of row in his lettuce crop. He counts 45 plants in 15 metres. His wheel spacings are 1.6 metres with three rows of lettuce on the bed.

Plants/ha = a / 15 x b / c x 10000
= 45 / 15 x 3 / 1.6 x 10000
= 56 250 plants/ha

B. Collecting product and residue samples

Some vegetable crops have multiple harvests of the same plants over time (e.g. tomato, capsicum, eggplant, zucchini, cucumber etc). For these crops you need to make sure you sample and measure the total yield over all harvests. For other crops a single harvest is conducted and this may be a harvest of the whole plant (e.g. lettuce, potato, carrot etc), or parts of the plant (e.g. broccoli and cauliflower).

Make sure you choose random plants and avoid plants that are not typical of the crop, for example diseased or stunted plants. Some crops may mean you sample a specific area rather than a number of plants.

Sampling plants in the field: Just before harvest collect 10 whole plants above ground (including product and plant parts that would normally be left in the field as residues, without roots).

For multiple harvest crops tag 10 random plants in the field and harvest these same 10 plants by hand until final harvest (at about the same number of harvests and harvest intervals as commercial harvesting). Record the weight of product at each harvest. You must make sure that the plants you are sampling are not accidently harvested by staff during commercial field harvest. You will also need to sample the plant residues (i.e. the unharvested plant parts) to work out residue yield. To sample residues collect 10 typical (healthy) plants (excluding the roots) after the final harvest.

Onions, carrots and shallots: For high density crops such as onions, carrots and shallots 10 plants is not enough sampling. For these crops, sample 3-4 one metre lengths of row and count how many plants sampled in total.

Vine crops: For sprawling vine crops, where individual plants are not easily distinguishable in a row (for example sweetpotato, melons and pumpkins), sampling individual plants will be difficult so sampling from field yields is recommended.

Sampling from the packing shed or field yields: You can also sample harvested product from the packing shed or field harvested yields. However, you will still also need to sample plant residues from the field as above. For sprawling vine crops, where individual plants are not easily distinguishable in a row (for example sweetpotato, melons and pumpkins), seek agronomic advice for measuring crop residue yields.

Potatoes: Potatoes are best sampled from the shed rather than hand digging in the field as yields based on shed receivals are likely to be more accurate and easier. Potatoes will not be able to be sampled for residues.

C. Weighing samples

Separate your samples into two parts:

- Marketable product that is normally removed from the field with harvest (for example, lettuce heads or sweet corn cobs).
- Crop residue, i.e. those plant parts that are normally left in the field (e.g. lettuce wrapper leaves or sweet corn stems and leaves). You may need to adjust yield based on the percentage of product left in the field. Crop residues may also include unmarketable product that pickers reject and leave in the field.

Record the fresh weights of both the product and the crop residue sample separately.

D. Calculating yield

There are various ways to calculate yield. How you do this will depend on how you sampled the crop.

Sampling plants in the field (see Example 3): If you sampled a known number of plants use the fresh weights of your product and residue samples to calculate yield using the following:

Yield (t/ha) = a / b x c / 1000

a = plant population (plants/ha)

b = number of plants sampled

c = total weight of product or residues sampled (kg)

Example 3. Calculating yield

Grower B sampled ten plants (b) from his lettuce crop just before harvest. The total combined weight for the ten marketable heads sampled was 11.1 kg (c_{market}). The total plant population was 50 600 plants per ha (a). The weight of the unmarketable wrapper leaves (crop residues) for the ten plants was 0.85 kg ($c_{residue}$).

Crop yield (t/ha) = a / b x c_{market} / 1000
= 50 600 / 10 x 11.1 / 1000
= 56.2 tonne/ha

Wrapper leaf (residue yield) = a / b x $c_{residue}$ / 1000
= 50 600 / 10 x 0.85 / 1000
= 4.3 tonne/ha

For multiple harvest crops make sure that the weight of sample includes all harvests (see Example 4).

Example 4. Calculating yield—multiple harvest crops

A tomato grower tagged ten plants (*b*) and hand harvested them five times, each time the rest of the field was harvested. The total weight of product at each harvest was 4.5, 7.7, 9.1, 7.2 and 3.3 kg giving a total from the ten plants of 31.8 kg (c_{market}). The total plant population was 18 000 plants per ha (*a*).

Yield tomato (t/ha) = a / b x c_{market} / 1000
= 18 000 / 10 x 31.8 / 1000
= 57.2 tonne/ha

The same tomato grower sampled tomato plants at final harvest for crop residues. He sampled ten plants (*b*) which had a combined foliage and stem mass of 14.3 kg ($a_{residue}$). The total plant population was 18 000 plants per ha (*c*).

Tomato residue yield (t/ha) = $a_{residue}$ / *b* x *c* / 1000
= 14.3 / 10 x 18 000 / 1000
= 25.7 tonne/ha

Shed recievals (see Example 5): Use the blocks total harvested tonnage (shed receivals or packout figures) and divide this by the area of the block that was harvested. Make sure you do not include tonnage from other blocks that may have been harvested and packed at the same time.

Example 5. Calculating yield—shed receivals

A tomato grower had five harvests on a block of tomatoes and the tonnage recorded at each harvest from the block was 4.3, 8.5, 14.9, 10.6 and 4.3 giving a total of 42.5 tonne. The total area of the block was 0.75 ha.

Yield through shed (t/ha) = 42.5 / 0.75
= 56.7 tonne/ha

E. Preparing your samples and sending to the laboratory

Take a 0.5–1.0 kg sample (some from each plant) of each of the product and residue samples.

- Weigh each product and residue sample and record the weight.
- Package and label your samples in clean plastic bags and refrigerate until sending (Do NOT freeze).
- Request an analysis from the laboratory for the nutrients you want to assess e.g. nitrogen, phosphorus, potassium as well as a dry matter analysis on each of your samples. Dry matter is needed because the laboratory dries your fresh sample before measuring nutrient content. We need this value to calculate the amount of nutrient removed.
- Send the product and residue samples to a laboratory for testing. Make sure samples **will** be delivered overnight. Send samples at the start of the week to make sure they are not in the post over the weekend.

F. Calculating nutrient removal and nutrient returned to the system

Once you have your laboratory test results you can calculate crop nutrient removal. The pieces of information you need to calculate nutrient removal are:

- yield (t/ha) of harvested product and crop residues
- dry matter content (%) of harvested product and crop residues
- nutrient content (nutrient %) of harvested product and crop residues.

Nutrient removed (kg/ha) = *a* x *b* / 100 x *c* / 100 x 1000

a = yield (t/ha)
b = dry matter (%)
c = sample nutrient content (%) (note: If nutrient content is in mg/kg then convert to a % by dividing by 10 000)

Step 3. Calculating your fertiliser use efficiency

To calculate your fertiliser use efficiency you need the applied nutrient values from Step 1 and the nutient removal values from Step 2.

See Examples 6 and 7 for calculations of fertiliser use efficiency for both the whole plant and harvested product.

Example 6. Calculating fertiliser use efficiency—whole plant

In Example 1 we calculated that 99.1 kg (*b*) of nitrogen was applied to a lettuce crop and we calculated that 95.1 kg (*a*) was required to grow the whole plant including the harvested part, wrapper leaves and roots.

Nitrogen use efficiency = *a* / *b* x 100
= 95.1 / 99.1 x 100
= 96%

This indicates a high nitrogen use efficiency and that applied fertiliser closely matches plant use to grow the crop.

Example 7. Calculating fertiliser use efficiency—product removal

In Example 1 we calculated that 99.1 kg (*b*) of nitrogen was applied to a lettuce crop and we calculated that 83.6 kg (*a*) was removed in the harvested part.

Nitrogen use efficiency = *a* / *b* x 100
= 83.6 / 99.1 x 100
= 84%

This still indicates a high nitrogen use efficiency and also gives an indication of the amount of fertiliser that may need to be applied to replace that removed in product.

Fertiliser use efficiency (%) = *a* / *b* x 100

a = nutrient used in the plant (kg)
b = the amount of nutrient applied (kg)

Please note: This is not a full nutrient budget as it does not take into account all sources and losses to and from your system.

Nutrient budgeting

This only considers fertiliser inputs so is not a complete nutrient budget. When developing an accurate nutrient budget additional nutrient sources and various other factors will need to be considered, including:

- residual soil nutrient levels,
- nutrients removed in product,
- nutrients returned to the system,
- other nutrient sources eg irrigation water,
- field yield losses due to disease or quality issues which will result in more nutrient being retained in the system,
- potential nutrient losses from the system, leaching, runoff, etc.
- subsequent crop rotation nutrient requirements

This information can be used to assist with your nutrient budget.

- Harvested product fertiliser use efficiencies suggest how well your current fertiliser program matches nutrient removal in product.
- Whole plant use indicates what nutrient levels are needed to grow the plant to produce your product. All of this does not necessarily need to be supplied by fertiliser applications. As nutrients in crop residues are returned to the system some of this nutrient is available to subsequent crops. The nutrients in crop residues can provide an indication of how much is returned to the system and potentially available to future crops.

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Further information

Fertililser Industry Federation of Australia and CSIRO, 2006, *Australian soil fertility manual*, 3rd edition, ed. G.H. Price, CSIRO Publishing, Melbourne.

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