AFRICA soil health consortium

Nutrient management

Rice

Rice nutrient management

To ensure sustainable production and avoid depleting and degrading the soil, the nutrients removed when the rice crop is harvested need to be replaced. For every tonne of rice grains plus straw harvested around 22 kg of nitrogen (N), phosphorus equivalent to 10 kg of P_2O_5 and potassium (K) equivalent to 27 kg of K_2O are taken up from the soil by the crop.

These nutrients can be replaced by application of mineral fertilizers and organic matter (such as manure and rice straw) to the soil, and also by the use of nitrogen-fixing legumes such as green manures and in crop rotations.

Not all the fertilizer applied to the soil is available to the crop. To allow for this – which is known as 'fertilizer use efficiency' - for every additional tonne of grain harvested, fertilizer containing around 60 kg N, 30 kg P_20_5 and 30 kg K_2O needs to be applied to support long-term sustainable cropping.

Fertilizer use

The optimal type and amount of mineral fertilizer that is needed will vary in different locations and situations. Some general guidelines are provided in the tables below – see *The 4Rs: right source, rate, time and place,* below. The aim of these guidelines is not to maximise production; rather it is to increase yields by about one tonne per hectare for upland and rainfed lowland rice, and by up to 3 tonnes per hectare for irrigated lowland rice (see Table 1, below). Although higher yields are possible, aiming to increase yields by between 1 and 3 tonnes per hectare is more cost-effective and also likely to be within the reach of smallholder farmers.

These recommendations are based on the use of five fertilizers that are commonly used on rice: diammonium phosphate (DAP); muriate of potash, also called potash (MOP); urea in the form of small granules (about 2mm in diameter) and urea in the form of 'super granules' or pellets (3-5 g each); and NPK 15-15-15.

Table 1: **Average current yields and achievable yields when good seed and fertilizer are used other and good agronomic practices are followed.**

Rice system	Average current yield tonnes per hectare	Achievable target yield tonnes per hectare
Upland rice	1	2
Rainfed lowland rice	2	3-4
Irrigated lowland rice	5	6-8

Fertilizer response curves

The way that crops, including rice, respond to fertilizer can be described by a fertilizer response curve (*see Figure 1*): this shows the impact of increasing amounts of fertilizer on yield.

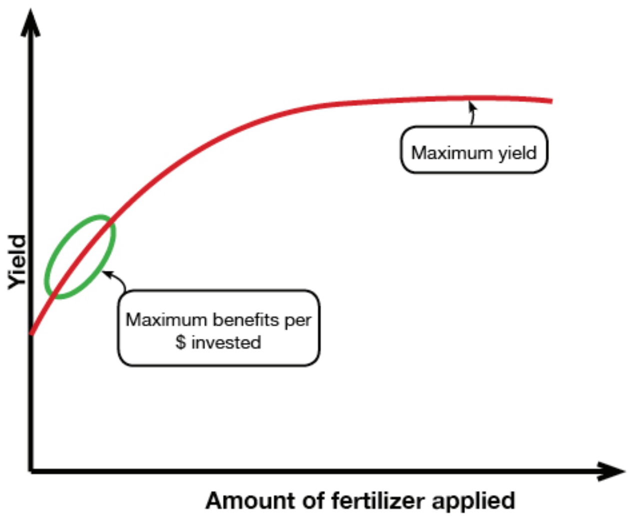

Figure 1: Fertilizer response curve

As the figure shows, to begin with the yield increases steeply as more fertilizer is added, but as the amount of fertilizer applied increases, the extra yield achieved decreases. Eventually adding more fertilizer will have no further impact on yield.

The best return on investment in fertilizer is achieved where the response curve is steepest– here the greatest increase in yield is achieved per unit of fertilizer added (circled in yellow in the diagram). So the recommendations given below aim to fall on this, the steepest part of the curve.

Actual increases in yield will, however, vary depending on many variables. These include:

- the characteristics of the site, for example the soil may be locally deficient in one or more nutrients in addition to N, P and K (which are the focus of these recommendations)
- weather – especially rainfall and amount of sunshine
- pests and diseases present
- other management practices, such as varieties used, water management and weeding
- incorporation of organic matter to the soil, including livestock manure and rice straw
- quality of mineral fertilizer being used: some fertilizers are sub-standard – they may not contain the amount of nutrients shown on the label. Fertilizer should therefore only be purchased from trusted sources, such as local agro-dealer shops.

So, if target yields are not achieved following these recommendations, then expert assistance should be sought to work out what factor is holding back production.

Short term gains and sustainable cropping
In comparison to use of little or no fertilizer, the fertilizer recommendations given below are likely to increase yields and generate higher incomes from sales of surplus production in most situations, at least in the short term. Although adopting the recommendations provided below is better than applying little or no fertilizer, the soil might still be 'mined' – more nutrients might be taken out with the crop than are being replaced each season by application of mineral and organic fertilizer.

Ideally farmers should, therefore, use these recommendations for a few seasons only. After this they should consider reinvesting some of their increased profits from their higher yields, for example by paying for laboratory soil and leaf tests. The results of these tests can be used by experts to design much better fertilizer recommendations suited to their farms which will maintain soil health and support sustainable production in the future. In some cases multi-location nutrient omission trials to determine soil nutrient supply potential and N, P and K responses may be possible, but these are outside the scope of this guide.

The 4Rs: right source, rate, time and place

If site specific fertilizer recommendations are available these should be followed. In case these are not available, this section provides some examples of basal and top-dressing options.

The guidelines below are simple, blanket recommendations based on the ‘4Rs’ - that is the right source, right rate, right time and right place of nutrient management.

Usually nitrogen is the first most limiting nutrient to rice production followed by phosphorus and potassium, and so these guidelines focus on these three major nutrients.

These guidelines are intended for use in situations where the soil preparation and planting advice given in this cropping guide has been followed; in seasons where rainfall is close to normal and/or irrigation water is available in adequate amounts; and the soil either has no problem with soil alkalinity or salinity, or appropriate steps have been taken to address these issues (see *What can go wrong*).

The fertilizer recommendations below are provided as both kg per hectare and g per square metre[3]. Farmers are, however, likely to find it difficult to measure or accurately estimate small amounts of fertilizer. To help overcome this problem see box, *Farmer friendly fertilizer measurements*, which shows how cheap, locally available items can be used as scoops to measure fertilizer.

Basal fertilizer is applied when the plot is being prepared for planting or at the time of sowing or planting. It provides nutrients needed by the crop early in its growing cycle and also nutrients which are slowly released over the growing season. For lowland rainfed rice, where water levels cannot be managed, all fertilizer has to be applied as basal fertilizer.

Top-dressing is application of fertilizer after the crop has started growing. It

3 There are 10,000 square metres in a hectare: grams per square metre is therefore the amount in kg per hectare divided by 10,000.

provides nutrients, especially nitrogen, which are needed later in the crop's growing cycle, for example when the panicle (grain) is forming and also nutrients which, if applied earlier, would be lost into the air or water.

Upland rice: The following tables give some examples of the right amounts of basal and top-dressing fertilizers for upland rice.

Applying these fertilizers can help farmers to increase their yields from about one tonne per hectare to about 2 tonnes.

The combination of either Example 1 basal fertilizer plus Example 1 topdressing, or Example 2 basal fertilizer plus Example 2 topdressing will both supply a total of about 60 kg N, 30 kg P_20_5 and 30 kg K_20 per hectare.

	Basal fertilizers for upland rice	
	kg per hectare (number of 50 kg bags)	**grams per square metre**
Example 1	200 kg (4 bags) NPK 15-15-15	20 g NPK 15-15-15
Example 2	65 kg (1.3 bags) DAP AND 50 kg MOP (1 bag)	6.5 g DAP AND 5 g MOP

Basal fertilizer should be applied when the soil is being prepared for the upland rice crop. The fertilizer is broadcast and then harrowed into the soil.

The top-dressing should be applied in two equal splits: the first around 21 days after seeding and the second at panicle (seed head) initiation, around 45-50 days after seeding. Top-dressing should be applied after a good rain when the soil is moist: do not apply to dry soil. If a mechanical weeder is being used, the top-dressing can be applied at the same time as weeding.

	Top-dressing for upland rice	
	kg per hectare (number of 50 kg bags)	**grams per square metre**
Example 1	65 kg (about 1.3 bags) urea split into 2 equal applications	6.5 g urea split into 2 equal applications
Example 2	100 kg (about 2 bags) urea	10 g urea split into 2 equal applications

Lowland rainfed: Because the water level cannot be managed in this system, all fertilizer needs to be applied when the soil is being prepared for the rice crop (basal) – no top-dressing is applied.

The following table give some examples of the right amounts of basal fertilizers for lowland rainfed rice.

Applying these fertilizers can help farmers to increase their yields of lowland rainfed rice from about one tonne per hectare to about 2 tonnes. In both examples, the basal fertilizer will supply about 60 kg N, 30 kg P_20_5 and 30 kg K_20 per hectare. The basal fertilizer should be broadcast and then harrowed into the soil.

	Basal fertilizer for lowland rainfed rice	
	kg per hectare (number of 50 kg bags)	**grams per square metre**
Example 1	200 kg (4 bags) NPK 15-15-15 AND 65 kg (about 1.3 bags) urea	20 g NPK 15-15-15 AND 6.5 g urea
Example 2	65 kg (1.3 bags) DAP AND 100 kg (about 2 bags) urea AND 50 kg MOP (1 bag)	6.5 DAP AND 10 g urea AND 5 g MOP

Lowland irrigated: The following tables give some examples of the right amounts of basal and top-dressing fertilizers for lowland irrigated rice.

Applying these fertilizers can help farmers to increase their yields of lowland irrigated rice from about 5 tonne per hectare to up to 8 tonnes. The combination of either of the basal fertilizer options with Example 1 of the top dressing options will together supply about 150 kg N, 45 kg P_20_5 and 45 kg K_20 per hectare. Either of the basal fertilizer options can also be combined with top dressing Example 2: although this supplies less N, this option is more efficient and so either top dressing option will support similar levels of production.

The basal fertilizer should be applied by broadcasting before puddling.

	Basal fertilizer for upland irrigated rice	
	kg per hectare (number of 50 kg bags)	**grams per square metre**
Example 1	100 kg (2 bags) DAP AND 30 kg (0.6 bags) MOP	10 g DAP AND 30 g MOP
Example 2	300 kg NPK 15-15-15	30 g NPK 15-15-15

For normal granulated urea (Example 1, below), the top dressing should be applied in two equal splits: the first 10-15 days after transplanting and the second at panicle initiation. To apply urea, the field should be drained so it is muddy, the urea applied by broadcasting and, after 2–3 days, the field re-flooded. Urea should not be broadcast on flooded fields as this will lead to high losses of N.

The pellets (also called super granules) used in the deep urea placement (DUP) method (Example 2, below) are much larger than normal urea fertilizer granules – typically 3 to 5 grams. They release N slowly and losses are reduced compared to ordinary granules; they are also more efficient, resulting in larger increases in yield per unit of urea applied – so less urea can be used when pellets are used in place of granules. For the DUP method, the urea is applied once only at the tillering stage. One 3 gram super granule should be placed between every four plants in every other row at a depth of 7-10 cm^2.

Crops grown in irrigated lowland systems in the dry season, when sunshine is abundant, need more N than crops grown in the lower yielding wet season. Rice that is deficient in N is paler than healthy crops.

	Top-dressing for upland irrigated rice	
	kg per hectare (number of 50 kg bags)	**grams per square metre**
Example 1	230 kg urea split into 3 equal applications	23 g urea split into 3 equal applications
Example 2	187.5 kg super granules for DUP in one application at tillering only	19 g super granules for DUP* in one application at tillering only

Farmer friendly fertilizer measurements

It is difficult for farmers to know what small amounts of fertilizer, such as 10 g of urea, looks like and they will not have access to weighing scales.

The solution to this problem is to identify a locally available container, such as metal crown cork bottle-top for beer or soda[3]. The bottle-top can then be used as a scoop for measuring fertilizer.

For larger amounts, discarded water bottles make useful containers.

Different fertilizers have different densities, so while a bottle-top full (level, not heaped) of NPK 15-15-15 will weigh 3 g, a bottle-top full of DAP will weigh just under 5 g.

For those with access to the internet, a tool (the OFRA fertilizer calibration tool) is available at CABI-ASHC website (www. africasoilhealth.cabi.org). This tool enables the user to calibrate any circular container that can be filled with a range of different fertilizers.

See table, below, for other fertilizers: values in this table have been calculated using the CABI tool.

To apply 10 g of urea per square metre of soil, two and a half bottle-tops full of normal (granular) urea fertilizer are needed: 2.5 x 4g = 10 g

To apply 6 g of NPK 15-15-15, two bottle-top measures are needed per hole: 2 x 3g = 6g

Once farmers have some experience of using the measure they will know what the appropriate amount of a given fertilizer looks like. They can then stop using the measure and apply a three-finger pinch of fertilizer which corresponds to the right amount. From time to time it would be advisable to check that their pinch is delivering the right amount of fertilizer.

Fertilizer type	Weight of fertilizer (g) per metal beer or soda bottle-top full
CAN	3
DAP	5
MOP	6
NPK 15-15-15	3
SSP	3.5
TSP	7
Urea	4

2 Assuming row and plant spacings of 20 cm x 20 cm, that is 250,000 plants per hectare. One 3 gram urea pellet between every 4 plants in every other row (equivalent to one pellet per 4 plants) totals 62,500 x 5 g = 187,500 g (187.5 kg) hectare.

3 The standard metal crown cork bottle-top has a 2.8 cm diameter and a depth of 0.5 cm, giving a volume of 3 ml (3 cm3). It has 21 ‘teeth’.

Use of CAN and other nitrate fertilizers
Nitrate-containing fertilizers, such as ammonium nitrate or calcium ammonium nitrate (CAN) are not suitable for rice when applied at or before planting. Unlike ammonium-containing fertilizers (such as DAP and ammonium sulphate, and also urea, which is hydrolysed to ammonium), the nitrogen in nitrate-containing fertilizers can be lost quickly by denitrification once the field is flooded. They can, however, be used for topdressing when uptake of nutrients is proceeding rapidly as the topsoil is covered with a mat of roots and N losses are therefore minimized.

Use of manure
When available, animal manure can be an important resource for improving rice yields. Addition of manure helps to maintain soil organic matter at good levels. Manure is also an important source of nutrients, which are mostly released following its decomposition.
However, manure contains a lower density of nutrients compared with mineral fertilizers and the amount of nutrients contained in manure available on smallholder farms is usually insufficient to sustain required levels of rice productivity. If manure is purchased it can be more expensive than equivalent amounts of mineral fertilizer and is also much more bulky, which makes transport expensive.

Using manure in combination with fertilizer gives better yields than using either input alone. Ideally, 5–10 tonnes of animal manure per hectare (0.5 to 1 kg per square metre) should be applied each year on the surface and incorporated during ploughing. Some studies have suggested that with addition of manure at this level, the requirement for mineral fertilizers can be reduced by half. So, farmers who apply manure in this way could reduce the amount of mineral fertilizer suggested in the table by half.

The nutrient content of manure varies considerably. So, if farmers reduce mineral fertilizer they need to be on the look-out for signs of nutrient deficiencies, especially of N, in their rice crop; see Section 6, *What can go wrong,* for descriptions and photographs of rice crops with various nutrient deficiencies and details of what to do when these signs are seen.

Use of green manure
Green manures are mostly nitrogen-rich legume crops grown to provide nitrogen for the next rice crop and to add organic matter to the soil. Green manures are planted before or after rice, when the land is vacant, allowed

to grow for some time, then slashed and either left on the soil surface or ploughed into the soil.

Although green manure can be used in all rice growing systems, they are especially useful for improving poor upland soils, which are often acid or easily eroded. They are also useful in situations where timely availability of mineral fertilizers is unreliable. Green manures should be considered when soil organic matter and N levels are low and fertilizer prices are high, particularly in regions with long growing seasons.

Incorporation of a green manure crop before planting rice can add the equivalent of around 2 bags (100 kg) of urea per hectare, so the top-dressing can be adjusted accordingly saving the farmer significant amounts of money. For upland rice the green manure could save all the urea topdressing; for lowland rainfed rice it could save all the urea in both basal fertilizer examples; and for lowland irrigated rice it could reduce the amount of topdressing urea by about 40%.

If farmers plan to use green manure as part of their nutrient management package they need to chose the right green manure:

- It needs to suit their growing conditions –the climate, soil and water available.
- It must be easy and cheap to grow.
- Good quality seed that germinates well needs to be readily available.
- It needs to grow without need for irrigation, fertilizer or pesticides.
- Its growing season must fit the time available between rice crops: it must not delay rice planting.
- The benefit in terms of nitrogen fertilizer saved must be significantly greater than the cost of seed and labour needed. So, if the green manure provides 100 kg N per hectare, the cost of seed and labour should be no more than the cost of about 2 bag of urea per hectare

Some examples of green manure crops suitable for use in rice cropping systems in Africa include:

Sesbania *(Sesbania rostrata)*: A small semi-aquatic leguminous tree that naturally occurs in Africa. It has nitrogen fixing nodules on both stem and roots. Sesbania is fast growth and able to convert large amounts of atmospheric nitrogen into a usable form for plants – the equivalent of 1 to 2 bags of urea per hectare in between 40 and 60 days. A constraint to growing this green manure can be availability of seed.

Sesbania seed is best broadcast at the rate of 30 kg per hectare (3 g per square metre) before the onset of rains. The better the land is prepared, the better the crop establishes; also the seed rate can be reduced on well prepared seed beds to 16 kg per hectare. Germination rates are improved if the seed is immersed in very hot water (100°C) for just 3 seconds. In irrigated systems, water should be applied if the soil cracks and leaves are shed. The crop is incorporated into the soil before it becomes too woody, which is between 45 and 60 days after sowing. To do this the crop can be slashed by hand prior to ploughing; alternatively it can be knocked down using a plank drawn by draft animals, and then ploughed in. If available, machines such as hydrotillers or tractors and rototillers can be used.

Other legume crops: Various legume crops, such as soybeans, pigeon peas and mung beans, can be grown as fast growing green manure crops that can accumulate significant amounts of nitrogen within 45–60 days of sowing.

Residue management

If farmers are able to return the rice straw to the field and use mineral fertilizers then the soil's nutrient balance will be much improved. However, demand for alternative uses for straw, including as fuel for cooking, as a thatching material and as feed for livestock, may make this difficult or even impossible.

Rice straw and stubble contains about 40% of the nitrogen (N), 33% of the phosphorus (P),85% of the potassium (K), 44% of the sulphur (S) and 85% of the silicon (Si) taken up by rice plants. Incorporation of straw into the soil therefore returns much of the nutrients taken up by the crop. The straw should be spread uniformly in the field to avoid creating 'nutrient hotspots'.

Where mineral fertilizers are used and all the straw is incorporated, reserves of soil N, P and K are maintained or even increased and micronutrients (e.g. zinc) are also returned to the soil.

Burning straw results in the loss of almost all the N content, but losses of P, K and S are smaller. Burning also results in 'hotspots' of nutrient accumulation in parts of the field where the fires occurred while other parts of the fields get depleted. Burning is, however, less labour intensive than incorporating straw into the soil.

Early, dry, shallow tillage (5–10 cm depth) to incorporate crop residues and enhance soil aeration during fallow periods has been shown to increase N availability up to the vegetative growth phase of the succeeding rice crop. Shallow tillage of dry soil requires a four-wheel drive tractor and should be carried out up to 2–3 weeks after harvest in cropping systems where the dry-moist fallow period between two crops is at least 30 days.

Note: Incorporation of straw and stubble when wet soil is ploughed results in a temporary immobilization of N. Crop establishment should be carried out 2–3 weeks after straw incorporation; alternatively, urea (as a source of N) should be applied along with straw. However, the benefits to yield from incorporation of crop residues are greater in the long term.

Crop rotations

In **upland rice:** Rice can be rotated with crops including maize, sorghum, millet, cotton and legumes, such as cowpeas and beans.

Farmers tend to prefer to apply nutrients to rice and maize rather than sorghum and millet as the returns to investment are higher. Rice is the most profitable crop to apply fertilizer because it responds well to fertilizer and also because of the high price it attracts in the market. Although minimal amounts of nutrients are applied to legumes, legumes that fix nitrogen can contribute to improved soil fertility and hence indirectly lead to improved rice yields in subsequent rotations.

In **lowland rainfed rice:** Rice can be rotated with vegetables like potatoes (sweet and Irish), okra, tomatoes and aubergine, and also with legumes such as beans.

In **lowland irrigated rice:** A rice crop can be followed by another rice crop, or vegetables such as onions (shallots), tomatoes and okra. Vegetables tend to be more profitable than rice. Farmers tend to apply mineral fertilizers and a lot of organic fertilizers to vegetables and less on rice, but rice grown after a vegetable crop can benefit from the residual fertilizer.

Africa Soil Health Consortium – improving soil fertility, improving food production, improving livelihoods

ASHC works with initiatives in sub-Saharan Africa to encourage the uptake of integrated soil fertility management (ISFM) practices. It does this primarily by supporting the development of down to earth information and materials designed to improve understanding of ISFM approaches.

ASHC works through multidisciplinary teams including soil scientists and experts on cropping systems; communication specialists, technical writers and editors; economists; monitoring and evaluation and gender specialists. This approach is helping the ASHC to facilitate the production of innovative, practical information resources.

ASHC defines ISFM as: A set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at optimizing agronomic use efficiency of the applied nutrients and improving crop productivity. All inputs need to be managed following sound agronomic and economic principles.

This nutrient management guide series is part of the wider cropping systems guide series and is an output of the Africa Soil Health Consortium (ASHC), which is coordinated by CABI.

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