AFRICA soil health consortium

Nutrient management

Maize

Maize nutrient management

The best option to ensure sustainable and profitable maize production is to combine the use of quality seed of an improved variety of maize that is well suited to the location with the application of mineral fertilizer and organic matter along with legumes as intercrops or in rotations – in brief, to practice integrated soil fertility management (ISFM).

Fertilizer use

Ideally, farmers should use fertilizer at optimum rates for their purpose in their local area. This should be based on knowledge of the nutrients present in the soil and of local agricultural practices, such as intercropping with suitable legumes and incorporation of manure and crop residues into the soil, and also on expected returns to investments.

Very often, however, such optimum recommendations are not be available. In this case, some blanket recommendations are provided below.

The aim of these recommendations is <u>not</u> to maximise production; rather it is to increase yields from around 1 tonne of grain per hectare, or even less, up to as much as 6 tonnes per hectare (see Table 1, below). Although even larger yields than this are possible, and commonly achieved on large-scale commercial farms in developed countries, the aim here is to increase yields in a cost-effective way that is likely to be within the reach of smallholder farmers in Africa.

The recommendations are intended primarily for use when improved varieties are being grown: it is less likely to be cost-effective to use fertilizer on traditional varieties.

Table 1: Average current and achievable yields in maize-legume systems when good seed, fertilizer and other good agronomic practices described in this guide are followed

Crop	Yield under traditional system (tonnes per hectare)	Potential yield with adoption of good agricultural practices (tonnes per hectare)
Maize	0.5-1.2 or less	1.5-6
Legume	0.5 or less	1-3

Fertilizer response curves
The way that maize and other crops respond to fertilizer on responsive soils (see box *Responsive and non-responsive soils*) can be described by a nutrient response curve: this shows the impact of increasing amounts of nutrients (fertilizer) on yield.

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 – it is here the greatest increase in yield is achieved per unit of fertilizer added. So, the recommendations given below aim to fall on the steepest part of the response 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 deficient in one or more nutrients in addition to nitrogen (N) and phosphorus (P), which are the focus of the recommendations
- whether the soils are responsive or non-responsive to fertilizer (see box)
- weather – especially rainfall
- varieties used
- pest and disease attack
- management practices, such as plant density and arrangement , weeding, timely fertilizer application, incorporation of organic matter to the soil
- quality of mineral fertilizer being used: some fertilizers are sub-standard – they may not contain the amount of nutrients shown on the label

So, if target yields are not achieved following these recommendations, then expert assistance should be sought.

Responsive and non-responsive soils
Soils vary. Some soils respond well to application of mineral fertilizer – the yields achieved increase as more fertilizer is applied (as shown by the nutrient response curve in Figure 5): such soils are called 'responsive soils'. Responsive soils are usually of medium fertility.

Other types of soil do not respond to application of mineral fertilizer - yields increase little or not at all when fertilizer is applied: these soils are called 'non-responsive soils'.

There are two types of non-responsive soils: 1) fertile soils that already contain high levels of nutrients; and 2) soils having another parameter limiting plant growth such as chemical (e.g. soil acidity), physical (e.g. soil hard pan), or biological (e.g. presence of striga weed) constraints, or a combination of all these, and also degraded soils.

Degraded soils are often caused by human activity, such as clearing of natural vegetation and growing of crops such as cereals as monocrops and removing both the grain and the crop residue.

Even though degraded soils are likely to contain low levels of nutrients, often they will need large amounts of organic materials to be applied for a number of years before they respond to application of mineral fertilizers.

The 4Rs
The guidelines below are based on the '4Rs' - that is the right source, the right rate, the right time and the right placement of fertilizer.

Right source and rate
If site specific fertilizer recommendations are available these should be followed. In case these are not available, Table 2 provides some examples of basal and top-dressing options for neutral to alkaline soils (pH greater than 6.5) and Table 3 for soils with acidic soil (pH of 6.5 or less).

Usually nitrogen is the first limiting nutrient for maize production followed by phosphorus, so these guidelines focus on just these two key nutrients.

In addition to N and P, potassium (K) should be applied on sandy soils or soils low in or lacking potassium: Table 3 includes N, P and K.

Basal fertilizer is applied when the plot is being prepared for planting or at the time of sowing seed. It provides nutrients needed by the crop early in its growing cycle and also nutrients which are slowly released over the growing season. The main nutrient needed by maize at this stage in the growing cycle is phosphorus (P). About a third of fertilizer nitrogen (N) can also be applied at planting.

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

It provides nutrients, especially nitrogen, that are needed later in the crop's growing cycle and also nutrients which, if applied earlier, would be easily lost from the soil before the plant could take them up. The main nutrient needed by maize at this stage in the growing cycle is nitrogen (N). About two thirds of fertilizer N can be applied as top-dressing.

Table 2: Examples of basal and top-dressing fertilizer options for maize grown in neutral to alkaline soils (pH of 7 and above)

Target yield t/ha[1]	Nutrient rates kg/ha			Basal fertilizer at planting	First topdressing		Second[4] topdressing	
	N	P	K	DAP kg/ha (g/hole[2])	Either urea kg/ha (g/hole)	Or CAN kg/ha (g/hole)	Either urea kg/ha (g/hole)	Or CAN kg/ha (g/hole)
2	30	10	20	60 (2.3)	20 (0.7)	40 (1.5)	20 (0.7)	40 (1.5)
3	60	20	40	120 (4.5)	40 (1.5)	80 (3)	40 (1.5)	80 (3)
4	90	30	60	180 (6.7)	60 (2.3)	120 (4.5)	60 (2.3)	120 (4.5)
5	100[3]	40	80	240 (9)	80 (3)	160 (6)	80 (3)	160 (6)

[1] Current yield assumed to be around 1 tonne per hectare.

[2] Based on spacing of 0.75 m between rows and 0.5 m along rows, equivalent to 26,667 planting holes per hectare, with 2 plants per hole.

[3] Not more than 100 kg N should be applied per hectare.

[4] If applying top dressing only once, apply the amount recommended for the first and second top dressing together, e.g. for a target yield of 2 tonnes per hectare apply 40 kg per hectare of urea.

DAP and urea can make soils more acidic. Maize does not grow well in acidic soils so, for soils with a pH of 6.5 or less, other fertilizers should be used, such as an NPK fertilizer at planting and topdressing with CAN. Table 3 provides examples of suitable basal and top dressing fertilizer recommendations for acidic soils.

Table 3: Examples of basal and top-dressing fertilizer options for maize grown in acidic soils (pH of 6.5 or less)

Target yield (t/ha)	Nutrient rates kg/ha			Basal fertilizer at planting	Topdressing
	N	P	K	NPK 15-15-15 kg/ha ((g/hole)	CAN kg/ha ((g/hole)
2	30	10	20	150 (5.6)	30 (1.1)
3	60	20	40	300 (11.3)	60 (2.3)
4	90	30	60	450 (16.9)	90 (3.4)
5	100	40	80	600 (22.5)	120 (4.5)

For a legume intercrop, fertilizer P can be applied at planting at a rate of about 20 kg P per hectare (e.g. about 100 kg of TSP or DAP). If the legume is grown after a maize crop that had P applied, then the legume can benefit from the residual P left in the soil – so in this situation, it may not need to be fertilized with P.

Farmer friendly fertilizer measurements
It is difficult for farmers to know what 2.3 g of DAP or 5.6 g of NPK fertilizer 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[1]. The bottle-top can then be used as a scoop for measuring fertilizer.

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 or rectangular container filled with a range of fertilizers.

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

To apply 2.3 g of DAP per planting hole, about 1 bottle-top measure is needed for every 2 holes.

To apply 5.6 g of NPK 15-15-15, about two bottle-top measures are needed per hole.

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 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
NPK 15-15-15	3
SSP	3.5
TSP	7
Urea	4

Right time and place

The basal fertilizer should be placed in the bottom of the planting hole and covered with a little soil. The seed is then planted on top – the seed and fertilizer must not touch as this can damage the seed. The hole is then covered with more soil.

1 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 cm^3). It has 21 ‘teeth’.

Before the top-dressing is done, or at the same time, the plot should be weeded so the fertilizer benefits the maize not the weeds. The top-dressing fertilizer should be applied when the maize is knee-high (45-60 cm tall). In high rainfall areas (greater than 1000 mm during growing period) and also where soils are sandy it is best to top dress in two equal splits, at 3 and 6 weeks after germination.

Top dressing should be done when the soil is moist. Fertilizer can either be applied in a circle around each plant or along the row; in both cases the fertilizer should be applied about 10 to 15 cm from the base of the plants and covered. The fertilizer should not be allowed to touch the plants. It should be covered with soil, for example by hoeing.

Farmers need to think carefully before they decide to top dress their maize crop as they could be wasting their money. Top dressing can lead to increased yields, but only if the crop is developing well under favourable climatic conditions; increased yields can then be profitable if good crop prices are expected. The value of the expected increase in yield should be at least twice the total cost related to fertilizer use. If the crop has developed poorly because of poor rainfall and/or the price of maize is expected to be low, top dressing can be cancelled and the fertilizer set aside for the next planting season.

Use of manure

When available, livestock manure can be an important resource for improving maize yields. Applying manure together with mineral fertilizers gives better yields than using either manure or fertilizer alone.

Other than N and P, manure also contains potassium, calcium and magnesium in addition to other nutrients. These nutrients become available to plants as the manure decomposes.

Apart from contributing to improved soil fertility, manure also:

- improves soil structure, soil aeration, soil water infiltration rate and soil water-holding capacity
- if soil is acidic, helps reduce soil acidity – this improves the capacity of the soil to store nutrients.

These attributes make manure a key resource in low production systems on smallholder farms across sub-Saharan Africa, particularly on sandy soils.

However, manure contains a lower density of nutrients compared with mineral fertilizers and the nutrient content varies due to management and other factors: as an example, 100 kg of farmyard manure might typically contain about 1 kg of N and 0.8 kg of P (1.8 kg P_2O_5); 100 kg of urea contains 46 kg of N, and 100 kg of DAP contains about 18 kg N and 22 kg P (46 kg P_2O_5).

If the same amounts of nutrients provided by mineral fertilizers in Table 2 were to be supplied only by farmyard manure, the farmer would need to apply 5-10 tonnes per hectare, or about 200-400 g per planting hole, to meet the demand for nitrogen for just a 1 tonne per hectare increase in yield. In most cases, this amount of manure will not be available; even if it is, it might not be cost-effective to transport the manure to the field and pay for labour to apply it.

Because using manure in combination with fertilizer gives better yields than using either input alone, if possible some manure should be applied. Compared to mineral fertilizer alone, applying both farmyard manure and mineral fertilizer means that the amount of mineral fertilizer can be reduced. However, unlike for mineral fertilizers where nutrients are readily available to plants for uptake, not all nutrients in manure are readily available immediately after application – they will become available over the next few years as the manure decomposes and releases its nutrients. So, for example, for every 1 tonne of farmyard manure applied per hectare, the amount of urea can be reduced by 12 kg in the first year after manure application, 6 kg in the second year and 3 kg in the third year. So, for example, if the target yield is 2 tonnes per hectare, in which case the recommended first top dressing would be 20 kg per hectare, this could be reduced to 8 kg in year 1, 14 kg in year 2 and 17 kg in year 3.

Other organic matter

There is a wide range of organic inputs other than manure that are used by farmers for soil fertility management. These include:

- Cereal residues, for example maize stover. These residues have low nutrient densities: they do not have as much N as legume residues and take longer to release nutrients.
- Legume residues, for example soybean, cowpea and groundnut residues. These residues have more N and take less time to decompose than

cereal residues.

- Organic inputs derived from nitrogen-fixing trees or green manure crops, which generally have relatively high N contents and release nutrients in the short term.

Legumes, nodulation and inoculation

Legumes have the ability to take nitrogen gas from the atmosphere and make this available to plants by forming nodules with soil-inhabiting bacteria called rhizobia.

Some of the benefits of successful biological nitrogen fixation include:

- Reduced uptake of soil N by the legume therefore sparing soil N for use by other crops, e.g. in maize-legume intercrop
- The stover and fallen leaves from the legume enrich the soil with N, hence successive crops are able to use the released nutrients.

Legumes vary widely in their ability to form root nodules with indigenous rhizobia. Some, such as soybean and chickpea, nodulate with a restricted number of rhizobial strains or species and are thus considered as 'specific' in their rhizobia requirement. Cowpea, however, is 'promiscuous'-it nodulates with a wide range of rhizobia found in many soils.

In many cases, therefore, soybean and chickpea need inoculation unlike cowpea and groundnut. Some soybean varieties are promiscuous – but inoculation can still improve their yields (see box *Legumes should be inoculated if...*). Inoculation simply means bringing the appropriate rhizobia into contact with legume seeds.

The situation with common bean is less clear. Most experimental results indicate small and highly sporadic responses to inoculants, though some scientists recommend inoculation with rhizobia.

Box : Legumes should be inoculated if...

Research or previous experience shows it is beneficial. The number of rhizobia in the soil may be inadequate or of poor quality.

The legume is being introduced to an area. Effective rhizobia for the legume may be absent in the soil.

More effective rhizobia for a legume, or for a legume variety, have been identified and packaged for use.

When to intercrop

Intercropping of maize with grain legumes can be practical and beneficial on small farms (less than 2 hectares). Higher yields are achieved when the intercrops have different rooting systems, a different pattern of water and nutrient demand, and a different aboveground habit. This results in more efficient use of water, nutrient and sunlight. Many grain legumes meet these criteria and are therefore suitable for intercropping with maize.

Where to intercrop

Intercropping should be practiced in areas with soil and climatic conditions that meet the requirements of both maize and legumes as indicated in Table 3.

The choice of the legume intercrop should be based on local recommendations which are adjusted to the agro-ecological conditions, growing season crop and local demand.

Table 3: Climatic and soil requirements of selected maize-legume intercropping systems in tropical and sub-tropical Africa.

Type of inter-cropping system	Altitude (metres above sea level)	Rainfall during growing period (mm)	Temperature (minimum -maximum)	Soils
Maize-bean	800-1,800	700-1500 mm	10-30°C	Well-drained loams, moderate to high fertility pH 5-7.5
Maize–soybean	900-1,500	700-1500mm	20-30°C	Well-drained sandy clay loams, moderate to high fertility pH 4.8-7
Maize–groundnut	900 -1,500	250-650 mm in 3-4 months or 650-1,300 mm in 4-5 months	20-30°C	Well-drained, light sandy soils, pH 5.2-6.5

Maize–cowpea	500 -1,500	400 -900 mm	20 - 30° C	Well-drained, heavy to light sandy soils moderate to high fertility pH 4.8 – 7
Maize - pigeopea	900 -1,500	800– 1,000 mm	20 - 30° C	Well drained, sandy clay loam soil, moderate to high fertility, pH 4.8 – 7 (for maize) Pigeonpea can tolerate saline (salt) soil

How to intercrop

Spatial arrangement of maize and legume is critical in determining the growth, yield of intercrops and other benefits accruing from intercropping.

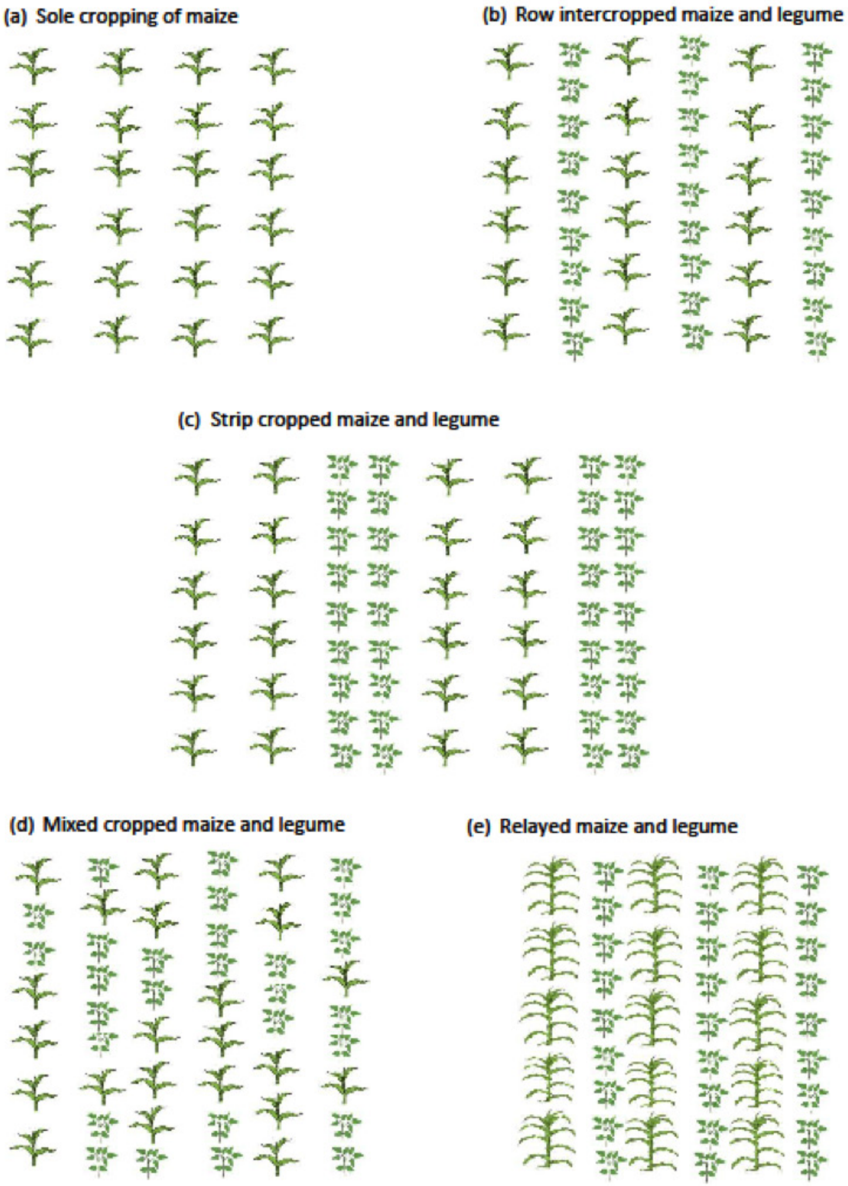
Intercrop planting arrangements often involve the **substitution** of maize with the legume so that the total number of maize plants per hectare is decreased. Other arrangements are **additive** where the maize is maintained at the same population density as in the sole crop and the legume is simply planted in between.

Types of intercropping maize and legumes

See Figure 3 for examples of plant arrangements. Note: The figures are not drawn to scale, and spacing between and within rows is not representative of actual spacing.

Figure 3: Examples of maize-legume intercropping arrangements

Row intercropping - Figure 4 (a): Growing maize and a legume in well-defined rows. Sometimes the plant population for the two crops can be close to that found in sole crops. For example, maize is planted at its recommended planting density, but every-other row is shifted to provide a wider alternate inter-row for legume. This arrangement works best where peak nutrient demands and duration to maturity for the two crops differ. A good example is maize-bean, in which maize and beans are planted in alternate rows, and the spacing of maize is close to that found in sole crops (e.g. spaced at 75cm


(a) Sole cropping of maize
(b) Row intercropped maize and legume
(c) Strip cropped maize and legume
(d) Mixed cropped maize and legume
(e) Relayed maize and legume

between rows, 50cm within rows, 2 plants per hole).

Strip intercropping – Figure 4 (c): Growing maize and legume in strips wide enough to permit independent cultivation but narrow enough for the crops to interact. This plant arrangement permits more light to reach the shorter legume. Legumes that benefit from this arrangement include groundnuts, soybean, common beans and cowpeas. In strip cropping the maize plant population may be lower than in sole crops but similar yields can be achieved. A good example is the MBILI System: two rows of maize alternating with two rows of legume. This arrangement gives better yields and is more profitable than row intercropping. It requires less labour and gives better increase in yield on application of modest amounts of fertilizer.

Mixed intercropping – Figure 4 (d): Traditional practice where maize and a legume are grown together in no distinct row arrangements.

Relay intercropping – Figure 4 (e): Planting legume into a standing crop of maize. The aim is to avoid the legume smothering young maize plants and reduce competition compared to if both are planted at the same times. For good yields, the rainfall distribution should allow for adequate moisture during peak growth periods and dry periods during harvesting of both crops. A good example is sowing of cowpeas about 6 weeks after the maize is sown. This ensures that the faster growing cowpea does not smother maize plants. In case of drought, there is a good chance that cowpea will give some yield even if maize fails to give any yield.

Within row intercropping – Figure 5: Growing maize and legumes in alternate planting stations within rows. A good example is the additive mixed intercrop design for maize-pigeonpea intercrop. The maize is planted in stations of three plants rather than evenly spaced within the row, which leaves space for stations of three pigeonpea plants in between. This arrangement gives the same maize plant population as when maize is evenly spaced within the row, but gives space for planting a legume intercrop. Perhaps surprisingly, the yield of maize when grown in these clusters of three plants is the same as if the same number of plants is spaced individually – i.e. the competition effect on the maize is minimal.

Advantages and disadvantages of intercropping and rotations

The decision on whether to intercrop or rotate maize with legumes should depend on careful consideration of the advantages and disadvantages. These in turn depend on many factors including varieties available and biophysical and socio-economic conditions under which the farmer is operating.

The following are advantages of growing maize and legumes in the same system:

- **Soil fertility improvement:** With the presence of the right bacteria (rhizobia), legumes can fix nitrogen gas from the atmosphere thereby reducing the need for nitrogen from mineral fertilizers or manure. Some grain legumes with deep roots, such as pigeonpea and lablab, also take up nutrients from deep layers thereby recycling nutrients leached from the surface. The fixed nitrogen and other nutrients in the legume intercrop become available to the subsequent maize crop when the nitrogen-rich leaves fall and decompose.
- **Improved utilization of resources:** Intercropping allows for a more efficient use of available resources (sunlight, moisture and soil nutrients) and can result in higher productivity per field when the yields of both crops are taken into consideration. Properly chosen intercrops, such as pigeonpea, may be grown in the same field as maize without reducing maize yields -so, the pigeonpea becomes a 'bonus' yield. Also, the next crop can benefit from the residual fertilizer applied to the previous crop; for example, the legume can utilize residual phosphorus applied to a previous maize crop.
- **Improved soil cover:** Intercropping results in better soil cover. This has advantages of better weed control, reduced erosion and nutrient leaching, and improved soil structure and soil microbial activity.
- **Reduced risk:** Different crops have different periods and patterns of growth. If one of the crops fails because of adverse conditions, such as drought, disease, or attack by pests, the other crop may not respond in the same way to the stress and may give some yield. This will help improve food security in the household.
- **Improved diet for farming households:** Carbohydrates from maize can be supplemented with protein-rich legume grains, and vitamin and mineral-rich legume leaves for improved nutrition and health.
- **Improved availability of fodder and manure:** The nitrogen-rich residues of legume can be fed to livestock. The manure produced can be applied in the field to recycle back the nutrients contained in crop residues.

- **Reduced spread of pests and diseases:** Pest and diseases can be less serious in intercrops. This is because the pest or disease may not spread as easily in the intercrop as in the monocrop. One crop may produce substances that drive away the pests from the other crop or may attract their natural enemies. For example, when maize is intercropped with desmodium (a fodder legume), desmodium produces a chemical that 'pushes' stem borer moths away from maize plants.
- **Provision of staking materials** – Climbing beans planted in relay with maize: the stem of the maize plant can act as staking material.

Disadvantages of maize-legume intercropping

- Limited scope for some agronomic operations in intercrops. Carrying out operations, such as weeding and even harvesting, can be more difficult than in sole crops.
- Depending on the intercrops, competition for water, light and nutrients may give lower yields. This is why it is important to select the correct spatial arrangement for the intercrop being grown to minimize competition between the two crops, e.g. adopting the MBILI system instead of alternate rows.

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.

AFRICA soil health consortium

CABI

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CABI, Canary Bird, 673 Limuru Road, Muthaiga, PO Box 633-00621, Nairobi, Kenya Tel: +254 (0)20 2271000/ 20 Fax: +254 (0)20 4042250 Email: Africa@cabi.org http://africasoilhealth.cabi.org/