Maize-legume cropping guide

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Maize-legume cropping systems

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Please cite this publication as: Frederick Baijukya, Lydia Wairegi, Ken Giller, Shamie Zingore, Regis Chikowo and Paul Mapfumo (2016) Maize-legume cropping guide. Africa Soil Health Consortium, Nairobi.

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The Africa Soil Health Consortium (ASHC) mission is to improve the livelihoods of smallholder farmers through adoption of integrated soil fertility management (ISFM) approaches that optimize fertilizer use efficiency and effectiveness.

ASHC books are available at special discounts for bulk purchases. Special editions, foreign language translations and excerpts can also be arranged.

ISBN (paperback): 978-1-78064-554-4
ISBN (e-book): 9781780645971
Typeset by Sarah Twomey

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Acknowledgements

The preparation of this guide was supported by the Bill & Melinda Gates Foundation.

We thank:

Farmers for information and for allowing photographs to be taken on their farms.

IPNI for giving permission for use of nutrient deficiency photographs from the IPNI library.

Leonard Rusinamhodzi for sharing and allowing use of his data.

Wondimu Bayu for reviewing the guide.

Keith Sones for editing the guide.

IITA, WUR, IPNI, University of Zimbabwe and CABI for the time the authors spent writing this guide.

Contents

1. Introduction

This is the full-colour version of the maize-legume cropping guide. French and Portuguese versions are also available. Black and white (easy print) versions are also available in all three languages.

This cropping guide is one in a series being produced for extension workers by the Africa Soil Health Consortium (ASHC). The series also covers banana-coffee, cassava, groundnut, rice, sweetpotato and sorghum-millet systems, but this one is focused on maize-legume systems. For legumes, it mostly focuses on the 'big five' – common bean, groundnut, cowpea, soybean (also called soya bean) and pigeonpea.

The guide aims to provide, in a single publication, all the most important information needed to design and implement effective systems which combine maize and legumes – but with the primary focus on maize. It starts with simple clear explanations of the underlying principles before going on to provide practical guidance.

ASHC is primarily focused on the needs of smallholder farmers in Africa but the content will also likely be relevant and useful to emerging and commercial farmers.

The ASHC mission is to improve the livelihoods of smallholder farmers through adoption of Integrated Soil Fertility Management (ISFM) approaches that optimise fertiliser use efficiency and effectiveness. The overarching framework for the guide is therefore provided by ISFM.

The overall objective is to provide guidance on how to achieve sustainable increases in yields through the adoption of best practises that exploit the advantages of maize-legumes systems, increasing maize yields from around 0.5-1.2 tonnes per hectare (or even less) to 1.5-6 tonnes per hectare and increasing legume yields from less than 0.5 tonnes per hectare to 1-3 tonnes per hectare.

Maize does well in suitable sub-humid zones. Increasingly, however, farmers are growing maize in more marginal areas. Maize can be successfully grown even in areas sometimes considered to be too dry. This guide therefore provides practical guidance for growing maize-legumes in the sub-humid zones as well as in more challenging environments.

This guide has a bias towards East, Central and Southern Africa – due to the experience of the authors - but it will also be relevant and useful in West Africa.

2. Choosing from the basket of available options

This chapter explains the principles which determine which options should be used in maize-legume systems. This is followed in the next chapter by practical guidelines based on these underlying principles.

Soil and climatic requirements for maize

Soils

Maize grows well in deep fertile soil that is well drained, with good water holding capacity and rich in organic matter. The soil can range from heavy clay to light sandy soil but loam or sandy-loam soils are preferable.

Ideal soil pH is 5.6 to 7.5 (slightly acidic through neutral to slightly alkaline).

Temperature

The optimum air temperature for maize growth ranges between 18 and 32°C. Growth is severely reduced at air temperatures above 35°C and below 10°C.

Germination will be faster and less variable at soil temperatures of 16 to 18°C.

Water

Maize usually needs about 500-1500 mm of rainfall per growing season although some maize types can do well with as little as 250 mm of rainfall. The crop requires more moisture during flowering and grain filling. Actual rainfall requirements depend on type of maize.

Soil and climatic requirements for intercropping

If intercropping, the choice of the legume intercrop should be based on presence of soil and climatic conditions that meet the requirements of both maize and the legume of choice (see Table 1).

For sole-cropped legumes, rainfall requirements during the growing period (not total annual rainfall) are about 300-500 mm for most beans; climbing types, which take longer to grow, can require up to about 1000 mm; 400-900 mm for cowpea; 700-1000 mm for soybean and 500-700 mm for groundnuts.

Table 1: Soil and climatic requirements for selected maize-legume intercrop systems.

System	Soil pH range	Other soil characteristics	Temperature range (°C)	Growing period rainfall (mm)
Maize-bean	5.5-6	Well-drained loams	15-27 Bean germination requires a soil temp of at least 15	500-1500 Excessive rain & hot weather cause bean flowers and pods to drop & disease incidence to increase
Maize-cowpea	6-7	Well-drained, sandy loam to clay loam soils	20-30	400-900
Maize-groundnut	5.5-7	Well-drained, light sandy loams, groundnut harvesting difficult in heavy soils	18-33 Groundnut germination requires a soil temp of at least 20	500-1300
Maize-pigeonpea	5-7	Well drained, heavy to light sandy soils	18-30 Pigeonpea germination requires a soil temp of at least 19	600-1000
Maize-soybean	6-6.5	All except sandy, well-drained	18-30	700-1500

Maize types

Maize is commonly grouped according to the approach used to develop varieties and also according to the length of growing/maturity periods.

Maize grouping by method to develop varieties

Several maize plants with different characteristics can be allowed to cross among themselves and produce seed. These types of maize are referred to as ‘open pollinated’ varieties (OPVs). Traditional maize types fall under this category. These maize types tend to have modest yields (Table 2) and after successive generations yields become poor.

Sometimes, seed from several OPV genotypes is grown together and encouraged to cross to form a ‘composite’ variety - this mixture is normally promoted as ‘improved OPV’.

For OPVs, farmers can use seed from the previous crop for 2-3 seasons after which they should obtain fresh seed.

When two inbred lines are crossed by skilled plant breeders, the yield of the plants grown from the resulting seed can be greatly increased compared with that of the parents. Such plants are called hybrids. Hybrids also have better yields than the OPVs, especially when grown under favourable conditions.

Grain from a crop grown from hybrid seed should not be used as seed - fresh hybrid seed has to be acquired every season as yield from such seed would be much less than that obtained in the first crop.

Table 2: Comparison of open pollinated and hybrid maize varieties.

Factor	Open pollinated varieties (OPVs)	Hybrids
Yield potential (rainfed)	3-6 tonnes per hectare	Up to 8 tonnes per hectare
Seed requirements	Can use farmer-saved seed	Fresh seed every season
Cost of seed	Usually cheaper per kg and does not need to be bought each year	Usually more expensive and needs to be bought every season
Characteristics	Tend not to be uniform Local OPVs more tolerant to low soil fertility	Vigorous growth Uniform
Local acceptance	Some farmers believe they taste and store better	
Response to fertilizer	Moderate responses (moderate nutrient use efficiency)	Tends to be good if nutrients are deficient in soil (high nutrient use efficiency)
Ecologies	Suitable for ecologies with modest potential and erratic rainfall	Suitable for high potential areas

Maize grouping by length of growing season

Maize varieties can also be grouped according to the time taken to reach maturity after planting (Table 3). For example, some varieties mature in about 3 months while others can take 6 months or more. A variety will mature earlier at lower altitudes where it is warmer than at upper, cooler altitudes.

Table 3: General characteristics of different maize types grouped by maturity period.

Maturity group	Days to harvest	Rainfall required in growing period (mm)	Yield potential (tones/ hectare)	Additional notes
Very early	Up to 95	250-500	3-5	Can mature before drought sets in Can permit growing of 2 crops in the same season Tend to be OPVs
Early	130-135	250-700	3-5	Escape drought Permit double cropping Tend to be OPVs
Medium	130-155	750-1000	5-10	High potential areas Hybrids and OPVs
Late	More than 150	800-1500	5-10	High potential areas

Legume types

Legumes can be grouped into three main groups depending on how they are used: grain legumes provide food for people, fodder legumes are used to feed livestock and tree legumes provide fodder and wood.

This guide focuses on grain legumes because they are most associated with the maize systems – here the term 'legume' will in most cases be used to refer to grain legumes.

Important grain legumes in Sub-Saharan Africa include common bean, soybean, cowpea, pigeonpea, groundnut as well as lentil, chickpea, faba bean, green gram, field pea, dolichos bean and butter bean. This guide will focus more on the first five of these which are the most widely grown in the region.

Different legume types can be grouped according to their architecture (e.g. erect, bush, creeping, runner or climbing varieties), duration to maturity (see examples in Table 4), whether all pods mature at about the same time requiring one harvest or over a long period requiring several harvests, seed size and seed colour.

Climbing beans yield better than non-climbing types (up to 3-times more) and fix more nitrogen (N) and therefore can contribute more to improved soil fertility. Many varieties of climbing beans do well at high altitudes but there are also varieties suitable for medium altitudes. Climbing beans can also grow in poor soils and some are more tolerant to diseases like root rot and ascochyta blight than bush beans. A disadvantage of climbing beans is that they need something to climb up, such as wooden stakes (see also Box 5).

To meet the plant's requirements for water, early maturing legume types should be grown if the expected duration of rainfall is short or if planting is done late after onset of rains.

Sometimes growing seasons are long enough to allow growing of two crops, one after the other. For example, an early maturing cowpea variety can be planted at the beginning of the rainy season and harvested after two months and then maize can be planted soon after and harvested at the end of the season.

Medium and late maturing pigeonpea varieties can be intercropped with early maturing maize as the maize will mature early and competition between the two crops will not be intense. Early maturing pigeonpeas are not suitable for intercropping. Unlike medium and late maturing pigeonpeas, early maturing types have peak nutrient demands at about the same time as maize. They also do not have a very deep tap-root (Box 1): a deeper taproot allows the plant to access moisture and nutrient reserves at deeper depths.

Table 4: Beans, soybean, cowpea and pigeonpea grouped according to days to maturity.

	Maturity group	Days to maturity
Beans	Early	Up to 94
	Medium	95-104
	Late	More than 104
Soybean	Early	Up to 100
	Medium	100-120
	Late	More than 120
Groundnut	Early	Up to 110
	Medium	111-130
	Late	More than 130
Cowpea	Early	Up to 70
	Medium	70-90
	Late	More than 90
Pigeonpea	Early	Up to 150
	Medium	151-180
	Late	More than 180

Box 1: Pigeonpea compared to other legumes

Pigeonpea can do well even in low phosphorus (P) soils. The deep root system of medium and late maturing types allows uptake of nutrients at greater depths. Some of these nutrients become available to the next crop.

Pigeonpea is drought tolerant.

If parasitic yellow witchweed (*Alectra vogelii*) is an issue – pigeonpea and dolichos bean are less susceptible than soybean, cowpea and groundnuts.

Maize-legume cropping systems

Maize-legume cropping systems can be divided into two major classes: 'simultaneous' systems, in which the components are grown together at the same time, and 'sequential' systems or rotations, in which one crop follows the other in the next cropping season.

The simultaneous systems include all types of maize-legume intercropping.

Examples of sequential systems are grain legumes in rotation with maize.

Some systems have features of both types; for example, in relay intercropping, grain legumes are planted into the developing maize crop and become a sole legume crop once the maize is harvested and removed from the field.

The primary interactions between plant species in simultaneous systems are direct and can be either negative (interspecific competition) or positive (facilitative).

Interactions in sequential systems are principally due to modification of the environment for the succeeding crop, often termed residual benefits.

Whether it is best to grow legumes and maize together as intercrops or separately in rotations depends on the balance between complementarity in growth and competition, as well of course as the priorities given to yields from the different crops.

Simultaneous systems

The advantages of growing maize and legumes simultaneously result from many factors, including benefits from nitrogen-fixation, more efficient capture and use of resources for growth such as light and water, and reduction of pest and disease damage due to avoiding a monoculture.

The advantage of intercropping over sole cropping is commonly expressed in terms of the land equivalent ratio (LER) (see Box 2). This is simply an expression of the relative area required by sole crops to produce the same yield as intercrops. A value of LER greater than 1 indicates an overall biological advantage of intercropping.

The crops should be grown at their optimal densities in both sole stands and mixtures otherwise the advantages of intercropping may be overestimated. Of course the economic value of crops and other reasons for growing legumes, such as impacts on household nutrition, must also be considered when evaluating benefits from intercrops.

Box 2: Calculating the LER

The benefit of growing maize and legume intercrops can be assessed by calculating the land equivalent ratio (LER) where:

$$\text{LER} = \left[\frac{\text{yield of intercrop maize}}{\text{yield of sole crop maize}}\right] + \left[\frac{\text{yield of intercrop legume}}{\text{yield of sole crop legume}}\right]$$

This equation provides the means to compare the yield of intercrop with the yield of sole crops per unit area. The LER is greater than 1 when the intercrop yields more than sole crops grown on the same area. For example, if the yield of sole maize is 2 tonne/hectare and sole legume yield is 0.5 tonne/hectare and the intercrop yields 1.5 tonne/hectare maize and 0.25 tonne/hectare legume, the LER is:

$$\text{LER} = \left[\frac{1.5}{2.0}\right] + \left[\frac{0.25}{0.5}\right] = 1.25$$

In this example, the overall yield is greater in the intercrop compared with the sole crops. This means that an area planted as a sole crop would require 25% more land to produce the same yield as the same area planted in an intercrop combination.

However, to tell if the increased yields were profitable, it is important to compare benefits and costs (see Section 6: *Economics of maize-legume systems*).

The interactions between crop species can be divided into competitive interactions in which the crops compete for the same resource, and facilitative interactions in which one crop alters the environment of the other in a positive way so as to benefit the growth of the other species. Most of the benefits of growing crops in intercrops come from differences in the way they exploit the environment, for instance by rooting to different depths and thus exploiting different parts of the soil (Figure 1), or by having leaf canopies at different heights which might increase the total amount of light intercepted, leading to greater overall resource capture.

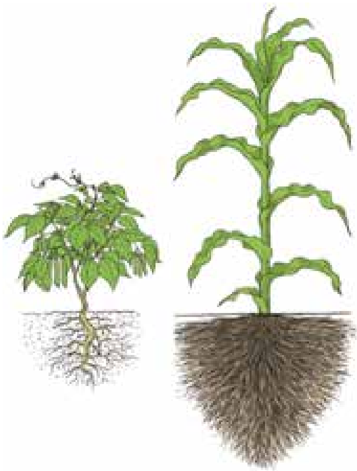

Figure 1: A legume and maize– above and below ground level

In such examples the benefits of intercropping are due to weak competition for resources. In maize-legume intercrops, the benefits of increased N uptake by the cereal are due to the nitrogen-fixing plant 'sparing' soil N, rather than a direct contribution of fixed N for use by the intercropped maize.

Spatial arrangements of maize-legume intercrops

There are many ways that maize and legumes can be planted in intercrops: **within row intercropping** is when maize and legumes are planted in alternate planting stations within rows; **row intercropping** is when maize and legumes are grown in alternate rows; **strip intercropping** is when two or more rows of maize are alternated with two or more rows of legumes, close enough to allow interaction between the crops but wide enough to allow their separate cultivation.

The best spatial arrangement to use depends on the farmers' priorities for maize or legume production, the relative (economic) value of the two crops, but above all on which legume crop is grown: the major grain legumes have different varieties with a wide-range of growth habits (from erect bush varieties to creeping, runner or climbing varieties) and growth durations (from as short as 60 days to maturity to up to 270 days). This means that the choice of legume variety is also important when considering what planting arrangement should be chosen.

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.

A good example of an additive maize-legume intercrop is maize-pigeonpea intercropping.

Maize-pigeonpea intercropping

Medium and late maturing pigeonpea are ideally suited to grow as an intercrop with maize as they develop slowly in the seedling stage and therefore do not compete strongly for water or nutrients (unlike early maturing pigeonpea which would compete with maize). Medium and later maturing pigeonpea should be sown at the same time as maize, in a mixed or row intercropping arrangement. The pigeonpea continues to grow into the dry season, after maize is harvested.

The impacts of maize-pigeonpea intercropping can be spectacular! For example, after three years continuous cropping with no fertilizer added, monocropped maize in Mozambique was yielding less than 0.5 tonnes per hectare due to infestation with witchweed (*Striga asiatica* – Figure 2). By contrast, intercropped maize yielded almost 5 tonnes per hectare with an additional 0.3 tonnes per hectare of pigeonpea grain.

In this example, an NGO was previously recommending to intercrop maize with pigeonpea by substituting rows of maize, which gave less than half the maize yield (less than 2 tonnes per hectare) than when pigeonpea was grown *within* the maize rows in an additive design. In the additive mixed intercrop design three maize plants are planted per station rather than evenly spaced within the row, which leaves space for stations of three pigeonpea plants in between. This local planting 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 was the same as if the same number of plants was spaced individually – i.e. the competition effect on the maize was minimal. In different locations and contexts the results may, however, differ.

The benefit of the pigeonpea to maize is due to the large amount of nitrogen-rich pigeonpea leaves that fall to the ground as the crop matures and adds a lot of organic mulch (and nitrogen) to the soil for the next crop.

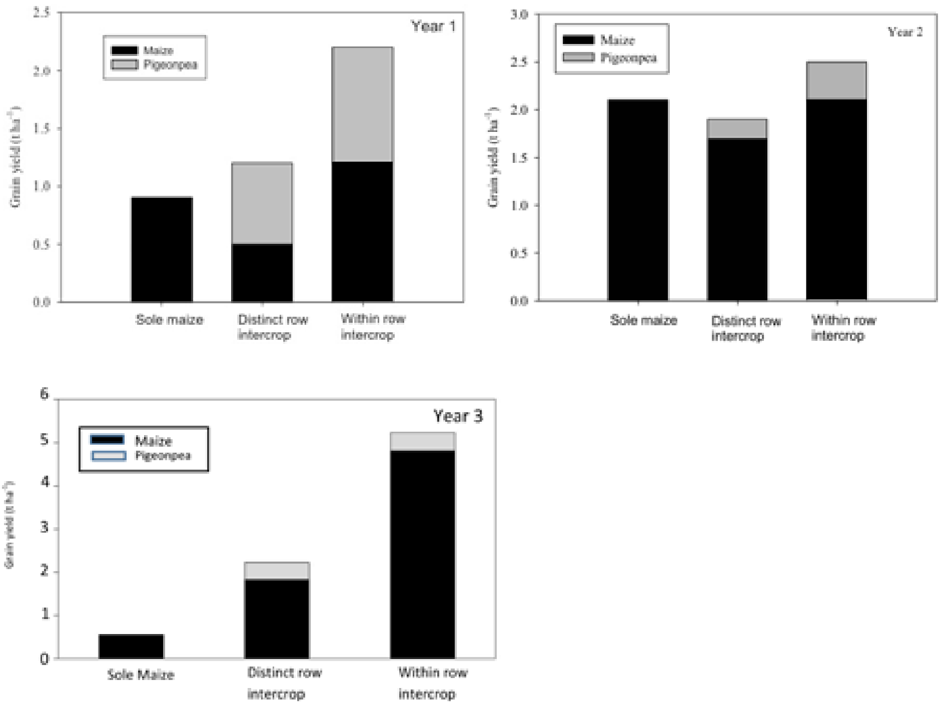

Figure 2: Alternative options of growing maize and pigeonpea, over a 3 year period in Mozambique

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 which varieties are available and the biophysical and socio-economic conditions under which the farmer is operating.

The following are advantages of growing maize and legumes as intercrops:

Soil fertility improvement: With the presence of the right bacteria (rhizobia) in the soil, 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 soil 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 and roots 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 impact 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.

The following are disadvantages of growing maize and legumes as intercrops:

- **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 (see *Types of intercropping maize and legumes*).

Maize-legume rotations

As described above, residual benefits are seen when legumes enhance the growth of maize grown in the next cropping season. Intercropped legumes can also have residual effects, though these are likely to be less than with sole crops as the overall legume biomass, and hence the amounts of N added to the system, are generally reduced.

Soil fertility management options

Legumes, nodulation and inoculation

Legumes have the ability to take nitrogen gas from the atmosphere by forming nodules with soil-inhabiting bacteria called rhizobia. The legume plant supplies the rhizobia with energy as carbon from photosynthesis and in return the rhizobia fix nitrogen gas into a form of combined N that is released into the root nodule and used by the plant for growth (Figure 3).

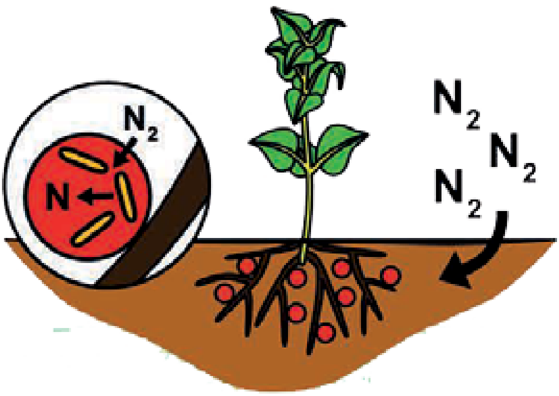

Figure 3: Biological nitrogen fixation

Legumes vary widely in their ability to form root nodules with rhizobia found naturally in the soil. Some, like 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.

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 3).

Inoculation simply means bringing the appropriate rhizobia into contact with legume seeds. Some companies in Africa now formulate, package and market inoculants that contain carefully chosen species and strains of rhizobia for use with specific legume crops. How to use the inoculants varies between products; farmers should check the instructions on the package or ask an agro-dealer or extension worker.

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.

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. maize 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.

Box 3: Pigeonpea compared to other legumes

- Research or previous experience shows it is beneficial. The number of rhizobia in the soil may be inadequate or of poor quality.
- If the legume is being newly introduced to an area. Effective rhizobia for the legume may be absent in the soil.
- If more effective rhizobia for a legume, or for a legume variety, have been identified and packaged for use.

Options for land preparation

Conventional tillage involves cultivating the soil using either a hand-hoe or ox or tractor pulled tools, such as ploughs and harrows. In the process the soil is physically loosened and broken down into a fine tilth, and usually the soil is turned over – surface layers are incorporated and deeper layers of soil brought to the surface. Crop residues and weeds are buried. Most smallholder farmers in Africa practice conventional tillage, many using hand-hoes.

Some experts believe that conventional tillage systems cause a range of problems including:

- Leaving soil exposed to rain, wind and sun leading to soil losses
- Destruction of soil organisms
- Soil compaction, especially if using heavy tractors or draft animals
- Increased water evaporation

- In the long-term, soil crusting which impedes rainfall infiltration, increases surface runoff and reduces groundwater recharge, and development of a hardpan at the bottom of the ploughed or hoed layer which reduces water infiltration and root penetration.

An alternative system has been developed to address these issues – it is called conservation agriculture and has been heavily promoted in Africa over the past few decades, although few smallholder farmers have adopted it.

Conservation agriculture is based on three major principles: disturb the soil as little as possible (minimum tillage); keep the soil covered as much as possible (crop residues and slashed weeds as mulch and also cover crops); and use of intercrops and crop rotations.

In conservation agriculture, planting holes in which the seed is planted are dug by hand or alternatively an ox or tractor pulled ripper is used to cut narrow furrows. The soil between the narrow furrows (or planting holes) is left undisturbed and even in the furrows the soil is not turned over as it is in conventional tillage. The seed is then planted along the ripped furrow.

In conventional tillage systems, weeds are destroyed by burying them during hoeing or ploughing. A major disadvantage of conservation agriculture is that far more effort is needed to control weeds during the growing season. A solution to this problem is to use herbicides, such as glyphosate, at planting time. Some researchers have concluded that conservation agriculture is only viable if farmers have access to appropriate herbicides.

Using herbicides, however, brings additional challenges including the availability of herbicides; the cost of purchasing the herbicides and equipment (sprayers) to apply them; and knowledge about how to use the herbicides in a safe and effective way. Unless farmers have access to expert local advice on conservation agriculture and safe and effective use of herbicides, they would probably be better advised to practice conventional tillage.

Options for soil and water management

The choice of practices should depend on slope of land, labour availability and financial status of the farmer.

As a general guide:

- If slope is slight, less than 2%[1], then intercropping and planting in rows running across the slope (not up and down the slope), and also carrying out farm operations (e.g. ploughing) across the slope, can reduce soil loss and run-off.
- If slope is steeper, 2-5%, physical barriers like trash lines (e.g. made from maize stover), stone bunds (stone lines), or grass strips, all laid across the slope, can be used. Also, the soil can be ridged to trap or slow movement of water down the slope.
- If slope is very steep, more than 5%, terraces (e.g. fanya-juu) should be used. Terraces can also be used on slopes of less than 5% if the soils are easily washed away or drought is a problem. Compared with other practices, terraces and ridging require more labour and are therefore more expensive.

These practices can be used in combination, especially for slopes greater than 5%. For example, grass can be grown on the sharp edge of the terrace, ploughing should be across the slope, and maize can be intercropped with beans.

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[1] 2% slope means for every 100 m travelled horizontally, the ground drops 2 m. This is also called a 1:50 gradient.

See Box 4 for tips on additional management practices for growing maize in dry environments.

Box 4: Tips for growing maize in dry environments

- Tied ridges increase water infiltration and improve rooting depth.
- Use wider spacing within and between rows to reduce competition for soil moisture, especially under drought conditions – up to 1 metre between rows.
- Deep ripping of dry soil allows for early land preparation and trapping and conservation of moisture. Ripping means cutting a narrow slot or furrow in the soil about 5-10 cm deep; unlike ploughing, the soil is not turned over. Ripping is done using a special tool, a ripper, pulled by oxen or a tractor. It looks like a chisel and is attached to the plough frame in place of the ploughshare.
- Choose early maturing varieties.

Key messages

For maize select deep fertile soil that is well drained, with good water holding capacity, rich in organic matter with ideal pH of 5.6 to 7.5. Loam or sandy-loam soils are preferable.

Ideal air temperature for growing maize is 18-32°C.

Depending on maize type, rainfall of 500-1500 mm is usually needed during the growing season. In drier areas special techniques, such as tied ridging, ripping, planting at wider spacing and choosing short duration varieties, will be beneficial.

Choose a maize type suitable to the area, cropping system of choice, target yield and whether the farmer wants to recycle seed from harvested crop or use fresh seed next season.

Choice of legume should be influenced by soil and climatic conditions

Spatial arrangements for maize-legume intercrops depends on farmers' prioritisation of either maize or legume and also the relative value of the two crops, but above all on the legume being grown – whether it is erect, spreading or climbing, and how long it takes to be ready for harvest.

There are advantages and disadvantages associated with intercropping maize with legumes. Advantages include improved soil fertility, increased utilisation of resources, better soil cover, reduced risk, improved household diets, improved availability of fodder and manure and reduced impact of pests and diseases. Disadvantages include increased difficulty of carrying out some farming operations and potential decreases in yields if correct spatial arrangements not selected.

Legumes should be inoculated with rhizobia if it has been proven to be beneficial or a new legume is being introduced to an area.

Use conservation agriculture only if expert local advice is available, especially for safe and effective use of herbicides.

To reduce soil loss and run-off, if slope is less than 2%, intercrop and plant in rows running across the slope and carry out farm operations across the slope; if slope is 2-5%, use physical barriers like trash lines, stone bunds, or grass strips laid across slope, or make ridges across the slope; and if slope is more than 5%, make terraces across the slope.

3. Land preparation and planting

Land preparation

Conventional tillage

The objective of land preparation under a conventional tillage system is to produce a seedbed that is weed-free, with aerated soil into which water can percolate and in which maize seeds can have close contact with the soil, and from which the seedling can emerge easily. This can be achieved by hand using a hand-hoe, or with a plough and sometimes also a harrow pulled by oxen or a tractor.

Soon after harvesting, weeds should be slashed and ploughed or dug into the soil so they can start to rot down and release their nutrients. Any crop residues present can also be incorporated into the soil at this stage.

Preparing a conventional maize seed bed by hand using hoes requires about 8-10 days of manual labour per hectare.

Too fine a seed bed, especially on sandy soils, leaves the plot vulnerable to wind erosion. A coarser tilth reduces the risk of wind eroding the soil but still allows water to infiltrate. Clod sizes should be about 6 cm or less and the soil should be cultivated to a depth of 15-30 cm.

Conservation agriculture

Unless farmers have access to expert local advice on conservation agriculture (no or minimal tillage) and access to and knowledge about the use of inputs such as herbicides, they would be better advised to practice conventional tillage.

Intercropping

Intercropping of maize with grain legumes can be practical and beneficial on small farms (less than 2 hectares): on large, commercial farms intercropping makes mechanized procedures such as weeding and application of fertilizer or pesticides more difficult and so it tends not be used.

Higher yields are achieved when the intercrops have different rooting systems, a different pattern of water and nutrient demand, and a different above ground growth 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 5.

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

Type of intercropping system	Altitude (metres above sea level)	Rainfall during growing period (mm)	Ideal temperature for night-day (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 – pigeonpea	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 soils

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 4 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.

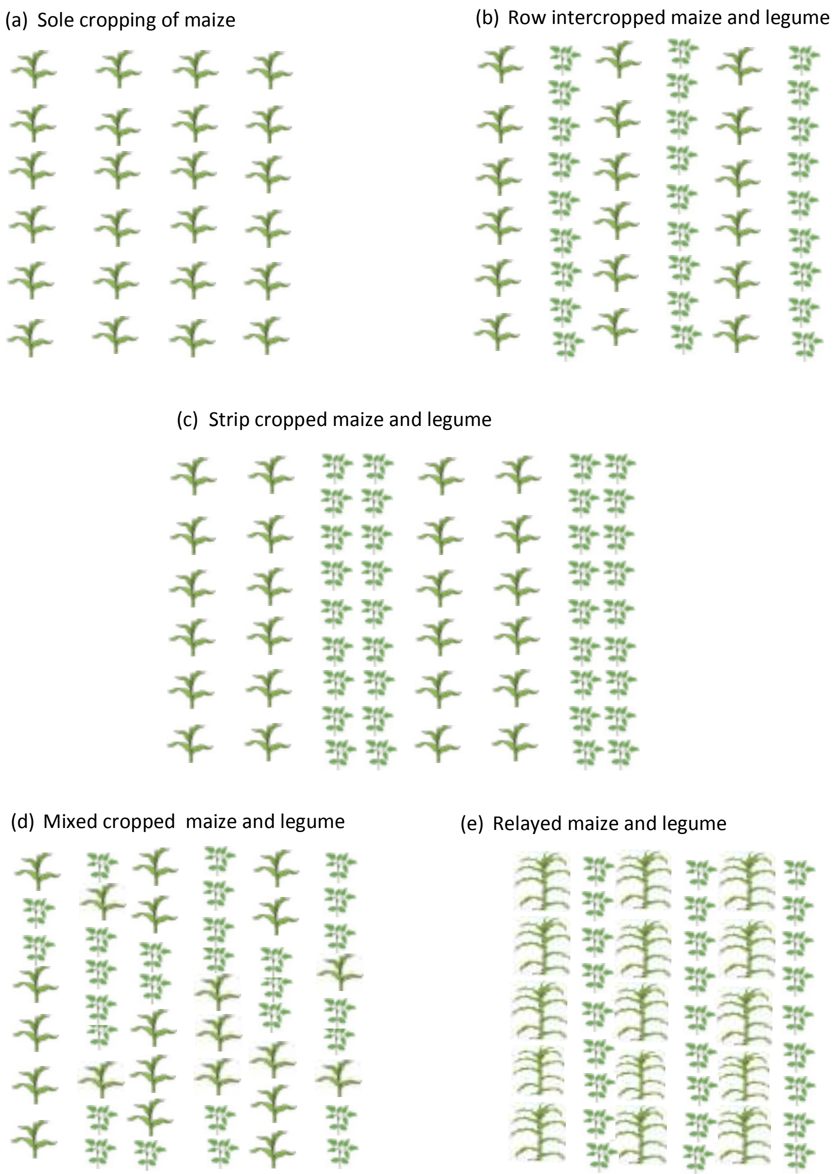


Figure 4: Examples of maize-legume intercropping arrangements

Row intercropping - Figure 4 (b): 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 75 cm between rows, 50 cm 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 groundnut, soybean, common bean and cowpea. 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.

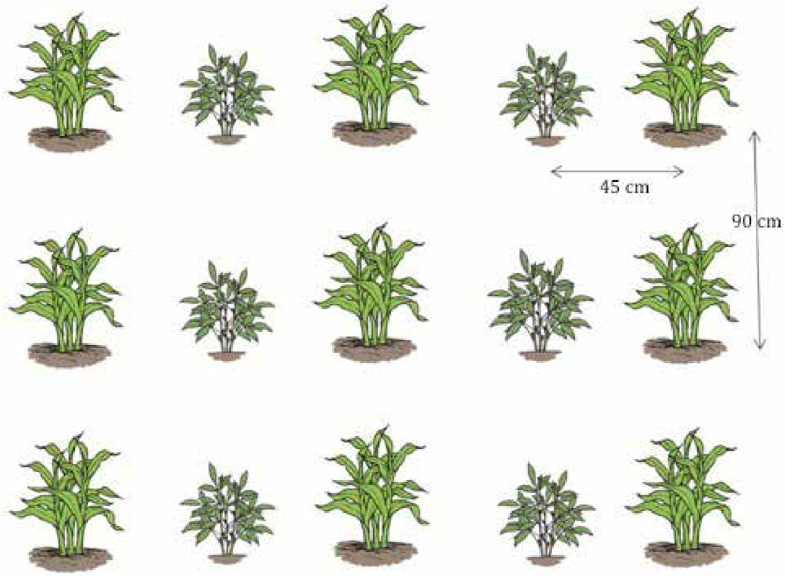


Figure 5: Within row intercropping

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 can be the same as if the same number of plants is spaced individually – i.e. the competition effect on the maize is minimal.

Maize and legume seeds

Hybrid maize must be grown from seed bought every season from a registered dealer.

Seed for OPV maize and legumes can be purchased from registered dealers every season or can be purchased once then subsequent crops for the next 2-3 seasons can be grown from saved seed.

If farmers are planning to save seed from the current crop, undesirable plants should be rogued out before harvesting. To ensure a high germination percentage, seed should be saved only from healthy plants and threshing should be done carefully to avoid damaging seed.

For crops like soybean and bean, threshing can be done soon after harvesting and seed stored for use in the next season. For groundnut, seed should be stored in pods and then removed from pods by hand about 1-2 weeks before planting.

If threshing before storing, seed should be cleaned by removing damaged seed and other material, such as stones.

For groundnuts, immature, mouldy and small pods should be removed before storing seed.

Seed should be stored separately from grain to be used for food, in a dry area that is well ventilated.

Germination test

A germination test can be a useful guide to how many seeds should be sown to get the desired plant population. The test gives an idea of how many ‘normal’ seedlings can be expected from a given number of seeds. Normal means the root and shoot parts are not deformed and look healthy, not diseased.

The test can be done at 10 days or more before time of planting. About 50 to 100 seeds can be sown onto a seedbed. The seedbed should be kept moist.

The number of normal seedlings that emerge in about 5-7 days should be counted and % germination calculated:

(Number of seeds germinated/number seeds sown) x 100 = % germination

Alternatively the test can be done in the house. For this, 50 to 100 seeds of the selected maize variety are placed between moist newspaper sheets. The paper with the seeds is placed in a safe area where neither children nor animals can disturb it. The paper and seeds are kept moist. After four days of incubation, count the number of seeds that have germinated and express it as a percentage.

If germination rate is over 95%, the number of seeds sown can be same as the desired plant population as most of the seeds planted will emerge. But if germination is 80%, on average only 4 of the 5 seeds planted will emerge – so to get the desired plant population, the number of seeds planted should be increased by 25%. If the germination percentage is 50%, it means out of the 2 planted, on average only one will emerge. In such a case it is advisable to double the seed rate.

Sowing maize

Factors that need to be taken into account with regard to sowing maize seed are:

Quality seed: Only plump, undamaged seed should be sown; shrivelled or damaged seed should be discarded.

When to sow: Maize seed should be sown in moist but not water-logged soil, when the soil moisture has reached at least 30 cm deep. This will usually occur soon after the onset of the rains. Delaying planting once the rains have started risks significantly reducing yields.

Spacing of planting holes: Spacing of planting holes will depend on the cropping system.

The normal recommendation for spacing of monocrop maize is 75 cm between rows with 50 cm between planting stations and 2 plants per planting hole. This gives a plant population of about 53,333 plants per hectare.

In drier areas, with less than 500 mm rainfall during the growing season, the spacing between rows and plants should be increased, which will give a lower plant population (see Box 4).

Spacing for intercrops varies with the legume being grown:

Maize-common bean intercrop: Maize is planted at the same spacing as for maize monocrop and the beans are planted in rows between the maize rows. The number of maize plants per hectare is therefore the same as for monocropped maize. For climbing beans, see Box 5.

Box 5: Maize-climbing bean intercrop

Climbing beans have some advantages over non-climbing beans. They yield better than non-climbing types (up to 3-times more) and fix more nitrogen (N) and therefore can contribute more to improved soil fertility. Many varieties of climbing beans do well at high altitudes but there are also varieties suitable for medium altitudes. Climbing beans can also grow in poor soils and some are more tolerant of diseases like root rot and ascochyta blight than bush beans.

A major disadvantage of climbing beans is the need to provide stakes to support the climbing plants.

Some researchers have experimented with growing climbing beans intercropped with maize, so the maize stalks act as living stakes for the beans.

In some cases the beans have been planted 10-14 days after the maize, while in others the beans are planted as the maize is becoming ready for harvest (relay intercropping).

There is, however, no consensus as to whether this is a useful intercrop. Some of the factors to consider before choosing this intercrop are:

- Planting densities of both crops have to be reduced compared to either as sole crops: although the combined crop may be greater, the yield of either crop compared to a sole crop will be lower. Smallholders need to decide which crop they are prioritising and whether a lower yield of that crop is acceptable.

- Proven recommendations for planting patterns and spacing are not widely available so smallholders will need to experiment on their own farms or look for local extension advice: as with any experiment, the outcome is unknown – it may be beneficial but it may also be disadvantageous.
- Relay intercropping ties up the land for longer.
- The maize stalks may not be strong enough to support the beans, in which case they will fall over and yields will be reduced.
- There may be other demands for maize stalks, such as feeding to livestock, so leaving them in the field may not be an attractive option.

Maize-pigeonpea intercrop: Maize is planted with 75 cm between rows and 75 cm between planting stations, with three plants per planting station. Clusters of 3 pigeonpeas plants (medium to late maturing varieties) are planted within the row, between each maize planting station. This gives the same number of maize plants per hectare as for monocropped maize.

Mbili system: In this system 2 rows of maize are planted with a row spacing of 50 cm with a one metre gap before the next pair of maize rows. In the gap, 2 rows of legumes are planted, such as groundnut, cowpea or common bean. The spacing within the row for maize is 50 cm. This arrangement gives the same number of maize plants per hectare as for monocropped maize.

<u>How deep to sow</u>

Maize should be sown deeper in lighter and drier soils. On sandy loams with adequate rainfall a planting depth of 2-3 cm is recommended; on dry, sandy soils a planting depth of 5-10 cm is recommended to enable a deeper root system to develop.

<u>How many seeds per planting station</u>

For monocropped maize and most of the legume intercrops, the target is 2 maize plants per planting station. For maize-pigeonpea (see above), the target is 3 maize plants per planting station with the within row spacing increased accordingly to 75 cm between stations.

If the germination rate is above 95% then the number of seeds per planting station should be the same as the target plant population.

<u>Seed rate</u>

To achieve a plant density of 53,333 plants per hectare requires between 20-25 kg maize seed per hectare, assuming germination rate above 95%: if the germination test shows a lower rate of germination, more seed will be needed, for example, if the germination rate is 50%, the number of seeds per planting station should be doubled.

Fertilizer use

Ideally, farmers should use fertilizer at optimum rates 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 available. In this case, some blanket recommendations are provided below.

The aim of these recommendations is not to maximise production; rather it is to increase yields from around 1 tonne of maize grain per hectare, or even less, up to as much as 6 tonnes per hectare (see Table 6, 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 6: 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 6: Responsive and non-responsive soils) can be described by a nutrient response curve (see Figure 6): this shows the impact of increasing amounts of nutrients (fertilizer) on yield.

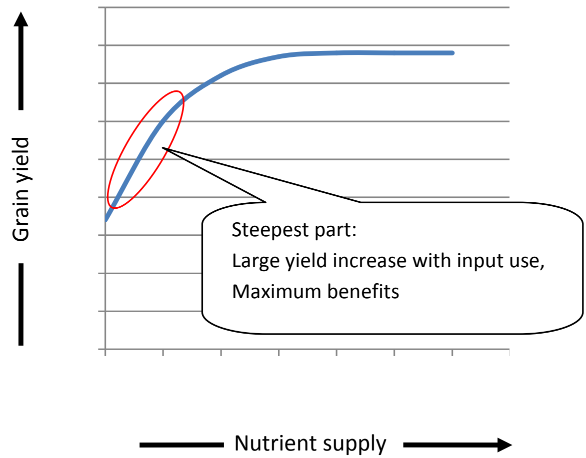


Figure 6: Example of a nutrient response curve

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 – 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 vary, however, 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 6)

- weather – especially rainfall
- varieties used
- intercrops and rotations
- pest and disease attack
- management practices, such as plant density and arrangement, weeding, timely fertilizer application, incorporation of organic material 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.

Box 6: 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 6): 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 7 provides some examples of basal and top-dressing options for neutral to alkaline soils (pH greater than 6.5) and Table 8 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 8 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 the recommended fertilizer nitrogen (N) rate 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 the recommended fertilizer N rate can be applied as top-dressing.

Table 7: Examples of basal and top-dressing fertilizer options for maize grown in neutral to alkaline soils (pH of 6.5 and above)

Target yield t/ha[1]	Target nutrient rates kg/ha		Basal fertilizer at planting	First topdressing		Second[4] topdressing	
	N	P	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	60 (2.3)	20 (0.7)	40 (1.5)	20 (0.7)	40 (1.5)
3	60	20	120 (4.5)	40 (1.5)	80 (3)	40 (1.5)	80 (3)
4	90	30	180 (6.7)	60 (2.3)	120 (4.5)	60 (2.3)	120 (4.5)
5	100[3]	40	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 8 provides examples of suitable basal and top dressing fertilizer recommendations for acidic soils.

Table 8: Examples of basal and top-dressing fertilizer options for maize grown in acidic soils (pH of 6.5 or less)

Target yield (t/ha)	Target nutrient rates kg/ha			Basal fertilizer at planting	Topdressing
	N	P	K	NPK 15-15-15 kg/ha (g/plant)	CAN kg/ha (g/plant)
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 per hectare). If the legume is grown after a maize crop that had P applied, then the legume can benefit from any residual P left in the soil, although yields are likely to be higher if P is applied.

Box 7: 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.

[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'.

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 the 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. If they wish, 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 at the right depth (see How deep to sow, page 29) – the seed and fertilizer must not touch as this can damage the seed. The hole is then covered with more soil.

Before the top-dressing is applied, 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 away from the base of the plants. 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 amount of nutrients compared to 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); in comparison, 100 kg of the mineral fertilizer 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 6 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, in Table 6 above, for every 1 tonne of farmyard manure applied per hectare, the amount of urea can be reduced by 12 kg per hectare 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 urea, this could be reduced to 8 kg in year 1, 14 kg in year 2 and 17 kg in year 3.

Other organic materials

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 contents: they do not have as much N as legume residues and take longer to decompose and 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.

Key messages

For conventional tillage, avoid too fine a tilth, especially on sandy soils. A coarser tilth with clods about 6 cm across reduces risk of wind erosion but still allows water to infiltrate into the soil.

Purchase hybrid maize seed from registered dealers every season.

Either buy OPV maize and legume seed either every season, or purchase one season and then grow subsequent crops for the next 2-3 seasons from saved seed.

If planning to use seed from the current crop, select healthy plants of desirable type for seed, thresh carefully to remove seed, clean seed by removing damaged seed and other materials, dry and then store the seed. For groundnuts, store seed in pods; remove seed from pods by hand about 1-2 weeks before planting.

Store seed separately from grain to be used for food, in a dry area that is well ventilated.

Before planting, test the germination of the seed by sowing 50 seeds in a moist seed-bed or indoors using damp newspaper. If over 95% germinate, sow the same number of seeds as the desired plant population, if 80% germinate, increase the amount of seed by 25%, and if 50% germinate, double the seed rate.

Sow maize when soil moisture has reached 30 cm deep, soon after start of rainfall.

Usual maize spacing is 75 cm between rows and 25 cm between plants in row with 2 plants per station – space wider in dry areas. Sow deeper (5-10 cm) on dry, light soils; 2-3 cm on sandy loams with adequate rainfall.

Apply basal fertilizer at time of planting and top dress when maize reaches knee-high. Basal fertilizer needs to supply N and P, such as DAP or NPK; top-dressing needs to supply N, such as urea or CAN. In high rainfall areas, above 1000 mm per growing season, apply top-dressing in 2 or 3 equal splits. For legumes, apply P fertilizer at planting.

Weeding

Weeds compete with crops for nutrients, water and light, and can harbour pests and diseases that can attack crops. Weed seeds can contaminate grain at harvesting.

Monocrops require more weeding than intercrops as more soil surface is exposed. If crops cover the ground surface, weeds are smothered or have less opportunity to grow.

How to weed

If using a hoe, damage to roots of crops can be reduced by digging to a depth of less than 5 cm. Digging deeper should only be done if necessary, for example to remove weeds with rhizomes that go deep into the soil.

If weeds are tall and few, weeds can be uprooted by hand.

Pre-emergent herbicides, which control weeds at the germination stage, can be applied to the soil immediately after planting, before weeds and crops emerge.

Post-emergent herbicides, which control young growing weeds, can be applied once crops and weeds emerge (see examples of herbicides in Table 9).

The decision on whether to weed manually or to apply herbicides should be based on which is the most cost-effective. There are more options for herbicide use in monocrops than intercrops. This is because herbicides used in maize tend to target broad-leafed plants, which include legumes, while those used in legumes target grass-like weeds and will also kill maize.

Table 9: Examples of herbicides that can be used in the maize-legume system

Time of application	Herbicide* chemical name	Type of weeds controlled	Use
Pre-emergence	alachlor	Grasses, broad-leaf	Maize, groundnut, soybean, bean, pigeonpea
	metalochlor	Grasses and some broad-leaf	All crops
	alachlor and atrazine	Grasses, broad-leaf	Sole cropped maize
Pre- and early post-emergence	atrazine	Grasses, broad-leaf	Sole cropped maize
Post-emergence	glyphosate	Grasses, broad leaf	Non-selective – kills all plants Applied before crops emerge Inactivated by contact with soil

* The herbicides listed here are the active ingredient (chemical name). In the agro-dealer's shop products based on these chemicals will be sold under different tradenames in different formulations made by different manufacturers. The instructions on the herbicide pack must be followed carefully to avoid damaging crops and prevent potential harm to people's health or the environment. See Guidelines for safe use of agricultural chemicals, page 81.

When to weed

The most critical stage of weed competition in the life of a maize plant is during the first 6 to 8 weeks after emergence. Weeds that emerge when the crop is young cause greater damage than those that emerge when the crop is older: the benefits gained by removing weeds that emerge when the crop is close to maturity are less than the benefits related to weeding when the crop is young. Also, as the crop grows weed density decreases: the growing crop canopy shades short weeds, therefore discouraging their growth.

First weeding should be 2-3 weeks after maize emergence and second weeding 2-4 weeks after first weeding. In high rainfall areas a third weeding may be necessary 3 weeks after second weeding.

In an intercrop, if maize matures after the legume (e.g. where maize is intercropped with beans or cowpeas), only the first 2 weedings (2-3 weeks after crop emergence, then 2-4 weeks later) may be required if the crop canopy provides good ground cover before 8 weeks after planting. If legume crop matures after maize (e.g. pigeonpea), the crop canopy may not provide good ground cover early and a third weeding may be necessary.

If legumes are grown in monocrop, the legume should be kept weed-free up to time of flowering, which is usually about 5-6 weeks after emergence. The first weeding can be at 2 weeks after emergence and the second weeding 2- 3 weeks later. Tall scattered weeds that appear after the second weeding can be pulled by hand.

Weeding depends on presence of weeds and weed load, and whether the value of yields gained by weeding will be more than the costs associated with weeding, such as hired labour or purchased herbicides. So, the numbers and timings of weedings proposed above are guidelines and not strict recommendations.

In addition:

- At legume flowering, weeding or other activities should be avoided as flowers can easily fall off if knocked.
- Weeding should preferably be done in the morning when soils are moist, to avoid soil moisture loss.
- Weeding using implements, hand tools, draught animal or

tractors, should not be carried out during dry spells. In such cases, manual uprooting of weeds or use of herbicides is better as disturbance to the soil is reduced or avoided – which reduces loss of water from the soil.

- Uproot weeds *before* they flower and set seed.
- If weeds have a lot of soil attached to roots after uprooting, shake off soil from roots of weeds and leave the uprooted weeds on soil surface.
- Ideally, fields should be free of weeds at time of applying fertilizer. If weeds are present at time of fertilizer application, covering the fertilizer and weeding can be done at the same time.

To control Striga, a parasitic weed that attacks maize, an integrated approach is needed that takes advantage of the fact that Striga is less of a problem in fertile soils. This includes:

- If available, Striga-tolerant maize varieties should be planted.
- Remove Striga by hoeing and spot weeding before they flower and seed.
- Spot spraying with herbicide.
- Rotation and intercropping with legumes (e.g. soybeans, cowpea, groundnut).
- Applying nitrogen-rich fertilizer (such as urea) or applying manure or growing legumes that fix nitrogen.

Striga gesnerioides (also known as cowpea witchweed) in cowpea and *Alectra vogelii* (also known as yellow witchweed) in cowpea and many other legumes are important parasitic weeds. *Alectra* is a serious pest to cowpea in East, Southern and West Africa, and groundnut in East and West Africa, and also many other legumes, but does not seem to attack pigeonpea. *Striga* is also a serious pest to cowpea in West and Central Africa. It can also attack common beans but damage tends to be negligible. Both weeds tend to be a problem in the arid areas with poor soil fertility.

Harvesting

Maize

The visible sign of the maturing maize plant is senescence– dying back of leaves starting from the lower leaves continuing upwards. The crop is mature when the plant has become light brown and the grain hard; some of the cobs will droop downwards. Cob maturity can also be tested by checking for the black layer that forms at the base of grains (where they connect to the cob). The layer can be seen by removing grains from the cob and scraping the base with your fingernail. Harvesting is done by removing cobs from plants. The cobs are dried then threshed.

Legumes

Legumes are harvested when the pods are dry. If all pods dry at the same time, harvesting can be done by uprooting whole plants. If some pods are ready for harvesting while others are not, several harvestings may be necessary. The pods or uprooted plants are dried in the sun, then threshed on a clean surface,

Both maize and legume grains are sorted and chaff and foreign materials removed. The grains are dried further before storage (see Box 8 and 9 for examples of tests that can be used to check if grain is dry enough for storage). Storing grain before it is dry can lead to loss in quality due to attack by storage pests, moulds and diseases.

Dried grains may be treated with recommended storage chemicals to control attack by storage pests.

Residue management

Farmers should bear in mind that:

- Returning crop residues to the soil, or feeding such residues to livestock and then applying the manure to the soil, recycles but does not add nutrients to the system.
- Removal of plant parts from the field depletes the nutrient capital contained in the maize-legume system.
- Applying residues of crops/plants that have been grown elsewhere to the field/farm adds nutrients to the system.
- Grazing livestock in other fields (e.g. grazing lands on hillsides) and using manure from such livestock on the farm adds nutrients to the system.

Apart from supplying nutrients, applying crop residues to the soil also provides benefits including:

- Conservation of soil moisture.
- Mulch layer helps to reduce soil erosion on sloping land.
- Weed suppression and reduced requirement for weeding operations.
- Replenishment of soil organic matter.

Box 8: Tips for checking if maize grain is dry enough for storage

Based on experience, it is possible to tell if grain is dry enough for storage, for example from the way it looks and the feel when a hand is dipped into a pile of grain. You can also tell if grain is dry enough by carrying out simple tests. For example:

Take a few grains and bite them. If the grains crack, then the maize is dry enough for storage.

Alternatively, pour grain into a dry bottle until it is two-third full. Then add 3 tablespoons of dry salt. Shake for a minute, then let the bottle rest for 15 minutes and shake again. If salt sticks to sides of the bottle, then the moisture content is above 14-15% and the grain should be dried further. If the salt does not stick to the sides of the bottle, then grain is dry enough for storage.

Note: Confirm that salt is dry enough for use in test by placing salt in empty bottle and shaking. Dry salt does not cling to sides of bottle.

Box 9: Tips for checking if legume grain is dry enough for storage

Bite or pinch grain with your finger nails – if grain bends or sticks between teeth or fingernails, it is not dry enough for storage and should be dried further. When dry enough, grain should break or crack when bitten or pinched between finger nails.

Key messages

Keep sole cropped maize and intercrops weed-free for up to 6-8 weeks after emergence by weeding at 2-3 weeks after maize emergence, then at 2-4 weeks after first weeding, and at 3 weeks after second weeding if weeds are a problem.

Keep monocropped legumes weed-free up to time of flowering by weeding at 2 weeks after emergence then 2- 3 weeks later if weeds are a problem, and pulling tall scattered weeds that appear later by hand.

If using a hoe, try to dig to a depth of less than 5 cm; only dig deeper if necessary.

If using herbicides, pre-emergence herbicides can be applied immediately after planting, before weeds and crops emerge, and post-emergent herbicides can be applied once crops and weeds emerge.

Only weed beyond 6-8 weeks if the value of yields gained by weeding will be more than the costs associated with weeding.

At flowering, avoid going into a legume field.

Carry out mechanical weeding only when soils are moist.

If weeds are present at time of fertilizer application, apply fertilizer then cover the fertilizer and weed at the same time. Ideally, fields should be free of weeds at time of applying fertilizer.

If Striga is a constraint, plant Striga-tolerant varieties if available; remove Striga by hoeing, spot weeding and spraying with herbicide before the Striga flowers and sets seed; rotate and intercrop maize with legumes; apply nitrogen fertilizer and manure; and clean tools thoroughly after working in infested fields before working in clean fields.

Harvest maize by removing cobs from plants when plants become light brown, the grain is hard, some cobs droop downwards, and there is a black layer at the base of grains (where they connect to the cob).

Harvest legumes when the pods are dry. If all pods dry at the same time, uproot whole plants but if not all pods are ready for harvesting, pick ready pods and harvest the rest later.

Dry maize cobs, legume pods or uprooted legume plants in the sun, then thresh on a clean surface.

Remove chaff and foreign materials from maize and legume grains and dry the grains further.

Treat grains with recommended storage chemicals to control damage by storage pests, especially if storing in containers that are not air-tight.

Return crop residues to the field, or feed residues to livestock and then apply manure from these livestock to the field.

Nutrient deficiencies

Plants need nutrients to grow well. If nutrients are deficient, symptoms may be observed on plant parts during crop growth and at harvest for both maize (Tables 10) and legumes (Table 11).

If deficiency symptoms show in one crop but not on other crops grown in a cropping system (e.g. in maize but not in the legume in an intercrop or rotation), it is best to assume that the deficiency can affect all crops in the system.

It is not always possible to address deficiencies during the current growing season (in which symptoms are observed) but measures can be taken when preparing for the next crop to prevent these symptoms appearing again (Table 12).

Table 10: Nutrient deficiency symptoms in maize.

Nutrient	Symptoms on leaves	Other symptoms	Image
The following symptoms first appear or are more severe on younger leaves			
Calcium	Misshapen leaves (ribbed) Growing point dies		
Zinc	White to pale yellow bands in lower half of emerging leaves. Small leaves	Short internodes (resetting)	
Iron	Pale yellow between veins and veins prominent over length of leaf		

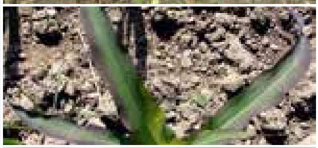
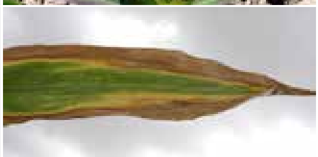
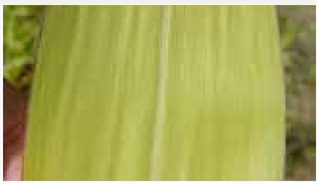
Boron	White irregular spots between veins	Cob sheaves remain closed, silks and tassels fail to emerge	
Manganese	Pale green to yellow discoloration between leaf veins		
Molybdenum	Leaves wilt and die along margins		
The following symptoms appear in older leaves that are lower down the stalk			
Nitrogen	Pale green plants. Yellow coloration in a ‘V’ shaped pattern progressing from leaf end to leaf collar. Pattern progresses from lower to upper leaves	Small, malformed cobs Unfilled grains towards tip of cob	
Phosphorus	Purple colour along leaf margins	Poor root development, small twisted cobs, scattered grains and unfilled grains in cob	
Potassium	Brown colour and scorching along leaf margins from tip to base	Stalk breakages, small cobs, light shrunken grains Unfilled grains towards tip of cob	
Magnesium	Leaves turn yellow at edge leaving a green arrowhead shape in the centre of the leaf		
The following symptoms appear on both young and old leaves			
Sulphur	Uniformly yellow leaves		

Table 11: Nutrient deficiency symptoms in legumes.

Nutrient	Symptoms on leaves	Other symptoms
Nitrogen	Lower leaves turn pale, then yellow Younger leaves pale	
Phosphorus	Young leaves small and dark green Old leaves die prematurely Plants stunted	Reduced nodulation and nitrogen fixation
Potassium	Brown colour begins at margins, moves inwards, starts in older leaves	Weak stems with short distances between nodes where leaves emerge from stem, reduced root growth, small grains
Magnesium	Pale yellow between veins of older leaves	
Calcium	Young leaves cup-shaped	Apical growth (at the shoot tips) stunted Unfilled pods in groundnut
Manganese	Young leaves pale yellow between veins	
Zinc	Young leaves pale yellow between veins	
Iron	Young leaves turn yellow, but the veins remain green	
Boron	Leaves crinkled	Death of the main growing tip Flowers and subsequently pods not formed Poor root growth
Molybdenum	Symptoms resemble those of N deficiency	Reduced nitrogen fixation
Aluminum	Leaves yellow	Stunted root growth

Table 12: How to address nutrient deficiencies.

Nutrient	To save the current crop*	To prevent deficiency occurring in future crops
Nitrogen	Apply N- fertilizers (e.g. CAN) before tasseling stage for maize	Apply N-fertilizers (e.g. urea) in splits
Phosphorus	Do nothing	Apply P-fertilizers (e.g. triple superphosphate), manure at planting. If soil pH is low, apply lime together with P-fertilizers. Phosphate rock can be applied but is poor in solubility and contains less P than manufactured P-fertilizers

Potassium	Do nothing	Apply K-fertilizers (e.g. potassium nitrate, potassium sulphate or potassium chloride), manure before sowing
Calcium	Do nothing	Apply Ca-fertilizers (e.g. gypsum, calcium nitrate or calcium chloride). In low pH soils, apply lime or calcium carbonate to correct the pH and reduce manganese and aluminum toxicity which could be present. But too much lime can cause magnesium deficiency. Both nitrogen and calcium can be supplied by applying CAN fertilizer.
Magnesium	Apply soluble salts such as magnesium sulphate, chloride or nitrate with irrigation water.	Apply Mg-fertilizers such as magnesium sulphate or magnesium chloride to the soil before planting. If both magnesium and calcium are deficient (e.g. in soils with low pH), apply dolomite (has both magnesium and calcium) to the soil before planting.
Sulphur	Apply ammonium sulphate, magnesium or potassium sulphate with irrigation water.	Apply elemental sulphur or gypsum to the soil, mix, before planting crop.
Iron	Apply ferrous sulphate as 3-4% solution (30-40 g per litres) at rate of 220-440 litres per hectare (22 ml per square metre) as folira. As iron is immobile in plant, repeat sprays every 10-15 days.	Apply ferrous sulphate (25 kg/ha) or iron chelates (10 kg/ha) as basal fertilizer.
Manganese	Apply manganese sulphate (0.2 to 0.3% solution) as foliar spray. Repeat sprays if symptoms reappear.	Add organic manures before sowing. Also, apply soluble salts of manganese, such as manganese sulphate, as basal fertilizer.
Zinc	Per hectare, mix 3.0 kg zinc sulphate and 1.5 kg of slaked lime in 500 litres water, 2-3 weeks after seedling emergence.	Add organic manures before sowing crop. Apply 25-30 kg zinc sulphate or 10 kg zinc chelates per hectare once in 2 years in zinc deficient soils. Do not mix Zn-fertilizers with phosphate fertilizers.

* The suggested ways of addressing nutrient deficiencies in the current crop, for all nutrients except N are more applicable to commercial than smallholder farmers.

Lack of response to fertilizer application

Not all soils have large responses to improved seed and fertilizer inputs. In some soils, the response to improved seed and fertilizer inputs is small – these soils can be referred to as non-responsive soils and they can be either already highly fertile or degraded. Some of the techniques which may be required to improve responses in degraded soils include use of soil amendments, organic inputs and micronutrients, and deep tillage. See Box 6.

Pests and diseases

Crops can be attacked by insect pests and diseases during the growing period. Pests can also attack the grain after harvesting. Regular field visits are required to scout for pests and diseases. If possible, pests and diseases should be managed using an integrated approach.

Integrated pest management (IPM) involves integrating a number of approaches to control pests and diseases in ways that are effective, environmentally friendly and economically sound. Attacks are prevented by use of varieties that are resistant or tolerant to pest attack, fields are monitored for attacks and control is carried out only if deemed to be economically viable.

Early detection is important before the pest or disease spreads, so that control is only required over small areas to save on cost of treatment and reduce impact.

Diseases can be carried on seeds so, if using seed from previous crop, only use seeds from disease-free field. Certified seed purchased from shops tends to be disease free.

Good pest management in maize-legume systems includes:

- Rotating legumes with maize and growing other crops after a maize-legume intercrop to reduce attack by insect pests and diseases left in the field from the previous season.
- Early planting at onset of rains, when soil is moist to at least 30 cm depth, so that the crop matures early and escapes attack by pests, or is strong enough to withstand infestation for pests that become serious as the season progresses, and also so that the crop does not have to compete early with weeds.
- Crops that are well supplied with nutrients, disease-free, strong and healthy can withstand pest pressure better.
- Remove plants that look infected if the infestation has not spread and also plants growing from grain that was left in field at harvesting of the previous crop to reduce spread of disease. If infestation looks severe consider controlling using chemicals.
- Keep fields weed-free. Some weeds can act as alternate hosts for some pests and diseases, and can also host insects that transmit disease from plant to plant.

Insect pests

Insect pests damage plants and can interfere with movement of nutrients in plants.

Both maize and legumes can be attacked by cutworms, which are moth caterpillars that hide in the soil by day and feed at night. Cutworms attack seedlings below or at the soil surface and can kill seedlings. The plants can wilt before dying if cutting is partial, or can fall over if the lower stem is cut through. In older plants, the insects feed on leaves. Control can be by ploughing in crop residues, turning the soil to expose the larvae to sun and bird feeding and controlling weeds.

If replacing affected plants, damaged plants should be removed. If cutworm can be seen in the planting hole it should be removed and killed, before a seed is placed in the hole. Also if attack is localized, the pest can be controlled by digging it out of the soil and killing it – digging should be up to 5cm deep.

Apart from cutworms, other main insect pests of maize are the stem borers, chaffer grubs, termites, maize weevil and larger grain borer.

Stem borers (first-instar larvae) eat leaves and make ‘windows’ in the leaves. Older larvae tunnel extensively in stems, eating out long frass-filled galleries which may weaken stems and cause breakages. The pests survive in crop residues after maize is harvested. The pests can be controlled by spreading crop residue on the soil surface in the hot sun after harvest, removing crop residues from field and feeding them to livestock or making compost. Intercropping maize with non-host plants, such as cowpeas or cassava, will reduce the damage. Adult moths will lay eggs on the non-host plants, but the larvae are unable to feed on them and will die. Alternatively, maize can be intercropped with a repellent plant such as silver leaf desmodium (*Desmodium uncinatum*) and a trap plant, such as Napier grass (*Pennisetum purpureum*), molasses grass (*Melinis minutiflora*) as a border crop around this intercrop to protect maize from stem borers. The trap plant draws the adult female away from the crop. More eggs are laid on the trap plant than on the crop but the larvae develop poorly or not at all on the trap plant. This practice is known as “push-pull”. Rotate maize with a non-host plant, such as a legume, this will break the cycle of the stem borer. Other control measures include planting early at on-set of rains and applying of insecticides; for example in many countries insecticides (e.g.

trichlorfon) are applied, as granules placed into the funnel of young plants.

Chaffer grubs feed on the rots of young maize plants causing them to dry and die. They are controlled by early planting at onset of rains, practising crop rotation, and applying animal manure that is well-decomposed instead of fresh or partially decomposed. Chafer grubs cause more damage in farms where cow dung which has not completely rotted and cooled is used as manure in the field. Chaffer grubs can be controlled by crop rotation; plant maize one season, the following season grow a different crop such as beans or cowpea in that field. Chafer grubs do not like eating roots of beans or cowpea, so they will not survive to attack maize the following season.

Termites damage above ground biomass, cause lodging (plant falls over) and also damage maize cobs. In young seedlings leaves can be damaged. In plants at different growth stages the inside of roots and stems can be eaten out then be packed with soil and the outside of the stem can also be coated with soil. The plants can topple over and the termites then destroy the whole plant. Termites can be controlled by destroying their nests and removing the queen and by intercropping maize with legumes instead of growing it as a sole crop.

The larger grain borer can attack crops in the field – symptoms are holes on stalk and end of cob. Both maize weevil and larger grain borer can attack grain during storage. To reduce attack in store, cobs should be harvested as soon as crop is ready for harvesting, grain should be cleaned by sorting out damaged grain and foreign materials, and the clean grain should be dried properly in the sun (dried to 14% moisture content) (see Box 8). Grain should be coated with insecticides (e.g. pirimiphos-methyl

+ permethrin, fentrothion+fenvalerat) to kill insects if present and stored in airtight containers such as polythene bags to prevent air that insects require for survival from getting into container. Storage containers should also be clean and dry.

In legumes, pests attack different parts of the plant when the crop is in the field and also attack harvested grain (Table 13). Many of these pests can be controlled by early planting, rotations, and other management practices. Use chemicals only when necessary (see Box 10 on how to store grains without applying storage insecticides) and use them safely (see guidelines in Appendix).

Table 13: Important insect pests of legumes in sub-Saharan Africa, damage symptoms and control measures.

Crop/pest	Crop affected	Symptoms/plant part attacked	Control measures
Bean stem maggot 'bean fly'	Mostly beans, but other legumes can be affected	Stems of young seedlings swell, split & seedlings die	Rotate legumes with maize and other crops Plant early, at onset of rains Earth up soil around damaged young plants to encourage growth of new roots Apply mulch around damaged plants
Aphids	Beans, cowpeas, other legumes	Found on underside of leaves, stems; leaves curl, plants stunted and may die Aphids excrete honeydew which encourages growth of black sooty mould on plants Aphids spread viral diseases	Apply insecticides (e.g. pirimicarb) if infestation/ damage is serious and crop is young and still forming new leaves Aphids are more serious during dry spells

Spiny brown bug	Beans, cowpeas, other legumes	Depressions on pods and seed coats, seeds rot or shrivel	Intercrop beans with non-legume crops such as maize Apply insecticide (e.g. cypermethrin) if infestation is serious
Giant coreid bug	Beans, cowpeas, other legumes	Depressions on pods and seed coats, seeds rot or shrivel	Spray with insecticide if infestation is serious e.g. cypermethrin
Maruca (legume pod borer)	Most legumes	Flowers wilt and drop, pods and seeds damaged Form webs that join together flowers, pod, and leaves	Plant crops at onset of rains Intercrop with maize or other non-legume crops Spray with insecticides, e.g. cypermethrin, dimethoate, when infestation is severe (e.g. 1 larvae per plant at flowering stage, 5-10% pod damage in pigeonpea; 40% flowers infested by larva in cowpea
Bruchids (storage pests)	All legumes	Holes in seeds	Store grain in airtight, clean, pest-free containers (see Box 6) Coat seeds with edible oil, ash or insecticides like pirimiphos-methyl + permethrin, fenitrothion+ fenvalerate

Box 10: Airtight storage bags

The PICS (Purdue Improved Crop Storage) bag is a triple-layer plastic bag that can be used to store grain under air-tight conditions. Initially developed for storage of cowpeas, it is now being evaluated for use in other crops. One polyethylene bag is fitted inside another, and then the two bags are placed inside a sack composed of woven polypropylene. Grain is placed inside the innermost bag, the bag is then tied tightly, then the middle bag is tied, and finally the outermost bag is tied.

The inner bags reduce the movement of air across the wall of the bag and if the grain is infested by insects before storage, the insects soon die from lack of oxygen and dehydration. Insects cannot move into bags to attack grain that is stored.

There is no need to coat grain with insecticides before storage.

The GrainPro Super grain bag is similar consisting of an airtight inner bag which is placed inside jute or other ordinary sacks.

Diseases

As with insect pests, maize has fewer and less important diseases than legumes. For maize, this guide will concentrate on disease of storage grains as these diseases are common and affect yield and quality of grain.

Aflatoxins are dangerous chemicals that are produced by Aspergillus flavus, a greenish-yellow fungus. Maize becomes contaminated with aflatoxins due to the presence of this and other fungi in the field and during storage. Aflatoxins are invisible but they cause severe disease and death in people and livestock which eat contaminated grain. Even if the fungus cannot be seen, maize may still be contaminated with aflatoxins.

Risk of infection with Aspergillus flavus in the field is greater if maize plants are stressed, e.g. drought conditions and nutrient deficiencies. Good agronomic practices, such as timely planting to ensure adequate rainfall to support growth but harvesting occurs in the dry season, application of fertilizer observing the '4Rs', control of insect pests and effective and timely weeding, will help avoid or minimize the risk of aflatoxin contamination.

In the store, infection is greater if grain is harvested in wet conditions, stored while wet or gets wet during storage. Infected cobs may rot and leaves covering the cob may be stuck to the cob. Infected grain may have an odour, slimy surface and moldy appearance, e.g. may be green, red or black, or may have white streaks. After harvesting, if grain is too wet, the cob should be dried before threshing to avoid damaging the grain – damaged grain is more easily attacked by storage diseases. Grain should be dried soon after harvesting and as rapidly as possible. Before grain storage, infected and broken grain should be sorted and removed. Grain for storage should have moisture content of 14% (see Box 8). It should be stored in airtight containers and checked regularly for infection.

Important diseases in legumes include anthracnose, bacterial blight and rust (Table 14). Many of the diseases can be controlled by good management practices.

Table 14: Important diseases of grain legumes in sub-Saharan Africa, symptoms and control measures.

Crop/disease	Symptoms	Control measures
Bean		
Anthracnose	Dark red to black damaged areas appear along leaf veins, lesions enlarge to become sunken lesions on pods	Use seed that is certified or from a crop that was not infected with anthracnose (best option) If field is infected, plant maize (or other crops) for at least 2 years
Angular leaf spot	On the three youngest leaves at tip of branch or stem damaged areas are angular in shape, surrounded by a pale yellow halo On other leaves, the parts are round and larger than on trifoliate leaves (leaves with 3 leaflets) On petioles (stalk attaching leaf to stem), branches, stems and pods lesions are reddish-brown	Use seed that is certified or from a crop that was not infected with angular leaf spot Bury infected plant material after harvest, or sick plants that are removed during the growing season Intercrop/rotate with non-legumes, such as maize Use resistant/tolerant varieties
Rust	Small yellow raised spots on top and underside of leaves, petioles and pods Leaf spots become large, powdery reddish-brown	Intercrop with non-legume crops
Rhizoctonia	Reddish brown damaged parts on taproot and lower stem of young seedlings Damaged area expand, merge to encircle stem and kill plant	Rotate with non-legumes Plough deep, use raised beds, avoid deep sowing
Common bacterial blight	Water-soaked spots on underside of leaves Spots enlarge, merge, become surrounded by yellow border Symptoms can also be seen on pods and seeds	Plant resistant/tolerant varieties Use seed that is certified or from a crop that was not infected with common bacterial blight

Soybean		
Rust	Small orange spots on underside of leaves Spots enlarge and become orange-brown in colour Rust can also be seen on other plant parts	Plant resistant/tolerant and early maturing varieties Plant early in season If detected early, spray with fungicide, e.g. mancozeb, but if it looks bad do not spray as plants cannot recover
Groundnut		
Rosette virus	Plants stunted, leaves produced are progressively smaller, pale yellow and often curled	Plant early in season Remove infected and volunteer plants Control aphids as they spread the virus
Early leaf spot and late leaf spot	In early leaf spot, dark brown spots with yellow halos on top leaf surface; spots are brown on underside of leaf In late leaf spot, black spots on underside of leaves	Intercrop/rotate with non-legume Plant resistant varieties Remove volunteer groundnut plants Spray with fungicides, e.g. mancozeb, chlorothalonil, carbendazin

Key messages

If N deficiency is observed in the growing crop and the crop has not reached flowering stage, N fertilizer should be applied to the crop. Other nutrient deficiencies observed can best be addressed by applying fertilizers in the next season's crop.

Fields should be visited regularly to scout for pests and diseases.

If insect pests and/or diseases are a problem, these can be controlled by planting varieties that are resistant or tolerant to the pests and diseases, using seed from disease-free fields or using certified seed and implementing integrated pest and disease management practices.

Legumes should be rotated with maize and other crops should be grown after a maize-legume intercrop to reduce infection by insect pests and diseases left in the field from the previous season.

To minimise pest problems, planting should be done early, at onset of rains when soil is moist to at least 30cm depth. This is to allow the crop to mature early and escape attack by pests, or become strong enough to withstand infestation for pests that become serious as the season progresses, and also so that the crop does not have to compete early with weeds.

Pesticides should be applied as recommended if the costs of using insecticide are less than the expected yield benefits.

If disease is a problem in the field, plants should be removed that look infected if the infestation has not spread.

Plants growing from grain that was left in field at harvesting of the previous crop (volunteers) should be removed to reduce spread of disease.

To control pests and diseases, fields should be kept weed-free as weeds can act as alternate hosts for some pests and diseases, and can also host insects that transmit disease from plant to plant.

6. Economics of maize-legume system

Many of the changes required for improved production require use of scarce resources like fertilizer, manure, seeds and labour. It is important to have an idea of whether a new farming practice will be profitable (before introduction) and whether the technology is actually profitable (after introduction). The likely benefits of a new practice are calculated based on estimated data while actual benefits are based on actual data collected on introduction of the new farming practice.

It may not be easy to assess whether investments in maize-legume system are worthwhile due to the complexity of farming systems. However, simple calculations that can provide useful insights into the likely costs and benefits, which only need a minimal amount of data/information, can be done.

The minimum increase in yield required to recover expenses incurred while implementing the new technology can give an idea of whether the new practice could be worthwhile. For example, if a farmer who has been planting hybrid maize varieties with application of 1 bag of DAP but has not been topdressing, would now like to apply 2 bags of DAP at planting and top-dress with 3 bags of urea, the increase in yield required to recover additional cost of fertilizes (if price of DAP is USD 70 per bag, urea is USD 50 per bag and price of maize is USD 500 per tonne) can be calculated as:

$$\text{Minimum increase in yield required} \left(\frac{t}{ha}\right) = \frac{\text{Cost of additional DAP + urea fertilizer}}{\text{Price of maize}}$$

$$\frac{(1\times70)+(3\times50)}{500} = 0.44 \text{ t/ha}$$

So, in this case for every USD 1 invested in the new fertilizer regime (the cost) the farmer would generate an additional USD 4.5 (the benefit), which would make this investment worthwhile.

A VCR of 1 means that the additional benefits are equal to the additional costs (break-even point). In general, a VCR needs to be 2 or more to make the investment worthwhile.

If the maize in the above examples was grown with a legume intercrop and the legume grain yield increases from 0.5 tonne to 1.2 tonne per hectare with the new fertilizer regime and the price of legume grain is USD 1000 per tonne, the VCR can be calculated as:

$$\text{VCR} = \frac{\overbrace{[(\text{Yield with fertilizer - Yield without fertilizer}) \times \text{Price}]}^{\text{Maize}} + \overbrace{[(\text{Yield with fertilizer - Yield without fertilizer}) \times \text{Price}]}^{\text{Legume}}}{\text{Total cost of fertilizer applied}}$$

$$= \frac{[(4-2)\ \text{x}\ 500]+[(1.2-0.5)\ \text{x}\ 1000]}{(1 \times 70)+(3 \times 50)} = 7.7$$

So, in this case for every USD 1 invested in the new fertilizer regime, the farmer would generate an additional USD 7.7, which would make the investment very worthwhile.

If additional information, for example on costs of labour, weeding, and pest control is available, more detailed calculations can be carried out.

A point to note is that prices of inputs and produce, and yields of crops can vary. For example, if secure storage facilities are available, higher income can be obtained by storing produce after harvest and selling when the market is not flooded and the price is higher. Also, less fertilizer should be applied when rains are late and drought is expected, and more fertilizer can be used when rains are on time and adequate.

Appendix: Guidelines for safe use of agricultural chemicals

1. Place of purchase

- Purchase chemicals from licensed/registered dealers
- Pesticide should be accompanied by an information leaflet on guidelines on proper use and handling of chemical
- Do not use banned or prohibited chemicals. If unsure, consult your local agricultural agent, or buyers of your produce

2. Choice of chemical

- Use the correct chemical for crop and pest. Follow information leaflet on pest and crop
- Use recommended chemicals that are accepted in the market. Confirm with your local extension agent or buyer of coffee

3. Correct timing

- Follow guidelines. Check how many days you must allow between spraying and harvesting

4. Correct quantity

- Apply the recommended quantities

5. Correct mixing

- Follow guidelines on compatibilities

6. Correct application

- Follow guidelines on correct application method

7. Correct handling

- Wear protective clothing covering body, head and face to prevent contact with skin, eyes, or inhaling. Do not face into the wind when spraying.

- Keep materials for handling spillages ready for use if needed
- Wash off chemical that comes into contact with body with water and soap
- Wash your hands with soap and water before eating, smoking or going to the toilet
- Bathe and change clothes after spraying
- Wash containers used to mix and spray chemicals
- Visit doctor if sick after spraying. Provide doctor with name of chemical and the information leaflet for chemical to read.

8. Disposal of chemicals and containers

- Dispose excess diluted chemical as per manufactures' guidelines
- Do not leave empty containers lying around
- Follow manufacturers' instructions on disposal

9. Storage and storage period

- Store pesticides away from human and animal food, away from children, in locked place, with warning signs
- Keep chemicals in their original containers
- Storage for period recommended by manufacture. Do not use after expiry date

10. Records

- Keep records of chemicals used, when used, where used

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

Africa Soil Health Consortium (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.

The Integrated Soil Fertility Management Cropping Systems Guide series is an output of the Africa Soil Health Consortium (ASHC), which is coordinated by CABI.

This guide was first published in 2017 by ASHC
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