AFRICA soil health consortium

Cassava system cropping guide

Stefan Hauser, Lydia Wairegi, Charles L. A. Asadu, Damian O. Asawalam, Grace Jokthan and Utiang Ugbe

Africa Soil Health Consortium: Cassava cropping guide

By Stefan Hauser (IITA), Lydia Wairegi (CABI), Charles L. A. Asadu (University of Nigeria), Damian O. Asawalam (MOUAU, Nigeria), Grace Jokthan (National Open University of Nigeria) and Utiang Ugbe (Development Input Limited, Nigeria)

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The 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.

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Addresses of authors

Stefan Hauser
International Institute of Tropical Agriculture
PMB 5320, Oyo Road
Ibadan, Nigeria
www.iita.org

Lydia Wairegi
CABI
ICRAF Complex
P.O. Box 633-00621
Nairobi
Kenya

ASHC@cabi.org
www.cabi.org/ashc

Charles L. A. Asadu
Department of Soil Science
University of Nigeria, Nsukka

Damian O. Asawalam
Michael Okpara University of Agriculture (MOUAU)
Umudike, Nigeria

Grace Jokthan
National Open University of Nigeria, Lagos

Utiang Ugbe
Development Input Limited
Block C, Suite 1, Barumark Estate
Wuye Junction Wuye District,
Abuja FCT, Nigeria

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Contents

1. Introduction

This cropping guide is one in a series being produced for extension workers by the African Soil Health Consortium (ASHC). The series also covers banana-coffee, maize-legumes, sorghum and millet-legumes, and rice systems but this guide is focused on cassava grown as either a monocrop or intercrop.

Rural extension workers will find this handbook particularly useful for guiding their clients as they shift from producing cassava under traditional cropping systems for subsistence to more market-oriented enterprises through sustainable intensification.

The guide aims to provide, in a single publication, all the most important information needed to design and implement effective systems which combine cassava with a range of other crops, either as intercrops or in rotations, but with the primary focus on cassava.

Although ASHC's work is focused on the needs of smallholder farmers in Africa, emerging and established commercial farmers will also find the contents relevant and useful.

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

Due to the experience of the authors, this cassava guide has drawn examples mainly from West and Central Africa, but will be relevant and useful to cassava producers in other parts of Africa as well.

Unlike cocoa, coffee and rubber, which are purely cash or export crops in Africa, cassava has historically been a food crop and is increasingly becoming a commercial crop. Whilst its production has intensified, it is still mostly grown in intercrop systems with other crops. Many cassava farmers are, therefore, cultivating cassava both for household use as food and for income.

The overall objective of the handbook is to provide simple, useful tips on how farmers with small to medium-sized farms can intensify their cassava production to increase yields from about 10 tonnes per hectare to 16 tonnes per hectare (fresh roots), while decreasing unit cost and increasing profitability.

For this handbook, a small cassava farm is considered to be between 0.25 and 2 hectares in size. Most such smallholder farms depend on household labour with, perhaps, some seasonal hired labour. A medium-sized cassava farm is 2 hectares or more, uses more hired labour and is generally more commercially oriented than smaller farms.

2. Cassava cropping systems

Cassava production in Africa occurs within a variety of cropping systems which, on a given parcel of land, could be in the form of:

- **Monocrop –** cassava is the only crop on the plot; this is found mainly on large-scale commercial farms.
- **Intercrop –** cassava is grown alongside other crops on the same plot at the same time.
- **Crop rotation –** this can take two forms:

  (1) Crop rotation under continuous cropping: This involves continued use of the same parcel of land while alternating the crops grown from one season to the next or from one year to the next.

  (2) Crop rotation nested in fallow: Fallow involves leaving a parcel of land unused for some time to enable soil fertility to build back up before reuse. Some fallows are natural (i.e. the land is left unsown, as commonly practiced in West and Central Africa) while others are managed (i.e. a cover crop is planted on the land to enhance the soil fertility restoration process).

Under the traditional cropping system, which involves growing a mixture of different crops and varieties of crops on the same plot of land at the same time, there is limited scope for the intensification of any one of the crops. Furthermore the system is complex and difficult to analyze to come up with evidence-based recommendations for improvements. More simple systems with just two or three crops are easier to analyze and therefore enable research results to be communicated and applied. Therefore, to achieve sustainable commercial production of cassava, the farmer should consider reducing the number of accompanying crops on the same plot.

The crops grown together with cassava in Africa vary from region to region, country to country, and locality to locality, due to differences in agro-ecological conditions and socio-cultural practices. The common intercrops with cassava include (see Photo 1 for examples):

- Cassava and maize
- Cassava and a legume (cowpea, soybean, groundnuts, pigeonpea)
- Cassava and vegetables (chilli peppers, fluted pumpkin, okra, melon (*Cucumeropsis* species), spinach, *Solanum nigrum* and other *Solanum* species (black nightshade).
- Cassava, yam and maize
- Cassava, maize and groundnut

Most smallholder cassava farmers are struggling to increase their farm yields, maintain soil health and achieve a more commercial orientation. On the other hand, a number of new factories requiring cassava as their basic raw material are being established; the current output level from the traditional smallholder cassava farming systems is insufficient to meet the raw material needs of the factories. To respond to these commercial opportunities, cassava farmers could adopt a basket of improved agronomic practices, which this handbook has tried to identify and describe. The topics range from land selection and preparation to variety selection, planting time and density, weed management and harvesting. This handbook focuses on cassava production; however, the enormous post-harvest economy of cassava is well recognized.

Photo 1: Cassava intercrop combinations (**A**) When soil is ridged, maize is planted on the ridge instead of in the furrow because the soil is better on the ridge — consequently the cassava and the maize are closer together than they would be on flat land — good farmers assess where best to put the maize to neither cause too much competition by being too close and still avoiding the maize being in the subsoil (photo: Stefan Hauser, IITA) (**B**) Cassava and yam intercrop (photo: Damian Asawalam) (**C**) Cassava, yam, okra and pumpkin intercrop (photo: Damian Asawalam) (**D**) Cassava and vegetable intercrop (photo: Damian Asawalam)

3. Requirements for cassava cropping systems

Cassava farming could be a good option if the following biophysical, socio-economic and cultural requirements can be met.

Biophysical conditions:

- **Rainfall** – preferably annual rainfall of 1000 mm or more; a minimum of 6 months of rain a year with at least 50 mm rainfall per month.
- **Soil** – the best soils for cassava are well-drained and not extremely stony or shallow (not less than 30 cm). Cassava is tolerant of high levels of aluminium and manganese in the soil, but does not thrive well in extremely sandy, salt affected, clayey or waterlogged soils.

Recommendation for water logged soils: If land is waterlogged, cassava can be grown by making soil mounds (3 metres wide and 2 metres high) or ridges sufficiently high so the tuberous roots are above the waterlogged soil. Cassava should be planted along with other crops such as yam, maize and vegetables (for example, yam is planted at the top of the mound, cassava on the side or slope of the mound or ridge, maize half-way down the side of the mound and vegetables around the base) (Figure 1).

- **Spear grass infestation** - Areas with severe Imperata (spear grass) infestation are not ideal for cassava because the Imperata rhizomes can penetrate the roots and cause rot.

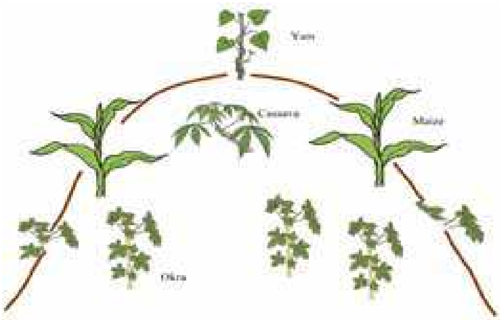


Figure 1: Cassava grown with other crops on a mound. A mound can have about 3 maize plants, 2 cassava plants and several vegetable (e.g. okra) plants

Recommendation for Imperata infested soils: Consider herbicide treatment before soil preparation to eliminate Imperata, for example glyphosate, a broad-spectrum systemic herbicide.

Socio-economic and cultural conditions:

- **Management skills** – Minimal skills are needed to select and cut planting sticks and to place these in the soil. However, care should be taken to avoid the spread of diseases like cassava mosaic disease (CMD) and cassava brown streak disease (CBSD). Farmers in areas with CMD and/or CBSD infestation need to select clean planting materials and take care to avoid the use of cutting implements contaminated by the disease. During the growing phase cassava requires little or no pest and disease management, but should receive timely attention on weed control.

In order to embark on commercial production of cassava, it is necessary to consider the following questions:

- **Market** – Is there a locally accessible market or outgrower scheme? What does the market require (does it require fresh roots or processed products?) Can what the market requires be supplied?
- **Processing** – Are there processing possibilities? How many alternative products can be made from the fresh cassava roots? Is there access to supporting infrastructure (public or private)? Is there a developed cassava value chain in the locality?
- **Supportive policies** – Are there any policies that support the production, utilization, processing and marketing of cassava or cassava-based products in the area?
- **Cultural perception** – Are there any cultural perceptions that limit the potential economic uses of cassava in the locality (e.g. local perception of gender roles in relation to activities in cassava subsectors)? Does the locality have social stigma associated with cassava as a ‘poor person’s crop’?

Key checks

- Cassava does well if annual rainfall is 1000 mm or more; a minimum of 6 months of rain a year with at least 50 mm rainfall per month is needed.
- Soils should be well-drained, and not sandy, clayey, stony, or salt-affected, and at least 30 cm deep.
- In waterlogged land, cassava should be planted on soil mounds or ridges.
- Cassava can be intercropped with other crops such as yam, maize and vegetables.
- If land is severely infested with Imperata (spear grass), apply herbicides before soil preparation to eliminate the grass.

Photo 2 : Cassava growing on shallow soil, and on ridges (A) Shallow and stony soil in which roots cannot grow down and thus have little anchorage (photo: Stefan Hauser, IITA) **(B)** Cassava growing on ridges — ridges improve drainage if soils are waterlogged (photo: Stefan Hauser, IITA)

4. Plot selection, preparation and planting

Land selection

Ideally, fertile land on a flat terrain or gentle slope should be selected (Table 1). Farmers often rely on their traditional knowledge and observations, such as presence of certain plant species or earthworm casts, as an indicator of fertile soils. Steep slopes should be avoided as they could be erosion-prone. If starting from a fallow, 3-5 years of fallow is optimum.

Land preparation

Land preparation depends on whether the land:

- has previously been under cultivation
- has been under a short natural or managed fallow
- has been under a long fallow (more than 5 years) – natural or planted, e.g. alley cropping
- is young forest growth, mature secondary forest or virgin forest

Table 1: Land types and recommended preparation

Types of land	Recommended preparation
Land previously under cultivation	The objective is weed control and preparation of a seed bed. If infested with stubborn weeds, e.g. Imperata (spear grass), use of herbicides is recommended. For less weed-infested land, simply slash and till by hand, oxen or tractor. The minimum option is to slash the vegetation.
Land under short natural or managed fallow	The objective here is seed bed preparation and biomass management. For planted fallows (e.g. mucuna and pueraria cover crops, which are legumes) simply plough the cover crop biomass into the soil or retain as mulch on the soil surface to increase soil organic matter. Large, woody material should be removed. The minimum option is to slash the vegetation, or spray with herbicide.
Land under long fallow	The objective here is seed bed preparation and biomass management. With a longer fallow, more woody debris that is hard to incorporate in the soil will be present. Cutting the vegetation and selective controlled burning of woody material should be carried out. Remove tree stumps if tractor tillage is foreseen; stumps can be retained if zero tillage or manual tillage are used. Avoid use of bulldozers as they damage the top soil.
Mature secondary or virgin forest	The objective here is seed bed preparation and biomass management. Treat as for land under long fallow, but expect much more woody debris. Generally the use of virgin forest should be avoided as much as possible.

Note:
- Heavier soils need more tillage than lighter soils.
- Avoid burning as much as possible. Consider taking the woody material away for firewood or to make charcoal.

Soil tillage

Tillage involves all forms of moving and turning the soil:

- Ploughing to 15-30 cm depth
- Disc harrowing to a depth of about 10 cm to produce friable topsoil
- Ridging

In general, root crops, especially yam and cassava, are not amenable to zero tillage or other forms of conservation agriculture. Under a mechanized system, the best option is to carry out any single or combination of the above-listed tillage operations in order to achieve weed removal, biomass incorporation and good establishment of the cassava cuttings, easier weed control later in the season, easier harvesting and higher yields. However, handmade (hoe) mounds or ridges serve the same purpose in a smallholder, non-mechanized system, which is more common (Photo 2).

Selection of cassava varieties for planting

There are many improved varieties of cassava which are adapted to various agro-ecological zones and production purposes. Usually, farmers tend to know the varieties which are locally preferred and available.

In commercial cassava production, market requirements are a major consideration in deciding the variety to plant.

In both commercial and subsistence production it is recommended that farmers should use disease-resistant varieties.

Farmers should be advised to check with local extension advisors for information on the common prevalent diseases in the locality and the varieties that are resistant to these diseases.

When introducing new varieties, exposing farmers to demonstration plots and making them aware of the potential commercial utilization of cassava can be an effective approach for kindling interest in adoption of the varieties.

Selection and planting of cassava cuttings

Once the variety to be grown has been selected, the farmer should ensure that the plants from which the cuttings are taken are free of signs of disease, such as cassava mosaic disease and anthracnose, the implements used to cut plants are clean and have not been used on sick plants, and that the cuttings themselves are:

- freshly harvested (of at least 2 cm diameter and 20-25 cm long), ideally taken from the bottom-end of the stem and not with green bark or still bearing leaves (Photo 3)
- clean-cut, not splintered and bark not chipped off (cut with a sharp implement and handle the cuttings with care to avoid damage) (Photo 3)
- kept upright in the shade with the base partly buried in the soil to avoid drying (if there is need for temporary storage)

If there is need to store planting material for a longer time, long stems can be stored upright under a tree, with the bases buried in moist soil. At planting, the top and bottom ends of the stem should be cut off and discarded, the rest of the stem should be cut to the right size for planting.

Photo 3: Planting materials (**A**) The portion of cassava stem suitable for planting is between the upper and lower points held. Where the stem is still green or leaves are, cuttings are not suitable as they may dry out easily (photo: Stefan Hauser, IITA) (**B**) Reasonable length, 25–35 cm cassava cuttings with around 8 nodes (photo: Stefan Hauser, IITA) (**C**) Reasonably sized cuttings of 2.5 to 3 cm diameter (photo: Stefan Hauser, IITA) (**D**) Correctly cut materials with minimal splintering and chipping off of bark due to cutting with sharp tools (photo: Stefan Hauser, IITA) (**E**) Badly cut planting materials with severe splintering and chipping off of the bark due to the use of blunt tools (photo: Stefan Hauser, IITA)

Planting

Cuttings can be planted on ridges, mounds or, if the soil is soft but not waterlogged, on flat ground.

Planting is done manually using a cutlass (machete) to make a hole. Then the cutting should be inserted vertically or at an angle of about 45°. Cuttings can also be pushed into the soil directly by hand (Photo 4).

If planted on ridges or mounds, the base of the cutting should be located near the centre of the ridge or mound. This helps to increase the stability of the cassava stand and makes it more resistant to being moved by the wind.

Two-thirds of the cutting should be below the soil with the remaining one-third above the ground (Photo 4).

In general, cassava planting is carried out manually. There are currently no established mechanical planting operations for cassava that can insert the planting stick vertically or at a 45° angle: all mechanical planters apply the stick horizontally in the soil, a technique that has been shown not to attain maximum yields.

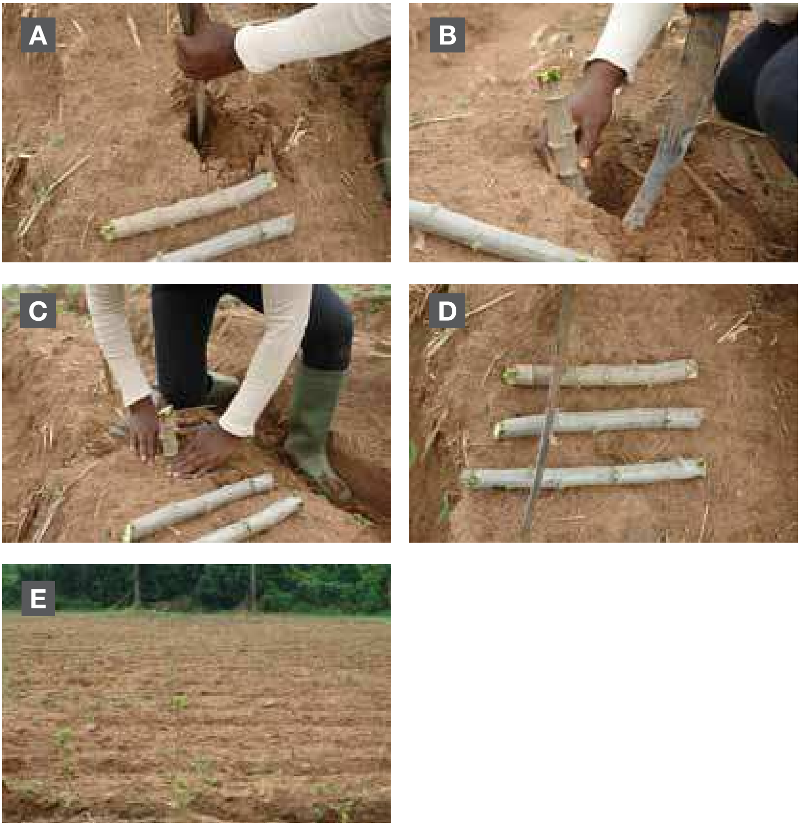


Photo 4: Planting cassava **(A)** Digging a planting hole (photo: Stefan Hauser, IITA) **(B)** Inserting the stake on the crest of the ridge (photo: Stefan Hauser, IITA) **(C)** Pressing the soil around the planted stake to ensure good cover and contact with the soil (photo: Stefan Hauser, IITA) **(D)** Cutlass across planting stakes indicating the depth to which they should be inserted into the soil – right hand side underground / left hand side aboveground (roughly 2/3 underground, 1/3 above ground) (photo: Stefan Hauser, IITA) **(E)** Newly planted cassava field after ridging with a tractor, rows are visible due to exact distances between stakes on the ridges (photo: Stefan Hauser, IITA)

Spacing

The currently recommended spacing is a square arrangement, 1 m x 1 m, i.e. one cassava plant per square metre. This gives 10,000 plants per hectare.

For varieties that grow upright without branching (as opposed to low and profusely branching varieties), a higher density of 1 m x 0.5 m or 1 m x 0.75 m may be used.

For multiplication of stems, rather than production of roots, a closer spacing of 0.5 m x 0.5 m can be used.

Spacing in cassava intercrops

The recommended optimal planting density in a cassava-maize intercrop is 10,000 cassava plants (1 m x 1 m spacing) and 40,000–50,000 maize plants per hectare. Maize should be planted at 20 cm linear spacing with one plant per stand (Photo 5) – avoid clusters of several maize plants in the same stand. This arrangement is most likely to have little or no detrimental effect on the cassava yield. The maize is sown in a single row between the cassava rows (Photo 6).

Irrespective of the type of legume intercropped with cassava, the plant density of cassava should remain at 10,000 per hectare (Figure 2).

The spacing for the legumes varies with the type of legume used as intercrop:

For groundnuts, the recommended planting arrangement is to broadcast at 25 plants per square metre.

For soybean and cowpea, two rows can be planted between the rows of cassava, while for pigeonpeas, which grow taller, a single row can be sown.

Experienced farmers know how to position the accompanying crops relative to the position of the cassava; however, a minimum distance for those seeded in rows is recommended so weeding can still be done along the rows.

For some legumes it may be recommended to increase the distance between cassava rows but reduce the distance within the cassava rows so to retain the 10,000 per hectare cassava density yet provide larger space for the legumes. For example cassava can be planted at 1.5 m distance between rows yet at 0.67 m distance within the row, or at 2 m between rows and 0.5 m within the rows. In all cases cassava density is 10,000 per hectare but operations for the intercropped legume are easier and may produce higher yields because more space is allocated to them. After the legume harvest, widely spaced rows could be filled with additional cassava plants.

If using ridges or mounds, as a general rule erect growing intercrops (such as maize and soybean) are planted half-way down the side of the ridge or mound; more spreading intercrops (such as groundnuts) should be planted first (before cassava) on top of the ridge or mound. If it is a supporting crop to cassava, it should be planted between the ridges.

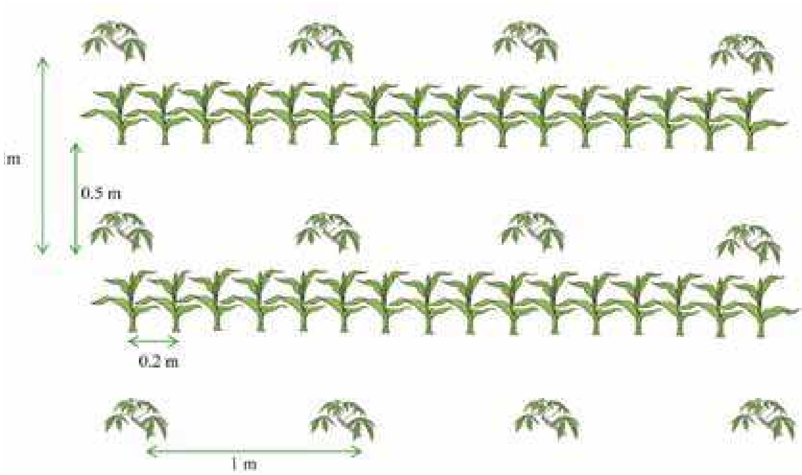
The timing for planting of the accompanying crops depends on the crops involved. Generally, yams, legumes, melons and maize are planted first before cassava.

Key checks

- Select fertile land that is flat or on a gentle slope.
- For land that was previously under cultivation, slash and till but use herbicides if *imperata* (spear grass) is present; for short fallow, plough cover crop into the soil; for land under long fallow or forest, cut the vegetation and do selective controlled burning of woody material before tillage.
- Under a mechanized system, plough to 15-30 cm depth, disc harrow to 10 cm depth or ridge, or carry out a combination of these operations. In non-mechanized system, make mounds or ridges.
- Use disease-resistant varieties and, if growing for sale, select varieties that meet market requirements.
- Use cuttings that are free of signs of disease, freshly harvested, at least 2 cm diameter and 20-25 cm long, clean-cut and are taken from the bottom-end of the stem.
- Insert cuttings vertically or at an angle of about 45° into the soil, with two-thirds of the cutting below the soil. If planted on ridges or mounds, the base of the cutting should be located near the centre of the ridge or mound.
- Generally space cuttings at 1 m x 1 m (10,000 per hectare), but varieties that grow upright without branching can be grown at 1 m x 0.5 m or 1 m x 0.75 m. If growing for multiplication of stems instead of roots 0.5 m x 0.5 m can be used.
- If intercropping, maintain 10,000 plants per hectare but distance between cassava rows can be increased e.g. 2 m x 0.5 m. Two rows of soybean and cowpea can be planted between the rows of cassava, while for pigeonpeas, which grow taller, a single row can be sown.

Figure 2: Examples of suggested plant arrangement in cassava-intercrops

a) Cassava-maize intercrop



b) Cassava-cowpea intercrop

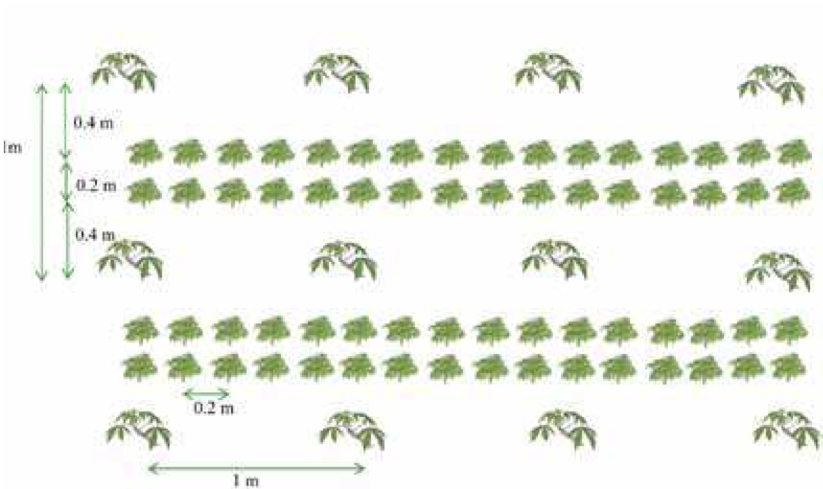


Photo 5: Examples of measuring units for length (**A**) The distance from the fingers to the chin is about 1 m (photo: CABI) (**B**) Close-up of (a) showing “1 m” on tape measure (photo: CABI) (**C**) The distance from thumb to middle finger is about 20 cm (photo: CABI) (**D**) The distance from palm to the elbow is about 30 cm (photo: CABI)

Photo 6: Monocropped and intercropped cassava (**A**) Cassava monocrop spaced at 1 m × 1 m (photo: Stefan Hauser, IITA) (**B**) Cassava intercropped with maize on ridges spaced 1 m apart. Cassava is planted on the ridge, maize on the side (photo: Stefan Hauser, IITA)

Replacement of failures

Under normal conditions, about 90% of all cassava cuttings planted sprout within 2 weeks of planting. Cuttings that do not sprout should be removed and disposed of away from the cropping area in order to prevent the transmission of any disease that may have caused the failure of the cuttings (Photo 7).

New healthy cuttings should be acquired and planted by the third week after the initial planting in order to maintain the planned plant density. However, the new cuttings should not be planted in exactly the same hole from which the failed cuttings were removed, to avoid the risk of repetition of the original problem.

Drought conditions could cause a much higher failure rate. In such a situation, the farmer should wait until rains resume before replacing failures.

If the higher failure rate is due to other factors, the extension worker should seek advice from the nearest agricultural research station or some other accessible expert.

Weed control

Weeds can retard the growth and reduce the performance of cassava (Photo 8). A well-weeded cassava farm can yield 30–40% more roots than a poorly weeded farm. Weed control forms a significant part (30% - 50%) of the labour costs in cassava production.

The exact weeding frequency will depend on the type and severity of the local weed problem, but in general:

It is important to start weed control 3–4 weeks after planting. This can be done at the same time as the replacement of the failed cuttings (in week 3) in order to maximize the use of labour.

Weeding should be repeated in weeks 8 and 12, while the final weeding should be done between 20 and 24 weeks after planting, depending on the rainfall. During dry phases weeding may not be required but it is always recommended to destroy weeds before dry phases and after the resumption of rains.

Once the canopy of the cassava and of the intercrops (if any) has closed the shading will effectively control most weed growth.

The overall total number of weeding cycles depends, in part, on the resilience of the weeds, and this depends on agro-ecological conditions.

Weeding can be done manually (hoe and cutlass), mechanically (using a tractor) or chemically (although there are no specifically prescribed herbicides for cassava). However, mechanical weeding beyond the first 4 weeks after planting can damage the roots. Therefore, manual or chemical weed control is preferred after this period.

Farmers should use their local knowledge to decide which weeded material should be left on the plot or removed and discarded. Generally, small broad-leaved weeds can be left on the field because they will die from the heat of the sun and become mulch. Bulky weeds, weeds with rhizomes and weed species with the capacity to form roots from stem pieces tend to re-sprout if cut and left on the soil surface, so the farmer should uproot and dispose of these types of weeds away from the field.

Tall grasses should be uprooted and removed from the field before they flower in order to prevent seed formation and germination, which will further propagate the weed species.

When cassava is intercropped with legumes this limits the choice of herbicides that can be used. Expert assistance should be sought from local officials who can supply a list of suitable and legally permitted herbicides. In some parts of Africa, chemical weed control services are offered by trained mobile operators; if available, this might be a good option for farmers.

Photo 7: Germinating cassava (**A**) Germinating cassava planted on ridges (photo: Stefan Hauser, IITA) (**B**) Typical error in planting – the cutting was inserted upside down and the shoot is emerging from underground (photo: Stefan Hauser, IITA) (**C**) Replacing non germinated or wrongly inserted cassava cuttings at around 4 weeks after planting (photo: Stefan Hauser, IITA)

Photo 8: Weed control (**A**) Closed canopy discourages growth of weeds (photo: CABI) (**B**) Poorly weeded cassava (photo: CABI)

Application of nutrients

Fertilizer use

By using chemical fertilizers on their cassava, smallholder farmers can increase their yields from about 10 to 16 tonnes fresh roots per hectare. The optimal use of fertilizers involves observing four basic principles (the ‘4Rs’):

- Right type of fertilizer
- Right rate of application
- Right timing of application
- Right method of application

Applying nutrients to the soil enables the maintenance of soil health and improves depleted or poor soils. Nutrient depletion can occur after land has been under continuous cultivation for many years.

For every one tonne of cassava roots harvested about 2.3 kg of nitrogen (N), 0.4 kg of phosphorus (P) and 3.0 kg of potassium (K) are removed from the soil. This means an average harvest of 10 tonnes of roots removes 23 kg N, 4 kg P and 30 kg K.

If cassava stems are removed from the same plot for planting elsewhere the nutrient export can easily double, triple or quadruple, because stems contain more nutrients than roots.

The application of nutrients helps to replace the lost nutrients and maintain soil fertility to enable continuing good yields in subsequent farming seasons.

Standard compound fertilizers, known as N-P-K, supply nitrogen (N), phosphorus (P) and potassium (K). Most of the N-P-K brands illustrate the combination of these three nutrients in ratio form, for example N-P-K 15-15-15 which contains 15% N, 15% $P_2 0_5$ and 15% $K_2 0$.

Other N-P-K formulations are available that provide other relative proportions of nutrients; for example, N-P-K 17-17-17 contains 17%

N, 17% P205 (about 11% P) and 17% K20 (about 14% K).

However, N-P-K fertilizers are not ideal for cassava because they provide:

- too much nitrogen (N), which causes the cassava to produce too much foliage: cassava does not require a high dose of nitrogen
- too much phosphorus (P), which incurs unnecessary expense: cassava does not require high amounts of phosphorus
- too little potassium (K), which the cassava requires for the formation of roots: cassava requires a lot more of this nutrient.

Determining the exact quantity of fertilizers to apply on a given plot depends on many factors and can vary from one soil type to another. However, a simple way to determine the fertilizer requirement is linked to the cassava root yield.

Fertilizer use on cassava mono-crop

Nutrient requirements: About half the weight of a mature cassava plant is made up of roots; leaves and stems make up the other half of the plant's biomass. So, if a farm produced 10 tonnes per hectare of roots we can assume that the entire crop produced around 20 tonnes of biomass (roots, leaves and stems).

The nutrient content in the different plant parts are not the same: leaves and small stems, for example, contain 10 times more nitrogen than roots, while larger stems have about the same nitrogen content as roots but higher P and K contents.

Also, different cassava varieties and the environment affect the nutrient uptake and thus the nutrients exported with roots and planting material. Therefore, although a concrete and exact recommendation is not possible, here we give a range of reasonable yields and nutrient concentrations to determine nutrient uptake and export of a cassava crop.

The key points to note are:

- $P_2 0_5$ contains 43.6% P; $K_2 0$ contains 83% K
- 100 kg of compound fertilizer N-P-K 15-15-15 contains 15 kg N, 6.55 kg P ((15/100)x(43.6/100)x100))=6.55kg and 12.5 kg K ((15/100)x(83/100)x100))=12.5kg
- One tonne of harvested cassava roots removes from the soil about 2.3 kg of nitrogen (N), 0.4 kg phosphorus (P) and 3.0 kg of potassium (K)
- To produce one tonne of roots, the crop also needs to produce around one tonne of above ground biomass (leaves and stems) which removes an additional 7.7 kg N, 0.5 kg P and 3.9 kg K

Table 2 shows the amount of the nutrients removed from the soil for crops yielding 1, 10 or 16 tonnes fresh roots.

Table 2: Amounts of N, P, K in cassava roots, leaves and stems, and the entire crop at various cassava root yield levels.

	Nutrient amounts (kg) for crop yielding 1 tonne fresh roots per hectare		
	In cassava roots	In leaves and stems	Total uptake
Nitrogen	2.3	7.7	10.0
Phosphorus	0.4	0.5	0.9
Potassium	3.0	3.9	6.9
	Nutrient amounts (kg) for crop yielding 10 tonnes fresh roots per hectare		
	In cassava roots	In leaves and stems	Total uptake
Nitrogen	23.0	77.0	100.0
Phosphorus	4.0	5.0	9.0
Potassium	30.0	39.0	69.0
	Nutrient amounts (kg) for crop yielding 16 tonnes fresh roots per hectare		
	In cassava roots	In leaves and stems	Total uptake
Nitrogen	36.8	123.2	160.0
Phosphorus	6.4	8.0	14.4
Potassium	48.0	62.4	110.4

If we consider that the natural soil nutrient reserves are sufficient to produce around 10 tonnes per hectare roots then the nutrients removed from the soil to achieve 16 tonnes per hectare (Table 2) is the difference between the amounts in 10 tonnes versus 16 tonnes per hectare. In this case:

- 160 kg N – 100 kg N = 60 kg N per hectare
- 14.4 kg P – 9.0 kg P = 5.4 kg P per hectare
- 110.4 kg K – 69 kg K = 41.4 kg K per hectare

Meeting nutrient requirements with N-P-K fertilizer: To supply 60 kg N using N-P-K 15:15:15 would require: 60 kg N x 100/15 = 400 kg N-P-K, or 8 x 50 kg bags for each hectare (Table 3).

400 kg N-P-K would also supply: 400 kg x (15/100) x (43.6/100) = 26.2 kg P

400 kg N-P-K would also supply 400 kg x (15/100) x (83/100) = 49.8 kg K

Although the amounts of N and K are about right, this is almost 5-times more P than required, as Table 3 shows.

However, in applying fertilizer to supply the nutrient needs of the crop, the farmer needs to keep in mind that not all the nutrients applied are absorbed and used by the crop: the‘standard use efficiency’ for inorganic fertilizers is about 50% - this means that only half of the nutrients applied are actually utilised by the crop.

The farmer should, therefore, apply twice the quantity required to allow for this and to avoid depletion of soil nutrients. In our example this would mean 800 kg or 16 x 50 kg bags of N-P-K fertilizer. But this would mean the farmer was wasting a lot of money supplying P which is not required for the cassava crop (which is why N-P-K fertilizers are not a good choice for cassava; they may, however, in some cases be the only fertilizers available).

The amounts of N-P-K fertilizer that should be used per hectare for every additional tonne of cassava roots over the unfertilized yield (10 tonnes) are: 134 kg N-P-K 15-15-15 or 118 kg N-P-K 17-17-17. This is shown for yields up to 16 tonnes per hectare in Table 4.

Table 3: Nutrients supplied by 400 kg N-P-K.

Nutrient	Amount needed to produce 16 tonnes/ hectare roots (kg)	Amount supplied by 400 kg N-P-K 15-15-15 (kg)	Comment
N	60	60	Right amount
P	5.4	26.2	Nearly 5-times more than required
K	41.4	49.8	About right amount

Note:

Proportion of phosphorus and potassium indicated on fertilizer bags refers to the oxide form (P_2O_5 and K_2O) and not the element (P and K).

To convert from P_2O_5 to P multiply % shown on bag by 43.6/100 (that is 0.436 as shown in Look-up Table 2).

To convert from K_2O to K multiply % shown on bag by 83/100 (that is 0.83).

Table 4: Amount N-P-K needed for yields of 10-16 tonnes per hectare.

	Either of these N-P-K fertilizers	
Yield tonnes/hectare	N-P-K 15-15-15	N-P-K 17-17-17 kg
kg	N-P-K 17-17-17	0
kg	134	118
12	268	236
13	402	354
14	536	472
15	670	590
16	804	708

If the farmer is using N-P-K compound fertilizer, the total quantity of fertilizer required should be applied in three phases (also called splits):

One-third of the total quantity required should be applied 4-6 weeks after planting (using quantities calculated from the anticipated or targeted crop yields). Farmers should use gloves to protect their hands. To apply fertilizer:

1. Using a small weeding hoe (10–15 cm across), scrape a half-moon shaped furrow 20 cm from the base of the cassava plant (Figure 3).
2. Apply the correct measure of fertilizer into the furrow.
3. Cover the applied fertilizer with soil.

Figure 3: Fertilizer applied in half-moon.

A second dressing should be applied 10–12 weeks after planting.

The third dressing is recommended 16–20 weeks after planting. However, this depends on the rainy season: it should not be applied just before the rain stops (Figure 4).

For example, if the target yield is 16 tonnes per hectare and N-P-K 15-15-15 is being used: 804 kg x 1/3 = 268 kg per hectare N-P-K, which should be applied in each of the three splits.

If the second rainy season is short and unreliable then the three dressings should be scheduled in closer intervals so as to supply all fertilizer in the first season.

If second season rains are reliable the last dressing could be applied once the second season rains have established.

For later dressings the use of a hoe may not be appropriate as cassava roots near the surface could be damaged. The fertilizer should be applied in a circle or semi-circle around the cassava at 10-20 cm distance. If the cassava is planted in wider rows and closer distances within the rows the fertilizer may also be banded along the cassava row at 10-15 cm from the cassava row.

Some regions have a bimodal rainfall which allows cassava planting at either the first or the second rains. For such regions, fertilizer application needs to be scheduled according to the length of the rains in each season. For example, if planted at the start of a long rainy season that will be followed by a shorter one, then two dressings should be scheduled in the first season and one in the second. If cassava is planted at the start of a short rainy season, only one dressing should be applied and the others be given in the following longer season. However, farmers should avoid application of fertilizer too late because under dry conditions nutrient uptake is limited or can cause damage.

Farmer-friendly fertilizer recommendations

Farmers are likely to find it difficult to apply accurately fertilizer when the recommendation is presented in terms of kg per hectare. A more farmer-friendly approach is to suggest a volume of fertilizer to be applied per cassava plant, with the volume being compared to a locally available measuring unit.

The crown cap of a soda or beer bottle, or plastic caps of specified sizes and brands of bottled water, fruit squashes etc, or matchboxes all make very useful, free measuring scoops (Photo 9). Once farmers get used to the volume to be applied per plant, they can dispense with the measuring aid and apply directly by (gloved) hand, which will be much faster.

In the above example, 268 kg per hectare of N-P-K 15-15-15 was needed for the first split applied 4-6 weeks after planting. With cassava cuttings planted at row and line spacings of 1 m x 1 m, the planting density is 10,000 plants per hectare:

268 kg = 268,000 g

268,000 g per hectare/10,000 plants per hectare = 26.8 g per plant

The extension officer therefore needs to find a locally available measure which contains about this weight of N-P-K fertilizer: in some cases it may be necessary to use 2 or 3 scoops of the measure to total the required weight.

Photo 9: Examples of measuring units for fertilizer (**A**) A soda bottle top can hold up to about 6 g of fertilizer. For example, if applying 26 g of fertilizer per plant, four full bottle tops and a half of fertilizer can be applied to each plant (photo: CABI) (**B**) The top of a water bottle can hold up to about 8 g of fertilizer. For example, if applying 26 g of fertilizer per plant, three full bottle tops and a half of fertilizer can be applied to each plant (photo: CABI) (**C**) Close-up of a water bottletop containing fertilizer (photo: CABI) (**D**) This top holds about 26 g of fertilizer (photo: CABI) (**E**) The top in (D) can hold about 78 g of fertilizer. If applying 26 g of fertilizer per plant, one full top can be applied to every three plants (photo: CABI)

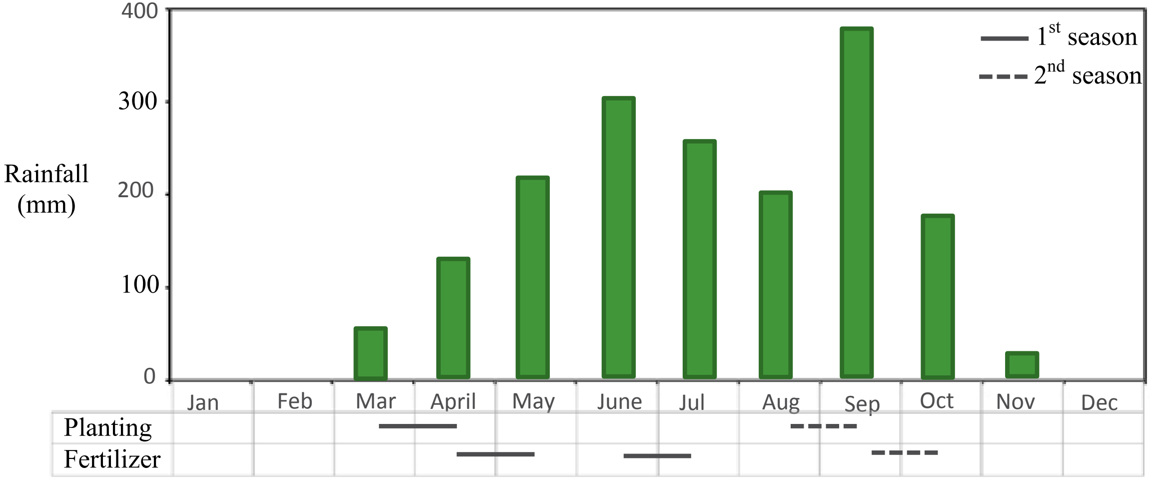


Figure 4: Calendar of 1^{st} and 2^{nd} season planting and fertilizer application. In the 1^{st} season, fertilizer is applied in two splits, $^{1}/_{3}$ in April-May and $^{2}/_{3}$ in June-July. In the 2^{nd} season, all the fertilizer is applied in a single split.

Figure 4: First and second season planting and the fertilizer application periods.

Single nutrient fertilizers: A more cost-effective way of supplying the required nutrients would be to replace N-P-K, partially or completely, with single nutrient sources such as urea, single superphosphate (SSP) or triple superphosphate (TSP) and potassium chloride (KCl, also called muriate of potash). By using a combination of several single nutrient fertilizers, the exact amount of N, P and K needed can be applied - unlike with N-P-K where the ratios of the different nutrients are fixed.

Urea supplies only N (no P or K). It contains 46% N, so a 50 kg bag supplies 50 kg x 46/100 = 23 kg N

Triple superphosphate supplies only P. It contains 19.8% P, so a 50 kg bag supplies 50 kg x 19.8/100 = 9.9 kg P

Potassium chloride supplies only K. It contains 48% K, so a 50 kg bag supplies 50 kg x 48/100 = 25 kg K

The nutrient content of these and other fertilizers are shown in Look-up Table 1.

Use of single nutrient fertilizers requires more calculations but may be less expensive and more efficient.

As with N-P-K, in applying single nutrient fertilizers the farmer should keep in mind that not all the nutrients applied are absorbed and used by the crop. The standard use efficiency of soils for inorganic fertilizers is about 50% - this means that only half of the nutrients applied are actually utilised by the crop. The farmer should, therefore, apply twice the quantity required to allow for this and to avoid depletion of soil nutrients.

Using the nutrient amounts calculated earlier removed from the soil for a yield of 16 tonnes fresh cassava roots per hectare (60 kg N, 5.4 kg P and 41.4 kg K) the following amounts of single nutrient fertilizers are required:

To supply 60 kg N requires: 60 kg x 100/46 = 130 kg of urea. This amount needs to be doubled to allow for the 50% use efficiency: 130 kg x 2 = 260 kg, or about 5 standard 50 kg bags for each hectare.To supply 5.4 kg P requires: 5.4 kg x 100/19.8 = 27.2 kg triple superphosphate (TSP). This amount needs to be doubled to allow for the 50% use efficiency: 27.2 x 2 = 54.4 kg, or about one standard 50 kg bag for each hectare. To supply 41.4 kg K would require: 41.4 x 100/48 = 86.25 kg potassium chloride (KCl). This amount needs to be doubled to allow for the 50% use efficiency: 86.25 kg x 2 = 172.5 kg, or about three and a half standard 50 kg bags per hectare.So, supplying the required nutrients with single nutrient fertilizer requires a total of 9.5 bags per hectare, compared to 16 bags if N-P-K 15:15:15 had been used.

To decide which option is best for them, farmers need to check prices and availability of fertilizers.

If diammonium phosphate (DAP) is the only available source of P, or both TSP and DAP are available but DAP is cheaper, DAP can be used to supply P. DAP would then also supply some of the N required, then urea can be applied to supply additional N.

For example to supply 5.4 kg P requires: 5.4 kg x 100/19.8 = 27.2 kg DAP.

The N in 27.2 kg of DAP is 27.2 × 18/100 = 4.9 kg N

If supplying 60 kg N (as in the above example), additional N required is 60 - 4.9 = 55.1 kg. This can be supplied by 55.1 × 100/46 = 120 kg of urea.

To supply 41.4 kg K would require: 41.4 x 100/48 = 86.25 kg potassium chloride (KCl).

Assuming 50% use efficiency, about 27.2 × 2 = 54.4 kg of DAP (about one 50 kg bag), 120 × 2 = 240 kg urea (about five 50 kg bags), 86.25 kg x 2 = 172.5 kg of KCl (about three and a half standard 50 kg bags) are needed per hectare.

Example of how to compare costs of N-P-K 15-15-15 versus single nutrient fertilizers in the case used above, with target yield of 16 tonnes per hectare

Assumptions:

Cost per 50 kg bag: N-P-K US$ 30; urea US$ 25; TSP US$ 40; KCl US$ 40 (actual prices need to be checked locally).

Cost of N-P-K:

16 x US$ 30 = US$ 480

Cost of single nutrients:

(5 x US$ 25 for urea) + (1 x US$ 40 for TSP) + (3.5 x US$ 40 for KCl) = US$ 125 + 40 + 140 = US$ 305

So, in this case using single nutrients would save a significant amount: US$ 480 – 305 = US$ 175 per hectare.

The application of the single nutrient fertilizers is different from that of N-P-K. It also allows the different nutrients to be applied when they are most needed.

The TSP should be applied at planting in a single dressing.

The urea and the KCl should be applied in three splits at 4-6, 10-12 and 16-20 weeks after planting, with the same technique and the same considerations as for N-P-K, avoiding application when heavy rains are imminent and not applying in or before dry phases.

The following amounts of single nutrient fertilizers should be used for every additional tonne of cassava roots over the usual unfertilized yield (10 tonnes per hectare): 45.5 kg urea, 9.1 kg TSP and 28.8 kg KCl per hectare (see Table 5).

Table 5: Amount of single nutrient fertilizer needed for yields of 10-16 tonnes per hectare.

	All 3 of these single nutrient fertilizers kg/hectare		
Yield tonnes/hectare	Urea	TSP	KCl
10	0	0	0
11	45.5	9.1	28.8
12	91	18.2	57.6
13	136	27.3	86.4
14	182	36.4	115.2
15	227.5	45.5	144
16	273	54.6	172.8

Practical considerations: One additional matter to observe when applying fertilizer is the canopy development of the cassava: a lush dark green and dense canopy indicates that the N supply is sufficient, so if this is observed by farmers they may reduce or eliminate N (urea) application. This is particularly advisable for dressings close to the start of dry phases.

For efficient use of labour, a 'production line' approach should be used when applying fertilizer. For example, 3 people working together in a well-organised system should be able to apply fertilizer to 10,000 plants, i.e. 1 hectare, in 1-2 days.

Major factors to consider when applying fertilizer are:

- **Labour requirement** – do you have the required number of people for your farm size?
- **Weather conditions** – do not apply fertilizer just before heavy rain is expected, or when the soil is too wet or waterlogged, because the nutrients could be washed off or leached into inaccessible soil layers. Do not apply fertilizer under dry conditions because the high salt concentrations in a soil with low water content can damage the crop (commonly called 'burn').
- **Fertilizer type** – do you have the right type of fertilizer for your crop? Have you considered the crop requirements and the status of your soil? Note that nutrients can be supplied by straight or compound fertilizers. However the decision on type of fertilizer to use should depend on availability and cost.
- **Fertilizer availability** – do you have enough fertilizer for your farm to achieve the target yield? It is recommended that if the quantity of fertilizer is not enough for the entire plot, the farmer should apply the recommended amount to the portion of the farm for which the available quantity is enough, and to leave the remaining section of the farm without any fertilizer. This enables farmers to see for themselves the benefit of fertilizer application in terms of yield increases – the farmers are actually doing a mini with/without trial on their own farms.

Fertilizer use on intercrops

For cassava cultivated as an intercrop, the following fertilizer application tips apply.

Cassava intercropped with maize

In the maize-cassava intercrop, nitrogen (N) application is mostly targeted at maize while phosphorus (P) is targeting both crops and potassium (K) is largely for the cassava. The P should be applied at planting (preferably as TSP) or shortly after planting (then preferably as DAP). To provide maize with N, a total of 60 to 90 kg of N per hectare should be applied in 3 equal splits at 2, 4 and 6 weeks after planting.

So, for one split of 20 kg N, this requires: 20 kg x 100/46 = 44 kg urea (or about one 50 kg bag) per hectare.

The K requirements of maize are relatively low so the supply can be scheduled to serve the cassava which has the highest demand during the bulking phase of the tuberous roots, which commences in most varieties around 3 months after planting.

However, the amount applied should be adjusted based on the observed colour of leaves of the maize: if the leaves are pale green-yellow this indicates nitrogen deficiency, therefore add more N. The urea is applied by banding 10-15 cm from the base of the maize stand (i.e. applying in a narrow band along the row of maize). Although the urea application is targeting the maize in an intercrop system, fertilizer applied primarily to one crop will most likely impact on the cassava as well.

Cassava intercropped with legumes

In this intercrop arrangement, the most likely deficient soil nutrient is phosphorus (P). Low P supply reduces the ability of legumes to fix nitrogen. This limits the grain yield and the legume's contribution to soil fertility restoration.

The recommended fertilizer for this intercrop is triple superphosphate (TSP) applied when the legume seed is sown in a single dressing at the rate of 1 x 50 kg bag per hectare, followed by urea and KCl applications as for a cassava mono-crop (see above).

Farmers should observe the cassava canopy: if the canopy is sparse and of pale yellowish colour the amount of urea should be increased and applied when these symptoms are observed.

Cassava intercropped with vegetables

This intercrop requires more nitrogen (N) than cassava monocrop. The fertilizer application is similar to cassava intercropped with maize, but probably with a lower nitrogen requirement. The N needed will vary depending on the vegetables being grown: green leafy vegetables are nitrogen-hungry, therefore, more N should be applied.

Micronutrients

Micronutrient deficiencies are hard to diagnose in cassava because the signs may be mistaken for disease symptoms. If you have followed all the tips offered on nutrient application of N, P and K in this handbook and your cassava yield remains below 16 tonnes per hectare in a good rainfall year, the problem might be micronutrient deficiencies.

For example, zinc deficiency, whose symptoms are yellow or white spots between veins, can sometimes be observed in young cassava plants. Symptoms, such as rotting stem or root, may indicate boron deficiency.

Many of the nutrients can be supplied by applying fertilizers (Look-up Table 1). Multi-micronutrient products exist (including in spray formulations), but the farmer should seek advice before acquiring and using these products. In general, advice should be sought on how to address problems caused by micronutrient deficiencies in cassava.

Organic matter

Cassava tends to be grown in non-cattle areas, limiting access to cattle and farmyard manure. In these areas small ruminants usually run free making manure collection difficult. Livestock markets can, however, be a source of manure. Industrial poultry and pig farms co-exist in some regions with cassava producing areas and they too can be a source of manure.

Organic matter – including poultry manure, cow dung, household waste and compost - provides both nutrients and organic carbon, which improves the soil's physical properties, water retention and microbial activity, all leading to a 'healthy soil' with fewer pests and diseases.

For land under continuous cultivation, the recommendation is to apply as much organic matter as possible before tillage. Often manure is used closer to the homestead (where livestock are housed) and on high-value crops, and also because this limits labour and costs of transporting bulky organic matter. Organic matter is often a scarce resource, and should be applied to the crops which will result in greatest economic return. In many cases, this will not be cassava.

Organic matter from crop or household residues should be composted for 4-6 months before application on the farm.

In terms of nutrients, manure mostly supplies N, which may not be the most limiting nutrient for cassava. However, it also contains other nutrients, which help to improve the soil nutrient status.

The key challenges regarding organic fertilizer use include:

1. Limited quantity of suitable organic matter for composting or conversion to manure.
2. Bulkiness, which increases the cost of handling, as well as transportation over long distances
3. High variability in nutrient content
4. High variability in nutrient availability and release to the crop.

Due to these challenges, farmers using organic inputs need to observe their cassava crops more intensively than if they rely only on inorganic fertilizer.

As a general rule, phosphorus (P) in organic materials is not very easily available. The full amount of P-containing inorganic fertilizer should therefore be applied with no reduction made for the organic matter supplied.

Potassium (K) content in manures and composted materials is usually low. The full amount of K containing inorganic fertilizer should therefore be applied with no reduction made for the organic matter supplied.

Nitrogen (N) availability depends on the type of organic material and may be rapidly or slowly released to the crop. Farmers therefore need to carefully observe cassava canopy development and colour – if it looks sparse and pale, then N should be applied as urea. Such N application often triggers decomposition of organic matter and leads to accelerated release of N, so N rates from fertilizer should be small to avoid excess N supply.

Residue management under intercrop arrangements

It is recommended that the maximum amount of crop residue should be left in the field where it was grown. This is easier for maize, where only the cobs are carried out of the field, but more difficult for legumes. For example, groundnuts and soybean plants are usually cut or pulled and carried from the field to pick the pods, while cowpea plants remain in the field in some regions and pods are continuously picked from the still growing crop. In regions with intense competition for crop residues as livestock feeds, cooking fuel, thatching or fencing materials, it is likely that all biomass of the intercrop is removed. In some regions, cowpea fodder can fetch the farmer more income than the grain.

If possible, cassava leaves and peels should be left in the field and incorporated into the soil.

Where livestock is fed crop residues, manure may be brought back to the field – especially if the farmland is near the homestead.

Generally, avoid burning of crop residues: carbon (C), nitrogen (N) and sulphur (S) will be lost to the atmosphere: it is much better to leave the crop residues as mulch on the surface. The ash left is a poor fertilizer and tends to be blown away or leached into deep soil layers. Burning also exposes the soil to erosion.

Harvesting cassava

To harvest cassava manually, do the following:

- Cut the stem at knee to waist height (as preferred)
- Use a hoe or cutlass to free the roots
- Avoid damaging the cassava roots
- Pull out the roots by hand

- Check the base of the cassava for any broken-off roots and dig for them out of the soil

For mechanical harvesting, a special cassava harvesting tool has been developed which employs the principle of leverage and therefore makes the task easier. There is also a tractor-pulled cassava harvester. For details of these devices, visit the IITA website **http://www.iita.org**.

On a well-managed cassava farm planted at the recommended density of 10,000 plants per hectare, each cassava stand will need to produce an average of 1.6 kg of useful roots to generate 16 tonnes of fresh cassava roots per hectare. When processed this will give about 3.2–4 tonnes of edible dry matter.

Cassava leaves can also be harvested periodically and used as a leafy green vegetable. There is varietal variation, but root yield reductions of up to 40% have been recorded where leaves are harvested. The farmer should be aware that harvesting the cassava leaves may reduce the root yield.

Key checks

- Two weeks after planting, cuttings that have not sprouted should be removed and disposed of away from the cropping area. If failure was due to drought, wait until rains resume before replacing failures.
- Failures should be replaced with healthy cuttings by the third week after the initial planting but the new cuttings should not be planted in exactly the same hole from where the failed cuttings were removed.
- Weed control should start 3–4 weeks after planting, and then repeated at 8 and 12, and the final weeding should be done between 20 and 24 weeks after planting, depending on the rainfall. Weeds with rhizomes and weed species with the capacity to form roots from stem pieces and grasses should be uprooted and disposed away from the field.
- If cassava is intercropped with legumes, choice of herbicide is limited. Pre-planting application of glyphosate is permissible.
- For every 1 tonne fresh cassava roots harvested, farmers need to apply about 20 kg N,
  1.8 kg P and 13.8 kg K. These amounts are double the plant requirements because only half of fertilizer applied is utilized by plants. Fertilizer can be N-P-K or single-nutrient.
- For N-P-K, one-third of the total quantity of fertilizer required should be applied 4–6 weeks after planting, one-third at 10–12 weeks, the rest at 16–20 weeks. Fertilizer can be applied in a half-moon shaped furrow 20 cm from the base of the cassava plant then covered.
- If canopy is a lush dark green and dense, nitrogen application should be reduced or eliminated.
- Fertilizer should not be applied just before heavy rain, when the soil is too wet or waterlogged, or under dry conditions.

- In cassava intercropped with maize, target N to maize, P to maize and cassava and K to cassava. Apply about 60–90 kg of N per hectare to maize, in 3 equal splits at 2, 4 and 6 weeks after planting. In cassava intercropped with legumes, 1 x 50 kg bag TSP per hectare to the legume at seeding, followed by N (e.g. urea) and K (e.g. KCl) to cassava.
- When harvesting, leave as much cassava crop residue in the field as possible and incorporate the residues into the soil.

6. What can go wrong?

Cassava production involves many technical, social and financial processes that have been described in this handbook. Even if the farmer has done everything right, unexpected problems could still occur. Some of these problems (Photo 10) and how to respond to them are presented in the table below (Table 6).

Table 6: What can go wrong?

Problem	What to do
Drought (i.e. low rainfall or no rain at all)	Select drought tolerant varieties especially in areas with less than 1000 mm of rainfall per year
Viral and bacterial diseases	Choose disease-free planting material Choose varieties that are tolerant to prevailing disease Uproot and burn diseased plants to avoid transmission For localized diseases in the field, spray with legally permitted insecticide to prevent further transmission by insect vectors
Rodents – rats, grass-cutters, etc which can damage roots	Limit their habitat cover by proper weeding Trap or snare as legally permitted
Birds – e.g. quails scratch the soil surface and damage roots	Use an effective scare-crow Trap or snare as legally permitted
Post-harvest market glut	Consider field storage (delay in harvesting) Consider processing into valuable secondary products (Photo 11) Explore guaranteed contract production opportunities Take out an appropriate agricultural insurance policy (e.g. on guaranteed minimum price or inventory credit) Seek useful market information on distant markets

Photo 10: Pests and diseases (**A**) Stunted plant infected with cassava mosaic virus (photo: CABI) (**B**) Leaves of plant infected with cassava mosaic virus (photo: CABI) (**C**) Cassava plant damaged severely by cassava mealy bug. A mealybug is enclosed in the red cycle (photo: CABI) (**D**) Plant damaged by termites (photo: CABI)

Photo 11: Processing cassava roots (**A**) Processed cassava (photo: CABI) (**B**) Processed cassava roots can be packaged and sold when prices are good (photo: CABI)

7. Cassava production economics

Economics of cassava systems

It is important to have an idea of whether a new farming practice, such as use of fertilizer, 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 after introduction of the new farming practice.

Simple calculations can provide useful insights into the likely costs and benefits while needing only a minimal amount of data/ information.

For example, if a farmer who has been obtaining yields of 10 tonnes per hectare of fresh roots with no fertilizer decided to use 16 bags each of 50 kg of N-P-K 15-15-15, the increase in yield required to recover the additional cost of fertilizes (assuming price of N-P-K is USD 25 per 50 kg bag, and price of cassava is USD 40/tonne fresh roots) can be calculated as:

Minimum increase in yield required (t/ha) =

$$\frac{\text{Cost of N-P-K fertilizer}}{\text{Price of cassava}} = \frac{16 \times 45}{40} = 10 \text{ t/ha}$$

So, in this example, the farmer would need to obtain 20 tonnes per hectare just to recover the cost of the investment in fertilizer.

To take the analysis a step further, the extra costs incurred with use of a new technology can be compared with the additional benefits obtained through the use of the technology.

For example, if in the above example the previous yield was 10 tonnes per hectare but with use of 16 bags of N-P-K fertilizer per hectare the yield increased to 21 tonnes for a cassava variety that responded well to fertilizer ('efficient variety') and 13 tonnes for a variety that responded poorly to fertilizer ('inefficient variety') the economic benefits can be calculated using the following steps (Table 7):

Step 1: Calculate the change in yield brought about by use of fertilizer

Step 2: How much the change in yield is worth

Step 3: The amount of money required to purchase fertilizer

Step 4: How much money the farmer is left with after deducting cost of fertilizer

Step 5: The value of yield can be compared with the costs, in the value/cost ratio (VCR)

As a rule of thumb, a value/cost ratio greater than 2 is needed for an investment to be economically attractive to farmers. So, in the above example use of fertilizer would not have been cost-effective; a significantly higher price for cassava would need to be obtained for this level of fertilizer usage to make economic sense.

If additional information, for example on costs of labour, is available, more detailed calculations can be carried out. Reductions in costs of labour due to herbicide application may prove economical, particularly where persistent weeds are present.

Remember, the best use of a resource should be explored in order to get the best return from the input.

A point to note is that prices of inputs and yields of crops can vary. For example, better incomes could perhaps be obtained by processing raw cassava roots into an added value product. 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.

Table 7: Examples of economic benefits of a technology.

		'efficient variety'	'inefficient variety'
Step 1: Difference in yield	Yield with fertilizer - yield without fertilizer	21 – 10 = 11	13 – 10 = 3
Step 2: Value of yield	Difference in yield × price of cassava	11 × 40 = 440	3 × 40 = 120
Step 3: Cost of fertilizer	Amount of fertilizer × price of fertilizer	16 × 25 = 400	16 × 25 = 400
Step 4: "Profit" or "loss" made	Value of yield - cost of fertilizer	440 – 400 = 40	120 – 400 = -260
Step 5: Value cost ratio (VCR)	Value of yield ÷ cost of fertilizer	440 ÷ 400 = 1.1	120 ÷ 400 = 0.3

8. Look-up tables

Look-up Table 1: Nutrient content (%) of fertilizers commonly available in sub-Saharan Africa.

Fertilizer		N	P_2O_5	K_2O	MgO	CaO	S	Other
Urea	–	46						
Ammonium chloride	AC	25						66 Cl
Ammonium nitrate	AN	34						
Calcium nitrate	CN	15				26		
Calcium ammonium nitrate	CAN	27			2	4		
Ammonium sulphate	AS	21					24	
Monoammonium phosphate	MAP	11	48–55		0.5	2	1–3	
Diammonium phosphate	DAP	18–21	46–53				1–1.5	
Rock phosphate	RP		25–41			25–50		
Fused magnesium phosphate	FMP		12–20		10–15	12–16		
Single superphosphate	SSP		16–22			28	11–14	
Double superphosphate	SP36		32–36				5–6	
Triple superphosphate	TSP		44–53		0.5	12–19	1–1.5	
Potassium chloride	KCl			60–62				47 Cl
Potassium sulphate	SOP			50–53			17–18	
Potassium nitrate	KN	13		44	0.5	0.5	0.2	
Kieserite	Kies				27		22	
Langbeinite	SKMg			22	18		22	
Dolomite	GML				10–22	35–45		
Fertilizer		N	P_2O_5	K_2O	MgO	CaO	S	Other
Agrilime (calcite)	–					47		
Gypsum	–					22–30	13–16	
N-P-K 15–15–15	–	15	15	15				
N-P-K 16–16–8	–	16	16	8			1	
N-P-K 13–13–21	–	13	13	21				
N-P-K 12–12–17+2(Mg)+(TE)	–	12	12	17	2			Micro
N-P-K 15–15–6+4(Mg)	–	15	15	6	4			
N-P-K 5–18–10		5	18	10			8	
N-P-K 5–17–15		5	17	15				
N-P-K 8–14–7		8	14	7	34			

Look-up Table 2. Nutrient conversion factors.

From	Multiply by	To get/From	Multiply by	To get
NO_3	0.226	N	4.426	NO_3
NH_3	0.823	N	1.216	NH_3
NH_4	0.777	N	1.288	NH_4
P_2O_5	0.436	P	2.292	NH_4
K_2O	0.83	K	1.205	K_2O
SO_2	0.500	S	1.998	SO_2
SO_4	0.334	S	2.996	SO_4
SiO_2	0.468	Si	2.139	SiO_2
MgO	0.603	Mg	1.658	MgO
CaO	0.715	Ca	1.399	CaO
$CaCO_3$	0.560	CaO	1.785	$CaCO_3$

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

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

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

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

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CABI, ICRAF complex, P.O. Box 633-00621, Nairobi, Kenya
Tel: +254-20-722 4450/62 Fax: +254-20-712 2150 Email:Africa@cabi.org
Website: www.cabi.org/ashc