AFRICA soil health consortium

Sweetpotato cropping guide

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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.

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Photo 2 Sweetpotato planting material leaflet NRI/CIP

Photo 3, Figure 6, 7 Schulte-Geldermann, E., Agili, S., Ndolo, P. and Low, J. 2012. Net tunnels to protect sweetpotato planting material from disease a guide to construct and maintain tunnels. International Potato Center (CIP).

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Photo 10, 11 T. Ames, N.E.J.M. Smit, A.R. Braun, J.N. O'Sullivan and L.G. Skoglund. 1996. Sweetpotato: Major Pests, Diseases, and Nutritional Disorders. International Potato Center (CIP). Lima, Peru. 152 p.

Simon Ndonye for the illustrations.

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, cassava, maize-legumes, sorghum and millet-legumes, groundnuts and rice systems but this guide is focused on sweetpotato.

Rural extension workers will find this handbook particularly useful for guiding their clients as they shift from producing sweetpotato 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 including those that combine sweetpotato with a range of other crops, either as intercrops or in rotations, but with the primary focus on sweetpotato.

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.

The overall objective of the handbook is to provide simple guidance and useful tips on how farmers with small to medium-sized farms can benefit from more efficient and profitable sweetpotato production and utilisation. By following the recommendations in this guide, smallholders should be able to increase production from around 5 tonnes fresh roots per hectare to 20 tonnes per hectare or even more.

2. Sweetpotato cropping systems

Why grow sweetpotato?

The sweetpotato is primarily a starchy root crop but the leaves can also be eaten as a leafy green vegetable.

It can be grown as a staple food but is more often grown as an alternative foodstuff for household consumption or, increasingly, as a cash crop.

The area in which sweetpotato is grown in Sub-Saharan Africa is expanding faster than for any other food crop. Between 1996 and 2006, it increased by over 70% to about 12 million hectares.

There are several reasons for this, including:

- The development of sweetpotato value chains: this provides the means for moving the food product into commercial and institutional markets.
- Many smallholders have turned to sweetpotato in response to severe disease outbreaks affecting other staples, especially cassava brown streak virus and bacterial wilt diseases of banana.
- Growing recognition of the superior micronutrient content of sweetpotato compared to other crops, especially the role of orange-fleshed varieties of sweetpotato in addressing widespread vitamin A deficiency.
- The need for crops, such as sweetpotato, that are more drought tolerant than maize.
- In some countries, such as Malawi, the government has actively promoted the crop to smallholder farmers as part of the strategy to diversify away from maize following devastating drought in the 1990s. In Malawi, annual consumption has

increased twenty-fold from just 12 kg per person in the 1970s to 240 kg per person in 2012.

The sweetpotato has a number of beneficial features:

- It is a low input crop that is robust and fast maturing, producing reliable yields even under adverse conditions and on marginal soils.
- The deep (up to 0.9 m) and branching root system of sweetpotato enables the plant to absorb water in deeper soil layers than occurs in most crops. Once roots are established they can survive reduced soil moisture, resuming growth when the rains occur.
- It is among the most productive crops with regard to production per unit area and time.
- Depending on the variety and production zone, sweetpotato can be ready for harvesting from 3 to 8 months after planting.
- Sweetpotato can provide food during the hunger gap, before cereals and other crops are ready for harvest.
- Unlike a cereal crop, which all has to be harvested at the same time, the roots can be harvested as they are needed by the farming household (piecemeal/staggered harvesting).
- Sweetpotato offers greater flexibility around planting and harvesting times, requires lower management compared to grain crops and makes less demand on labour. This is especially important where availability of adult labour has been reduced due to HIV.
- Sweetpotato is nutritious. All varieties are good sources of iron, zinc and potassium, B vitamins and also vitamins K, C and E. The orange-fleshed varieties of sweetpotato are also

rich sources of beta-carotene. The body turns beta-carotene into vitamin A, which is required for healthy skin and mucus membranes, an effective immune system and good eye health and vision. In 2013, nearly half of all children under 5 years of age in Sub-Saharan Africa had vitamin A deficiency (VAD), a risk factor for blindness and for mortality from measles and diarrhoea. Just 125 g of boiled, mashed orange-fleshed sweetpotato (OFSP) provides the recommended daily intake of vitamin A for children.

- In addition to the roots, fresh leaves can be eaten as a nutritious green leafy vegetable. They are a good source of protein, niacin (vitamin B3), calcium and iron, and a very good source of dietary fibre, vitamin A, vitamin C, thiamine, riboflavin (B2), vitamin B6, folate, magnesium, phosphorus, potassium and manganese. The sweetpotato leaf is also an excellent source of lutein which appears to have a role in maintaining healthy eyes. They are especially useful during the dry season when few other fresh vegetables are available.
- Sweetpotato vines, which can be very productive, are a nutritious, highly digestible and palatable feed that can be fed to cattle, goats, sheep, pigs and rabbits, fresh, dried as hay or made into silage.
- Sweetpotato flour or puree can be used as wheat flour substitute in breads, cakes and other bakery products. It can contribute towards household and national food and nutrition security, as well as offering the potential for cash income from sales and creates employment and business opportunities, such as through commercial production of clean planting material.

Sweetpotato varieties

There are many varieties and local cultivars of sweetpotato and plant breeders are developing new varieties with desirable qualities to meet today's needs, such as earliness of maturing, drought tolerance, resistance to pests and diseases, and high yields of attractively shaped roots with desired qualities for diverse end uses.

The flesh of sweetpotato can be white, cream, yellow, purple or orange depending on variety.

Sweetpotato varieties can be spreading, semi-erect or erect. They also range from early maturing (3 months after planting) through to late maturing (up to 10 months after planting).

While most varieties are grown primarily for roots, the leaves are also valued as a green vegetable by many communities and some varieties are grown primarily for the vines, which are fed to livestock, with root production being of secondary consideration.

Towards better yields

Using high-input systems and under excellent management, commercial growers in South Africa routinely achieve yields of over 50 tonnes of fresh roots per hectare. Average production in the rest of Sub-Saharan Africa is much lower at less than 5 tonnes per hectare. This is due to poor agronomic practices and challenging production conditions, such as late planting, inadequate weeding, incorrect spacing and inadequate soil fertility and water management.

A major constraint is the use of disease and pest-infected planting material.

Experts suggest that sweetpotato yields can be increased in three main ways:

1. Adoption of better agronomic practices can increase yields by around 60%; if mineral fertilizers are used this can increase to 100%.
2. Use of clean, healthy planting material – free from sweetpotato virus – can increase yields by around 40%.
3. Finally, better control of sweetpotato weevils can increase yields by 10-20%.

Some smallholders regard sweetpotato as a poor man's crop; however, successful promotional campaigns, such as the one in Malawi, have helped change attitudes. Increasingly it is now recognised as a high-value crop, which can play an important role in food security and increasing cash income.

By following the recommendations in this cropping guide, smallholders should be able to increase yields from around 5 tonnes of fresh roots per hectare to 20 tonnes or more and avoid post-harvest losses.

3. Site selection, land preparation, production of planting material and planting

Requirements for sweetpotato

Soils: Sweetpotato can be grown in a wide range of soils but does best in well drained, deep, moderately fertile sandy loams with a pH of 4.5 to 7.0 (slightly acidic to neutral).

If the soil pH is less than 5, agricultural lime needs to be applied to the soil.

The sweetpotato is moderately tolerant to aluminium toxicity, although this varies amongst different varieties. Liming is recommended in soils where aluminium toxicity could be a problem.

Because adequate drainage and aeration is important sweetpotato is usually grown on mounds or ridges; the crop is not tolerant of water-logging and a loose soil structure helps the roots to develop.

Climate: Growth is optimal at day-time temperatures of 25-30°C and night-time temperatures of 15-20°C. Sweetpotato can, however, be grown at between 15 and 33°C. In less ideal conditions the crop takes longer to be ready for harvest.

Annual rainfall of between 750-1,000 mm per year is required with a minimum of 500 mm falling during the growing season. The crop is especially sensitive to drought at establishment and from 20 to 30 days after planting when the storage roots start to develop. There is considerable variation among cultivars with regard to sensitivity to environmental conditions, including drought and variation in soil fertility.

Elevation: Sweetpotato grows well from sea-level to 1,700 metres above sea-level (masl), although some varieties can grow up to 2,500 masl.

Inputs: In Africa, sweetpotato is usually grown without the use of mineral fertilizers or irrigation, although many commercially-oriented farmers recognize the need to use fertilizers.

Market access: If smallholders increase production beyond their household requirement they will need access to markets for the surplus and/or will need to invest in improved storage technologies. Currently, however, there is very little use of controlled storage in Sub-Saharan Africa, though efforts are under way to develop appropriate technologies, including in-ground, improved pit storage and cold storage. Commercially important varieties are marketed quickly following harvest and may also be somewhat resistant to rots and shrinkage that occur during transportation and marketing.

Land preparation

Sweetpotato can be grown on mounds, ridges or flat beds.

Growing on mounds or ridges ensures good drainage and aeration of the soil, makes it easier to harvest the roots and gives higher yields than growing on flat beds. They are especially beneficial on land prone to water logging. Mounds and ridges require more labour for land preparation than flat beds.

Mounds are usually made by hand using a hoe. The mounds should be about 30 cm high and 30 cm wide with between about 60 cm (erect varieties) to 1 metre (spreading varieties) between mounds. One metre between mounds gives 10,000 mounds per hectare.

Ridges are usually made by ox-drawn ploughs or tractors. The ridges should be about 30 cm high with between about 60 cm (erect varieties) to 1 metre (spreading varieties) between the top of adjacent ridges (Figure 1).

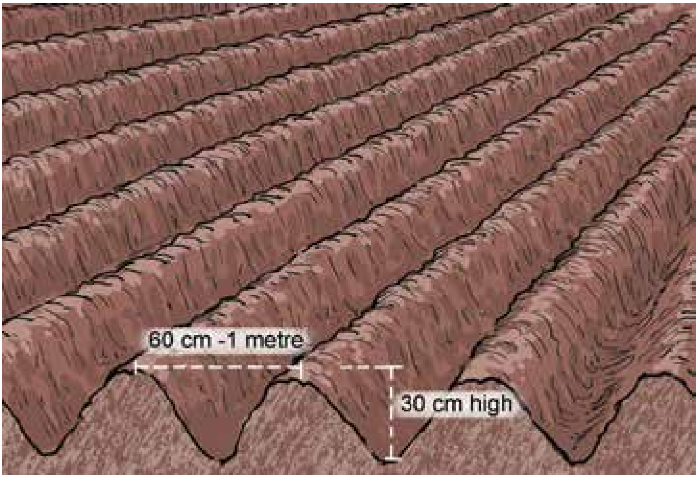

Figure 1: Ridges and mounds prepared for planting sweetpotato – spaced 60 cm to 1 m apart

When making either mounds or ridges the soil should be heaped up over the residues of the previous crop or vegetation from a fallow period. This provides nutrients and also loosens compacted soil which helps root formation. Farmyard manure, poultry manure, compost or green manure can all be beneficial and if available should be incorporated at this time. Incorporation of organic matter contributes to soil quality, including fertility and water holding capacity.

Rotations: To avoid build-up of pests and diseases, sweetpotato should not be grown on the same plot every year, though there are instances where this is successfully done. A three-crop rotation with cereals, legumes and sweetpotato is ideal, for example sweetpotato grown in year 1, cereal or legume in years 2 and 3, then sweetpotato in year 4.

If sweetpotato has to be grown on the same plot in successive years, sanitation is important, with old roots and vines being incorporated into the soil or removed to prevent carry-over of pests and diseases to the new crop.

Smallholders rarely apply mineral fertilizer to their sweetpotato crops. If sweetpotato is grown as part of a rotation system they can, however, benefit from nutrients associated with the previous crop. So, sweetpotato does well after cereals and legumes as the crop can benefit from fertilizer applied to cereals and nitrogen fixed by the legume crop.

Sweetpotato should not be planted after other root crops, especially cassava, which has similar nutrient requirements.

Sweetpotato is also well suited as the first crop after a fallow period as it leaves the soil easy to prepare for the next crop.

Intercropping

Intercropping means growing two crops at the same time in the same plot.

Benefits of intercropping sweetpotato with other crops, such as maize or legumes, include:

- Increased diversity of crops and foods grown
- Increased efficiency of labour
- Increased productivity per unit of area
- Reduced risk of total crop failure compared to when just one crop is grown

- Increased soil fertility due to fertilizer application to the intercrop, for example, maize, or nitrogen fixation by legumes
- Decreased impact of weeds as the two crops outcompete the weeds for space, light, water and nutrients
- In some cases, reduced threat of pests and diseases.

Some examples of successful intercrops with sweetpotato include:

Sweetpotato and maize: Experience from Malawi suggests that the best productivity is obtained with a strip intercropping planting pattern of two rows of sweetpotato with one row of maize. Local farmers preferred to grow two rows of maize with one row of sweetpotato because of the value they attached to the maize crop (Photo 1).

Photo 1: Sweetpotato and maize intercrop; two rows of sweetpotato with one row of maize

A relay intercropping system in which sweetpotato is planted as the maize approaches harvest has proved to be effective in Ghana. Such a system needs a long rainy season.

Sweetpotato and beans or soybeans: A row of common bean or soybean can be intra-cropped together with the sweetpotato in the same ridge. Experience from Malawi suggests that the best productivity is obtained with a planting pattern that has a repeat pattern along the ridge of three sweetpotato plants followed by six soybean or bean plants.

Sweetpotato and pigeonpea: Two rows of sweetpotato alternated with two rows of pigeonpea has proved to be an effective planting pattern in Nigeria. In addition to fixing nitrogen, pigeonpea has some other beneficial features: it grows slowly at first and therefore does not compete strongly with sweetpotato. It is also deep-rooted and can therefore continue to grow after the sweetpotato has been harvested, during the dry season and when nothing else can be planted.

Sweetpotato alley cropping: Sweetpotato can also be grown in alley cropping systems. Here rows of shrubs and trees, many of which are legumes, are grown 4–8 metres apart with between 4–8 rows of sweetpotato grown in between.

The shrubs and trees are pruned regularly and the prunings used as a green manure, releasing nutrients, acting as a mulch and improving the structure of the soil. Alternatively, the prunings are fed to livestock and their manure can be applied to the soil.

Species of trees and shrubs grown will vary locally but common species include: the river bean tree (*Sesbania sesban*); the ear leaf acacia (*Acacia auriculiformis*); the kassod tree (*Cassia cajan*); pigeonpea (*Cajanus cajan*); mother of cocoa or Nicaraguan cacao (*Gliricidia sepium*); and elephant ear tree (*Enterolobium cyclocarpum*).

Planting vine cuttings

Sweetpotato are not grown from seed in the way that cereals, legumes and vegetables are. Instead they are grown from fresh vine cuttings, usually about 30 cm long, consisting of 3–5 nodes, taken from vigorously growing plants (Figure 2). The best results are obtained with tip cuttings, but often the cuttings are taken from the length of a vine. Cuttings from the base of the vine should be avoided as these may harbour weevils and will also result in the least vigorous plants.

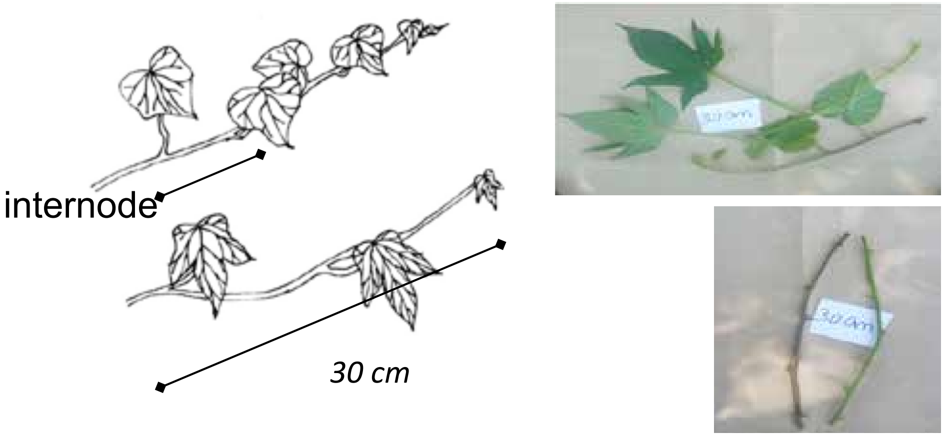

Figure 2: Taking vine cuttings

A major challenge for smallholders growing sweetpotato is to have enough pest- and disease-free planting material available ready for planting: planting soon after the rain begins is necessary to ensure a high yield. This is especially difficult in regions with unimodal rainfall (one rainy season a year followed by a long dry season).

Cuttings are quite bulky: to plant a one hectare plot using the mound/ridge system requires about 30,000 cuttings which weigh about 600 kg – 30 large sacks full.

Cuttings are also perishable: the cuttings need to be planted soon after they have been taken from the parent plants.

Vine cuttings should have at least 3–5 nodes (the place where the leaves are attached – see Photo 3): depending on the variety this can vary between 20 and 30 cm long.

To plant, a small hole is made with a stick, hoe or machete and the cutting inserted so that at least two nodes are under the soil with just the tip sticking out. It is not necessary to remove the leaves. The cutting is then firmed in. To plant one hectare takes about 32 person-hours of labour.

For mounds, three cuttings are usually planted towards the top of each mound with the cuttings evenly spaced: with 10,000 mounds per hectare around 30,000 vines are needed per hectare.

For ridges, cuttings are planted along the top of the ridge (or in rows on flat beds), either upright or at a slant, with 30 cm between cuttings in a row and between 60 cm and one metre between rows: 33,333 cuttings are needed per hectare when rows are spaced one metre apart (Figure 3).

Erect growing varieties can be planted more closely, from 60 cm between rows or mounds, and spreading varieties more widely, up to one metre.

Some farmers like to place two cuttings per hole but this needs twice as many cuttings. It is better to use just one cutting per hole and then fill any gaps after about two weeks.

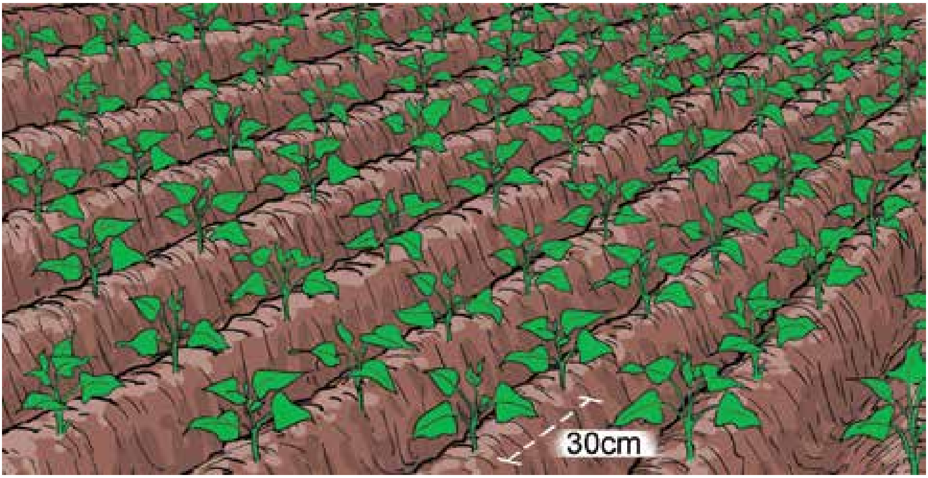

Figure 3: Cuttings planted at 30 cm intervals along top of ridges

Source of planting material

To ensure a good yield, farmers need to have access to sweetpotato planting material at the start of the rainy season: planting at the beginning of the rainy season compared to a few months later can result in double the yield, particularly if the rainy season is short.

In areas with two rainy seasons a year (bimodal rainfall) farmers can usually obtain planting material from the previous season's crop.

In areas with one rainy season a year (unimodal rainfall) followed by a long dry season, planting material can easily be lost between crops.

There are several options to obtain planting material in the unimodal areas including:

- A small area of sweetpotato can be maintained through the dry season in a damp area: a shady area near the homestead, such as under the canopy of a banana plant, or a washroom drainage area. The rapid multiplication method, in which 3 node vine cuttings are planted at spacings of 10 cm by 20 cm would be suitable (see below).

- Roots left in the field, accidently or deliberately, will sprout when the rains begin and planting material can be gathered a few weeks later.
- Roots can be stored and planted out in nursery beds a few weeks before the rain is expected to start. The roots sprout and rapidly produce large amounts of planting material (see Triple S: Storage in sand with sprouting), below.
- Cuttings can be purchased from neighbouring farmers who have good access to water and who grow sweetpotato planting material as a business.

Before taking the vine cuttings, any plants showing signs of virus disease should be pulled up and destroyed. This technique is usually called the 'negative selection method'. Cuttings should be taken from the tip of the vine. Each cutting should contain three to five nodes (places on the vine where the leaves grow from). If the vine is long enough, several cuttings can be taken but all cuttings should be taken at least 30 cm above soil level to avoid weevil eggs, larvae or pupae, or stemborer eggs.

Triple S: Storage in sand and sprouting

The Triple S system is a simple and inexpensive way for smallholders in unimodal rainfall areas to ensure they have planting material available at the start of the rainy season.

1. At the end of the rainy season, small to medium sized roots (which have little market value) are selected from parent plants

that are healthy looking and that are free from weevil or other damage.

2. The roots are carefully placed in layers in a container about 30 cm deep, such as a large plastic bowl lined with newspaper. Starting with a layer of sand, layers of roots are added, each covered with dry sand. Ideally the roots should not touch. About 30–40 roots will fit in a large bowl with two layers of roots (Figure 4). Tip: Sand can be obtained for free by sweeping roads and around the house. Sand should be thoroughly dry and cool before use.

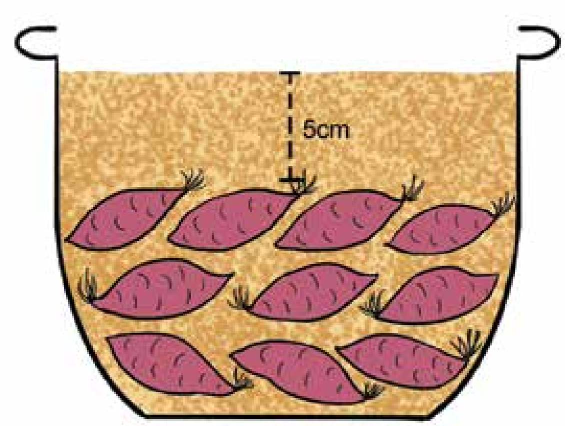

Figure 4: Ideally the roots should not touch

3. The container is stored in a cool, dry, safe place away from animals and children.
4. The roots will sprout but usually the sprouts remain short. If they get very long the shoots can be removed and planted out in the garden/nursery while continuing to store the roots in dry sand.
5. 6–8 weeks before the rains are expected, the sprouted roots are planted in a garden near the house. The site should have fertile

soil and be fenced or hedged to keep out animals. The roots are planted in shallow depressions spaced 50 cm apart each way with the root about 5 cm below the soil surface (Figure 5). Some long spouts may protrude above the soil surface. A plot for 40 roots will be about 3.5 metres long and 2 metres wide. They need to be watered at planting and then every 3-4 days.

Figure 5: The root should be planted about 5 cm below the soil level and watered at planting and then every 3-4 days

6. By the time the rains begin the roots will have produced lots of vines which can be cut for planting material (Photo 2). Forty roots can produce around 1,600 cuttings. These can either be planted out for root production or, if more cuttings are needed, planted in a rapid multiplication nursery (see below). Once initial sprouts are removed from the bedded roots, they will re-sprout, producing more cuttings.

Photo 2: Each root will produce around 40 cuttings

Rapid multiplication nursery

Often smallholders will not have enough planting material available at the start of the rainy season, even if they have maintained a nursery to keep sweetpotato growing throughout the dry season. In this case, additional planting material can be produced using a rapid multiplication nursery. There is also an opportunity for farmers to specialise in producing cuttings for sale as a business; farmers can either focus only on producing cuttings or operate a dual system in which they produce both cuttings and roots although, because the vines have been cut, the roots will be smaller than usual.

The rapid multiplication nursery consists of beds each about 1 metre wide and 5 metres long with 50 cm between beds. Available cuttings are planted in flat beds with 10 cm between cuttings in a row and 20 cm between rows. This is equivalent to 50 cuttings per square metre or 250 cuttings per 5-metre-long bed.

The nursery needs to be sited close to a reliable source of water as the beds need frequent watering. The soil is prepared as a loose bed with mineral fertilizer (see below), compost or manure added: for manure this should be added at least 2 weeks before planting to allow it to start to decompose. The bed should be raised 20 cm above ground level and situated on level ground to avoid run-off of water. If the nursery is established in the dry season, beds may be sunken as opposed to raised, in order to reduce requirements for watering.

If it is very hot and dry, a light shade structure can be erected to protect the cuttings, for example using sticks and dry grass. The shade must not be too dark or kept on for more than 2 weeks otherwise the cuttings will grow too long and be pale in colour and weak.

The nursery needs to be protected from livestock and wild animals.

Weed control is important to prevent weeds competing with the cuttings for nutrients, water and light.

Any gaps need to be filled and cuttings showing signs of virus disease need to be removed and destroyed.

At the start, at least two-thirds of each cutting need to be kept covered in soil. If the soil is washed away during watering it needs to be replaced.

After 6–8 weeks, the cuttings will have grown into vines which can be harvested. Each vine should provide about three 30-cm-long cuttings, but the last 10 cm from the ground should be left to regrow and also to minimise the risk of infestation with weevils.

The cuttings should be cut either early in the morning or late in the afternoon to avoid exposing the delicate cuttings to the hot sun. The cuttings can then be left in the shade to wilt for 2 hours; they will then take less space and be easier to transport.

A second batch of cuttings can be cut after an additional 6-8 weeks and a third batch 6-8 weeks after that. The cuttings can be planted out in the production field as they become available.

Alternatively, the first batch of cuttings can be replanted and these in turn can then be harvested as cuttings. In this way, the amount of planting material available can be increased dramatically: for example, in a 12-16-week period, for every one cutting at the start of the process the farmer can have 14 at the end. So, if the farmer starts with 4 beds each containing 250 cuttings, at the end of the process they can have 14,000 cuttings, enough for about half a hectare grown using the mound or ridge system.

After wilting for a few hours, cuttings are most conveniently transported by tying them in bundles of about 200 secured with sisal twine. The bundles can then be placed in jute sacks, taking care not to squash them. The cutting should be labelled with the variety name. If inspected and passed by the relevant officials under a system of quality declared planting material, which is being established in a number of countries, they should be declared as 'disease free planting material'. With 50 cuttings weighing about 1 kg, depending on variety, a sack weighing 20 kg will contain around 1000 cuttings.

Sweetpotato needs nitrogen to encourage vine production and so the nursery beds need to be well-fertilized with compost or manure to begin with and also a nitrogen fertilizer applied after harvesting the vines. Options for providing nitrogen from mineral fertilizers include:

Urea: Urea is a mineral fertilizer that supplies only nitrogen (N). The recommended rate of application for sweetpotato vine production nurseries is between 13 and 50 g per square metre. This should be applied to wet soil as a band after harvesting cuttings: to do this a shallow furrow should be prepared 10 cm away from and parallel to the row of cuttings. After applying the urea, the fertilizer should be covered in soil. 50 g per square metre of urea is equivalent to 10 g per row of 10 cuttings. A farmer-friendly way of applying this would be to use a locally available measure, such as a discarded plastic water bottle lid. Assuming the lid had a volume of 8 ml (the extension worker should check this and adjust the recommendation accordingly), a full lid would hold about 10 g urea - so one lid full of urea should be spread along 1 metre of row (10 cuttings with 10 cm spacing).

NPK: A fertilizer blend that contains phosphorus (P) and potassium (K) in addition to N can also be used; often NPK fertilizers are the most readily available fertilizers. Application of 25 g per square metre of NPK 25:5:5 or 42 g per square metre of NPK 23:21:0:4S at planting have proven to be successful for vine production. Ideally the NPK fertilizer should be applied in a band 10 cm from the row of cuttings and covered with soil, but it can also be broadcast and incorporated into the bed.

NPK and urea: Application of an NPK fertilizer at planting can be followed by later application of urea at 13 g per square metre when the first batch of cuttings is being harvested. Applying fertilizer following vine harvest is important to stimulate rapid re-growth of vines.

Tip: With NPK fertilizers, the numbers refers to the amount of N, P and K they contain. The first number is the percentage of N the fertilizer contains, so the higher the first number, the more N the NPK fertilizer contains. NPK 25:5:5 contains 25% N; NPK 15:15:15 contains 15% N.

Net tunnels for production of disease-free planting material

Research stations often use large, expensive screen houses covered in fine but strong insect-proof netting to produce disease-free planting material.

The netting keeps out weevils, the larvae of which damage vines and roots, and also aphids and whiteflies, which can infect sweetpotato with serous viral diseases, thus maintaining a high quality 'mother plant' which is used to produce disease-free cuttings for further multiplication in the field. These pests and disease have a major impact on the productivity of sweetpotato and the market value of the roots.

This technology has now been adapted to make it suitable for some smallholder farmers: simple and effective net tunnels can be built for around USD 120 and their use has been shown to be highly profitable. Using the net tunnels, smallholders can produce pest- and disease-free planting material – just like the research stations.

The net tunnels offer smallholders the opportunity to establish themselves as suppliers of disease-free planting material to their local communities. This is beneficial to:

- local farmers, who can buy disease-free planting material from a knowledgeable neighbour

- the net tunnel owner, who can operate a profitable new business
- research stations, which can disseminate their improved varieties more widely.

In some countries, systems are being developed in which the planting material will be inspected and certified by trained inspectors. When established, these systems will mean that smallholders can buy quality declared planting material (QDPM) in the same way that they can buy quality assured seeds for maize and other crops in some countries.

A typical net tunnel suitable for smallholders, measuring 3 metres long, 1.8 metres wide and 1.4 metres tall, can be built using:

- Locally available bendable wooden poles, each 3.6 metres long and about 4 cm in diameter. If shorter poles have to be used, they should overlap by around 50 cm where they join. Three-quarter inch (20 mm) PVC pipe can also be used as a substitute where flexible poles are not available.
- 20 square metres of 50 mesh multi-fibre netting, such as Optinet 50 mesh (small enough to keep out aphids and whiteflies; ‘50 mesh’ means 50 strands of multi-fibre per inch). Suitable netting is usually made from polyester, a tough man-made fibre, which has been treated to make it long lasting in tropical conditions.
- 5 metres of binding wire.

The construction details for the framework for the net tunnel are shown in Figure 6 and the mesh in Figure 7. Figure 3 also shows one option for the spacing of cuttings.

Although not visible in the diagram, along each side of the tunnel, where the netting meets the soil, an additional pole is secured to the netting and buried 20 cm deep to make it more storm-proof (see Photo 3).

This size of tunnel was selected because it proved to be very stable to wind and other adverse weather conditions.

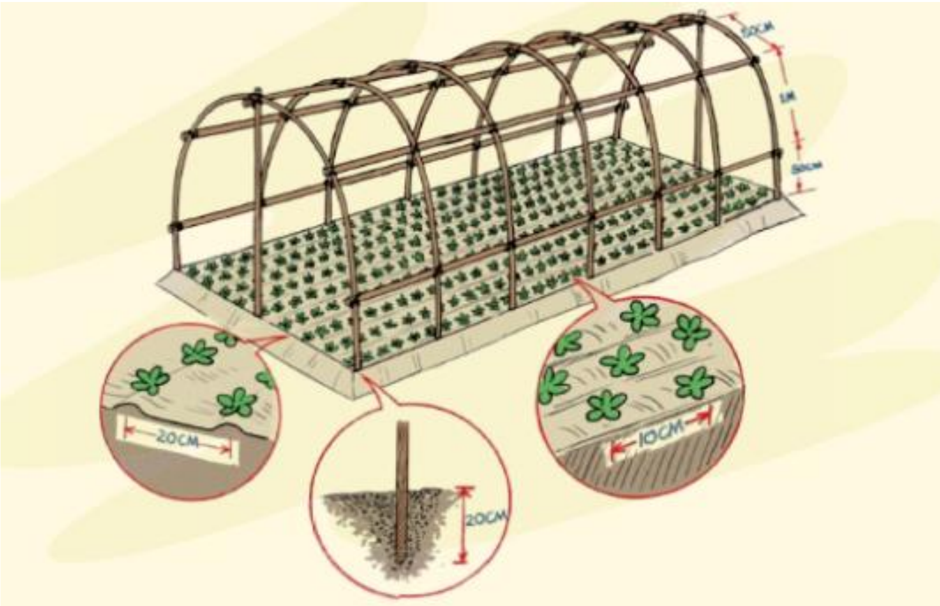

Figure 6: Details of net tunnel framework

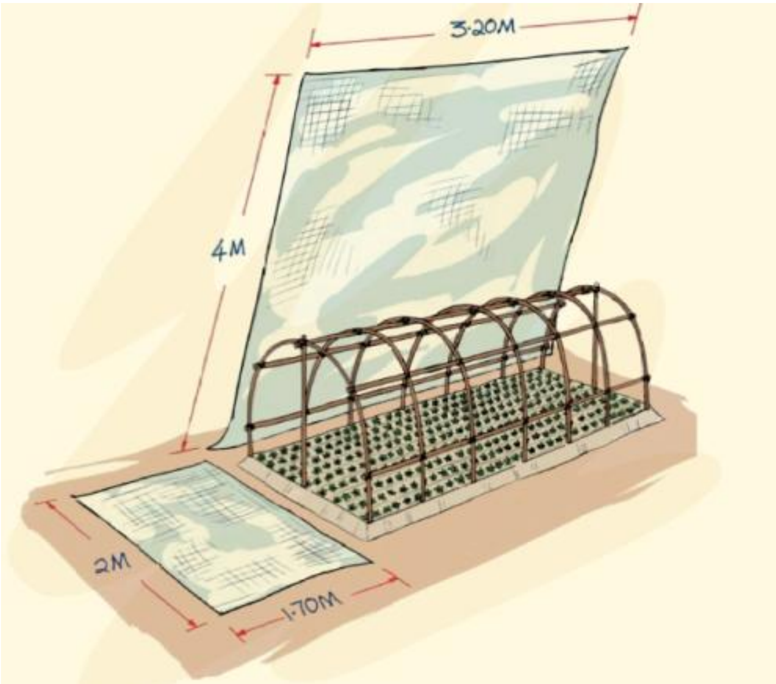

Figure 7: Details of net tunnel mesh

Photo 3: Left: the additional pole being placed along the side of the tunnel as the netting is carefully fixed to the poles with binding wire. Right: the completed insect-proof net tunnel

The net tunnel should be sited on fertile, easy to work and well-drained soil, and near a permanent source of water. Fields recently used for sweetpotato should be avoided as these can be sources of pests and diseases. If the soil is poor, about five wheelbarrows full of well-rotted manure should be incorporated into the bed. If manure is not available, mineral fertilizer can be used - see below for recommendations. Cover bed with a mulch of dry grass to help retain water and deter weeds.

Planting material for use in the tunnel must be pest and disease-free; a research station is the most likely source of such clean material. The station may also be able to supply recently developed varieties with improved characteristics that are well suited to the locality, such as improved drought tolerance.

Pest and disease-free vines obtained from the research station can be cut into cuttings, each of which has 2 or 3 nodes. These are planted with one or two nodes below the soil. If the tunnel is going to be harvested for cuttings every 80 days, the spacing can be closer than shown in Figure 3: 10 cm between plants and 15 cm between rows. With the closer spacing 360 cuttings are needed for one tunnel; with the wider spacing 270.

After planting, seal the netting with binding wire to keep out all insects. Except for harvesting and other essential tasks the net tunnel is kept closed.

Remove weeds growing around the tunnel and any weeds that appear in the tunnel.

If it does not rain, water twice a day. Avoid overwatering and water-logging, but also do not allow the beds to dry out, especially soon after planting. Watering, with a watering can or sprinkler irrigation, can be done through the netting.

Keep livestock away from tunnel to avoid damage to netting.

Harvesting of planting materials can take place about every 45–60 days, with up to six harvests before replanting with fresh material. Fresh planting material should again be obtained from the research station to ensure it is pest and disease free.

To harvest, cut 25–30 cm lengths of vine, ensuring each has 3–5 nodes. Leave at least 10 cm of vine above soil level to allow rapid regrowth.

After harvesting, apply NPK 17:17:17 fertilizer at the rate of 200 g per tunnel (this is equivalent to 34 g N), or any other available fertilizer to provide around 34 g N, for example 74 g urea per tunnel. Apply in shallow furrows alongside the rows of plants and then cover with soil. Spray the tunnel with an insecticide, such as a natural or synthetic pyrethroid, taking care to follow the manufacturers' recommendations to ensure safety and efficacy. After harvesting, carefully seal up the netting again.

A trial in Kenya showed that the tunnels produced more cuttings than an equivalent area not protected by netting. Also, when the cuttings produced in the tunnels were planted out they produced much higher yields than from cuttings that had not been protected. For an initial investment of about USD 120 to construct the net tunnel, over a 3-year period the benefit of increased production was worth an additional USD 839 compared to cuttings produced under normal unprotected conditions. In the trial, on average, each tunnel produced about 1,200 vine cuttings, each 30 cm long, every 6–8 weeks.

When the cuttings are harvested from the tunnel, they can be further multiplied by planting out in unprotected rapid multiplication beds (see above). The cuttings produced from the unprotected beds are then planted out in the production fields or sold to other smallholders for planting out, or used for further multiplying.

Weeding

Weeding is especially important during land preparation and during the first two-months after planting. If weeds are not controlled at these times, they compete with the sweetpotato plants for nutrients and water, and may harbour pests and diseases. After two months, the sweetpotato vines will have joined up, covering the ground, which leaves little space for weeds.

There are three main types of weed that impact on sweetpotato:

- 414 grasses such as spear grass, *Imperata* species – the roots can pierce and damage the sweetpotato roots
- Sedges such as *Cyperus* species
- Broad leaved plants such as *Lantana camara* and nightshade (*Solanum incanum*)

When the mounds or ridges are being prepared stubborn perennial weeds and annual weeds need to be pulled up. Annual weeds that have not yet set seed can be buried under the soil.

The sweetpotato plot will need to be weeded again 4-6 weeks after planting.

In very wet areas additional weeding may be needed, especially hand pulling of stubborn, vigorous perennial weeds. If a hoe has to be used, this needs to be done with care to prevent damage to the developing sweetpotato roots.

Weeds can also be controlled by mulching: slashing weeds and leaving them on the soil surface during soil preparation can help prevent more weeds emerging in the future.

Crop rotation can help prevent the build-up of weeds and also helps prevent build-up of pests and diseases.

Intercropping can also help reduce the impact of weeds: growing two types of plants together, such as maize and sweetpotato, provides less room for weeds, out-competing them for light, water and nutrients.

Many farmers also use pre-planting herbicides, such as glyphosate. Suitable post-emergence herbicides are less widely used and are unlikely to be appropriate for most smallholder farmers who will find them both too expensive and difficult to apply correctly and safely.

Vine lifting and hilling-up

If the stem of the sweetpotato vine touches moist soil it will form roots, which can grow into small storage roots that cannot be marketed. To prevent this happening, some producers lift the vines to raise them above the soil surface (Photo 4). Care should be taken when doing this to ensure that the vine is lifted but not turned over as this will cause the leaves to rot.

Photo 4: Lifting the vine

As the storage roots grow, especially during hot, dry weather, cracks appear in the soil. Also, as rain runs down the mound or ridge and washes soil away from the crown of the plant, this exposes the storage roots to sunshine, which may cause discolouring and expose roots to weevils. Weevils enter the soil via cracks, or access the exposed roots, and lay their eggs. The larvae which hatch from these eggs burrow through the storage roots, causing damage and reducing their market value due to the damage caused and also because of a bitter-tasting chemical that the plants produce in response to the weevil infestation. To prevent these problems, the crop needs to be regularly inspected; where exposed roots or cracks are seen, hilling up – that is carefully hoeing soil back over the root and to fill in cracks – is necessary. This task is often done during piecemeal harvesting (Photo 5).

Photo 5: Hilling up

Nutrient management

Sweetpotato does well in marginal soils but, like all crops, nutrients are removed from the soil with the harvest. Root crops, such as sweetpotato, remove more potassium (K) but less nitrogen (N) and phosphorus (P) than cereals such as maize.

Nutrients can be added to the soil by the application of organic materials, such as farmyard manure, poultry manure, compost or crop residues, or by the application of mineral fertilizers.

Residual fertilizer from rotations and intercrops

Application of mineral fertilizer to sweetpotato has not been traditionally practiced, but is increasingly common in commercial crops, particularly where soil fertility is low. If sweetpotato is intercropped or follows a well-fertilized crop in rotation, it can benefit from fertilizer applied to the previous crop or intercrop.

Maize: If local recommendations for fertilizer application to maize are available then these should be followed. In case these are not available, Table 1 gives some recommendations for fertilizer options for maize grown in acidic soils as a sole crop. These recommendations could be used for maize grown in a rotation with sweetpotato or as a strip or relay intercrop. The basal fertilizer should be applied when the maize is planted and the topdressing when the maize is knee-high. The fertilizer can be applied by spot application – that is applied in the planting hole when the seed is sown (taking care the fertilizer and seed do not touch) or for topdressing, applied in a small hole close to the plant with fertilizer covered with soil.

Table 1: Examples of basal and top-dressing fertilizer options for maize grown in acidic soils (pH of 6.5 or less)

Target yield (t/ha)	Nutrient rates (kg/ha)			Basal fertilizer at planting	Topdressing when knee-high
	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)

Fertilizer recommendations for sweetpotato

It is difficult to provide detailed recommendations for fertilizer application that will be applicable throughout sub-Saharan Africa: results from trials and published recommendations vary widely.

Some general principles and rules for applying fertilizer to sweetpotato include:

- Sweetpotato and other root crops take up more potassium but less nitrogen and phosphorus than cereals.
- On many soils in Africa, sweetpotato responds well to application of potassium (K) fertilizers, such as muriate of potash (MOP).
- Ash is rich in K and can be used as a low-cost source for K for sweetpotato, especially when mineral fertilizers such as MOP are not available. Ideally about 500 g wood ash should be applied per mound (equivalent to 150 kg K per hectare; 5,000 kg ash per hectare).
- Applying potassium during the second half of the crop's growth cycle helps promote development of a strong skin.
- Too high levels of nitrogen (N) fertilizer, such as urea, can cause excessive growth of vine and reduced root development; too

low levels of N, however, result in limited vine growth and low yields.

- Farmers could run their own mini on-farm trials, applying fertilizer to part of their crop and leaving the rest untreated. By comparing how the crops grow and the yields obtained, and bearing in mind the cost of the inputs and the additional value of the outputs, they can decide whether it is worthwhile to apply mineral fertilizer in their own circumstances. Some options for applying fertilizer include:
    - NPK 15:15:15 applied at 400 kg per hectare (60 kg N and 30 kg K per hectare). This is equivalent to about 13 g of fertilizer per mound or 120 g per 10 metres of row (ridge or flat bed). This should be applied at planting. This is a relatively low rate of K fertilizer.
    - MOP applied at 400 kg MOP per hectare (120 kg K per hectare). This is equivalent to 13 g of MOP per mound or 120 g MOP per 10 metres of row (ridge or flat bed). This should be applied as a top dressing: a shallow furrow should be made in the valley between ridges or 15 cm from the row on a flat bed, the MOP applied and then the furrow covered with soil. This should be done at 6 weeks after planting when the roots are bulking. This is a higher rate of K fertilizer.
- Observing the sweetpotato crop for signs of nutrient deficiencies, especially N and K, can be a useful way of deciding which mineral fertilizers should be applied.

Deficiencies of N and K

Signs of N deficiency in sweetpotato include:

- Leaves become light green to yellowish and dull in appearance (Photo 6)
- Reduced growth of the vine
- Old leaves become reddish at the edges, yellowish in the middle, then reddish to brown all over
- Stems of old plants become reddish
- Short petioles, that is the stalk that joins a leaf to the vine stem
- Symptoms develop at the base of the plant first, then spread towards the top

Photo 6: Signs of nitrogen deficiency in sweetpotato

If these symptoms are seen, an N fertilizer, such as urea, should be applied at a rate of 65 kg urea per hectare (30 kg N per hectare): this is equivalent to about 2 g urea per mound or 20 g urea per 10 metres of ridge or row. It should be banded, that is applied in a furrow alongside the ridge or row, or around the mound, and then covered with soil.

Signs of K deficiency in sweetpotato include:

- Short vines with short internodes (stem between where two sets of leaves emerge) and small leaves are the first symptoms
- Leaves are of a darker colour (dark green), especially at the edges
- Short and pale petioles
- Small, shiny brown spots emerge on the leaves, first on the bottom of the leaves and on old leaves
- Old leaves become yellowish or reddish, starting at the top of the leaves and developing via the edges to the leaf base
- Plants wilt faster and leaves easily fall off
- When experiencing heavy deficiency, the whole leaf becomes yellow except the leaf base and the leaf tissue just next to the veins which becomes dark green
- Low number of storage roots
- Storage roots are long and thin
- Storage roots are more easily infected by root rots and nematodes.

Photo 7: Signs of potassium deficiency in sweetpotato

If these symptoms are seen, a K fertilizer, such as MOP, should be applied at a rate of 160 kg per hectare (80 kg K per hectare): this is equivalent to about 5 g MOP per mound or 48 g MOP per 10 metres of ridge or row. It should be banded, that is applied in a furrow alongside the ridge or row, or around the mound, and then covered with soil.

Harvesting

Extending the period when fresh roots are available

Sweetpotato varieties differ in the time taken from planting to harvest. Early maturing varieties can be ready in just 3 months while later maturing varieties can be ready after 4-4.5 months or longer. The late maturing varieties can be left in the ground and harvested a few storage roots at a time to meet the households need for the next few days, namely piecemeal harvesting; once harvested, fresh roots deteriorate quickly unless special measures are taken to store them. So, fresh sweetpotato roots can be harvested from 3-8 months after planting, or even longer, depending on variety and environment.

One benefit of piecemeal harvesting is that the crop is regularly inspected in the field; if cracks appear in the soil, which would enable weevils to attack the roots, these can be filled. If roots become exposed to the sun they can be covered in soil to prevent damage occurring. Piecemeal harvesting can also result in higher yields as the remaining roots have more room to bulk up.

The period over which sweetpotato can be harvested can be increased by growing several varieties that have different maturing periods and also by staggering the planting time as planting material becomes available, although this is dependent on adequate rainfall during the growing season.

However, unlike cassava, which can be left in the ground throughout the dry season, sweetpotato roots tend to deteriorate if left in the soil during the dry season: as the soil cracks, weevils can access the roots and considerable damage can be caused as the larvae make tunnels through the roots.

Experience from mid-elevation sites in Malawi suggests that when intercropping sweetpotato and maize, the sweetpotato can continue growing in the field up to 7 months after planting and still produce clean storage roots and vines clear from sweetpotato weevils at harvest.

However, leaving sweetpotato roots in the ground after they are ready for harvesting, even during the growing season, can be risky as the roots are vulnerable to being taken by monkeys, porcupines and other wild animals, and also to theft by people.

Alternatively, some smallholders will want to harvest their entire field at one time, for example if they have sold the crop to a trader.

When and how to harvest

If sweetpotato is harvested too early the roots will be too small.

If harvested too late the roots may have become fibrous and unpleasant to eat, depending on variety, and there is a higher risk of damage due to weevils.

Smallholders need to be aware how long the variety they are growing is likely to take to reach maturity and they also need to check the crop regularly.

The skin of sweetpotato roots is thin, delicate and easily damaged. Care needs to be taken, therefore, when harvesting roots as damage to the skin makes the roots less attractive and increases the risk of rots, both of which will reduce the market value of the crop and the length of time they can be stored. Roots are often harvested using a simple homemade digging stick, machete or hoe.

Two weeks to a few days before harvesting sweetpotato the vines may be cut off at ground level. These are nutritious and can be fed to livestock including cattle, sheep, goats, pigs and rabbits. The vines and leaves can be fed fresh, dried or made into silage. Cutting the vines helps the skin of the sweetpotato to become firmer and less easily damaged – this process is called in-ground curing.

Post-harvest handling

Fresh roots should not be exposed to the hot sun any longer than necessary as this causes sun burn and reduces post-harvest shelf life, hastening shrinkage and shrivelling.

The most common way of packing sweetpotato roots for transporting them is in polypropylene or jute sacks. Care should be taken when doing so; if the sacks are either over- or under-filled the roots can easily be damaged, which will reduce their market value. A better option is to pack the roots in cardboard, plastic or wooden boxes if these are available. However, this is not yet standard practice, and the additional costs need to be justified. Avoiding bruising the skin of sweetpotato roots will enable them to be stored for longer.

Adding value to fresh roots

Taking care when harvesting, packing and transporting sweetpotato roots will help ensure they attract higher prices at market.

Other ways of increasing the value of the roots are to wash them and then sort by grade and size. This is usually only done directly before marketing.

Washing should involve gentle rinsing not scrubbing, which could damage the delicate skin.

A small quantity of liquid bleach (one tablespoon full per gallon (4.5 litres) of water) added to the rinse water can help to prevent the roots rotting.

Storing fresh roots

Left in the open, fresh sweetpotato roots deteriorate quickly, particularly if damaged during harvesting and transport to the market. For this reason, traders like to sell their roots within 3–4 days after they receive them to avoid losses due to rot.

There are simple technologies available that can be used to store fresh roots so they stay in good condition longer – for 3–5 months or even longer. Storing fresh roots means that smallholders can benefit from the higher prices that sweetpotato attract in some markets in the off season. Alternatively, it means that households can enjoy fresh sweetpotato roots throughout all or most of the year, enhancing household food and nutritional security.

Controlled storage techniques are used by commercial growers in temperate climates where sweetpotatoes must be stored during the cold winter months. The first step for good storage is curing which heals wounds and allows for long-term storage at cool temperatures. This is done by maintaining roots at warm temperatures (30°C) and high relative humidity (85 to 90%) for 3–5 days. Then roots are stored at 13°C and high relative humidity (85%) with good ventilation and can keep for over six months. In the tropics, curing and cool storage are rarely practiced, due to unreliable and expensive electric supply. However, the warm, humid conditions required for curing are relatively easy to create under tropical conditions, and alternatives to cold storage can, in some cases, be used for medium-term storage.

The traditional method for storage in Sub-Saharan Africa has been in pits, but these are not very reliable, being prone to total loss due to rots and weevil infestations if not closely monitored. Recently, the technique of sand storage for planting material production (described above) was successfully adapted for storage of sweetpotato for consumption. While not suitable for commercial quantities, storage in sand in pits or in earthen ‘boxes’ in buildings has proven successful for home consumption.

For pit storage, a hole should be dug in an area of dry ground, which is not prone to flooding, and in a location that is safe from attack by wild animals or thieves, such as near the house. The hole should be large enough to take the roots that the smallholder wishes to store, or for large quantities several pits may be needed. A pit design with steps cut into the ground was preferred by women in Malawi, as it permits easy access to the roots deeper in the pit as roots are removed.

Two to four days before harvesting the roots, the vines should be cut off at ground level. This ‘cures’ the skin, making them harder and less easily damaged. In Bawku, Ghana, harvested roots are piled in the field and completely covered with a thick layer of sweetpotato vines for a few days after harvest. This creates the warm, humid environment required for curing.

Stores are packed by placing a layer of sand on the floor and then placing a single layer of roots, covering them with sand, and then adding another layer of sand. For the sand box method, an adobe (clay) ‘box’ is constructed in a thatched hut and the roots are layered, covering each layer with dry sand.

Finally, a simple roof should be built to cover the pit. This can be made of locally available poles, sisal twine or wire, and grass for thatching. A gap should be left between the top of the pit and the bottom of the roof to allow ventilation. The roof provides shade and shelter from the rain.

The pits can be reused in subsequent seasons but should first be sterilized by lighting a small fire in them or by spreading ash.

Experience in Malawi suggests the storage roots can be kept up to seven months in pits, while in Ghana they could be stored up to four months in sandboxes or pits (Photo 8).

Photo 8: Storage pit

Storing sweetpotato as dried chips and flour

Most people prefer to eat sweetpotato as fresh roots – roast, boiled, mashed, fried or cooked in other ways. Sweetpotato can also be processed and stored as dried chips, an indigenous food in regions with a long dry season. Four kilograms of fresh roots make about one kilogram of dried chips.

Although the chips will keep for up to 6 months in strong, black (to exclude sunlight), airtight plastic bags, the nutritional value deteriorates so it best not to keep them longer than 2 months.

To use, the dried chips are boiled in water until they become soft and can be mashed and incorporated into other foodstuffs.

The chips can also be milled to produce flour. This can be used as a wheat substitute in baked products or alone or mixed with millet and/or cassava flours to make porridge.

To make dried chips:

1. Carefully select healthy fresh sweetpotato roots.
2. Clean and peel the roots. The peel can be fed to livestock.
3. Wash the roots in clean water (a washing drum can be used for large-scale production).
4. Dry the roots on a clean surface in the sun for 10 minutes.
5. Cut the roots into slices about 5 mm thick using a clean sharp knife, or into thinner chips using a mechanised slicer or chipper for large-scale production.
6. Sun-dry the slices on a raised tray. A solar drier covered with black plastic can protect the beta-carotene in orange-fleshed varieties from degradation during drying.
7. The dried slices can then be stored in clean opaque or black polypropylene sacks, or milled into flour and stored in opaque polythene bags.

Storing dried chips

Dried chips can be stored in sacks placed in houses or stores, or in traditional woven and mud-plastered granaries.

Before use, storage facilities should be thoroughly cleaned. The previous year's produce should be removed to prevent carry-over of any pests.

Only good quality chips should be stored.

If using sacks in buildings, the sacks must not touch the walls and they should be raised off the floor to prevent moisture coming up from the ground and to allow good ventilation. Rodent traps should be placed along the walls and be regularly checked: if rodent poisons are used, extreme care should be taken to prevent accidental poisoning of children or domestic animals; the manufacturer's instructions for safe and efficient use should be fully observed.

For granaries, ideally these should be raised one metre off the ground, have rodent guards fitted to the legs and be protected from sun and rain by a thatched roof.

The stored chips should be inspected regularly for signs of dust due to insect attack, rodent damage or droppings, strange smells and signs of rotting or dampness.

Options for protecting chips from insect damage during storage include adding table salt at the rate of 20-30 g per kg fresh chips and/or to place the chips in sealed clay pots. Parboiling the sliced sweetpotato for 5 minutes prior to sun-drying will make the resulting chips harder and less attractive to insect pests.

Mashed sweetpotato (puree) as wheat flour substitute

An alternative to making chips and flour from sweetpotato is to use boiled, mashed sweetpotato as a wheat flour substitute. It takes 1.25 kg fresh roots to make 1 kg of mash.

Mashed sweetpotato, also called puree, has both advantages and disadvantages compared to sweetpotato flour. Puree is easier to make and, in the process, loses less nutrients, but when used in recipes in place of wheat flour the dough or batter is harder to work, the relative amounts of different ingredient needs to be changed and the final product has a different texture – which some consumers prefer.

Mashed sweetpotato has been used to substitute 45% wheat flour in bread, 40% in mandazi and up to 45% in biscuits.

Recipe: Sweetpotato mandazi

Ingredients:

½ cup sweetpotato mash or sweetpotato flour
2 cups wheat flour
2 tablespoons sugar
Pinch of salt
2 cups cooking oil
1 tablespoon baking powder
Adequate lukewarm water

Procedure:

1. Put the sweetpotato mash in a mixing bowl and sift in the dry ingredients.
2. Add water and mix into a dough.
3. Knead the dough well while adding 2 tablespoons of oil.
4. On a floured surface, roll the dough to about 1 cm thickness.
5. Cut into desired shapes.
6. Deep fry while turning till golden brown all over.
7. Remove from oil, drain and serve warm or cold.

Sweetpotato as animal feed

Sweetpotato vines, which can yield as much as the fresh roots, can be fed to cattle, goats, sheep, pigs and rabbits. They can be fed fresh, dried or made into silage.

Vines can be harvested 3-4 times during the growing season, with up to half of the stems being harvested each time: harvesting stems will, however, reduce the yield of roots and harvesting more than this will severely reduce yields.

Large amounts of vines and leaves become available in systems where these are cut off a few days before harvesting: doing so helps to strengthen the skin on the roots (cure) which reduces the risk of damage during handling.

Untreated, the vines will decay in a few days, before they can be consumed by livestock, but they can be dried to form a good quality hay or made into silage. Making hay is difficult, however, because the vines have a high water content, so making silage may be the best option, except in very dry regions.

Silage made from sweetpotato vines is a high-quality feed rich in protein, carbohydrate and vitamins. It can be stored for months if it well made. It can therefore be used as an animal feed during the dry season when fresh feeds and forages are scarce. It also has the potential to be a tradable commodity; smallholders with no livestock of their own could sell it to neighbours with cows, pigs or other livestock.

To make silage from the vines:

1. Chop the vines and leaves into small pieces, ideally about 2.5 cm lengths.
2. Wilt in the sun for up to 4 hours. Do not over-dry. To check if ready, squeeze a handful of vines; if they spring back to the original shape when released they are ready.
3. Mix wilted material with 10-30% sliced fresh sweetpotato roots and 0.5% salt. Tip: For every 10 containers (such as a large plastic bowl) full of chopped vines, add 1, 2 or 3 containers of sliced roots and salt equivalent to one-twentieth of a container.
4. Mix well.

5. Place mixture in air-tight plastic bags or in a pit sealed to make it air-tight with plastic sheeting.
6. The silage should be compacted to remove all the air. This should be done by adding a layer and then compacting it well, for example by standing on it.
7. The silage is ready in 40-45 days and lasts for several months.

5. What can go wrong?

Pests and diseases

Sweetpotato weevils

Sweetpotato weevils are the main pest of this crop. Female weevils lay their eggs in holes they bite in the vines and roots. The weevil cannot dig and so can only access roots when these are exposed; this can happen when soil is washed from ridges and mounds by rain and also when the soil is dry and cracks appear.

The weevil eggs hatch and the larvae feed, forming holes and extensive tunnels in the vines and storage roots. These lower the market value. When attacked by the larvae the roots produce a bitter-tasting chemical.

Measures which can be taken to help prevent damage from weevils include:

Use clean planting material: It is important to use planting material that is not infested with weevil eggs or larvae. Cutting should only be taken from healthy looking plants. Cuttings should be taken from the tip of the vine: the bottom 30 cm, near the base of the vine, should be avoided.

Resistant varieties: So far plant breeders have not been able to develop varieties that are resistant to weevils. However, deep-rooting varieties tend to be less attacked than shallow rooting varieties. Also, early maturing varieties can be harvested before the onset of the dry season, when cracks appear in the soil.

Mulching: Mulching the plot soon after planting has two benefits: helping to retain moisture and preventing the soil cracking. Mulching can be done using chopped weeds and residues of the previous crop.

Hilling up: The threat of weevil damage means that, unlike cassava, sweetpotato cannot be stored in the ground until needed, unless the smallholder invests time and effort in hilling up. This means mounding soil around the base of the plant and around the side of ridges and mounds to fill in any cracks and bury exposed roots which could give weevils access to the storage roots. This is most often done during piecemeal harvesting of roots.

Field hygiene: Old vines and roots need to be removed from the field and destroyed either by burning, composting or feeding to livestock. Any volunteer plants, that is sweetpotato plants that grow from vines and roots accidently left in the field, should be removed and destroyed.

If vines from the previous crop are used to improve the soil fertility and structure, they should be left on the surface where they are exposed to the hot sun until they are dead before being incorporated into the soil.

Other wild plants that can act as hosts for the weevils, such as morning glory (which is related to sweetpotato), should also be removed and destroyed.

Separate new and existing crops: In regions where two or more crops can be grown in a year, new plantings of sweetpotato should be as far as possible from existing crops.

Barrier crops can also be used. This means planting strips 3-5 metres wide of a different crop, such as cassava, maize, banana, sorghum or onion, between the existing crop and the new sweetpotato crop. This can help reduce the number of weevils moving from the previous to the new crop. These non-host crops can also reduce weevil populations and help produce clean sweetpotato storage roots and planting material.

Chemical control: In some countries cuttings are dipped in an appropriate insecticide prior to planting. This can delay infestation by weevils by several months. Expert local advice should be sought about which locally available pesticides can be used and the manufacturers' recommendations should be carefully followed to ensure safety and efficacy.

Weevils have many natural enemies such as ants and spiders, which are naturally present in smallholders' fields. Avoiding the use of pesticides will help maintain high levels of these natural weevil predators, which can help keep weevil populations in check.

Sweetpotato virus disease

Sweetpotato virus disease (SPVD) is the most serious disease of sweetpotato. It can reduce yields by up to 90%.

The disease occurs when plants are infected by two types of virus at the same time. One of these viruses is spread by whitefly, the other by aphid.

Symptoms of SPVD include stunted vines, narrow yellow leaves with deformed edges and yield reductions in roots; yields are especially reduced if infection occurs early in the growing season.

Photo 9: Sweetpotato virus disease affected plant (below) with normal plant (above). Photo: Erna Abidin

Measures to reduce the chance of a crop becoming affected by SPVD include:

Growing resistant varieties: Some varieties are rarely affected by SPVD.

Using clean planting material: Planting material should only be taken from healthy looking plants. Cuttings should be taken from either young or mature crops (3-4 months after planting).

Rather than collecting planting material from the field, growing cuttings in nurseries or net tunnels and planting these out only after checking for signs of the disease can be effective. Alternatively, if available, quality declared planting material can be used.

Field hygiene: During growth of the crop, check regularly for signs of the disease. Remove and destroy any infected plants – this is called rogueing.

After harvest, collect all vines and discarded roots and remove and destroy by burning, composting or feeding to livestock.

Separate new and existing crops: In regions where two or more crops can be grown in a year (bimodal rainfall areas), new plantings of sweetpotato should be sited as far as possible from existing crops – at least 15 metres and preferably more than 100 metres.

Avoid planting new crops where old crops were grown. Practice rotation: grow cereals, legumes or vegetables – any crop except sweetpotato or another root crop – or have a fallow period for two years after a sweetpotato crop.

Fungal disease

Various fungal diseases can cause problems for sweetpotato, both during production and post-harvest through storage rots.

Alternaria diseases, also known as blight, cause spots on leaves, leaf stalks and stems, causing leaves to fall and vines to die (Photo 10).

Photo 10: Sweetpotato with *Alternaria* leaf spot. Photo: CIP (International Potato Center)

Alternaria leaf and stem blight can be a serious problem in moist, highland environments but is not usually a problem at lower altitudes.

Java black rot (*Diplodia gossypina*) causes affected tissue to first turn yellowish to reddish brown, then black as the decay progresses (Photo 11). The decayed area is firm and moist. Infected roots often completely decay within 2 weeks and subsequently dry out.

Photo 11: Black rot. Photo: CIP (International Potato Center)

Soft rot (*Rhizopus stolonifer*) causes watery, soft rot inside the storage root, often starting at the tapered end of the root. White tufts growing out of the root are another sign.

Measures to prevent fungal diseases of sweetpotato include:

Growing resistant or tolerant varieties if available.

Use clean planting material, collected from healthy looking plants.

Field hygiene: After harvest, collect all vines and discarded roots and remove and destroy by burning.

Rotation: Practice rotation of sweetpotato with other non-roots crops grown for 2 years before growing sweetpotato again on the same plot.

Post-harvest curing: Curing at high temperature (30°C) and 85 to 90% relative humidity for 3 to 5 days after harvest can heal wounds and help to reduce incidence of post-harvest rots.

Damage caused by wild and domestic animals

A wide range of wild and domestic animals are attracted to sweetpotato and can damage the crop by eating vines and storage roots. These include porcupines, monkeys, baboons, elephants, goats, cattle and guinea fowl amongst others.

Some measures to reduce losses due to these animals include erecting thorn fences and planting hedges, and tethering domestic animals.

Rats and mole rats cause severe damage to roots either in the ground or during storage.

Rat control depends on community action as control is more effective if done over a wide area. Measures to control rats include:

Keeping fields and their surroundings clean and free from rubbish.

Setting traps, taking care so that children do not get harmed.

Destroying burrows.

Mole rat can be a serious problem in East Africa and control measures include:

Placing repellents in burrows, such as leaves of some plants, fermented cow urine, human faeces, and burning cow dung and chilli pepper.

Digging a ditch around the field.

Planting sesame around the field.

Planting the small tree *Tephrosia vogelii* (also known as fish bean) throughout the field and along the borders as it is believed to be a repellent. Care must be taken when disposing of this plant as it is poisonous to fish.

6. Economics of sweetpotato systems

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 sweetpotato 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 growing sweetpotato with no added fertilizer would now like to apply 400 kg per hectare of MOP as a top dressing 6 weeks after planting, the increase in yield required to recover the additional cost of fertilizer (if price of MOP is USD 50 per 50 kg bag and price of sweetpotato is USD 1,000 per tonne) can be calculated as:

$$\text{Minimum increase in yield required } \left(\frac{\text{t}}{\text{ha}}\right) = \frac{\text{Cost of additional MOP}}{\text{Price of sweetpotato}} = \frac{8 \times 50}{1000} = 0.4 \text{ t/ha}$$

So, in this case, an additional 400 kg per hectare of sweetpotato would need to be produced to pay for the additional cost of 8 bags of MOP.

The extra costs incurred with use of a new technology can be compared with the additional benefits got by use of the technology (cost/benefit analysis). For example, if in the above example the previous yield was 500 kg per hectare but with MOP topdressing the yield has increased to 1.5 tonnes per hectare, the value of additional yield with fertilizer compared with the cost of fertilizer, i.e. the value/cost ratio (VCR), also known as the benefit cost ratio, is calculated as:

$$\text{VCR} = \frac{\text{((Yield with fertilizer-Yield without fertilizer)} \\ \text{x Price of sweetpotato)}}{\text{Amount of fertilizer applied x Price of fertilizer}} = \frac{(1.5-0.5) \ \text{x} \ 1000}{(8\times50)} = 2..5$$

So, in this case for every USD 1 invested in the new fertilizer regime (the cost) the farmer would generate an additional USD 2.5 (the benefit).

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. So, in this example the benefit gained is sufficiently attractive to justify the investment in fertilizer.

7. Key references

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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 crop and pest.
- 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.

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