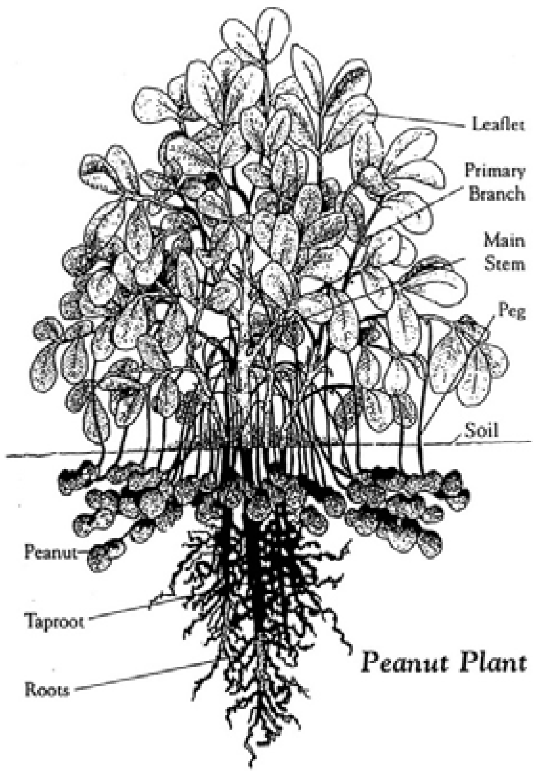
Groundnut cropping guide



Haile Desmae and Keith Sones

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By Haile Desmae and Keith Sones.

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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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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, rice systems and sweetpotato, but this guide is focused on groundnut.

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

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, useful tips on how farmers with small to medium-sized farms can benefit from more efficient and profitable groundnut production. Currently yields in Africa average under 1 tonne per hectare and can be as low as 500 kg or less: in comparison yields in Asia average over 2.2 tonnes per hectare and are close to 4 tonnes per hectare in the Americas.

By following the recommendations in this guide, smallholder farmers should be able to increase production from under 1 tonne per hectare to as much as 2.5-3 tonnes per hectare or more. By adopting optimal crop rotations, yield of crops such as cereals will also be increased and by adopting successful intercrop combinations and arrangements smallholder farmers will benefit from increases in overall production and profitability.

2. Groundnut cropping systems

What is groundnut?

Despite its name, groundnut, also called peanut, is not a nut. It is a member of the legume family, which also includes common bean, cowpea and soybean amongst others.

A common feature of all legumes is that, in partnership with certain types of bacteria, they can fix nitrogen from the air and use this important nutrient to help the plant develop and grow. Crops grown near to legumes (intercrops), or in the same plot the following season (crop rotation), can also benefit from this nitrogen.

Uniquely among legume crops, groundnut pods are formed in the soil. The groundnut flowers above ground, like other legumes, but after the flower has been pollinated and withers, the flower stalk grows longer, bends down and pushes the pollinated flower into the soil. The pod develops in the soil and usually 2-4 seeds develop in each pod. The elongated flower stalk, found only on groundnut, is known as a peg (Figure 1).

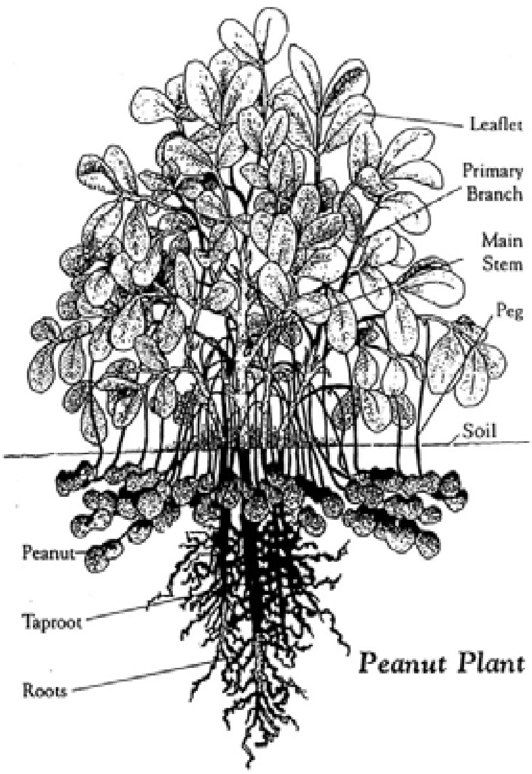

Figure 1: Groundnut plant

Why grow groundnut?

Groundnut is an important crop cultivated by smallholder farmers.

It is a nutritious and tasty foodstuff, and also an important cash crop for which there is often strong local demand as well as an export market.

The groundnut value chain employs significant number of people and makes an important contribution to the economies of producing countries in Africa. Globally, groundnut is cultivated in more than 100 countries, far more than any other legume.

Groundnut grows well in the arid and semi-arid tropics, does not require large amounts of inputs and fits well into rainfed crop rotations and intercrop systems. In some countries, it covers up to 60% of the area under crop production.

Groundnut is also relatively drought resistant: the tap root can grow down to 2 metres in depth, deeper than many other crops. Breeders are also working to develop new, improved varieties that are even more drought tolerant to increase productivity and enhance farmers' resilience in the face of changing climate.

Groundnut is rich in protein, oil and some vitamins and minerals. It can be eaten in a wide variety of forms including roasted as snacks, made into a butter and a range of confectionary products and also flour. When cooked and pureed, thick rich groundnut sauce is an important feature of daily cooking, especially in West Africa.

Groundnut contains up to 60% or more oil and groundnut oil is an important vegetable oil in Africa.

Groundnut therefore plays important roles in household food and nutrition security, and as a source of cash income for smallholder farmers.

Being a legume it can fix atmospheric nitrogen (N), which can benefit the crop planted after, so maize and other cereals do well after groundnut in a rotation. Overall, it contributes to stability and dynamism of farming systems as well as ecosystem sustainability.

The haulms – that is the leaves and stems – are protein-rich and are a valuable livestock feed for cattle, sheep and goats. This is especially useful in the dry season when fresh grazing is not available. Smallholder farmers who do not have their own livestock can sell the haulms to livestock farmers and traders.

When groundnut is used for oil production, the residue material (by-product) left after oil has been extracted – known as groundnut meal or groundnut cake - is a useful protein-rich animal feed for pig, dairy, poultry and other types of livestock. In some countries, the cake from domestic oil pressing is ground into flour and used in human foods.

In some parts of Africa, such as West Africa, groundnut is largely grown by women. The income they derive from selling part or the entire crop tends to be used for the benefit of the family, such as to pay school fees or meet other household needs. Any produce not sold is used for home consumption in various forms as a high energy and protein food source, or oil for cooking, thus contributing to household nutrition and health. In general, women and young people play important roles in the cultivation and small-scale processing of groundnut.

The challenge of growing groundnut

Yields of groundnut in Africa are generally low – on average about one-quarter or less of that achieved in the Americas and less than half that in Asia. The main reasons for this include:

Unreliable rainfall and lack of irrigation

- Lack of mechanisation
- Presence of pests and diseases, especially groundnut rosette, aflatoxin and leaf spot diseases (see page 48)
- Use of marginal land and poor fertility soils
- Use of low yielding, unimproved varieties

Lack of access to seed of improved groundnut varieties

- Generally, use of poor agronomic practices and little access to extension services.

Groundnut varieties

Throughout Africa many different varieties of groundnut are grown. These vary quite widely in important characteristics such as growth habit (either bunch types which grow upright, or runner types which grow close to the ground), number of seeds per pod, colour of seed coat, seed size, time to maturity of crop, dormancy of seed after harvest, oil content and taste.

The varieties grown include traditional local ones that have been grown by smallholder farmers for many generations as well as new, improved varieties. The improved varieties have been developed by breeders and researchers in the national research programmes and or regional/ international research institutes (e.g. ICRISAT) to have certain desirable traits, such as high grain yield, high oil content, early maturing to cope with increased risk of drought, or resistance and tolerance to drought and important pests and diseases.

The many different varieties of groundnut fall into four main groups:

Virginia types can be either spreading or upright in growth habit and are mostly late maturing. They have large kernels and are used in confectionary, roasted and salted, or roasted in the shell.

Runner types are spreading and mostly late maturing. They have medium sized kernels and are used for making confectionary and butter, and also for salting.

Spanish types are mostly upright and are easier to pull from hard soil because the pods cluster around the tap root and they also have strong pegs. They have small to medium sized kernels with high oil contents and so are good for crushing for oil. They are also used in confectionary, as salted nuts and made into butter.

Valencia types are upright with small to medium sized kernels. They are usually roasted and sold in the shell.

Smallholder farmers need to check which varieties are available locally. If they are aiming to sell their produce to a specific buyer then they need to ensure the variety they select meets the buyer’s requirements in terms of size, colour, taste and other characteristics.

3. Requirements for growing groundnut

Soil: Groundnut grows best on deep, loose, well-drained sandy soils without compaction layers. Such soils are easily penetrated by pegs and roots and permeated by water. The crop can also more easily be pulled up at harvest without leaving pods behind in the soil. Such soils are not prone to water-logging; groundnut cannot tolerate water-logging. Sandy, sandy loams or loamy sand soils are all suitable.

Tip: If a handful of soil rolled between the palms of the hand can be formed into a stable ball or flattened into a ribbon then the soil has a high clay content. This is not suitable for groundnut cultivation.

The soil should also be light coloured. This indicates that it is relatively low in organic matter, which helps prevent fungal diseases. It also means that the soil will not stain the pods, which can reduce the market value of the crop if it is sold in the pod.

The pH should be 5.5 to 7.0 (slightly acidic to neutral).

Groundnut cannot tolerate saline soils.

Water: Depending on the type of groundnut being grown, the crop requires between 250 and 1,000 mm of rain during the growing period: extremely early maturing varieties need 250-400 mm; early varieties 300-500 mm; late maturing varieties 500-1,000 mm.

If the rainfall is above 1,000 mm then groundnut should be grown on ridges unless the soil is very well drained.

Temperature: Optimum temperatures for growing groundnut are 25-30° C. Temperatures above 35° C are detrimental to groundnut production. Under lower temperatures, the germination is delayed; the delay in germination exposes the seeds to soil pathogen attack for a longer period. Below 17° C, crop growth almost ceases. Cooler temperature, especially at night, will also delay harvesting.

Altitude: Groundnut should not be grown in areas more than 1,500 metres above sea level as the temperature is likely to be low for groundnut.

4. Land preparation, rotations and intercrops, and planting

Land preparation

Groundnut requires a deep seedbed without compaction layers or a hardpan. This means that groundnut is more suited to conventional tillage than to conservation agriculture.

As soon as the previous crop has been harvested, the stalks and other crop residues should be cut into small pieces and incorporated into the top 10 cm of soil, either using a hand hoe or a tractor or oxen pulled disc plough. This allows the crop residues time to decay and helps prevent root rot disease in the groundnut crop.

Deep ploughing breaks the hardpan, buries weed seeds deeper making them less likely to be a problem later, and leaves the soil easier for roots and pegs to penetrate and for the pods to be pulled from the ground at harvest.

Groundnut can be grown either on flat beds or ridges. Ridges are recommended if water-logging is a problem. Also, groundnut grown on ridges tends to have higher yields. This is probably because the soil is looser which enables better rooting and pod formation.

If box ridges are spaced at 75 cm apart, double rows of groundnut can be planted along them at a row spacing of 30 cm. This results in the soil being rapidly covered, which shades out weeds.

If water scarcity is likely to be an issue, tied ridges can be used for moisture conservation by reducing runoff and enhancing percolation.

If the soil is acidic, lime should be applied.

Ideally, a phosphorus (P) fertilizer such as SSP or TSP should be applied before planting (see Mineral fertilizer, page 19).

Crop rotations

Groundnut should not be grown on the same piece of land for successive years. Rather it should be grown in a rotation system, with groundnut being grown every 2 to 5 seasons. There are several reasons for this, including:

- to prevent build-up of pests and diseases, such as nematodes, white mould, leaf spots and insect population
- to avoid depletion of soil nutrients and improve organic matter
- to improve physical structure of soil and avoid loss of humus due to the soil loosening that occurs at harvest.

Groundnut is considered a soil depleting crop if the whole plant is removed but a soil improving crop if the vines and leaves are returned to the soil.

Good crops to include in a rotation system with groundnut include maize, sorghum and millet. Other suitable crops include cassava, sweetpotato and sunflower.

Crops to avoid in rotations with groundnut include soybean and other legumes, tobacco, cotton and tomatoes. This is mainly due to the risk of nematodes and other soil-borne diseases.

Groundnut also does well on virgin land and after a grass fallow.

Groundnut and heavily fertilized cereals are an especially good rotation: maize following groundnut had been reported to show a 20% increase in yield. This is due to the groundnut's ability to fix nitrogen (N) from the atmosphere. Groundnut following on from heavily fertilized cereals benefit from the residual nutrients in the soil.

A good example of a groundnut-cereal rotation is groundnut grown in season 1, maize grown in season 2, 3 and 4 with heavy application of fertilizer, and then groundnut grown in season 5.

Alternatively, a cereal could be grown one season and then groundnut the next, reverting to a cereal in season 3.

If it is unavoidable to plant groundnut in successive seasons, soil fertility may be maintained with regular application of manure and fertilizer, and the risk of diseases can be reduced by deep ploughing to bury all crop residues as well as applying other crop protection measures.

Intercrops

Results obtained for groundnut intercrops by researchers have often been inconsistent and some experts are therefore reluctant to recommend this practice. In this section, some information is presented on intercropping. Based on the information given and their own preferences and conditions, farmers might like to try intercropping for themselves.

Groundnut is tolerant of shading - yields will only be reduced if subjected to very shady conditions. Groundnut has therefore been successfully grown as intercrops with crops, such as cereals and cotton, and can also be planted under tall crops such as bananas, pigeon peas (*Cajanus cajan*), castor beans (*Ricinus communis*), sugar cane, or even permanent crops such as coconut palms, oil palms, rubber and cocoa.

When groundnut is intercropped with maize, sorghum or millet, the total yield of the intercrop and the total profit can be higher than for either grown as a sole crop.

The choice of planting pattern will depend on whether farmers prioritise the cereal or groundnut. As an example, if sorghum and groundnut are being grown in an intercropping system and the farmers prioritizes sorghum, then an intercrop pattern with 2 rows of sorghum alternated with 1 row of groundnut should be used. Alternatively, if the farmer prioritises groundnut, then 2 rows of groundnut alternated with 1 row of sorghum should be used.

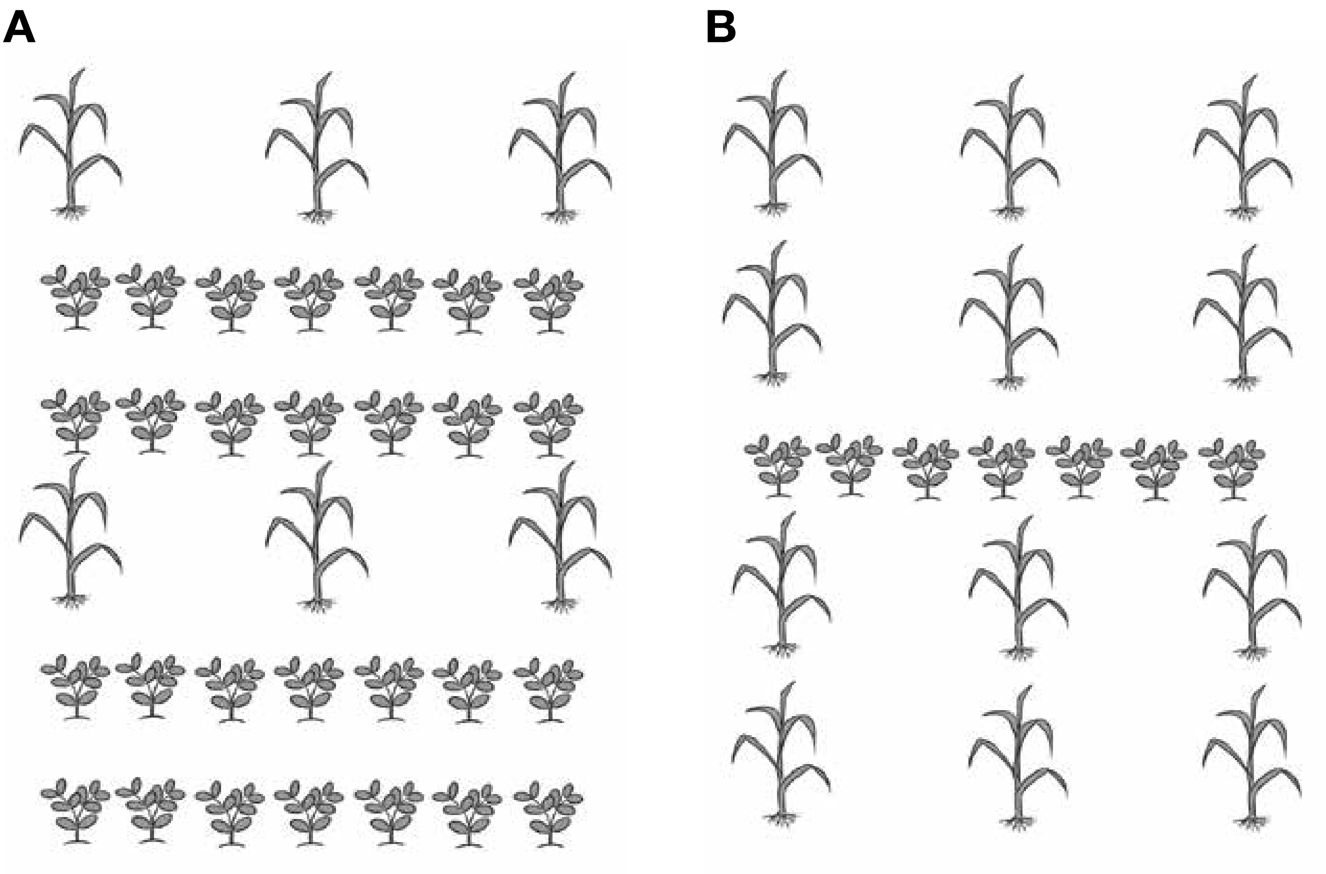

Figure 2: Planting arrangements for groundnut-sorghum intercrop. A: prioritising groundnut. B: prioritising sorghum

If the farmer just wants to achieve the highest combined yield and profit then 2 rows of groundnut alternated with 1 row of cereal will usually be the best option, as the following example shows:

If a farmer grows 1 row sorghum and 2 rows of groundnut and achieves a yield of 700 kg groundnut worth CFA 800 per kg and 300 kg sorghum worth CFA 150 per kg, the total value of the two crops would be (700 kg x 800 CFA/kg) + (300 kg x 150 CFA/kg) = 560,000 + 45,000 = CFA 605,000 (about USD 960).

If instead they had grown 2 rows of sorghum and 1 row of groundnut and achieved a yield of 300 kg of groundnut and 700 kg of sorghum, the total value of the two crops would be (300 kg x 800 CFA/kg) + (700 kg x 150 CFA/kg) = 240,000 + 105,000 = CFA 345,000 (about USD 550).

Groundnut-maize: Trials undertaken in the Guinea savanna zone in Ghana demonstrated that the highest combined yields were obtained using a pattern of either 1 row groundnut alternated with 1 row of maize (maize rows spaced at 90 cm with 40 cm between plants within a row giving 27,778 plants per hectare; groundnut rows spaced at 90 cm with 15 cm between plants in a row giving 74,074 plants per hectare) or 1 row of groundnut alternated with 2 rows of maize (maize rows spaced at 82.5 cm with 40 cm between plants giving 30,487 plants per hectare; groundnut rows spaced at 165 cm with 15 cm between plants giving 40,404 plants per hectare). The relative value of the two crops was not taken into account.

Groundnut-sorghum: Various planting arrangements for groundnut and sorghum intercrops have been shown to be beneficial. For example, a planting arrangement with 3 rows of groundnut and one row of sorghum has shown yield increases over sole cropping of more than 50%.

Mineral fertilizer

Groundnut responds well to fertilizers that contain useful nutrients such as P, N, K, Ca, Mg and others. Although affordability may be a problem for smallholder farmers, applying fertilizers is important to harvest optimum groundnut yields in a sustainable manner for market oriented groundnut production system.

In rotations in which groundnut follows heavily fertilized crops, such as maize, the groundnut can benefit from the residual nutrients remaining in the soil from the previous cropping season.

Usually the most important nutrient needed during the early stages of growth is phosphorus (P); most of the groundnut production regions in Africa are known to be deficient in P.

One option is to apply 20 kg P per hectare during land preparation just before planting (e.g. during making ridges), for example:

Either 250 kg per hectare single superphosphate (SSP): 25 g SSP should be broadcasted for every one square metre during land preparation for planting. This is equivalent to about 7 beer or soda bottle-tops level full of SSP fertilizer.

Or 100 kg per hectare triple superphosphate (TSP): 8-9 g TSP should be broadcasted for every one square metre during land preparation. This is equivalent to just about 1 beer or soda bottle-top heaped full of TSP fertilizer.

Or 100 kg per hectare diammonium phosphate (DAP): 10 g DAP should be broadcasted for every one square metre during land preparation. This is equivalent to 2 beer or soda bottle-tops level full of DAP fertilizer. Once the fertilizer is broadcasted, it has to be covered with soil, and then the groundnut seed can be planted.

In addition, if farmers have previously experienced a large number of empty shells – sometimes called ‘pops’ – gypsum should be applied to provide a readily available source of calcium (Ca): 400-1000 kg per hectare gypsum should be applied on top of the plants at peak flowering stage. This is equivalent to 40-100 g of gypsum applied to every square metre. The gypsum will fall to the soil at the base of the plants where it will make Ca available in the top 5 cm of soil, where the pods will be developing.

Under most conditions, groundnut fixes enough N from the air through symbiotic relations with rhizobium to avoid deficiency throughout its life cycle. However, N deficiency can occur due to poor and eroded soils, lack of or inefficient rhizobium in the soil, drought and high temperatures. Hence, N applied to the crop at the rate of 10 to 30 kg per hectare can be useful. The crop could obtain the required N if DAP is used as P source as DAP also supplies N: 100 kg DAP per hectare will supply 20 kg N per hectare.

Application of manure

In place of or in addition to mineral fertilizers, farmers can also apply manure.

In addition to supplying nutrients, manure also improves soil health, helps reduce aflatoxin contamination and also helps balance soil acidity. If available, 2 handfuls of manure can be applied per planting hole / hill.

Choice of variety

Over the years, more than 100 improved groundnut varieties have been released in Sub-Saharan Africa and often two or more varieties are available to choose within a country. Table 1 gives some examples of the improved varieties of groundnut together with the benefits associated with these varieties for some of the important groundnut producing countries.

Varieties of groundnut take varying times to reach maturity: from early varieties, which are ready to harvest in 85-95 days after planting, to medium varieties, which are ready to harvest in 95-120 days, and late maturing varieties, which are ready from 121 days onward after planting. Although early maturing varieties are more drought resistant or escape onset of drought, the later maturing varieties tend to have higher yields and larger sized seed.

The same variety can have different names in different countries so the table also gives examples of local names.

Smallholder farmers need to check which varieties are available locally and whether these meet their household or market needs.

Table 1: Some improved groundnut varieties and the benefits associated with them.

Variety	Local names in different countries	Some of the benefits of varieties
JL24	Sameké (Mali), Kakoma (Malawi), ICG 7827 (Mozambique), Luena (Zambia), JL24 (Congo), JL 24 (Sierra Leone), JL24 (South Africa)	Early maturity, drought tolerance, high oil, relatively high yield
ICIAR 19 BT	Samnut24 (Nigeria), ICIAR19BT (Niger)	Early maturity, high yield, high oil, rosette disease resistance
ICGV-SM 90704	Nsinjiro (Malawi)	Medium maturity, rosette disease resistance, early leaf spot resistance, high yield
ICGV-SM-93535	Serenut 5R (Uganda)	Drought tolerant, high yield, rosette and late leafspot resistance
ICGV 97049	Oboolo (Ghana)	Early maturity, high yield, large seed, confectionary type
ICGV-SM 01721	Masasi (Tanzania)	High yield, rosette and leafspots resistance
SRV1-19	SRV1-19 (Senegal)	Extra early maturing, high yield
RRB	RRB (Niger)	Early maturity, drought tolerance, high yield
ICGV 86015	Yirwa Tiga (Mali)	Early maturity, drought tolerance, tolerance to leaf spots

Planting

Sources of seed: The sources of seed for planting could be from the informal (e.g. own-saved seed) or the formal (e.g. certified seed) seed systems, or both depending on the amount required and accessibility.

Generally, there are three seed classes recognized in almost all groundnut producing countries – breeder (pre-basic) seed, foundation (basic) seed and certified seed. The seed classes differ in terms of quality standards. Breeder seed is used for producing foundation seed, which in turn is used for producing certified seed. In some countries, particularly in east and southern Africa, seed classes below certified seed, such as Quality Declared Seed (QDS) may be legally acceptable to be marketed as seed. However, these are not legal in ECOWAS member countries of West Africa under the current harmonised seed laws.

Breeder seed is directly controlled by the originating or sponsoring-plant breeder of the breeding programme or institution, and/or personally supervised by a qualified plant breeder. It provides the source for the initial and recurring increase of foundation seed.

Foundation seed may be produced by research institutes or private seed companies or both depending on the seed law of the country.

Certified seed is produced by private seed companies, community-based seed producers and individual seed entrepreneur farmers.

Seed certification is the responsibility of national seed service institutes, which may take varying names in different groundnut producing countries: Seed Agency, Seed Authority, Seed Service, Seed Unit and Seed Council amongst others. The certification process involves field inspection and laboratory testing of seed samples to ensure trueness to type of the variety and that it has met specific genetic or physical (varietal purity) limits. Generally, the breeder seed does not undergo a certification process; rather the breeder maintains production of high quality seed to ensure subsequent quality foundation and certified seed. Table 2 shows seed certification standards commonly used for groundnut.

Table 2: Common seed certification standards for groundnut.

Criteria	Seed classes	
	Foundation	Certified
Minimum isolation in meters	3	3
Off-type plants (maximum at final inspection stage)	0.1%	0.5%
Number of diseased plants/500 m^2	3	3
Specific purity (minimum %)	96	96
Inert matter (maximum %)	4	4
Other crop seed (maximum kg)	Nil	Nil
Weed seeds (maximum)	Nil	Nil
Germination (minimum %)	70	70
Moisture content (maximum %)	9	9

Farmers can use own saved seed for 1 - 3 years, but it is advisable to purchase certified seed every 2-3 years to avoid build-up of disease problems and to maintain the genetic integrity of the variety.

Seed treatment: If using own-saved seed, this should be stored in the pod until 1-2 weeks before planting when they should be carefully shelled. Prior to planting the seed should be sorted; small, shrivelled, immature, skinned, split or otherwise damaged and mouldy seed should be rejected.

Before planting, it is advisable to treat seed to prevent blight and other fungal diseases, and also some pests, such as termites and millipedes. In some countries, combined products are available that include both one or more fungicide plus an insecticide (e.g. Apron Star 45 WS[1]): smallholder farmers should seek advice from their extension officer or local agro-dealer.

The best way to treat seeds before planting is to half fill a manually operated mixing drum with seed and then to add the correct amount of pesticide, carefully following the instructions as indicated on the product label. The drum is then slowly rotated to ensure thorough coverage of the seed. Suitable drums can be made relatively inexpensively by local roadside manufacturers using largely scrap materials.

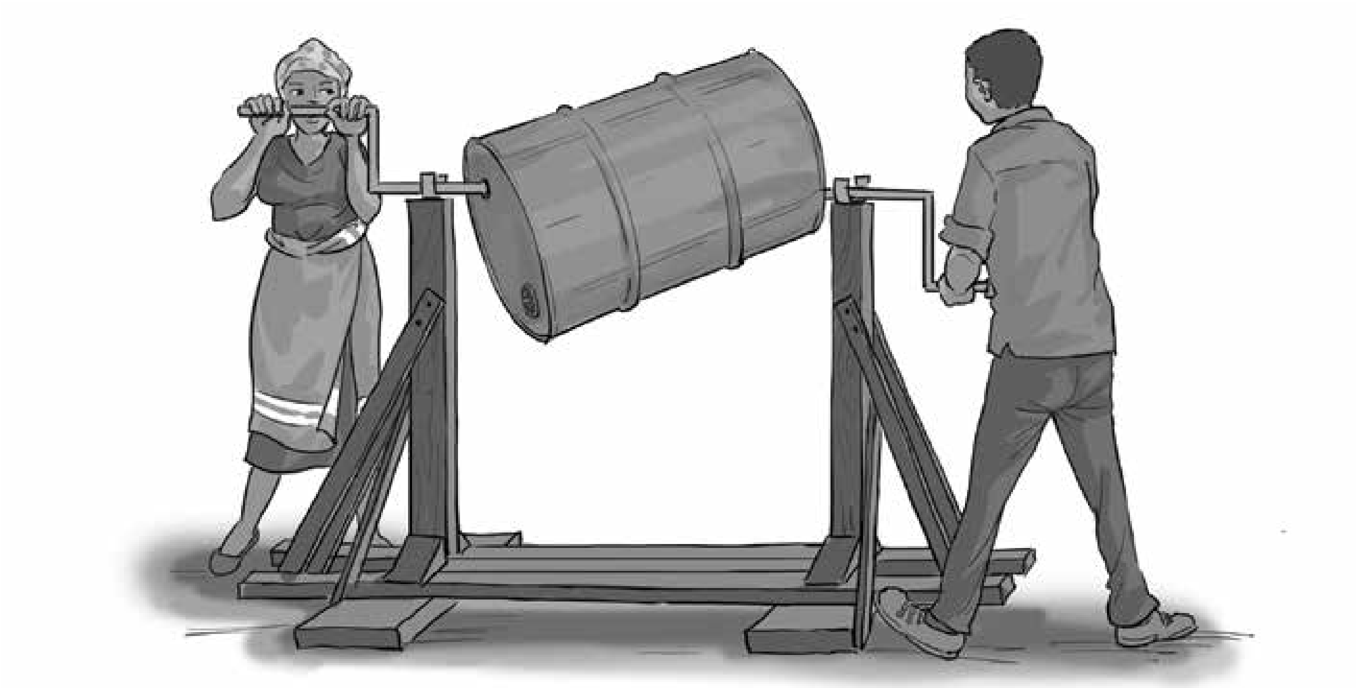

Figure 3: Simple hand-operated mixing drum for applying pesticides to seed

In some areas, it may be possible to buy pre-treated seed. This eliminates the need for the smallholder to treat seed themselves although safety precautions should be taken when handling and storing the seed – hands should be washed after handling the seed and the seed must be stored out of reach of children and animals.

[1] The active ingredients are thiamethoxam (insecticide) and mefenoxam and difenconazole (fungicides).

Before using any agrochemicals, the manufacturer's instructions must be carefully read and/or advice sought from the local agro-dealer or extension worker.

Seed sowing: Early planting is recommended, soon after the rainy season begins – delaying planting can reduce both yields and quality of grain/seed.

Planting should therefore occur within 2 weeks of the onset of the rains. A warm most soil is ideal. However, planting immediately after heavy rain should be avoided as the seeds can absorb too much water, which leads to rotting.

Seed should be planted about 6 cm deep in either holes or a shallow furrow. The holes or furrows should then be filled in and the soil compressed to ensure good contact between the seed and soil. Too shallow planting will result in patchy germination as the surface soil can dry out if there is no further rainfall after planting. Planting too deep will delay germination.

Some experts recommend planting two seeds per hole, which increases the quantity of seed required for planting. If this is done thinning is not needed: the seed is expensive and thinning can disturb the small plants. Preferably just one seed can be planted per hole provided the germination rate is high (more than 85%). It is important to determine germination percentage in the seed lot 3-4 days before planting so the seed rate can be adjusted accordingly and also to detect the presence of post-harvest seed dormancy. Gap filling can be done within the first 10 days of planting if uniform emergence is not achieved for good stand establishment.

Germination test: To determine the germination rate of groundnut seed, 50 seeds should be placed on 4 layers of newspaper which have been thoroughly wetted. The seeds should be spaced with 2 cm between seeds in a row and 4 cm between rows. The newspaper is then rolled and tied with thread or secured with an elastic band. The newspaper needs to be kept wet by adding water as needed each day. Five days later, the number of seeds which have germinated is counted. For example, if 50 seeds have been used and 44 germinate, the germination rate is: (44/50) x 100 = 88%, which is a good rate of germination, i.e. more than 85%.

Spacing: Recommended spacing varies with the growth habit of the variety grown and nature of crop cultivation (irrigated or rainfed, fertility level). Bunching varieties (e.g. Spanish types) are planted with smaller spaces between rows and plants than semi-spreading and runner varieties (e.g. Virginia types). The aim should be to obtain full ground cover as quickly as possible.

In general, bunching types should be planted with 30-45 cm between rows and 7.5-10 cm between plants in a row; runner types should be planted with 60 cm between rows and 10-15 cm between plants in a row.

The optimum spacing will, however, vary from variety to variety with the recommended spacing between rows reaching as high as 90 cm; ideally advice should be sought locally as to the optimum spacing for the chosen variety under the local conditions. A wider row spacing leaving uncovered ground allows proliferation of thrips/aphids, which can carry viruses (rosette, peanut bud necrosis, peanut stem necrosis, peanut mottle and peanut stripe diseases), and promotes weed growth.

In general, a lower plant population is used in rainfed cultivation to avoid inter-plant competition for soil moisture in case of prolonged dry spells. Smaller spacing could be used for irrigated groundnut production, as there will not be competition for moisture.

Inoculation

Being a legume, groundnut is able to fix atmospheric nitrogen and convert this important nutrient into a form that the plant can use to help it develop and grow. Like other legumes, the groundnut does this through partnership with certain types of bacteria, called rhizobia, which exist in nodules in the plant's root system.

The rhizobium species that can nodulate with groundnut is often naturally present in the soil. If groundnut has not been grown before in an area it may, however, be absent. In this case, it can be beneficial to artificially inoculate the seeds before planting with a commercially prepared inoculant that contains the right type of rhizobium.

Inoculants suitable for use with groundnut are available in some Africa countries, including Kenya and Zimbabwe.

Compared with other legume crops, the use of inoculants on groundnut can be difficult. One reason is that groundnut seeds are fragile; if they are split during handling they will not germinate, so it can be hard to apply the products to the seed. Secondly, it is usually recommended that groundnut seed is treated with a fungicide and insecticide to prevent problems with pests and diseases during the early stages of growth. These products may be toxic to the inoculants, which contain live bacteria, so it may not be possible to apply living inoculants as well as chemical pesticides.

Before using an inoculant together with chemical pesticides as seed treatments expert local advice should be obtained.

5. Groundnut management

Weeding

Groundnut does not compete well with weeds and yields will be severely reduced if the crop is not adequately weeded.

Weed control is especially important when the plants are small, during the first 6 weeks, and as the pod is setting. Usually 2-3 weedings will be needed. Later, if the correct plant spacing has been observed, the crop will cover the ground effectively preventing weed growth.

Crop rotation helps control weeds. Also, good preparation of the field, with deep turning of the soil, will help ensure the seed bed is weed-free.

Some farmers use pre- and post-emergence herbicides although many smallholder farmers may find these to be too expensive.

Weeding groundnut needs to be done with care:

- Avoid covering the developing plants with soil as this increases the risk of disease and reduced yield.
- Take care when walking through the field when the crop is flowering to prevent disturbing the flowers.
- At pegging, avoid disturbing the soil near the plants: at this stage pull weeds by hand and avoid use of hoes.

Earthing up

There is no consistent evidence about the benefit of earthing up, i.e. covering the base and lower nodes of the plant with soil. It is, however, commonly practiced and the indication is that it could increase yield if the timing is right.

If it is done at an early stage, researchers have found that the practice can increase the risk of some diseases, such as white mould, and may reduce flowering and pod development at the lower nodes, with an overall reduction in yield. Earthing up during flowering may also affect peg formation due to damage to delicate flowers.

However, earthing up done immediately after final weeding and gypsum application (i.e. 40-50 days after planting or at initial pegging stage) to make soil compact around effective root zone could increase yield by enabling all the pegs formed to develop into pods. This is particularly useful for varieties known to develop aerial pegs. Otherwise, many aerial pegs will be unproductive in un-earthen up plots - they will not enter the soil to develop into pods.

The practice also helps the late formed pegs to enter the soil to form pods. But while waiting for the late formed pods to mature, earlier set ones may sprout in case of lack of dormancy or the peg attachment may weaken resulting in their loss into the soil at the time of harvest.

In situations where the rainfall is torrential in nature, the developing pegs and pods may become exposed due to topsoil erosion making them vulnerable to pests and direct sun damage. Similarly, if water-logging is a risk, ridge planting is advised and the root system as well as pegs and pods of those plants on ridges may get exposed due to soil erosion. In such cases, light earthing up helps to cover the exposed pegs and pods.

Instead of earthing up, some farmers (e.g. in Mali) flatten the plants by walking on or stepping over a standing plant to bend the stem and branches to allow aerial and or late formed pegs to enter the soil.

Irrigation

Although groundnut is considered to be a relatively drought tolerant crop and performs well in the semi-arid tropics, some varieties are more tolerant than others. Smallholder farmers should check which varieties are available locally and which of these are most drought tolerant if this is a major concern.

To ensure high yields, groundnut requires adequate moisture at two critical stages in its growth cycle: during the first 2 weeks, from planting to emergence of the seedlings, and around the time of peak flowering, pegging and pod development – this period lasts around 8-9 weeks. If available and needed, light but frequent irrigation should be used during these periods. The sprinkler method of irrigation is found more efficient and beneficial to groundnut. Flood irrigation is not a good method as it wastes water, results in overwatering and trampling of plants in the field by persons engaged in irrigation.

Harvesting

Timing: Groundnut produces flowers daily over several weeks. This means that, even on the same plant, while some pods will be mature, others will be developing. This makes it difficult to know when to harvest the groundnut crop.

Correct timing of harvest is, however, important – harvesting too early or too late will lead to serious yield losses and decreased quality, and increased risk of contamination with aflatoxins, which can cause serious, life-threatening diseases.

If the crop is harvested too early, the seeds will shrink when drying which will lower the yield, oil content and quality.

If the crop is harvested too late, especially in hard or dry soils, the pegs will break off when the plant is pulled up and pods will be left in the ground. Also, if left too long in moist soil, the seed might germinate.

Leaf fall is not a good indicator of harvesting. To determine whether the time is right for harvesting, around 5 plants should be pulled up, the pods removed and shelled. If more than 70% of the pods are dark brown inside and the seeds are plump and are the correct colour for the variety being grown, then the crop is mature and ready for harvest.

Also, if the crop has lost its leaves due to disease, or if the soil is desiccated and the plant withers and the seeds in the pods begin to shrivel and take on a ripe appearance due to terminal drought, or if the seeds are sprouting in the field, the crop should be harvested immediately.

Method: There are two main options for harvesting groundnut:

For bunch/erect varieties and when the soil is moist or light the entire plant can be pulled up so the pods remain attached. A team of 12-14 people can harvest one hectare of bunching groundnut in this way in one day.

Spreading types have weaker pegs. If the plants are pulled up, the pegs are likely to break leaving pods in the ground. So, for spreading types and also when the soil is dry or heavy, the plants need to be dug up, either using a hoe or animal-drawn plough. The plough should be set to cut below the pods, which are 10-12 cm below the surface. Damaged pods are susceptible to infestation by Aspergillus fungus causing aflatoxin contamination, so care needs to be taken.

When the plants have been uprooted, they should be shaken to remove as much soil and moisture as possible to minimize rotting/mould and aflatoxin contamination during the drying process.

After the tap root has been cut away, smallholder farmers drying practices vary from area to area. Generally, farmers make heaps in batches and leave them in the field with some of the pods having direct soil contact and other pods exposed to direct sun for one or more weeks (Photo 1). In some cases, due to labour shortage, the harvested plants may be left in the field for too long exposing the pods and haulms to damage by animals, excessive heat, termites and rotting.

Photo 1: Bad practice: groundnut heaped in field without plants being turned upside down (Source: Waliyar et al., 2015[2]).

Some improved methods of drying groundnut have been developed. Some of these are used on the ground (e.g. windrow) while others involve lifting the harvested plants off the ground (e.g. Mandela Cock, A-Frame).

[2] Waliyar, F and Osiru, M and Ntare, B R and Kumar, K V K and Sudini, H and Traore, A and Diarra, B (2015) Post-harvest management of aflatoxin contamination in groundnut. World Mycotoxin Journal, 8 (2). pp. 245-252. ISSN 1875-0710

i. **Windrow or batch drying:** Harvested plants are stacked in windrows on the field or tied in batches for 2 - 3 days. In both cases, the plants are turned upside down, that is with the pods uppermost, to avoid pods having direct soil contact thereby reducing risk of aflatoxin contamination (Photo 2). The pods should not be left exposed to direct sun for a long time to avoid loss of viability of seed saved for the next season and reduced quality of groundnuts.

Photo 2: Good practice: Plants turned upside down (Source: Waliyar et al., 2015)

ii. **The Mandela cock:** This consists of a simple, raised platform made from soil (Figure 4 and 5). First soil is heaped into a mound 1-2 metres in diameter and 0.5 metres tall. A layer of groundnut plants is then placed around the edge of the platform with the pods towards the centre. More layers are added, each a little closer to the centre of the mound. Finally, when there is only a small opening remaining in the top, this is plugged with groundnut plants with the pods down into the opening. The completed cock can be 1 to 1.5 metres tall. The pods will be dry in 2-4 weeks. In this case, the pods are not exposed to aflatoxin contamination or direct sun that affects the quality of seed saved for the next season.

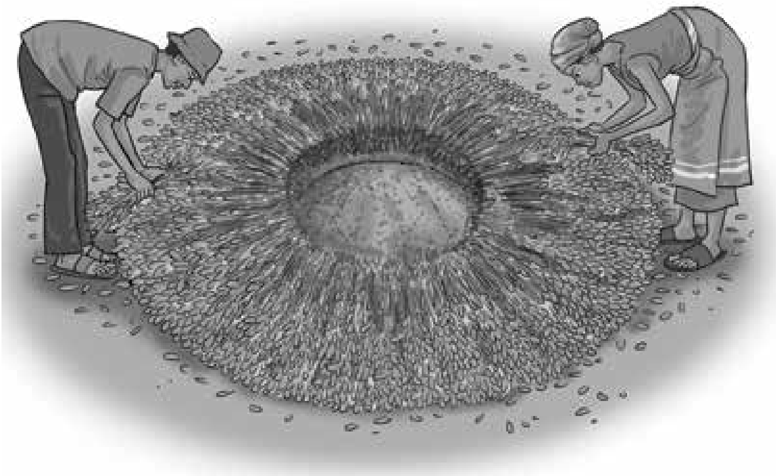

Figure 4: Mandela cock: layers of groundnut plants placed on top of soil platform

Figure 5: Completing a Mandela cock – plugging the small opening with a groundnut plant, pods positioned down into the opening

iii. **A-frame:** This consists of a simple wooden frame, resembling a hut, made from locally available poles and branches. At each end an A-frame is made from poles tied together with twine: ideally one of the poles making the sides of the 'A' should have a fork in the end. A ridge pole is then placed between two A-frames, in the fork, and tied into place. Finally, thinner horizontal poles are tied between the A-frames with the bottom pole 45 cm above ground level, leaving the ends open. The groundnut plants are then arranged on the horizontal poles with the pods facing inwards, starting at the bottom. More layers of plants are added, each with the pods facing inwards. In this way, the plants form a thatched roof which protects the pods from direct sunlight and rain, while the air can circulate freely through the structure. This allows the pods to dry in 3-4 weeks (Figure 6).

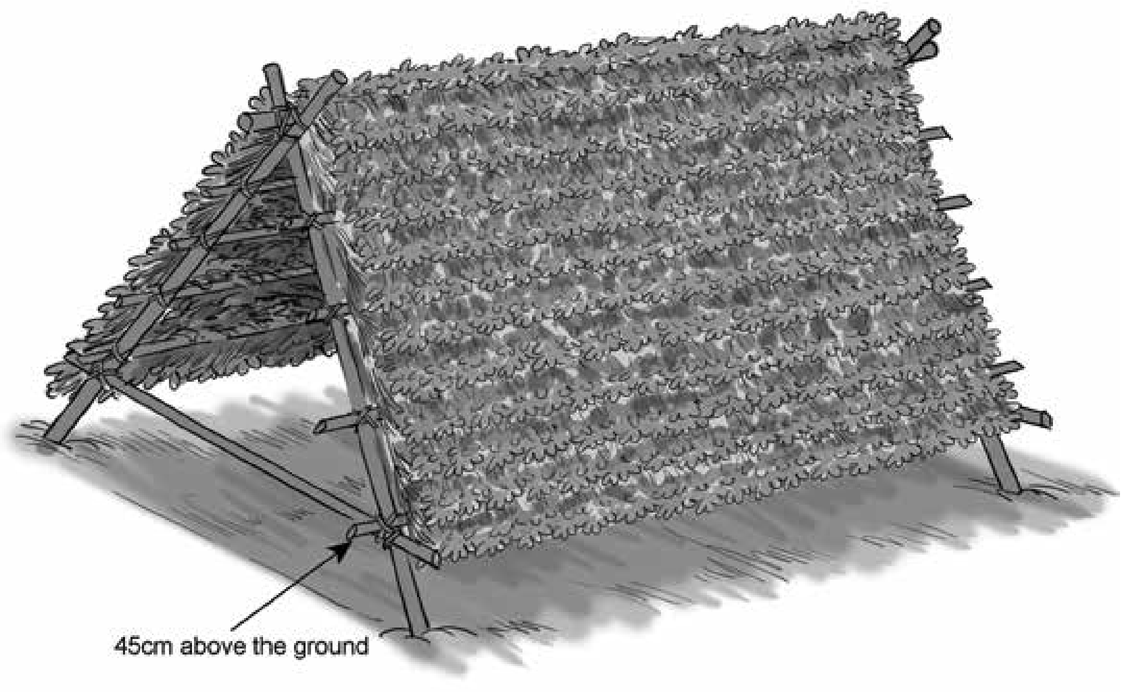

Figure 6: A-frame

iv. **Wooden or steel rack:** This is a simple rectangular rack with one or more shelves, with the lowest shelf 45 centimetres off the ground. Either wooden (Figure 7) or steel frames can be used depending on availability. The rack can be positioned so that the groundnuts are shaded from direct sun. Racks can also be stored inside structures, including houses. Pods dried on racks which are not protected from the rain by a shelter should be covered or taken indoors during wet weather.

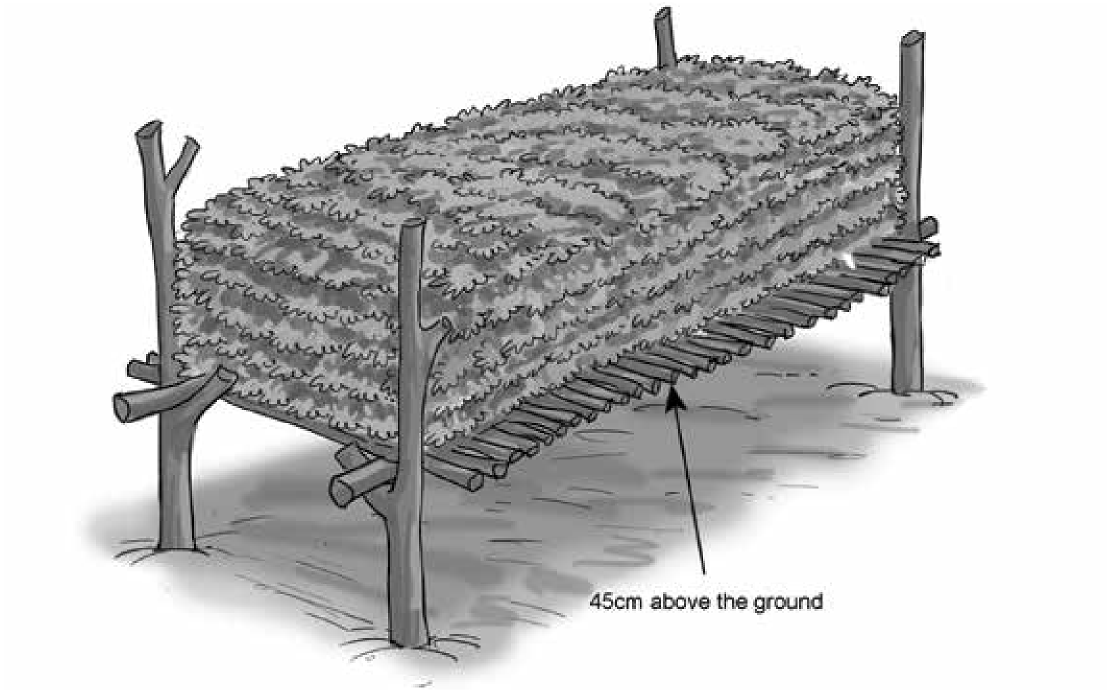

Figure 7: Wooden drying racks

After drying on the plant, next the pods are stripped from the plants and dried rapidly. The pods are ready for removing from the plant when:

- they can be cleanly pulled off the plant without leaving coarse threads breaking from the pods
- the kernels rattle in the pod and have a nutty taste.

Stripping pods: Pods can be stripped from the plants by hand or using a pod stripper. Pods should not be stripped by beating with a stick as this can damage the pods; this is especially important if the groundnut is intended to be sold in the shell.

A pod stripper is a simple tool made from a wooden or steel frame over which chicken netting or chain link mesh is stretched (Figure 8). The frame can be mounted on legs so it is at a convenient height. The dried plants are held by the stem and the roots and pods pulled across the netting: the pods get caught in the netting and fall through the frame.

Figure 8: Simple pod stripper in use

Due to shortage of labour, some smallholder farmers store their groundnut crops on the plant indoors until they have time to strip the pods and dry them. This is not advisable, as the groundnut will be exposed to aflatoxin contamination.

To dry the pods, they can be spread thinly on a tarpaulin or woven mat; they should not be placed directly on the ground. A better system is to dry the pods on raised platforms. If it rains the pods should be covered to keep them dry. Drying the pods takes from between 6 days and 6 weeks.

After drying, the pods are cleaned and they can be sorted into different grades before being bagged in hessian sacks – not polythene or other plastics as these are likely to promote growth of fungi. To prevent storage pests damaging the crop, the pods can be treated and/or the store can be fumigated with an appropriate formulation of a registered insecticide – local advice should be sought from extension workers or agro-dealers. The use instructions provided by the manufacturer should be carefully followed to ensure safety and efficacy.

Alternatively, dried neem leaves can be added to the storage containers - about 500 grams of leaves for every 10 kg of kernels.

It is much better to store groundnut in the pods rather than shelled. The pods (shells) offer some protection from moulds as well as insects and rodents.

The filled sacks can be stored indoors in piles up to 10 bags high but the bottom sacks must be raised off of the ground, for example on wooden boards, to avoid damage from dampness. Stacks of bags need to be separated to allow air to circulate between them.

Generally, shelled grains fetch higher price on the market. Farmers may therefore decide to shell. In such cases, the grain can be stored in airtight containers or bags such as PICS (tough, air-tight triple bags) to minimize quality deterioration due to humidity and pest damage.

The Institute of Rural Economy (IER) in Mali has developed an improved storage system whereby smoke from cooking fires is used to fumigate the crop. The granary is attached to the kitchen and smoke is channelled through an opening in the wall from the cooking fire in the kitchen to the granary thereby protecting the pods or grain from insects or dampness (Figure 9).

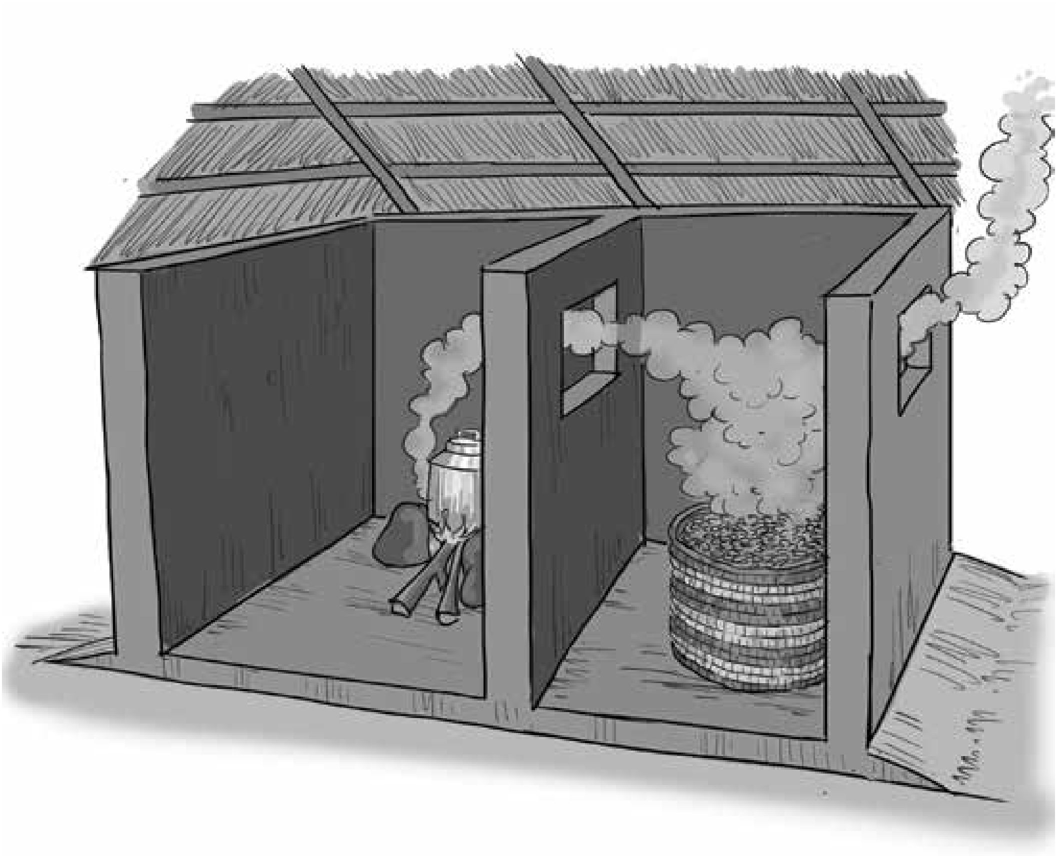

Figure 9: Smoke from the cooking fire in the kitchen is used to fumigate the crop in the improved granary, which is built adjacent to the kitchen

Is your groundnut dry enough to store?

Place one tablespoon (or a small handful) of dry salt and a large handful of shelled groundnuts into a dry, clean plastic bottle.

Close the lid.

Leave it in the sun for 30 minutes.

If moisture is visible on the inside of the bottle, the groundnut requires further drying to reach a safe level of moisture for storage.

Improving farmers access to seeds of improved groundnut varieties

In many countries, more than 80% of seed for planting is sourced from the informal seed system including own saved seed, exchange, gifts from family members or relatives and purchase from local markets. Quality of the seed is an issue in such arrangements in terms of genetic purity, viability and productivity. This seed is often from local unimproved varieties, which are normally low yielding and susceptible to major disease and pests. Therefore, there is a need to strengthen the formal groundnut seed system to improve access to seed of improved groundnut varieties so that farmers can increase productivity and production.

A number of factors contribute to the challenges of accessing quality groundnut seed of improved varieties by smallholder farmers in Africa.

The involvement of private seed companies in the production and marketing of legumes seed including groundnut is relatively limited compared to cereals such as maize. Besides, private seed companies often make large seed packs (50-100 kg), which make it difficult to access seed for those smallholder farmers who can only afford to buy smaller quantities.

Groundnut has a very low seed multiplication rate – for every 1 kg of groundnut seed planted, between 5 and 10 kg of seed can be harvested; in comparison, for every 1 kg maize seed planted, about 200 kg seed can be harvested and for every 1 kg sorghum seed planted, about 100 kg seed can be harvested under the prevailing productivity level of the respective crops in Africa. Hence, larger area is required to produce groundnut seed to meet demand.

The groundnut kernel is also relatively large – for every one hectare up to 100 kg of seed is needed (the exact amount varies between types and varieties of groundnut); in comparison, about 25 kg of maize seed or about 7-10 kg of sorghum seed is needed for every hectare. This has cost implications for the storage and transportation of groundnut seed thereby making it more expensive for smallholder farmers to access improved seed.

Groundnut seed is relatively fragile and can be easily damaged, and hence it requires additional care in storage and during transporting. The seed can easily split into two halves, in which case it will not germinate.

Groundnut seed deteriorates rapidly after harvest – much faster than non-oil seed crops, such as cereals. Hence it requires care during long-term storage.

Groundnut is a highly self-pollinated crop and farmers can save their own quality seed for 2-3 seasons and do not need to buy new seed each season once they got the first seed stock of improved varieties. This makes it challenging for seed companies to be able to predict demand for seed.

Supply of required quantity early generation (breeder and foundation) seed is another challenge for certified seed producers attributed to limited capacity of local research stations mandated to produce and supply early generation seed.

Opportunities to establish and strengthen sustainable seed systems exist such that producing stocking and marketing seed of improved varieties of groundnut become more attractive to individual entrepreneurs, community-based seed producers, seed companies and agro-dealers, and subsequently smallholder farmers have sustainable access to quality seed. These involve, among others, creating and strengthening linkages between seed actors (farmers, private seed producers, agro-dealers and research systems), capacity building of actors, awareness creation and creating suitable policy environment for the seed sector. Provided that local and regional seed regulations allow, private companies can be engaged in the production and marketing of early generation seed in addition to certified seed. Smallholder farmers could produce high-quality groundnut seed as an income earning business and provide this important input to their neighbours at affordable prices and in the quantities needed (including small packs), or sell it to seed companies in an out-grower scheme.

Seed as an income generating activity for farmers

Farmers groups and individual smallholder farmers could be engaged in producing and selling quality seed as an income earning activity. To do so they need to source foundation seed from the local research station or authorized private seed companies and may have to follow local regulations, which could include inspections of the crop. In some countries, seed companies contract smallholder farmers to produce groundnut seed as out-growers. This has the advantage that the seed company provides foundation seed, training and support, inspects the crop and, subject to meeting the agreed quality standards, buys the crop at a guaranteed price.

Experiences in many countries suggest that producing groundnut seed can be a profitable business opportunity for more able smallholder farmers. There are some encouraging success stories, such as the widely-recognized Malawi groundnut seed system (supported with a revolving seed fund) and Wacoro women group in Mali.

The Wacoro women seed production entrepreneurship started with their involvement in participatory variety selection activities organized by ICRISAT up to 2013. The farmers selected two improved varieties and started producing seed. In 2013, the women's group signed an agreement with Faso Kaba (a private seed company) to produce seed on 34 hectares. The company supported in the certification process and provided technical support. The income helped some of the group members to buy oxen for ploughing and to replace the grass thatched roofs of their homes with iron sheets. Today, most members of the association in the villages of Wacoro, and other villages including Bougoula, Sanambélé and Fanzan, are involved in seed production and marketing. They have accumulated good savings and some are providing credit services to members and neighboring farmers.

Saving own seed

If farmers intend to save own seed for 2-3 years after receiving initial stock of improved varieties seed, they should inspect their crop and remove any abnormal looking plants while the crop is growing. This process, called roguing, will help maintain the genetic purity and health of the variety being grown.

While drying groundnut for seed, the pods and seeds should not be directly exposed to the hot sun as this can damage the seed and reduce the germination rate.

Seed should be stored in the pod until a week or two before planting, when they should be carefully shelled by hand. Any split, damaged, mouldy or abnormal looking seeds should be rejected.

If the own-saved seed is to be carried over for next season's crop, then it should be stored in the pod.

Making hay

Hay made from groundnut stems and leaves is a valuable protein-rich feed for livestock. It is especially useful as dry season fodder for dairy cows or to keep draught oxen in good condition, or for fattening sheep and goats. A one hectare field can yield up to 7 tonnes of hay.

The best quality groundnut hay has both leaves and stems; the leaves contain the most protein. If the crop is harvested too late, the leaves will have started to drop and much of the protein will be lost.

When the hay is dry, it can be stored for dry season feeding. The hay should be raised off the ground and ideally should be protected from rain.

To reduce the space required for storing loose hay, simple manually operated baling tools can be made (Figure 10). These consist of simple wooden boxes without tops or bottoms. Two pieces of twine are laid along the length of the empty box, which is then filled with hay. The hay needs to be well compressed; this can be done by standing on the hay and pushing it into the box. When the box is full the twine is tied tightly and the bale pushed out of the box.

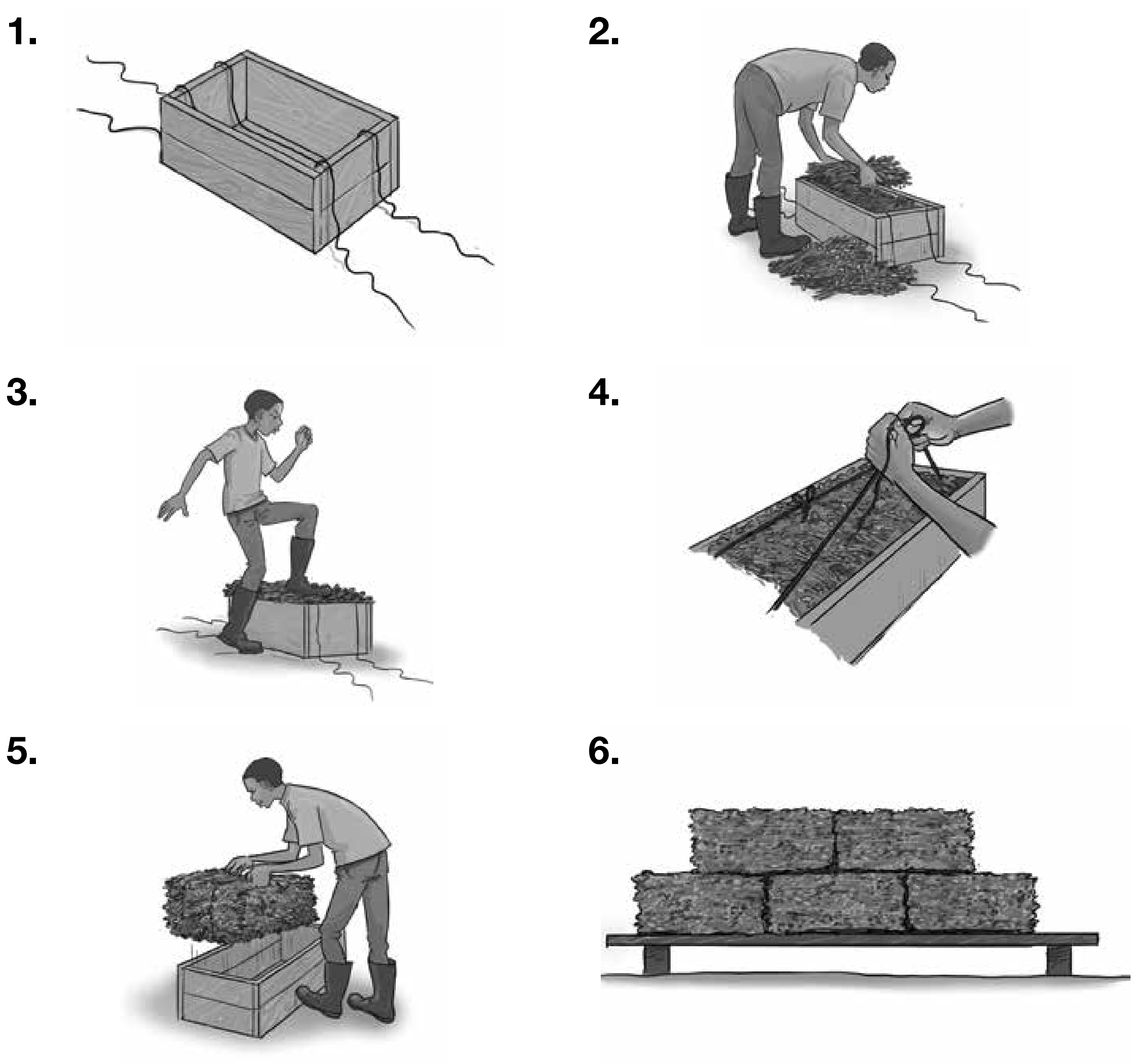

Figure 10: How to use a simple box baler

If smallholder farmers do not have their own animals, they can sell the hay to neighbours who do have cattle or other livestock and even to livestock traders. In some areas, the hay can be more valuable than the grain. Baled hay is easier to transport than loose hay.

6. What can go wrong

Diseases

Groundnut rosette disease is the most important disease of groundnut in Africa. It is caused by viruses transmitted by a species of aphid.

The disease occurs in three forms: chlorotic, mosaic and green mosaic rosette.

Plants with chlorotic rosette have bright yellow leaves, except for small parts that remain green; these are known as 'green islands'. The yellowing may affect the whole plant or only some shoots, or parts of shoots. Early infections result in severely stunted plants with small, deformed leaves (Photo 3).

Photo 3: Chlorotic rosette disease (Source: B. Motagi, ICRISAT-Nigeria)

Plants with mosaic rosette have yellow and dark green areas on the leaves. Plants are stunted, although less than those with chlorotic rosette (Photo 4).

Photo 4: Mosaic rosette disease (Source: B. Motagi, ICRISAT-Nigeria)

Plants with green mosaic have very dark green small leaves, or they have a light and dark green mosaic, and the edges of the leave are rolled downward. They too are stunted if infected early. In all forms of the disease, early infection causes severe pod loss (Photo 5).

Photo 5: Green mosaic disease (Source: B. Motagi, ICRISAT-Nigeria)

A number of measures help to delay infection with rosette disease:

- removing volunteer plants (self-sown groundnut) from the last crop
- planting at high densities, to cover the soil as quickly as possible (the landing behaviour of aphids, which spread the disease, is disturbed when the soil is covered)
- planting early in order to produce a crop before the arrival of winged aphids
- intercropping with beans, maize or sorghum
- crop rotation with maize or sorghum.

The most reliable method of control, however, is to plant disease-resistant varieties. High-yielding, long duration varieties for medium and high rainfall areas were the first to be bred. More recently short duration Spanish types, suitable for western, eastern and southern Africa, have become available. Smallholder farmers should check if these varieties are available locally (see Table 1, page 22).

Other control options include biological and chemical controls if available and affordable.

If rosette disease occurs, diseased groundnut plants should be removed as soon as they are seen and destroyed. Weeds should also be removed from within and around the plots. After harvest, all plant debris should be collected and destroyed by burning or used as fodder for livestock.

Early and late leaf spot of groundnut are severe diseases caused by two species of fungi (Mycosphaerella arachidis and Mycosphaerella berkeleyi, respectively). Early leaf spot (ELS) lesions, often surrounded by a yellow hallow, are roughly circular, dark brown on the upper leaflet surface and lighter shade of brown on the lower leaflet surface (Photo 6). Late leaf spot (LLS) lesions are nearly circular and darker than those of early leaf spot. On the lower leaflet surface the lesions are black and slightly rough in appearance. In addition to reducing yield and quality of the pods they also affect the yield and quality of the haulm. When the attack is severe, both early and late leaf spot cause severe premature defoliation (leaf fall).

The best way to manage the disease is to grow resistant varieties. Other useful approaches include controlling weeds and volunteer plants, removing and destroying all crop residues at harvest, deep ploughing and growing a different crop for at least one year.

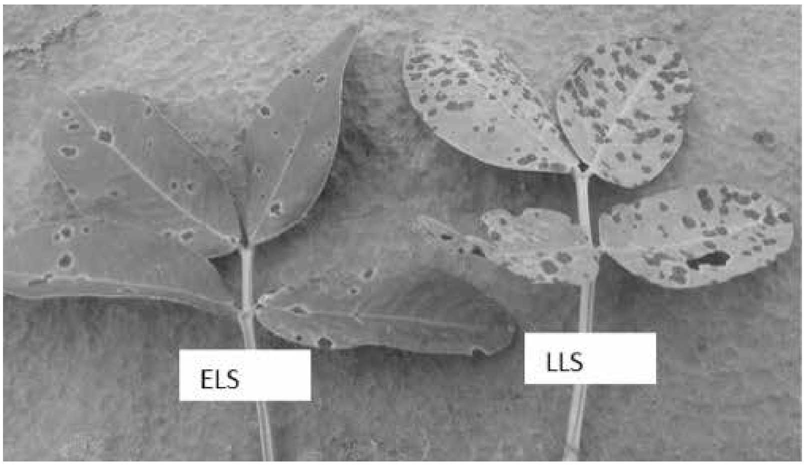

Photo 6: Early and late leaf spots of groundnut (Source: H. Desmae, ICRISAT-Mali)

Chemical control options, such as the fungicides chlorothalonil, thiram and mancozeb, can be used if affordable and locally available: smallholder farmers should seek advice from their agro-dealer and follow the manufacturer's instructions on the pack. The application should start as soon as the symptoms are observed and may be repeated every 10 to 15 days.

Groundnut stem and pod rot (southern blight) is a soil-borne fungal disease. The initial signs are dark spots on the stem just below soil level. At first one branch of the plant turns yellow and wilts, and a few days later the whole plant wilts. Sometimes a white cottony growth is seen on the lower stem and soil surface (Photo 7).

Photo 7: Cottony growth on the stem causing plant to wilt

Management of the disease depends on weekly monitoring of the crop. As soon as wilting plants are seen they should be removed along with soil from around the root.

Chemical control options, such as the fungicides chlorothalonil, thiram and mancozeb, can be used if affordable and locally available: smallholder farmers should seek advice from their agro-dealer and follow the manufacturer’s instructions on the pack.

Preventive measures include planting resistant varieties and practicing crop rotation with maize, sorghum, cassava or yam. Groundnut should not be grown after tomatoes, capsicum (peppers) or beans. Mulching the crop with maize or sorghum straw is also helpful.

The crop should be kept weed-free, although care needs to be taken to prevent damage occurring to the groundnut stems.

After harvest, collect and bury or burn all groundnut plant debris.

Rust is a fungal disease spread by wind, rain splashes and infected seed. The first signs are small flecks on the leaves, which develop into larger spots on leaves, stems and pegs; initially the spots on leaves are yellow before turning red (Photo 8). Unlike leaf spots, leaves infected with rust become necrotic (dead areas) and dry up, but tend to remain attached to the plant.

Photo 8: Groundnut rust (Source: B. Motagi, ICRISAT-Nigeria)

Rust can be controlled by spraying with a fungicide, chlorothanil, as soon as rust spots are seen; smallholder farmers should seek advice from their agro-dealer and follow the manufacturer's instructions on the pack.

Preventive measures for rust include crop rotation, for example, growing cereal crops for two seasons following a groundnut crop.

Volunteer plants should be removed and the plot kept as weed-free as possible.

New groundnut crops should be planted as far as possible from current groundnut crops.

There are improved varieties of groundnut that are tolerant to both rust and leaf spot, so smallholder farmers should check to see whether these are available locally.

After harvest, all groundnut plant debris should be collected and destroyed or used as fodder for livestock.

Aflatoxins

Aflatoxins are toxic substances produced by certain types of fungi (Aspergillus flavus and A. parasiticus), which can grow on groundnut (Photo 9) and other crops such as maize. Contamination can occur at any stage from pre-harvest to storage. These fungi (soil-borne and air-borne) get access to seeds through microscopic cracks in the pod wall and seed coat, mechanical injury to pods during growing and harvesting, and insect and nematode damage to pods. Moisture stress due to end-of-season drought at pod and seed development stage makes them more susceptible to aflatoxin contamination in the field. Poor post-harvest conditions in warm humid areas and bad harvesting and storage practices lead to rapid development of the fungi and higher levels of toxins. Storage of grains and pods before they are properly dry, or in damp conditions, also creates opportunities for contamination.

Photo 9: Groundnut seeds infected with aflatoxin (Source: D. Konate, ICRISAT-Mali)

Under high infestation level, contaminated kernels could be visually identified and sorted out. But generally, aflatoxins are invisible and impossible to detect without sensitive kits or laboratory tests.

Several methods including thin-layer chromatography (TLC), high-performance liquid chromatography (HPLC), mass spectroscopy, enzyme-linked immune-sorbent assay (ELISA) and electrochemical immunosensor, among others, have been described for detecting and quantifying aflatoxins, but they are all too expensive, time consuming, laborious and too difficult to implement. Efforts are being made to develop rapid aflatoxin test kits that are fast, simple and affordable for detection of aflatoxin even in the farmers' fields and granaries. Some of these kits are now commercially available; farmers need to check for local availability.

Regular exposure to low levels of aflatoxins in contaminated foods, such as groundnut, can cause severe life-threatening illness including hepatitis and liver cancer. Children can be exposed to aflatoxins in breast-milk or weaning foods that have been made with ingredients contaminated with aflatoxins; some experts think this can cause stunting.

Many countries have imposed regulatory limits on the maximum allowable levels of aflatoxin in groundnut (e.g. in the European Union, the limit is 4 μg/kg for direct consumption and 15 μg/kg for further processing). The regular occurrence of aflatoxins at levels greater than permitted means that groundnut cannot be exported from most African countries to the European Union or other potentially high-value markets. In the past, some African countries used to be major groundnut exporters: in the 1960s sub-Saharan Africa supplied more than three-quarters of global market share but today this has declined to around 4%.

Aflatoxins therefore impact on the health of people and also livestock consuming groundnut or other products contaminated with these dangerous chemicals and also reduce the markets available to groundnut producers. The negative health, nutrition and economic impact of aflatoxins can be minimized with proper application of aflatoxin management technologies. There are pre-and post-harvest aflatoxin management technologies that reduce infestation below the regulatory limit, 4 μg/

kg. Pre-harvest management options enable healthy and good plant growth, avoid drought stress and ensure seeds remain undamaged in pods to minimize fungus penetration and infestation. Post-harvest management options reduce the incidence and infection of groundnut with aflatoxin by creating unfavorable condition for the fungus growth.

Measures to minimize the risk of aflatoxin contamination include:

i. Pre-harvest

- Use resistant/tolerant varieties if available
- Select healthy seeds for planting
- Plough the land before planting
- Practice early planting
- Maintain optimal density of plants in the field
- Avoid mono-cropping
- Apply bio-control if available (for example, Trichoderma (a fungus) at 1 kg per hectare)
- Practice appropriate weeding
- Apply farmyard manure at 2.5 tons per hectare before planting
- Apply foliar sprays, using 1–2 applications: follow manufacturer's instructions
- Apply lime or gypsum at 400 kg per hectare at flowering
- Apply mulch with crop residues at 40 days after planting
- Avoid damaging pods during crop growth
- Avoid end-of-season drought through supplementary irrigation (if possible)
- Remove dead plants from the field before harvest

ii. Post-harvest

- Harvest the crop as soon as it is mature
- Remove soil from the pods before leaving to dry, remove immature pods attached to the haulms and avoid long-term contact of pods with soil after harvest
- Ensure that the correct drying procedures are used such as drying of groundnut pods on tarpaulin sheets rather than on bare ground, drying seed to 8% moisture level
- Stripping the pod immediately after drying
- Remove damaged, shrivelled, or rotten pods before storage
- Avoid mixing clean harvested pods with gleaned pods
- Store the pods under dry, well ventilated conditions to avoid re-humidification of pods
- Avoid pod damage by insects. Fumigation of pods with insecticide helps to avoid insect damage during storage: follow manufacturer's instructions

- Avoid damaging the seed during shelling; destroy any discoloured, shrivelled or mouldy seed
- Pre-harvest contamination is severe during drought: extra care should be taken to clean the seed, especially the smaller seed
- Apply cinnamon and clove oils if available
- Chemical control if available (e.g. methyleugenol)

Pests

Table 3 summaries the impact, signs and management options for the main pests of groundnut.

Table 3: Major pests of groundnut

Pest and impact	Signs	Management
Aphids mainly a threat because they spread viral diseases, e.g. rosette disease, but can also damage groundnut directly by sucking sap	Small brownish-grey insects mainly on growing tips and young foliage	**Control** – Spray with suitable insecticide, e.g. dimethoate: follow manufacturer's instructions for safety and efficacy **Prevention** – Plant early and plant close together Rotate groundnut with other crops Intercrop with pearl millet Destroy volunteer plants and weeds Plant aphid–resistant varieties if available
Groundnut leaf miner is the caterpillar of a moth, which tunnels into the leaf to feed, emerging when larger. Can totally destroy a crop	Distorted leaves due to caterpillars inside. Leaves folded over or stuck together with silk. Leaves turn brown, roll up and dry	**Control** – Spray with suitable insecticide, e.g. dimethoate: follow manufacturer's instructions for safety and efficacy **Prevention** – Plant early Rotate with cereal crop Plant tolerant/resistant varieties if available
Termites destroy roots and make holes in pods and seeds	Wilting and death of plants	Control - Apply insecticide to seed or soil, such as chloropyrifos: follow manufacturer's instructions for safety and efficacy Prevention - Avoid growing in areas with obvious signs of termites Plant early Maintain soil moisture through supplementary irrigation or other moisture conservation mechanisms if possible Dig out and destroy termite nests Prompt harvesting to avoid pod damage
Millipedes feed on young seedlings up to 20 days after planting and also soft pods	Presence of termite mounds	Prevention - Include insecticide in seed treatment along with fungicide, e.g. a product containing both thiamethoxan and metalaxyl: follow manufacturer's instructions for safety and efficacy Keep pods covered with soil; choose varieties with well-buried pods

White grub (larvae of chafer) C-shaped grubs with brown heads and 3 pairs of legs, feeds on roots and pods	Stunting and death of plants	**Prevention** – Apply manure well before planting Plough or hoe deeply to expose pests to sun and predators
Nematodes very small round worms that damage roots and pods, decreasing nitrogen fixing ability	Yellowing foliage, plants wilt at midday; drying and death of plants	**Prevention** – Apply appropriate pesticide such as carbofuran granules at planting: follow manufacturer's instructions for safety and efficacy Rotate crops, 2 years between groundnut crops
Thrips small yellow, green or black flying insects that feed on flowers and leaves	Dwarfing and distortion of leaves with yellow/green patches	**Control** – Spray with appropriate insecticide e.g. dimethoate: follow manufacturer's instructions for safety and efficacy **Prevention** – Grow resistant varieties if available

Nutrient deficiency symptoms

Some soils might be deficient in nitrogen (N) and potassium (K). Although groundnut is a legume and can fix nitrogen from the air, N-deficient soils may need some N fertilizer to be applied at land preparation/planting.

To supply N, P and K, one option would be to apply: 100 kg NPK 15-15-15, plus 100 kg SSP plus 50 kg muriate of potash (MOP, a source of K) by broadcasting at land preparation before planting. This is equivalent to 10 g NPK, 10 g SSP and 5 g MOP per square metre.

Table 4 shows the signs of deficiencies for the major nutrients of groundnut and suggests some measures to address these problems.

Table 4: Nutrient deficiency signs and measures to address in groundnut

Nutrient	Deficiency signs	Measures to address deficiency
Nitrogen (N)	Light green young leaves If severe, whole leaf becomes pale yellow Stems thin and long, turn red later Older leaves fall Growth stunted Poor pod and kernel development	Apply NPK fertilizer at land preparation to prevent reoccurrence in next season
Phosphorus (P)	Stunted Small leaves Bluish green leaves turning to deep green Older leaves orange-yellow, turning brown and falling	Apply SSP or TSP at land preparation
Calcium (Ca)	Local pitted areas on lower leaves, developing into dark brown spots If severe, leaf tips and end buds die Roots short, stubby and discoloured Young leaves wilt Aborted, shrivelled pods and seeds Pods with no seeds (pops)	Apply gypsum at early flowering stage
Potassium (K)	Yellowing at edge of leaves; sometimes also between the veins Older leaves yellow around edge, scorching, leaf edges curl up and leaf dries up	Apply NPK fertilizer and/or MOP at land preparation

7. Groundnut production economics

Many of the changes required for improved groundnut 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 groundnut 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 groundnut without application of fertilizer would now like to apply 2 bags of TSP per hectare at planting, the increase in yield required to recover additional cost of fertilizes (if price of TSP is USD 50 per 50 kg bag and price of groundnut is USD 1400 per tonne) can be calculated as:

$$\text{Minimum increase in yield required} \left(\frac{\text{t}}{\text{ha}}\right) = \frac{\text{Cost of TSP}}{\text{Price of groundnut}}$$

$$= \frac{2\times50}{1400} = 0.07 \text{ t/ha (70 kg per hectare)}$$

So, in this case, an additional 70 kg per hectare of groundnut would need to be produced to pay for the additional cost of 2 bags of TSP.

The extra costs incurred with use of a new technology can be compared with the additional benefits obtained by use of the technology (cost/benefit analysis).

For example, if in the above example the previous yield was 1 tonnes per hectare but with the application of TSP this 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:

$$\text{VCR} = \frac{\text{(Yield with fertilizer-Yield without fertilizer) x Price of groundnut}}{\text{Amount of fertilizer applied x Price of fertilizer}} = (1.5\text{-}1.0) \times \frac{1400}{(2\times50)} = 7$$

So, in this case the farmer would generate an additional USD 7 (the benefit) for every USD 1 invested in the new fertilizer regime (the cost), which would make this investment very worthwhile.

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

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

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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