Crop Production

FARMER EXTENSION GUIDE

for smallholder farmers in South Sudan

SECOND EDITION

THE REPUBLIC OF SOUTH SUDAN
MINISTRY OF AGRICULTURE AND FOOD SECURITY
FOOD AND NUTRITION FOR ALL

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Foreword

Achieving food security for the people of South Sudan remains a top Government priority. To meet its mandate of ensuring the people of South Sudan produce sufficient food for sustenance and export, the Ministry of Agriculture and Food Security has developed various policies and strategies to guide investments in the sector, in line with national development plans and goals. Some of these policy documents and plans include the National Agriculture and Livestock Extension Policy (NALEP) and the Comprehensive Agriculture Master Plan (CAMP) through which different projects will be designed and implemented.

As a Ministry, we fully recognise the importance of extension services in the enhancement of production and productivity, especially for rural smallholder farmers. However, due to resource constraints, our extension staff and experts are not always able to deliver on their mandate, especially at the local levels. It is with this in mind that we highly appreciate the contribution of donors and development partners operating in South Sudan, as they work to compliment Government efforts to ensure that smallholder farmers have access to current information to ensure they produce not only for their families but also have surplus for sale. This extension guide will therefore go a long way toward achieving this goal.

This Extension Guide is an updated version from the first one, launched in 2016. The publication of this revised guide is the culmination of immense contribution and efforts by different experts and stakeholders, including those from key Ministries, academia and the development sector. The content was also peer-reviewed and validated through an elaborate process which included the participation of an expanded agriculture and livestock technical working group of the Food Security Cluster and government specialists, thus ensuring its relevance. I am assured that this guide, along with the publication on seed production released earlier, are written in language that will be understood by our extension staff in all agricultural zones of the country.

We highly value and appreciate the support and efforts made by our development partners, in particular the support provided by the European Union. I am delighted that this edition and the technical information contained in it will be once again disseminated widely and used across the country.

Hon. Josephine Lagu Yanga
Minister of Agriculture and Food Security
The Republic of South Sudan

Preface

This is the first revision of the Crop Production Guide for Smallholder Farmers and Extension Workers of South Sudan, which was published in 2016.
During the five years of use, extension staff, farmers and development practitioners requested the need to update the information in the guide for the following reasons:

i. to update information contained in it,
ii. to ensure it addresses all agro-ecological zones of the country,
iii. to improve the layout of the booklet and include additional illustrations.

This 2nd edition took all these requests into consideration. It is once again the product of harmonising training and reference materials used by development partners as well as the extension staff of the Ministry of Agriculture and Food Security. The process of harmonizing the materials brought together academia, staff of both state and national Ministries of Agriculture and Food Security, the Ministry of Livestock and Fisheries, national and international non-governmental organizations, and UN agencies (FAO, WFP and UNIDO). Additional information was sourced from materials developed by academic, research and agricultural training institutions around the world especially those in Africa, Asia and the USA.

Specifically, in this revised edition, there is additional information on agronomic practices for eleven selected crops: sorghum, maize, rice, sesame, cowpeas, groundnut, beans, cassava, sweet potatoes, tomatoes, kale, amaranth and eggplant. In each of the sections you will find information on agronomic practices, seed varieties, cropping seasons, land preparation, spacing, pest and disease management, harvesting techniques, utilization and marketing. The European Union funded and facilitated the process through the South Sudan Rural Development (SORUDEV) Programme.

Measurements used

1 hectare	=	2.47105407 acres equivalent to 2.38 feddans
1 feddan	=	4200m^2
1 feddan	=	0.42 hectares, which is equivalent to 1.038 acres
1 malwa	=	3.5 kg
1 mug	=	0.5 kg
1 whawal	=	50 kg
1 kg	=	1000 g
1 tonne	=	100kg
1 hectare	=	10,000m^2

Introduction

South Sudan is located between coordinates 6.8770° N, 31.3070° E, in eastern Africa. The population is about 13 million consisting of different ethnic groups. Out of the total land mass of 644,329 km2, more than half is estimated to be arable. The vast majority of people live in the rural areas. Most of South Sudan has a sub-humid climate.

The rainfall varies across the country, gradually decreasing from south to north, from approximately 1,800 mm to 500 mm per year. Much of the country receives about 750–1,000 mm (30–40 inches) annually. Areas in the western part of the country receive slightly more, about 1,000–1,500 mm (40–60 inches) annually, while some areas in the north eastern and south eastern parts of the country receive less, about 500–750 mm (20–30 inches). The northern areas are dryer and experience more frequent drought, while there is abundant annual precipitation in the south and south-west areas. Served by many tributaries, the White Nile River is the main source of fresh water and is an important source of water for the Sudd Wetland. Along with many other smaller streams and rivers, the Sudd empties into the flood plains which are a major source of fishing and livelihood for riverine communities.

The rainfall pattern along the agro-ecological zones influences the crops grown and the operation timings of different agronomic practices undertaken by farmers. The three main vegetation belts run in succession from northwest to southeast, coinciding with rainfall patterns. They are low-rainfall savanna (grassland) and high-rainfall savanna, both with inland floodplains, and mountain vegetation regions. Low-rainfall savannas consist of grasses and thorny trees.

Figure 1: Map of South Sudan

The high-rainfall savannas of the south-central part of the country are lusher, with rich grasses along the Nile that support many cattle.The intermittent woodlands dotting this belt gradually merge southward with the true rainforest that is now found only in remnants in the southernmost portions of the country.

Cropping in most parts of South Sudan takes place twice, depending on the arrival of the rains. The main season for sowing cereal crops begins in June at the onset of the rains. From October through February, dry season farming occurs mostly for vegetables around water bodies using small irrigation systems, tools such as watering cans and in some cases the treadle pump. The bimodal areas cover much of

Greater Equatoria (Western, Central and Eastern Equatoria), while the unimodal areas characterize the rest of the country. This results in a range of growing seasons from 280-300 days in the southern parts of South Sudan to 130-150 days per annum in the northern parts.

The common farming system is split in two broad categories: (1) pastoralist and (2) agro-pastoralist. Pastoralist communities refer to the populations whose main livelihood activities are based on rearing livestock. The agro-pastoralist communities combine the rearing of livestock with the farming of major staple crops for their livelihoods. The country is zoned into seven agro-ecological zones, most of which are conducive for cultivating a variety of crops and which have vegetation that support pastoral activities. The agro-ecological zones are :

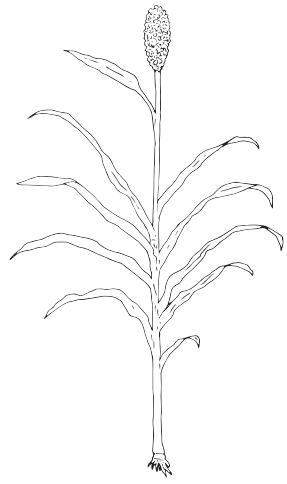
1) Greenbelt (Western Bahr el Ghazal, Western, Central and Eastern Equatoria);
2) Ironstone Plateau (Northern and Western Bahr el Ghazal, Warrap, Lakes and Western, Central and Eastern Equatoria);
3) Hills and Mountains (Central and Eastern Equatoria and Jonglei);
4) Arid/Pastoral (Jonglei and Eastern Equatoria);
5) Nile and Sobat Rivers (Jonglei, Unity and Upper Nile);
6) Western Flood Plains (Northern Bahr el Ghazal, Lakes and Warrap); and
7) Eastern Flood Plains (Jonglei and Upper Nile).

Most farming activities are at the subsistence and small holding level. The average subsistence family cultivates an average of two feddans (about 0.84 ha). They are mostly rain fed, with approximately 78% of households reliant upon crop farming and animal husbandry as their main source of livelihood. The main crops grown include sorghum, maize, groundnuts, cassava, vegetables, pineapples and oil palm in addition to coffee, tea and sugar cane.

Cereal Crops

Guide for Smallholder and Extension Workers

Maize, sorghum, millet and rice are the four most popular cereal crops cultivated in South Sudan. All cereals are members of the grass family Poaceae that are grown for their edible starchy seeds. They are characterised by the presence of a caryopsis, a type of fruit in which the seed wall becomes fused with the ovary to form a husk. Cereal and cereal products are prime carbohydrate food resources for humans and animals. Cereal grains provide a source for energy and nutrients in the form of protein, fat, fibre, minerals and vitamins. Examples of cereals are rice, wheat, maize, barley, oats, sorghum, rye, triticale and millet.



Sorghum Production
(Sorghum bicolor L.)

Background

In South Sudan, Sorghum (Sorghum bicolor L.) is commonly called sorghum, or dura.This gluten free grain belongs to the family Gramineae (Poaceae) and is believed to have originated in North-East Africa on the border between Sudan and Ethiopia, where it was domesticated 5,000-8,000 years ago. Wild sorghum plants still grow in this region. Sorghum is widely cultivated in all 10 states of South Sudan and is the staple food of most communities, which eat the grains and stalks. In most agro-pastoral communities the leaves and grains are also fed to livestock. Sorghum grain contains 11.3% protein, 3.3% fat and 56-57% starch. It is relatively rich in iron, zinc, phosphorus and B-complex vitamins.

Site selection

Sorghum is described as a resilient crop, as it is well adapted to a wide range of agro-ecological zones and is thus an excellent crop for food security. Well-drained soil is preferable, and areas of land that are waterlogged must be avoided. It adapts to brief drought conditions and is also more tolerant of moderate water logging than maize, meaning it can also be grown in areas of high rainfall. Sorghum is also widely grown in temperate regions and at altitudes of up to 2,300m in the tropics where it is well exposed to sunshine.

A temperature of 27°C to 30°C is required for optimum growth and development. The temperature can, however, be as low as 21°C without a dramatic effect on growth and yield.

The crop does well in most soils but thrives best in light- to medium-textured soils. Soils with a clay content between 10% and 30% are optimal for sorghum production. Sorghum can tolerate a soil pH of 5.0 to 8.5; the soil should preferably be well aerated and drained. When selecting a site for cultivation, it is important to choose areas that are safe from animals and theft and which are suited to animal traction (ox ploughing), especially if there is a desire to expand the area under cultivation.

Land preparation

The common practice is to start with felling trees and shrubs to reduce their number and shade, then to draw fire lines along which the land is burnt. However, burning is harmful to soils because it leads to loss of organic matter, kills beneficial soil micro-organisms, and destroys soil structure and nutrients. Therefore, uncontrolled burning for land clearing is discouraged. Tools used for land clearing are axes, machetes (panga), hoes (maloda) and slashers. Land clearing should begin as early as possible, preferably shortly after the harvest.

After land clearing, preparation of the soil should be done as early as possible after the start of the rains. Traditionally, South Sudanese farmers combine preparation with planting (sowing). However, farmers are advised to undertake three separate types of land preparation practice: primary (general clearing and ploughing), and secondary (fine seedbed tilth preparation). The tools commonly used by smallholder farmers for land preparation are hoes, cutlasses and the ox plough, while tractors are used for land preparation by large-scale farmers.

Figure 2: Demonstration of ox drawn wooden plough
(VSF-Germany)

Selection of planting materials

Propagation of sorghum is usually from seeds. In South Sudan, seeds are mostly selected during the harvest. Seed varieties are categorised according to the time it takes them to mature (short-, medium- and long-term sorghum varieties). When selecting seed, they should be wholesome (free of physical damage, pest infestation and diseases), and should be adequately dried (15% moisture content) before being stored in a clean and well-ventilated area. Farmers are encouraged to procure their seeds from reliable suppliers and to use certified seeds where available. Seeds should come from a stock kept in good condition to preserve their viability and to ensure that they germinate.

Varieties of sorghum and their description

Since Sorghum is native to the East African region, there are many varieties of the plant still growing in the wild. Sorghum varieties grown by farmers are classified based on their location and characters.

The classification are broadly into two: (i) the local varieties and (ii) the improved varieties of sorghum.

The common local sorghum varieties and their description are:

1. Short-maturing (45-90 days): Weerabor and Cam (Aweil), Akuoracot (Jonglei), Nyitiin, Matueel, Nyambor, Ayenawuut, Kamtolo, Maniong, Duor, Anyang, Adhukwongwut, Shuluk (Lakes).
2. Medium-maturing (120-140 days): Nyandok, Malualgot (diil), Chaal, Luwaya; mamawan (Warrap).
3. Long-maturing (160-180 days): Kech (yellow) and Mabior (known as Mabor in Lakes).

The commonly grown improved varieties of sorghum and their description are:

1. KARI Mtama 1, 2
2. Gadam el Hamam
3. Sesso I, II, III
4. Wad Ahmad
5. Macia

KARI Mtama

KARI Mtama plant height ranges from 50 to 170 cm tall depending on the altitude. It has one main erect tiller and sometimes has 2-3 straight tillers. The Grain colour is white with a hard endosperm and has no testa. It flowers in 58-65 days and matures in 95-100 days. It has a potential yield of 4,000 kg/ha with an average yield of 2500 kg/ha or 1000 kg/acre. KARI Mtama-1 is highly tolerant to stalk borers and aphids and it recovers from drought very fast. It is highly palatable and sweet making it attractive to birds. In order to minimize the losses due to birds, a cluster of farmers should plant or cultivate the variety to increase the acreage in a location.

Gadam el Hamman

Gadam, is a semi-dwarf sorghum variety with specific market traits, including its white colour, low tannin, and high starch content. It is harvested early, is drought tolerant and is good for kisra and malting. Plant height: 110 – 150 cm. Originates in Sudan.

Seso III

Seso is an open pollinated variety. Maturity is 90-100 days. The grain colour is brown. The plant height is usually 75-100 cm with an erect growth habit. It is tolerant to aphids, smuts, rusts, and leaf blight diseases. It is also drought tolerant, adapted to loam, sandy loams, and sandy soils in short season areas (+/-110 days) with an average 400-750 mm rainfall. Seso also does well in semi-arid areas in East Africa.

Wad Ahmad

Wad Ahmad is also an open pollinated variety. It matures between 90 to 100 days. The grain colour is white. The plant is erect, and the height is between 75-100 cm. It is tolerant to aphids, smuts, rusts, and leaf blight diseases. It is drought tolerant, very well adapted to loam, sandy loams, and sandy soils in short season areas (+/-110 days) with an average 400-750mm rainfall. It is successfully cultivated in semi-arid areas in East Africa and Sudan.

Macia

Macia is an open pollinated (pure line) variety selected from pedigree M91057 (SDS3220). The height could be dwarf to semi-dwarf (1.3- 1.5 m) with a thick stem. It mostly does not tiller, with an average of 1.2 tillers per plant. The maturity range is 115 to 120 days. The grain colour is creamy white with the grain size being medium. A testa (seed coat) is absent making is easily threshable. The tannin content is absent.

It has an excellent milling quality with 80% flour yield and white flour. Macia is drought resistant, adapted to loam, sandy loams, and sandy soils. It is resistant to aphids and common leaf diseases. Its yield potential is 3.0 to 6.0 tonnes/ha. It is a dual-purpose crop, utilizing both the grain and the crop residue for purposes such food in porridge; food in bread as a composite flour (20% sorghum and 80% wheat) and as animal feed for poultry and livestock.

Sowing of sorghum

The broadcasting method is the common sowing practice in a number of communities in South Sudan. As opposed to dibbling or drilling, broadcasting is random and has disregard for inter- and intra-spacing. However, dibbling or row planting is the preferred method because it ensures optimum plant population, higher yields and the development of good quality grains.

When using the drilling or 'dibbling' method, drop seeds directly by hand into holes in the row or seedbed. Since sorghum seeds are small, they are planted or placed at a shallow depth of approximately twice the size of the seed . Sorghum can be intercropped (mixed), most frequently with millet, cowpea, groundnut, sesame (simsim) and maize.

Dibbling

Planting procedure with dibbling. Dibbling is the process in which we place seeds in the holes or pits at equal predetermined distances and depths. This procedure is done by a dibbler, planter or manually.

Advantages of dibbling:

- Fewer seeds are required.
- Germination is rapid and uniform.
- Seedling vigour is good.

Disadvantages of dibbling:

- It is time consuming.
- More labour is required.
- This method is costly.

The advantages of drilling seeds:

- A more uniform depth.
- Some reduction (up to 20%) of seeding rate.
- More uniform emergence.
- Enhances the ability to place a starter fertilizer (a low-nitrogen, high-phosphorus fertilizer) with the seed.

The advantage of broadcasting seeds:

- It permits large acreages to be sown in less time.
- The manual method is cheap.
- It takes less time than other methods.
- This method is suitable only for small seeded and crops where plant to plant distance is small or does not matter.

Disadvantages of broadcasting seeds

- In this method the seed distribution is uneven.
- Some of the seeds are not be covered by soil resulting in poor soil to seed contact
- The planting depth of seeds is uneven.
- The germination of seed is not uniform.
- The crop stand is affected by uneven distribution.

Plant spacing

For sole cropping (Sorghum only on a farm) the recommended spacing when dibbling (this could vary based on ecological zones), generally,it should be 40-45cm between rows and 15-20cm between plants as mono crop.

When intercropped with other crops, sorghum rows can be 60-90cm apart. Plant population per row in a single hectare (ha) is about 3,000 when adequate water and soil fertility are available, giving a total plant population of 100,000 to 150,000 plants per hectare. The seed rate varies from 3kg/ha in very dry areas to 10-15 kg/ha under irrigation. In mixed cropping the spacing should be 60-75cm between rows with other crops planted in between.

Figure 3: Sowing seeds

Planting time

The appropriate planting time for sorghum depends on the variety. There are three categories of varieties based on their duration (long, medium and short). For long-duration crops, it is recommended to plant immediately at the onset of the rains. Due to changing climatic conditions, planting time may vary in different ecological zones in South Sudan. It is now common to start planting in April in the Equatoria region to June in Greater Bahr el Ghazal. Short-term seeds are typically planted in late May , but may vary based on the different ecological zones in South Sudan.

Thinning

When seedlings crowd together they compete for space, nutrients, light, air and moisture that the seedlings need to grow. Removal of excess plants after germination from the field or seedbed is called thinning. It is advisable to thin to two plants per stand within a period of 2-3 weeks after the seeds emerge to reduce competition between plants. Thinning should be done immediately following the first substantial rain. It is best done when the soil is wet to reduce damaging the roots of the plants. The strongest, best grown plants should be retained and the weak ones removed.

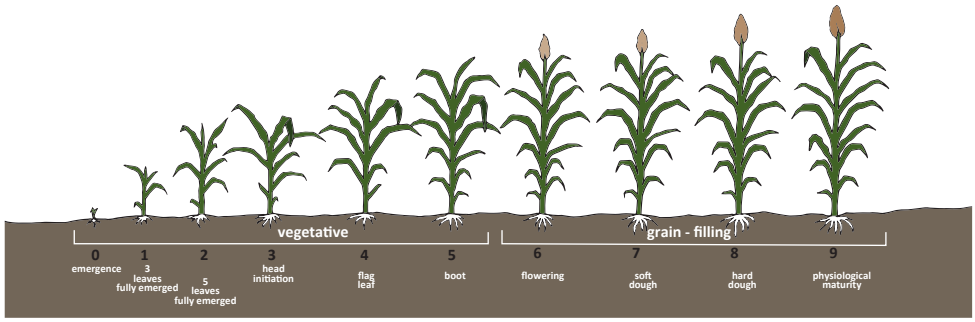


Figure 4: Growth stages of sorghum

Fertilizer requirements

In South Sudan, natural organic manure from cattle is used widely and to various degrees to fertilise sorghum fields. For example, in Northern Bahr el Ghazal (NBG) and Lakes States, farmers use cow dung to improve soil fertility, while in the greater Equatorial region, green manure and goat and poultry droppings are widely used as organic manure. At the national level, the Ministry of Agriculture and Food Security (MAFS) encourages the use of organic manure such as compost, dung, slurry, crop residue and liquid manure (a mixture of animal waste and organic matter used as an agricultural fertilizer).

For optimum production, inorganic fertiliser can also be used, the requirement for which is determined by both soil type and rainfall. A basic dressing of nitrogen, phosphorus, and potassium (NPK) may be required. The crop usually responds well to additional dressings of nitrogen during vegetative growth. A fallowed, loamy soil may not need fertiliser. Rotation with a leguminous crop can provide low-cost fertility build-up. Fertiliser requirements can be up to 60-80 kg/ha of nitrogen (N), 20-45 kg/ha of phosphorus (P) and 35-80 kg/ha of potassium (K) depending on the crop and soil type. Usually, 5 bags (25 kg each) of NPK 15:15:15 should be given to provide this level of nutrients for one hectare.

Weed control


Figure 5: Striga infested farm

In practice, weeding can be done once or twice per growing season. For instance, weeding is done once in Greater Bahr el Ghazal, once in Greater Upper Nile and twice in Equatoria because of the length of rains in each of the ecological zones. Weeding by small holder farmers is normally done using hand hoes (maloda and jembe). However, to best control most common non-parasitic weeds, it is recommended to weed twice (by the third and sixth week of growth).

For noxious and parasitic weed such as Striga hermonthica (see the picture), which can reduce crop yields by as much as 30-50% if not controlled, tolerant and/or resistant varieties of sorghum should be planted. In addition, striga plants should be pulled by hand and burnt whenever they are seen. When crops are cultivated in rows, weeding can be done using oxen. Weeding should be done when crops are in their vegetative and booting stages.

Pest and disease control

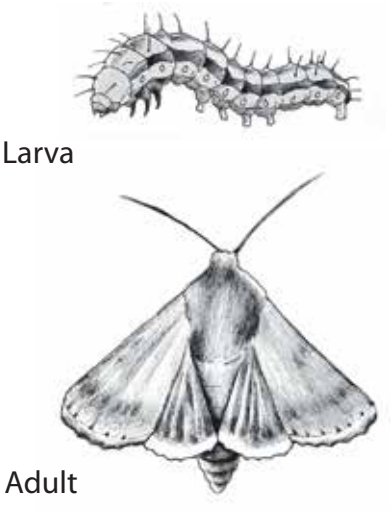
Pests of sorghum

The most common pests that attack sorghum in South Sudan are birds, livestock, wildlife and insects. These pests can attack at varying stages of sorghum growth and development. Common pests that attack during planting and germination include the guinea fowl, hornbill and crow. Pests that attack at the vegetative stage include animals such as goats, sheep, cattle, baboons and monkeys. At the seed formation stage, common pests include the Sudan bird, dove, and weaver bird, while at the storage stage, common pests are weevils, rats, etc.

Additionally there are other pests which are equally common and could even be more destructive on sorghum such as the grasshoppers, fall army worms, chafer grubs and cut worms.

Cutworms (Agrotis spp.)

Figure 6: Cutworm (Agrotis ipsilon) damage to maize seedling.
©W.M. Hantsbarger, Bugwood.org



Several species damage sorghum. They may cut off young plants at or slightly below the soil surface. Some feed on above-ground plant parts, and others feed on the roots. Plants with severed stems die, while plants cut above the main growing point may regrow. Leaf feeding by cutworms causes ragged leaves and feeding on roots may kill young plants or stunt older plants.

Typically, cutworms remain in the soil and feed at night where they cut off seedlings at or near ground level. Heavy infestations usually kill the main stem or destroy the plants. Risk of cutworm damage is greater in reduced tillage systems. To minimize cutworm attacks, control weeds several weeks before planting. Cutworms can be controlled preventively by using soil insecticides at planting or by using foliar sprays at pre-planting, planting, post-planting, or post-emergence. Spray the insecticide in a band over the row.

Stem borers: spotted stem borer (Chilo partellus)

Figure 7: Stem borer

Sorghum is attacked by several species of stem borers. The most important species include the spotted stalk borer (Chilo partellus), the pink stalk borer (Sesamia calamitis) and the maize stalk borer (Buseola fusca). The feeding activity of the caterpillars inside the stems causes stunted plant growth and sterile or poorly developed ear heads. Plants may dry and die if the infestation is severe.

What to do: plant early to ensure maximum pest escape; use resistant varieties; manage habitat; intercrop sorghum with pulses (cowpeas, groundnuts) in alternate rows; and feed stalks to livestock. These interventions may reduce stem borer incidence by 20-30%.

Chafer grubs (Schizonycha spp.)

Phyllophaga spp., a type of scarab beetle (Photo: Dow AgroSciences)

Figure 8: Chafer grubs

Chafer beetles belong to a very large family of insects called the Scarabaeidae, often referred to as the scarab beetles, which number some 20,000 species worldwide. Chafer grubs are the soil-dwelling larvae of chafer beetles. Grubs feed on roots and may kill very young seedlings. Stand loss can occur within 10 days after plants emerge in severely infested fields. They are creamy coloured with an orange head and are about 1.5 cm in length. They have distinctive legs and will be found in the grass roots.

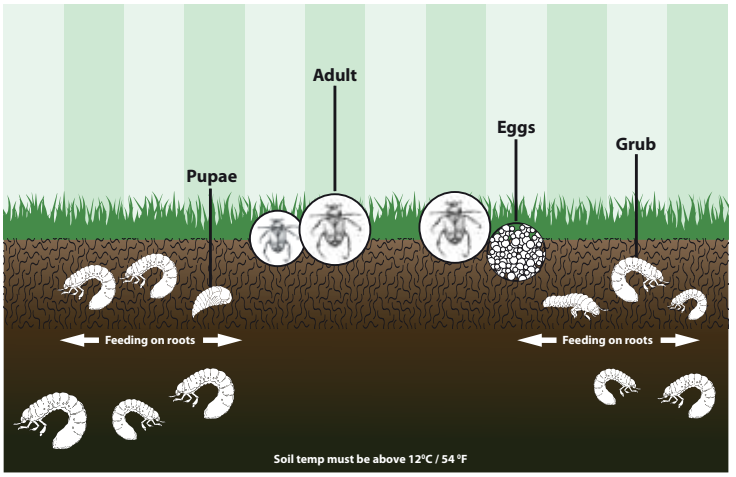


Figure 9: Illustration showing the development of chafer grubs

Chemical control is rarely necessary for chafer grubs. However, one can spray using chlorpyrifos-based insecticides such as Bullet 48EC at 40 ml/20L of water and Bulldock Star at 15 ml/20L of water. For direct control, prune trees around the crop that attract adult beetles. Burn or destroy pruned limbs/stems to kill the adults. Shake trees that harbour adult beetles for collection and destruction by burning. Visible larvae can also be picked and destroyed as well.

Diseases of sorghum

There are a number of notable diseases that affects sorghum at various stages of growth. This includes mould, smut and rust.


Figure 10: Sorghum head affected

Grain mould is a fungal disease that affects medium-maturing varieties of sorghum (and all varieties when stored). Mould can grow in grain stores due to moist air and limited ventilation. The initial symptoms of grain mould are discoloration of grains due to colonization by mould fungi.

Grain discoloration varies from light white, pink or grey, to shiny black depending on the infection and colonization by individual fungal species. Often grains are colonized by multiple fungi. In severe cases, grains turn completely black and grain development is affected resulting in chaffy florets or small grains on the panicle. Management: the selection of very clean and healthy seeds that are free of disease can help to reduce the incidence of mould.

Sorghum head smut (Sphacelotheca reilana)

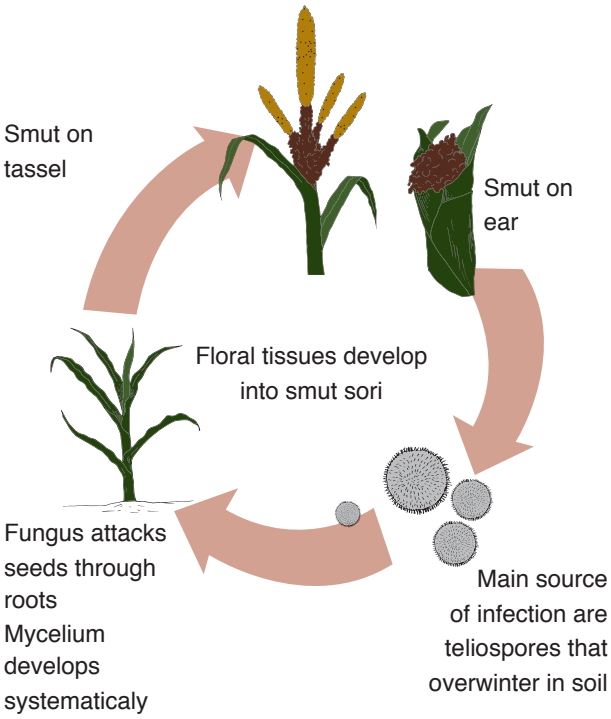


Figure 11: Sorghum head smut

Head smut is a soil-borne fungus Sphacelotheca reilana that initiates infection during pre- and post-emergence growth affecting the panicle head. Head smut is a serious panicle disease which completely destroys the entire head and widely spreads pathogens. It is common on both sorghum and maize crops. Most smutted plants have weakened root systems and commonly exhibit more severe stalk and root rots than smut-free plants. The fungus develops only in actively growing meristematic tissue. The smut spores may also cling to the surface of sorghum seed, introducing the smut fungus into the soil of fields not previously infested.

Symptoms: The entire head is either completely or partially replaced by a large whitish gall. The spores are blown away exposing the dark filaments.

Preventive measures: It is important to use resistant or tolerant varieties. Ensure good field hygiene and plant early. Infected crops should be removed and burnt to avoid spread of the spores. Plan crop rotation every four years.

Management: In the areas where the disease occurs commonly, the best practice is to plant resistant cultivars. Treat seeds with carboxin (Vivatax) at a dose of 2 g/kg of seed. Collect smutted ear heads in cloth bags and destruct them by dipping them in boiling water.

Sorghum rust (Puccinia purpurea)

Figure 12:
Rust on sorghum leaf

Sorghum rust is caused by a fungus. The typical symptoms of sorghum rust are seen in plants 1.5 to 3 months old. Scattered purple, red or tan flecks appear on both sides become completely covered with rust pustules, and the entire plant and field look brown.

Management: Rust control is achieved primarily by cultivating resistant varieties. Infected residues from both crop and weed hosts should be destroyed. Healthy seed should be used for planting. Earlier planted sorghum crops mostly escaped the disease compared to sorghum that was planted late.

Harvesting and post-harvest handling

Harvesting is done manually using sickles and knives once the crop has reached maturity. Grain sorghum plants mature when the moisture in the grain drops to about 30%; however, the seeds are usually too soft for harvesting when moisture content exceeds 25%. The optimum harvest moisture content, about 20%, minimizes harvest losses and drying expense.

Fresh and dry harvesting

Fresh harvesting is desirable, but not very popular due to the labour required and the inadequate drying facilities available. When the harvest is green, the leaves can be fed to cattle, goats and sheep. The stalks are left in the soil so that new shoots may sprout again from the base of the crop. This sprouting is known as ratooning.

Most farmers harvest their crops after they have completely dried out in the field. The moisture content of long-term sorghum ranges from 30-35% during harvest. Following the harvest, sorghum crops are temporarily dried on a rack outside the home for about two months prior to being stored. The primary aim is to reduce the moisture content of the grain to about 15% or below, which helps to protect the grain from attack by storage pests such as weevils and molds. When harvesting sorghum to be used as seed, it is advisable to pick good, well-formed heads which are free of pests and disease.

Yield

Under rain-fed conditions, grain yield can vary from 300 to 2,000 kg/ha depending on care. Grain yield under spate irrigation, with little or no rainfall and a total growing period of 90 days, can range from about 800 kg/ha to 1,300 kg/ha. A good yield under irrigation is 3.5-5 tonnes/ha with a 12-15% moisture content.

Storage

Sorghum grains are stored as either threshed or non-threshed (panicles). Farmers usually thresh seed during preparation for planting. Threshing includes beating the particles to separate the seeds from the shaft, followed by cleaning and sorting.

During long-term storage, grain sorghum quality is affected by several factors including moisture content, temperature and insect infestation, which if not properly controlled can shorten the safe storage period.

Grain with a moisture content of about 13.5% stores better and is often protected from moulds. When in sacks, ensure that grain is properly dried before moving it to the store. The sacks should be stacked properly on a pallet. It is essential to maintain store hygiene at all time. Ensure that the structures for storage are rain proof and rat proof.

Though storage is mostly done using traditional storage facilities such as sacks, tins, gourds and pots, there are also improved granaries (see picture below) sometimes owned by a household or a group of households in South Sudan.

Figure 13: Traditional grain storage stores with rat deterrence

The following are some tips by UAEX that may help sorghum producers to achieve better grain quality for sorghum and other grains during storage:

- Clean the area around the bin. As much as possible, keep the area around the bin clean. This area should be free from tall grass and spilled grain, as this environment attracts birds and rodents. Additionally, seal all areas around the bottom of the bins and keep transfer equipment sealed to prevent rodents from migrating into the system.
- Remove previously stored grain from the bin before filling it with new grain. Thoroughly sweep the bin wall and floor to remove the remaining kernels that may contain insect larvae and mould spores. Apply a recommended insecticide both inside and outside the bin to delay insect population development before placing grain in the bin.
- Adopt sanitation to avoid spoilage. All equipment involving grain transportation and handling should be cleaned and inspected on a regular basis to protect the new crop from any infested remains of old grain from the machinery.

- Clean trash from the grain. It is crucial to place clean sorghum in the storage bin. Set harvesting equipment to produce a minimum of trash in the grain prior to drying. Once dry if grain cleaning is not economically feasible; fill the grain bins by using spreaders. This prevents the trash from concentrating in the central core of the bin.

- Monitor stored grain regularly and aerate regularly. Stored grain should be monitored frequently to observe any identifiable spoilage early so action can be taken to prevent the loss of large sections of stored grain. Temperature sensors can be installed at various locations within the bin to monitor temperature on a continuous basis. These sensors are particularly good for monitoring those areas where handheld sensors cannot reach. Aerate grain often to maintain uniform temperature and moisture levels and prevent large temperature differences between that of the stored grain and the outside air.

- Cool grain sorghum to 40°F if possible. Apply aeration to cool sorghum after being dried with heated air. Aeration will control grain temperature, remove any heating occurring during storage and avoid further damage to grain quality. If aeration cannot control hot spots, move grain to another bin to break up these hot spots.

- Monitor the top 6 to 12 inches of grain sorghum. Monitor temperatures and insect/mould activity. Insert plastic insect traps below the grain surface to monitor insect activity and check them during weekly inspections to control damaging populations. Make sure to secure these traps to a fixed structural member of the bin.

- Cover fans and openings when not in use. This will prevent air, moisture, and potential insect movement. Monitor carefully and fumigate if needed. Check the grain and manually inspect it with your arm or a rod, smelling, feeling and looking for indications of trouble. Evidence of hot spots, warming, insect infestations or other problems that start in the grain mass can soon migrate to the surface. Be particularly sensitive to damp, warm or musty areas.

- Mix the upper and lower portions of grain in the bin using stirring equipment. This speed up the drying process and loosens the grain, so that additional air may be moved up through the grain. Stirring equipment also helps to keep the grain levelled in the bin. Stirring equipment should not be turned on unless the bottom end of the down auger is at least one foot deep in grain. They can run almost continuously after that point when the drying fans are running.

- Do not allow grain to cone or pile to one side of the bin. If coning or sloping occurs, the large particles will migrate to the outside and the small particles and trash will remain at the centre of the cone. This results in a non-uniform amount of air being passed through each portion of the grain. Most of the air will pass up the outside of the bin through the larger and cleaner grain. Allowing a large amount of grain to pile on one side of the bin can also cause structural damage to the bin, which is typically designed to support a uniform load provided by level grain.

- Do not mix dry and wet sorghum. Care should be taken not to mix dry grain (moisture content <15%) with moist grain (moisture content >18%). The wet grain can create hot spots and re-wetting may also occur as air removes moisture from the wet grain and deposits it into the dry grain.

Marketing and utilization

Sorghum grain and flour are sold in all markets across the country usually in small quantities measured in malwa or in kilograms. They are also sold in bags of 100kg and transported across locations and markets. For developed and organized markets such as the one provided by the World Food Programme, the following general requirements are desirable:

Quality Characteristics

- Shall be safe and suitable for human consumption.
- Shall be free from abnormal flavours, odours and living insects.
- Shall be free from filth (impurities of animal origin, including dead insects) in amounts which may represent a hazard to human health.
- Shall be stored under dry, ventilated and hygienic conditions. Only authorized insecticides (e.g. phosphine) may be used for fumigation control. Where needed, fumigation shall be performed by certified operators and as specified in the GAFTA Standard for Fumigation.

Contaminants

- Heavy metals: The commodity shall be free from heavy metals in amounts which may represent a hazard to health.
- Pesticide residues: The commodity shall comply with those maximum residue limits established by the Codex Alimentarius Commission for this commodity.
- Mycotoxins: The commodity shall comply with those maximum mycotoxin limits established by the Codex Alimentarius Commission for this commodity.

Non-genetically modified organism (GMO) status

The commodity shall comply with non-GMO crop standards if required by the recipient country or regulations.

Hygiene

It is recommended that the commodity covered by the provisions of this specification be prepared and handled in accordance with the appropriate sections of the Recommended International Code of Practice - General Principles of Food Hygiene (CAC/RCP 1-1969), and other Codes of Practice recommended by the Codex Alimentarius Commission which are relevant to this commodity.
When tested by appropriate methods of sampling and examination, the commodity shall:

- Be free from micro-organisms in amounts which may represent a hazard to health.
- Be free from parasites which may represent a hazard to health.
- Not contain any substance originating from pathogenic micro-organisms, including fungi, in amounts which may represent a hazard to health.

Packaging

They shall be packed in appropriate packaging which safeguards the hygienic, nutritional, technological, and organoleptic qualities of the commodity.
The packaging shall be made of substances which are safe and suitable for their intended use. They should not impart any toxic substance or undesirable odour or flavour to the commodity.
All the materials in contact with the food product (including inks and additives) shall comply with the last amendments of national regulations in the country of production (if not existing: compliance with EU or FDA legislations requested).
Bags shall be new, uniform, strong and fit for export and multiple handling; these shall be clean, sturdy and strongly sewn or sealed.

Sorghum is the leading staple of the majority of the South Sudanese population. Sorghum is eaten in a variety of forms that vary from region to region. In general, it is consumed as whole grain or processed into flour, from which traditional meals are prepared. As a result, most of the grain produced is consumed by farmers and their families; however, the bartering of grain in exchange for milk between farmers and cattle keepers is also popular. Sorghum is sold in all local markets as grain and flour.
There are four main sorghum-based foods:

- Flat bread, mostly unleavened and prepared from fermented or unfermented dough. The flat bread is called kisra and the dough asida in South Sudan.
- Thin or thick fermented or unfermented porridge, commonly consumed.
- Boiled products similar to those prepared from maize grits or rice;
- Preparations deep-fried in oil.

The grain is also used for malt or as an adjunct in the production of two types of beer: clear beer and opaque beer, a traditional, low-alcohol African beer that contains fine suspended particles. Sorghum is traditionally a major ingredient in home-brewed beer, which has a growing demand leading to a commercial industry in some countries.

Maize Production
(Zea mays)

Background

Maize (Zea mays) is the most widely cultivated cereal crop in the world after rice and wheat. It also has increasing global demand for stock feed. It is an important source of carbohydrates and is one of the most important cereals used for human and animal consumption. It is also grown for grain and fodder. Maize is a major source of food for many people in sub-Saharan Africa where the two largest producers are Nigeria and South Africa. The crop is grown in climates ranging from temperate to tropical during the months when the mean daily temperatures are above 15°C. Maize requires between 500-800 mm of water depending on climatic conditions. Generally, the growth phases of the maize crop depend on the variety being cultivated. The period of growth from germination to maturity ranges from 60-120 days.

Land selection

Maize can be grown in a wide range of soil types, but performs best in well-drained, aerated, deep, warm loam and silt loam soils that contains adequate organic matter and are well supplied with available nutrients. Maize usually grows well in a pH range of 5.5 to 7.8. Outside this range, availability of nutrients to maize plants can be strongly affected, causing a reduction in plant growth, but a moderately acidic environment of pH 6.0-7.0 is optimal.

Land preparation

Land clearance starts with the removal of any vegetation (trees, shrubs, and stumps) that may block sunlight, as maize does not tolerate shade. Land preparation is followed by tillage (ploughing and harrowing) of the soil to make it favourable for crop growth. In South Sudan, the following are the common tools used for land preparation:

- Hoes and slashers: These are mainly used by smallholder farmers. The method is slow and labour-intensive but reliable.

- Animal traction: This uses animals such as oxen and donkeys to plough land. This method enables the farmer to open more land and plant more maize than the use of hoes.

- Tractors: These are mainly used by large- and medium- scale farmers. Due to high purchasing prices, shortages of spare parts and expensive fuel, most smallholder farmers cannot afford to hire tractors.

Seed selection and varieties

Seed selection can have a significant impact on the yield and quality of the crop. Seed in South Sudan is most commonly sourced from farmers' own stock, purchased on the local market, given by family members or supplied by non-governmental organisations (NGOs) or UN agencies. When seed is selected from farmers' own stock, it is important to select seeds from healthy plants that are free of pests, diseases and weeds. White and yellow varieties are preferred by most people depending on the region. Local varieties of maize are the most common, with the Kantumi variety being popular. It is also common to source seeds from either Kenya or Uganda.

Seed can be either open-pollinated or hybrid. The following are seeds released by the national Ministry of Agriculture and Food Security:

- Recommended open-pollinated variety seeds includes: M45, KDV4, Longe 4 and Longe 5
- Recommended hybrid seeds: KH500-44A, KH 500-22A, Longe 6H, Longe 10H, Greengold (SC0923), Maxim (SC719)

The Longe varieties developed in Uganda are particularly well-suited to the Equatorial agro-ecological zone.

Table 1: Maize varieties and attributes

Category	Variety	Potential Yield (MT ha-1)	Physiological maturity	Desired attributes	Suitable production areas
Open Pollinated varieties (OPV)	Longe 1	3 – 3.5	120 days	Has some tolerance forfoliar diseases including MSV, GLS and NLB	All areas except highlands
	Longe 4	2 – 3	100 – 105 days	Early maturing, drought tolerant, resistant to MSV, GLS and NLB	All areas except highlands
	Longe 5 (Nnalongo)	3 – 4	100 – 115 days	Quality protein maize, very good tolerance to foliar diseases	All areas except highlands
Hybrid Varieties	Longe 2H	6 – 7	130 – 140 days	Quality protein maize	All areas except highlands and arid areas like Karamoja region
	Longe 5H (Nnalongo)	5 – 5	110 – 120 days	Quality protein maize, very good tolerance to foliar diseases	All areas except highlands
	Longe 6H	9 – 10	100 – 120 days	Quality protein maize, very good tolerance to foliar diseases	
	Longe 7H	6 – 7	100 – 120 days		
	Longe 9H	6 – 7			
	Longe 10H	6 – 8			
	Kayongo (Longe 7H-IR)			Snow white grain, good yields, highresistance to MSV, GLS, NLB and Turcicum treated with striga-away for effective control of striga weed (witch weed)	

Seed quality

If farmers choose to grow an open-pollinated maize variety, the seed may be kept for sowing the next season with no adverse effects on yield or quality. However, if the farmer is growing hybrid seed, such as long 6H, seed must not be harvested and kept for sowing the next season. If second-generation hybrid seed is sown, it will yield at least 20% less than first generation commercial seed. Colour will also be variable in second-generation seed. If this second-generation seed is kept, the decline in yield potential will continue in subsequent years. Attributes for good quality maize seeds are as follows:

- high germination rate (>85%);
- well-dried to 13% moisture content;
- purity >98%, ensuring all seeds are of the same variety;
- clean, not mixed with foreign matter like stones or dirt, or other seeds;
- not damaged, broken, shrivelled, mouldy, or insect damaged;
- not rotten, discoloured or faded;
- Uniform, with all non-conformity not exceeding 2%.

Planting

Most maize in South Sudan is rain fed and planting is done in April-May (first planting) with the second season in July-September, especially in the Equatorial region. In Greater Bahr-el-Ghazal planting is usually done at the onset of the rains. In the Equatorial region where they have two seasons, the second planting is mostly done in September at the same time as groundnuts, sesame and rice. The recommended planting depth is 2-3 cm for moist soils and 5-10 cm for dry planting.

Plant spacing

The recommended spacing of maize is 30 cm between plants and 60-75 cm between rows. In the Equatorial states where varieties with heavy vegetation are grown, 30 x 75 cm is recommended. The seed rate is 20-25 kg/ha. For approved seeds of optimum health, one seed per hole is recommended; if the farmer is unsure of quality, then planting two seeds per hole is highly recommended.

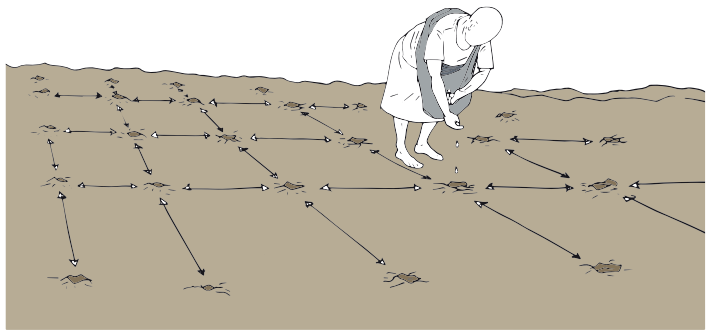


Figure 14: Plant spacing

Plant population ranges from 20,000 to 30,000 plants per ha for large, late-maturing varieties and from 50,000 to 80,000 for small, early maturing varieties such as Kantumi. When grown for forage (green maize), the plant population is 50% higher.

Planting methods

Hand planting is the most commonly used method in South Sudan. It is labour-intensive but can produce excellent results if done properly (including a uniform plant stand). Mechanical planting involves the use of planters pulled by either tractors or animals. This type of planting has the advantage of being quick and can also give excellent results if it is well supervised.

Growth stages of maize

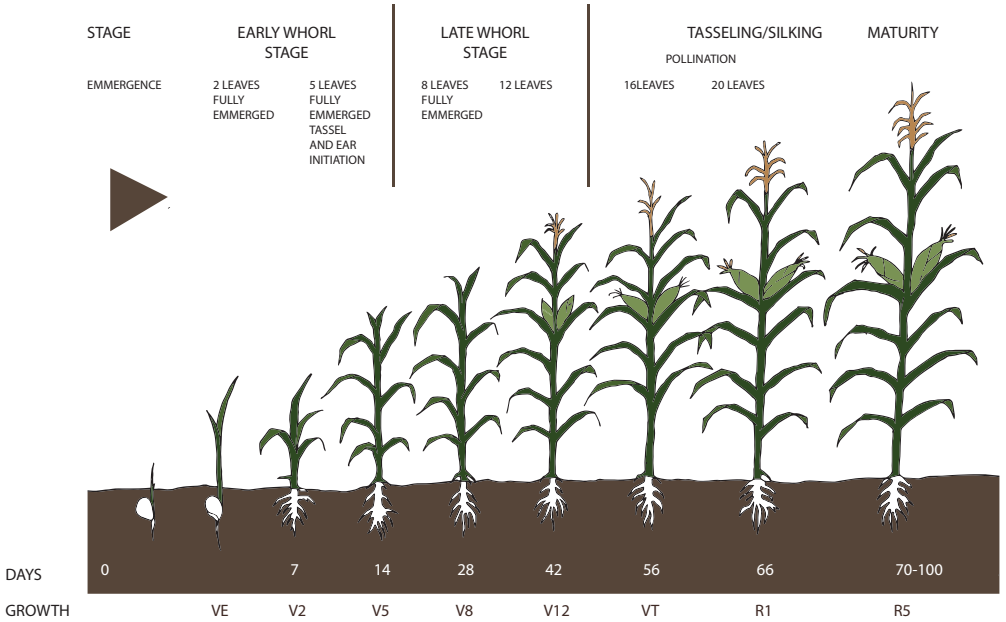


Figure 15: Growth stages of maize

Fertilizer requirements

In maize, the recommended fertilization rate is 200 kg of NPK (nitrogen, phosphorous, potassium) of 15:15:15 per hectare, but note that this recommendation may vary depending on location and the agro-ecological zone of the country.

Nutrition is extremely important when growing a maize crop as it has a high demand for nutrients, which the soil cannot always provide. Achieving high maize yields requires high levels of soil fertility. Fertiliser application for maize is often required to correct deficiencies of essential nutrients and to replace nutrients removed in harvested crop products. Fertiliser can be applied to provide the main essential nutrients, including N, P and K. Micronutrients can also be applied in the same way to supply nutrients needed in smaller quantities.

It is important to carry out a soil test to determine the level of soil fertility. In the absence of such a test, a blanket recommendation of 60:30:30 NPK kg/ha for Alfisols and of 40:20:0 NPK kg/ha for Vertisols should be adopted. The fertility demands of maize are substantial and for high-producing varieties, up to 200 kg/ha N, 50-80 kg/ha P and 60-100 kg/ha K may be required. In general, the crop can be grown continuously if soil fertility is maintained. Where rainfall is low, the crop should be irrigated.

Other management practices include crop rotation, weed control, pest and disease management, and harvest and post-harvest handling (drying and storage).

Weed control

Weeds are plants that grow where they are not required. They compete for water, nutrients, space and light with the main crop. They can also serve as hosts for pests and diseases. Some weeds are parasitic and poisonous to maize, e.g. striga. Maize plants compete poorly with weeds, particularly in their early stage (their first 3 weeks) when they are very sensitive to weed competition.

Weeds can be controlled by cultural methods including crop rotation, proper spacing, timely planting, hoeing, hand-pulling, improved soil fertility and the use of good seeds that are free of weeds. Mechanical methods involve the use of farm tools and implements such as hoes, cultivators and pangas, while chemical control makes use of herbicides (weed-killing chemicals). The use of herbicides is not popular among South Sudanese farmers. Caution must be taken when applying herbicides.

The following chemical application regimes are recommended:

- Application of a triazine herbicide at 0.25 kg/ha at the time of pre-emergence (3-5 days after sowing) using a knapsack sprayer fitted with a flat fan nozzle and 500 litres of water/ha. This should be followed by hand weeding 30-35 days after sowing.
- Application of a triazine herbicide at 0.25 kg/ha at the time of pre-emergence (3-5 days after sowing) followed by 2, 4-D at 1 kg/ha 20-25 days after sowing, using a backpack, knapsack or rocker sprayer fitted with a flat fan nozzle and 500 litres of water/ha.

Note that herbicides should only be applied when there is sufficient moisture in the soil, and users must wear protective apparel for safety. The soil should not be disturbed following herbicide application.

Pest and disease control

Maize is mostly affected by pests such as stalk borers, maize aphids, termites, maize seed maggots, maize seed beetles, cutworms and the fall army worm. It can also be destroyed by birds, rodents and other animals (both wild and domestic). The common diseases of maize in South Sudan are maize smut, maize streak, maize rust, stalk rot, maize mosaic and downy mildew.

Damage to corn caused by the common stalk borer is characterized by wilting and/or dying of the upper leaves or by ragged irregular holes chewed in the newly unrolled leaves. The "dead heart" is caused by the insect boring into the stalk at the soil level and tunnelling upward. Stem borers can be controlled effectively by ensuring good field hygiene, regular weeding and the destruction of host crops.

Figure 16: Stalk borer

Corn Smut

Corn smut is caused by a fungus, Ustilago maydis or Ustilago zeae. Its spores (the microscopic biological particles through which fungi are reproduced) can survive for several years in the soil and in maize debris. Corn smut is an abnormal growth that can appear anywhere on the above-ground parts of the maize plant – leaves, stalk, husks, tassels, ears and corn kernels – and any time during the growing season. All young plant parts are especially susceptible.

Prevention and control: Selecting resistant maize seed varieties is important to prevent smut disease. Smut has been found to grow rapidly where the spores may remain viable for 5-7 years in soil that lacks adequate levels of nutrients; therefore, applying the recommended quantities of nutrients through organic or inorganic fertilizers is critical in managing corn smut. In backyard gardens, collecting and destroying galls before the dark fungal spores are released is suggested. This will limit the number of available fungal spores and help break the disease cycle.

Figure 16:
Smut disease on fresh maize cobs
Photo Credit: Belize Ag report

Anthracnose leaf blight

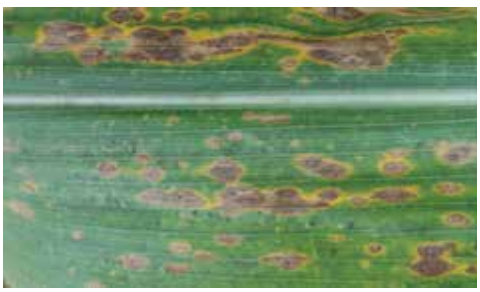


Figure 16: Anthracnose leaf blight

Anthracnose leaf blight in maize is caused by the fungus Colletotrichum graminicola. The first symptoms of anthracnose leaf blight are water-soaked, oval lesions with tan centres and reddish-brown borders.

Symptoms begin on lower leaves early in the growing season, then develop on the upper leaves late in the season.

Prevention of anthracnose leaf blight:

- Buy and plant resistant or tolerant seed varieties. Plant the maize seeds in a well-drained soil rich in compost, avoiding waterlogged areas.
- Keep ripening fruits from touching the soil especially if your maize plant lodges.
- Keep your farm clean from weeds and rotate your plants every 2 to 3 years.

Aflatoxin in maize

Aflatoxins are poisonous carcinogens and mutagens that are produced by certain moulds (Aspergillus flavus and Aspergillus parasiticus) which grow in soil, decaying vegetation, hay, and grains.

Figure 19: Aflatoxin on maize kernels and cobs

The crops most known to contain aflatoxins include maize, peanuts, cottonseed, and tree nuts. Exposure to aflatoxin is known to cause both chronic and acute hepatocellular injury. Acute exposure to aflatoxin poisoning could result in liver failure and death in up to 40% of cases.

Control: As a mould, aflatoxin flourishes in an environment high in moisture and humidity. Many moulds prefer warmth and grow faster in warm conditions. As a fungus, they do not need light to grow so they continue to grow in dark areas. Inadequate harvesting and storage techniques are among the conditions that encourage the growth of aflatoxin-producing fungi.

Therefore, allow maize to first field dried on the stalk for one to two weeks before harvesting to reduce the moisture content significantly. Shell the maize as quickly as possible (best within 24 to 48 hours of harvest) and continue to dry it to reduce the moisture content to 15% maximum. Maize dried uniformly to 14% moisture content can be safely stored for a minimum of two months with no increase in aflatoxin content. Stacking all sacks in the store on pallets is compulsory. Consider the use of double-lined hermetically sealed bags.

Maize Rust

Maize rust (Puccinaea polysora) is caused by a fungus that is transmitted by air and deposited on the leaves.

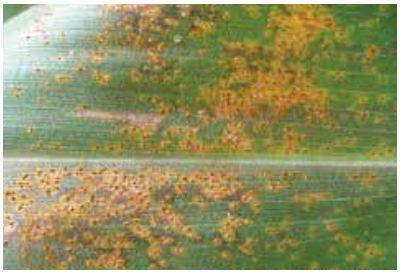


Figure 20: Rust on maize leaves

This disease has been found to be very devastating. Symptoms include numerous red to brown spots on leaves and stems, reducing yield that could lead to sudden death of crops. Grains may turn black.

Planting resistant seed varieties along with crop rotation have been found to be effective.

Methods of managing pests and diseases of maize

Improve plant health by use of recommended agronomic practices, such as appropriate plant spacing, soil management and crop nutrition through the use of organic or inorganic fertilizer or intercropping with nitrogen-fixing legumes. This helps to boost plant vigour to better withstand pest attack or escape pest damage.

Generally, cultural methods include crop rotation, proper weeding, optimum spacing, fencing, removal of infected crops and field hygiene. Mechanical methods include scaring the insects away, trapping, picking and crushing them or destroying their habitats. Biological control methods include the use of pest- and disease-resistant varieties of maize, while chemical control uses various chemicals to control both pests and diseases.

Harvesting

Maize is usually harvested by hand on the cob by smallholders. Maize that is to be eaten green is ready for harvest when the grain hardens or when the silky flowering at the top of the maize cob turns black. At full maturity the crop has a moisture content of about 30%, but for optimum storage, moisture content should be reduced to 14-15% by drying the cobs in the sun.

The average maize yield is 0.8 to 1.26 tonnes per hectare in most of South Sudan. However, in rain-fed conditions, maize yields average 2 to 3 tonnes/ha while under irrigation a good commercial grain yield is 6 to 9 tonnes/ha (10-13% moisture content).

Drying

Immediately after harvest, maize cobs should be properly dried in the sun before being shelled. If the grains are not properly dried, they will attract insect pests and mildew. A practical method of checking the moisture level of the grain is to drop a handful of grains and half a handful of salt into a dry soda bottle. Shake the bottle for 2 or 3 minutes and allow the grains to settle. If the salt sticks to the walls of the bottle, this means the grains of maize still contain moisture. These grains should be dried again and tested repeatedly (until no salt sticks to the bottle) before they may be stored. Another means of testing the dryness of the grains is to bite them using your teeth.

Threshing/shelling

This is done by hand by small-scale farmers, while medium- and large-scale farmers use threshers. The grains should be cleaned by winnowing, then collected and stored appropriately.

For proper storage, maize must be stored under dry, ventilated and hygienic conditions.

Marketing and utilization

Mature maize cobs are sold as fresh and dried. Dry maize kernels are milled and sold by traders. Milled maize flour is sold in most markets in South Sudan and consumed by many households particularly in the Equatoria States. It is common to see small milling machines and their operators in major villages and towns across the country. There is milled maize flour in shops and supermarkets packed by major trading companies in Uganda and Kenya. Generally, at a household level, milled maize is consumed as kisera (fermented fluffy flatbread), maize flour is prepared with hot water and called ugali. Across the country, the dough is also deep fried and made into a popular breakfast snack called mandazi. Mandazi making is a business popular among women.

The World Food Programme is a major buyer of maize in South Sudan. To attract better pricing and acceptance, farmers are encouraged to note and be conscious of the following:

- Broken grains are all pieces of grains which, after elimination of all the other components go through a 4.5 mm round-hole sieve.
- Defective grains include discoloured, germinated, immature/shrivelled, mouldy, pest damaged, rotten, diseased and stained grains, or otherwise materially damaged, which specifically do not include broken grains.
- Discoloured grains are all grains materially discoloured by excessive heat, including that caused by excessive respiration (heat damage) and dried damaged grains. Grains may appear darkened, wrinkled, blistered, puffed or swollen, often with discoloured, damaged germs. The seed coat may be peeling or may have peeled off completely, giving grains a checked appearance.

- Germinated grains are those grains showing visible signs of sprouting, such as cracked seed coats through which a sprout has emerged or is just beginning to emerge.
- Immature or shrivelled grains are all grains which are underdeveloped, thin and papery in appearance.
- Mouldy grains are maize kernels with visible mycelial growth on its tip or surface.
- Pest damage grains are all the grains eaten by insects or rodents.
- Rotten and diseased grains are grains that are discoloured, swollen, soft and spongy as a result of decomposition by fungi, bacteria or other causes.
- Stained grains are all kernels of grain whose natural colour has been altered by external factors. This includes ground or weather-damaged grains which may have darks stains or discolorations with a rough external appearance.

Toxic or noxious seeds

Maize shall be free from the following toxic or noxious seeds in amounts which may represent a hazard to human health:

- Crotolaria (Crotalaria spp.),
- Corn cockle (Agrostemma githago L.),
- Castor bean (Ricinus communis L.),
- Jimson weed (Datura spp.),
- Other seeds that are commonly recognized as harmful to health.

Contaminants

Heavy metals: Maize shall be free from heavy metals in amounts which may represent a hazard to health.

Pesticide residues: Maize shall comply with those maximum residue limits established by the Codex Alimentarius Commission for this commodity.

Mycotoxins: Maize shall comply with those maximum mycotoxin limits established by the Codex Alimentarius Commission for this commodity. Particularly, Total Aflatoxins (B1+B2+G1+G2) shall not exceed 20ppb.

Hygiene

To the extent possible in good manufacturing practice, the product shall be free from objectionable matter. When tested by appropriate methods of sampling and examination, the product:

- shall be free from micro-organisms in amounts which may represent a hazard to health;
- shall be free from parasites which may represent a hazard to health; and
- shall not contain any substance originating from micro-organisms in amounts which may represent a hazard to health.

Common pests of cereal crops

Grasshoppers (family Acrididae)

Figure 21: Grasshopper

Nymphs and adults of several species of grasshopper may chew holes in leaves causing a ragged appearance in sorghum. Grasshoppers can build up in field border areas and move into sorghum fields; consequently, damage often is concentrated along field margins. Grasshopper populations usually are greater in dry years than wet years.

Consider an insecticide treatment when eight nymphs per square yard are present, and damage is evident. Sometimes only a border treatment of the first 50-100 feet may be needed if grasshoppers are concentrated in the field margin.

Fall army worm (Spodoptera frugiperda)

The fall army worm (FAW) is a highly destructive pest to cereals and other important cultivated plants. Unlike army worm, fall army worm feeds during the day and night, but is usually most active in the morning or late afternoon. The larva feeds in large numbers on the leaves, stems and reproductive parts of many crops including sorghum.

Figure 22: Fall army worm on leaves

The symptoms of fall army worm on maize and sorghum includes the following:

- Small holes and "window pane" feeding in the leaves emerging from the whorl are common.
- Larger larvae are usually found deep in the whorl often below a "plug" of yellowish brown frass.
- Larvae will also move to the ear as plants begin to tassel and young ears become available. The ear may be partly or totally destroyed.
- At the seedling stage, different sizes of papery windows are seen on the infested maize plant leaves.
- Ragged-edged oblong to round hollows are seen on the leaves which may be infected by the 3rd instar larvae.
- When the infestation is greater, the leaves become loose and seem like may detach from the plants.
- At a severe stage, extensive defoliation of the plants is seen and the faecal matter of the fall armyworm insect pest can also be seen. It may be due to the voracious feeding of the larval instars.
- Finally, there is no growth and development of the crop plants, with no cob or tassel formation.

For the management of fall army worm the following is recommended:

- Hand pick and destroy egg masses and larvae or collect and drop larvae in hot water. Killing one caterpillar prevents immediate crop damage and the appearance of more than 1,500-2,000 new caterpillars within less than four weeks. Weekly or once in every three days, farm scouting should be done, and the insects manually collected and destroyed.
- Treatments must be applied before larvae burrow deep into the whorl or enter the ears of more mature plants.
- Use good quality seeds that can increase plant vigour and potentially reduce damage.
- Eliminate grassy weeds in maize fields and nearby because they become hosts for the pest.
- Plant at the recommended time. Do not delay planting. Take advantage of planting with the first effective rains, as FAW populations build up later in the crop season.
- Avoid late planting and staggered planting; plant all maize fields at the same time at the onset of sufficient rains.
- Put a handful of sand (mixed with lime or ash), sawdust, soil, soap solutions or grit in the whorl of attacked plants to kill bigger caterpillars.
- Remove and destroy volunteer plants and infested crop residues.
- Select single-cross fall armyworm (FAW) resistant maize cultivars which are under research and development.

• Deep ploughing helps in destroying the FAW eggs in the soil or plant debris of the previous crop.

• Grow napier grass in the borders of the maize field that acts as a FAW trap crop in the maize fields.

• Install FAW pheromone traps @ 5 to 7 per acre in maize fields.

• Establish bird perches @ 10 to 12 per acre as soon as possible after sowing.

• Ensure infested plant materials are not moved to areas where the pest has not been reported.

• Use plant extracts, such as neem products (dusts made from leaves and bark, extracts from whole fruits, seeds, or seed kernels, and oil expressed from the seed kernel). Neem is a feeding deterrent, a growth regulator and a repellent.

Desert locust (Schistocerca gregaria)

The desert locust poses a big threat to maize, sorghum and a host of other crops in South Sudan and the East African region.

Figure 23: Desert locust

Infestation by the common African locust on farms in South Sudan is not new, and farmers are generally aware of when they will arrive and their management. This is not the case with the desert locust. It is new and unknown, and they travel with such speed that they completely swarm farms and destroy crops.

Generally, Locusts are insects that are related closely to grasshoppers. All species of locust undergo three main life stages: (i) egg, (ii) nymph and (iii) adult.

Egg: Eggs are laid in pods in moist sandy soil at a depth of 10-15 cm at an interval of 7-10 days. Gregarious females usually lay 2-3 egg pods having an average of 60-80 eggs/pod.

The invasion of farms by the desert locust took global and regional stakeholders by surprise. FAO, the UN agency for agriculture, leads the awareness campaigns in the country, combats the spread of locusts and helps to mitigate the potential threat they pose to smallholder farmers in South Sudan. The following facts about desert locust will help in managing these pests:

Figure 24: Desert locusts

• An adult desert locust can consume roughly its own weight in fresh food per day – that is about two grams every day. A swarm covering 1 km² can contain between 40-80 million locusts and can consume 80-160 tons of fresh food per day.

• Desert locusts live for three months. Eggs hatch after two weeks, hoppers fledge and become adults after six weeks, and adults take at least one month to mature and lay eggs.

• There can be an exponential increase in locust numbers with every new generation of breeding. After three months their numbers increase 20 times; after six months the increase is 400 times; and after nine months it is 8,000 times.

• Desert locusts prefer semi-arid to arid areas and lay eggs in moist, sandy soil. Rainfall is conducive to desert locust survival and reproduction. They fly downwind during the day for up to 150 kilometres in a day.

• The best time to spray them is early in the morning and late in the afternoon when they are settled on the ground.

Rice Production
(Oryza sativa L.)

Background

Rice (Oryza sativa L.) belongs to the family of cereal grasses along with wheat, corn, millet, and numerous others. Rice is one of the most cultivated cereals in the world. Over 90% of the world's rice production is from Asia, with China, India, Indonesia, Bangladesh, and Vietnam leading the production. Rice contains mainly carbohydrates, but it is also a good source of vitamins and minerals such as niacin, vitamin D, calcium, iron, thiamine, and riboflavin. Brown rice is more nutritious than the processed white rice.

Figure 25: Rice paddy

Rice is one of the staple cereal foods and cash crops in South Sudan despite not being widely cultivated. While most of the various agro-ecological zones in South Sudan have high rice-growing potential, at present, rice is only widely grown in Aweil (Northern Bahr el Ghazal State) where the most intensive effort is led by the government through the Aweil Rice Scheme. However, some states such as Upper Nile (Renk), Western (Yambio, Nzara) and Central Equatoria (Lanya and Yei) also produce some upland rice. The potential for rice cultivation in Yirol is also high. Beyond the Aweil Rice Scheme, the cultivation of rice by smallholder farmers is very low despite the high potential.

Site selection

Rice is mostly grown in two types of ecosystems: the lowlands and uplands.

Lowland rice requires fertile, clay loamy soil which retains water for long periods to support vegetative growth. For lowland rice cultivation, it is important to select low-lying and swampy areas that stay wet for a period of 1-4 months. For instance, the water used in the Aweil Rice Scheme is from a mixture of rainfall and river water.

The extension agent must be able to recognize and understanding the growth stages of rice to time management practices properly (e.g., transplanting, irrigation, fertilization, weeding and harvesting).

Land preparation

Proper land preparation is necessary for rice seed production to minimise competition with weeds. Land preparation is done earlier (in February or March) through clearing and ploughing using a tractor or hoe.

Seedbeds should be prepared before the onset of the rains in each location. For new land, all stumps and roots should be removed before ploughing, and the land should be ploughed once.

Seedbed preparation starts with the first rains in May and continues throughout June if done together with sowing. Only viable seeds should be selected and sown. In most irrigated swamp farming systems, rice seedlings are first nursed then transplanted into puddled soil. Under lowland rice, land preparation is done by flooding the field to a depth of 10 cm. Poor or untimely land preparation will cause serious problems with weeds. It is recommended that land be tilled immediately after flooding the farm (at least 15 days before transplanting or direct sowing).

Seed rice varieties for South Sudan are:

Various seed varieties are grown in South Sudan. The Aweil Rice Scheme has more than 20 varieties, of which two (BG 400-1 and BR 4) have been developed for use at farm level, while the remainder are managed and bulked at the Agronomy Department. The following are the most popular varieties:

- Upland: NERICA 1, NERICA 4, NERICA 10, DKAP-27
- Low land: NERICA L-1, NERICA L-2, Komboka, Wita 9, Supa 1052

Description of popular NERICA varieties:

NERICA varieties (African Rice) are generally early maturing (75-100 days) and are relatively tolerant of major stresses of Africa's harsh growth environment. The growth of NERICA is divided into two phases: vegetative phase and reproductive phase:

1. Vegetative phase: Sowing → Germination/Emergence → Tillering → Panicle differentiation.

2. Reproductive phase: Panicle differentiation → Panicle initiation → Meiosis/ Booting→ Heading/ Flowering → Grain maturation → Harvest.

Variety Name	Optimal altitude range (m above sea level)	Days to maturity	Potential grain yield (Tonnes)	Special attributes
NERICA 1	1000-1600	120	2.0	Resistant to stem rust and yellow rust; tolerant to soil acidity
NERICA 4	1000-1600	120	2.0	Resistant to stem rust and yellow rust; tolerant to soil acidity
NERICA 10	1000-1600	120	2.0	Resistant to stem rust and yellow rust; tolerant to soil acidity
NERICA 6	1000-1600	125	2.0	Tolerant to RYMV, blast, BLB; long & soft but no sticky grains when cooked

Early maturity is much appreciated by farmers, especially women farmers, as it allows them to have food during the 'hunger period' while waiting for the harvest of other crops. Additionally, studies show that some NERICA varieties have on average 25 per cent higher protein than imported Asian varieties.

Selecting rice seed

Only the best seed should be selected for planting for the following reasons:

Good seed results in healthier, heavier, and potentially higher-yielding seedlings.

Good seed results in seedlings which recover quickly from transplanting shock.

Good seed results in rapid root growth, enabling seedlings to draw nutrients from the soil quickly and effectively.

Good seed results in uniform germination and growth of seedlings, making it easier for the farmer to time management practices (e.g., transplanting, irrigation, fertilization, and weeding).

Planting

Rice is planted either by broadcasting the seeds or by first establishing a nursery and subsequently transplanting the seeds. The depth of planting is about 3 cm. Spacing should be 20 x 20 cm depending on the tilling ability of the variety. It is advisable to transplant rice seedlings 3-4 weeks after germination.

On uplands (which are characteristic of Western, Central and Eastern Equatoria States), rice should be sown on very well-prepared land that has been both ploughed and harrowed. Rice is grown in these areas in March/April and in August/September as a relay crop with maize (in this case with a spacing of 45 cm). It can also be grown as a solitary crop. Sowing is done by drilling. In sole cropping the common spacing between stands is 30 cm and thinning is carried out after germination.

Fertiliser application

In most parts of South Sudan (except for Renk), chemical fertilizer is not common. Crops are therefore entirely dependent on the natural fertility of the soil, particularly in lowland conditions. The recommended practice is to test the soils and determine the level of nutrient available in it before applying fertiliser. However, if desired, rice plants do well when they have adequate amounts of NPK (nitrogen, phosphorus, and potassium) fertilizer.

General fertilizer recommendation based on agroecology:

Humid forest: Apply 60 kg N, 30-60 kg P_2O_5 and 30 kg of K_2O per hectare

Savannah: Apply 60-80 kg N, 30-60 kg P_2O_5 and 30 kg K_2O per hectare

Sudan/Sahel (under irrigation): Apply 100-120 kg N, 60 kg P_2O_5 and 60 kg K_2O per hectare

Basal Application of phosphorus and potassium:

Apply P and K within one week before transplanting and work the fertilizer well into the soil.

Top dressing of N fertilizer (e.g. urea):

Apply in three equal doses: deep placement (2-3 cm) at transplanting; broadcast at about mid-tillering (3-5 weeks after transplanting); and just about when cobs begin to form.

Table 2: Fertilizers function

Fertilizer	Application Timing	Recommended quality	Objective of application
NPK (20-10-10)	10-14days after seeding	200kg/ha	To increase the number of tillers
Urea	Panicle initiation stage (60-65days after seeding)	50kg/ha	To increase the number of grains par panicle
Urea	Meiotic stage (70-75days after seeding)	50kg/ha	To increase percentage of filled grains

Weeds and weed control

Weeds are the most common cause of crop loss in rice. In most irrigated swamp farming systems, rice seedlings are nursed and subsequently transplanted into puddled soil. This practice gives the rice a substantial head start on the weeds and competition is initially minimal. However, competition greatly increases as growth progresses. Common weeds can be controlled by early weeding. It is recommended that weeding be done three times per rice production cycle, with the first weeding done within 3 weeks of sowing (or within 1 month if germination is irregular or the rains are delayed).

Common pests and diseases

Rice is generally affected by a host of pests and diseases. Since the resumption of rice production under the South Sudan Aweil Rice Scheme in 2009, livestock (cattle, goats and other domestic animals that live near rice farms) and birds (crested cranes and ducks) are the most common pests of rice. Theft is also common during harvesting. Gall midge disease was noted by the rice scheme following a dry spell of weather.

The common insect pests of rice include:

Figure 25:
African rice gall midge

African rice gall midge: These are insect pests of lowland rice. The larvae attack the growing point of the plant (apex), causing leaf sheath tissue to form a tube-like structure called a “silver shoot gall”. The pests cause damage during rainy season. Elongate-tubular eggs (laid singly) and maggot-like larva feed inside developing buds. When young rice plants are attacked, the larval feeding induces development of light swellings or galls. Leaf sheaths are elongated and called onion leaf or silver shoot. The affected tillers inhibit leaf growth, and the plant fails to produce panicles. With 1% of tillers damaged, a 2% yield loss could result.

Rice mealybug

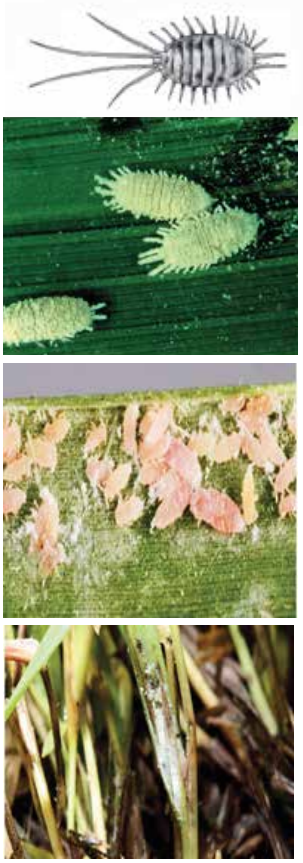


Figure 26:
Rice mealybugs
Photograph by Jo Catindig of IRRI and Lyle Buss

Rice mealybug Brevennia rehi (Lindinger): These are immobile plant-sucking insects. The damage is inflicted in patches on the plants since the nymphs do not move. The rice mealybug is found in upland and rain fed environments. It is not common in irrigated rice. It occurs in great numbers during the rainy season. Mealybugs excrete sticky honeydew on which sooty mildew (a fungus) grows. The nymphs are active until they moult. They first stay under the body of the adult female and later crawl from plant to plant. They are also dispersed by wind. After dispersal, they stay between the leaf sheath and stem to feed and complete their entire larval development. After moulting, the female attaches itself to the plant for life as it grows in size.

Mealybug damage causes wilting, plant stunting and yellowish curled leaves. It does not have a uniform pattern of damage. Stunting is also a damage symptom caused by other insect pests like root grubs and rice root aphids. To confirm the cause of damage, check for presence of the insect – hyaline to yellowish to pinkish eggs, crawlers or nymphs; wingless pink female adults and winged pale yellow males removing plant sap. There is also an appearance of wax covering the eggs, nymphs and adults that stick on the stem or leaf.

Stalk-eyed flies (Diopsis mayae sp.):

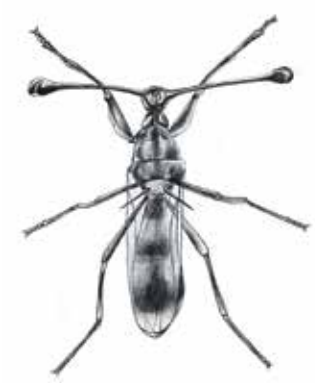


Figure 27: Stalk-eyed flies

The larvae of this insect bore into the rice stem and feed on the plant tissue, causing the death of the plant from the top. To minimize infestation, practice early and synchronized planting, and manage plant spacing.

There are indications that damage increases with an increase in plant density. Apply calcium silicate to strengthen stem tissues. Avoid panicle harvesting (leaving tall stems) and destroy stubbles after harvest. Manage water to ensure that the bases of the stems are always under water. Conserve natural enemies. Spiders are the main natural enemies of these flies. Use resistant cultivars.

Other common pests affecting rice are:

• **White stem borers:** These make holes in the central stem if the tillers are dry, and they cause discoloration of the panicle.

• **Brown plant-hoppers:** These are small, winged insects that feed on rice plants and leave circular patches of yellow or brown. They should be visible when the plant is tapped.

• **Rice weevil:** These are storage pests that bore into the grains and grind the interior soft content of the grain.

• **Termites:** These are white ants that affect fields of upland rice by destroying the plant stem at the base in areas of low moisture content.

• **Rodents:** These are usually rats and can be a major problem. Farmers should set rat traps if available (or get a cat). In all cases farmers should be encouraged to check the rice regularly for signs of spoilage and/or pest infestation.

• **Birds:** Birds are among the most destructive pests of rice. They begin to attack as soon as seeds are sown and at the stages when panicles are formed and about ready for harvest.

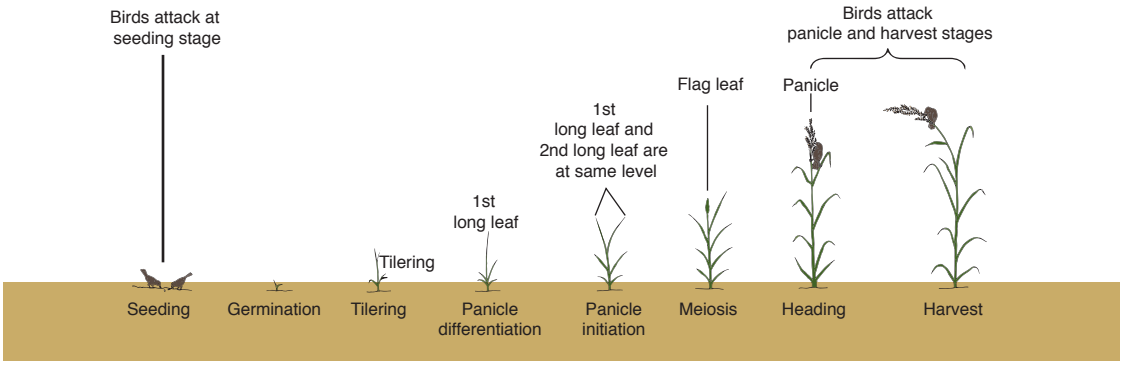


Figure 28: Birds on rice pinacles

Pest control methods

There are 3 main types of methods that can be used to control pests, namely:

1. **Cultural control**, or the placing of crop residues in the field at planting time to divert the pest from the growing crop.
2. **Chemical control**, or the treating of seeds with insecticide at planting time. The decision to use insecticide should be based on a history of termite damage in the field.
3. **Preventative practices**. These include:

a. Flooding. Many species of insect pests begin their resting phase after harvest. Flooding the plots immediately after harvest can thus drown many insects, especially stem borers. Flooding also effectively controls air-breathing insects, such as the mole cricket.

b. Draining. Draining the plots represents an easy, inexpensive and effective means of controlling caseworm. Farmers should be encouraged to drain the affected plot(s) dry for 7-10 days to prevent the spread of caseworm. It is, however, important not to drain the water from one plot and into another, since this will only spread the infestation.

c. Burning. Burning off straw and stubble after the harvest drives away any remaining insects and kills pupating insects in the soil. This also leads to dry conditions that can help control diseases.

d. Ploughing. The removal of paddy stubbles and wild grasses after harvest by ploughing them under will minimise the emergence of the next generation of insect pests by killing any larvae hiding in the soil. It will also eliminate a ratoon crop that serves as a host environment for rice-specific pests.

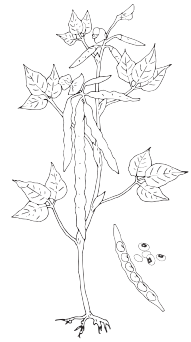
e. Brushing of bunds and peripheries. Many species of insect pests emerge from the plots during certain farming operations (e.g. brushing, burning and ploughing) and seek refuge in the weeds growing on the bunds and along the edges of the swamp. Brushing the bunds and peripheries deprives many insects of a valuable habitat and can significantly reduce their numbers.

Marketing and Utilization

Rice is not a staple for South Sudanese but it is gaining popularity in the country. Imported rice is sold in most rural and urban markets across the states. Rice (processed or rough) is a stable for most of the Asian countries and consumed in both developed and developing nations including countries bordering South Sudan. The global market for rice is huge, stable and rated second only to maize. South Sudan with enormous flood plains can be an active paddy rice producer.

Legumes

Legumes are plants belonging to the family Leguminosae (Fabaceae). They are characterized by having a legume-type of fruit (or pod) and compound, stipulate leaves. Many of them form root nodules where nitrogen-fixing bacteria reside. Leguminosae is the third largest group of land plants, behind Orchidaceae and Asteraceae. The legume family is comprised of the subfamilies Caesalpinioideae, Mimosoideae and Faboideae (syn. Papilionoideae). They may also be grouped as edible or inedible. Edible ones are pea legume, peanut, lentils, chickpeas, lupins and beans. Legumes fix atmospheric nitrogen, release high-quality organic matter in the soil, facilitate soil nutrients' circulation and improve water retention. Legumes are considered as a major source of important oils, micronutrients, vegetable proteins, fibre and minerals for both livestock and human consumption. Legumes are an inexpensive source of protein.



Groundnut Production
(Arachis hypogaea)

Background

Figure 29: Groundnut pods

The groundnut (Arachis hypogaea), also known as Ful Sudani, originated in South America. It has since spread all over the world, with production concentrated in Asia (50% of global area and 64% of global production) and Africa (46% of global area and 28% of global production), where the crop is grown mostly by smallholder farmers under rain-fed conditions with limited inputs.

The seed contains 25-30% protein (average of 25% digestible protein) and 42-52% oil. The crop is an annual herbaceous plant that grows to a maximum height of 60 cm.

It is characterised by bearing fruits that develop and mature underground. The fruit forms a pod with 1-4 seeds that develops underground within a needle-like structure called a peg.

Groundnut plants are produced in the tropical and sub-tropical regions of the world. Groundnuts require well-drained sandy loamy soils that facilitate penetration of the pegs after pollination, and easy digging without pod loss. They are highly practical as they fix nitrogen through their roots, maintain soil fertility and control soil erosion.

The groundnut was introduced to Sudan by the colonial administration. Most of the global production of groundnut is crushed for oil that is used mainly for cooking. The groundnut press cake (made from extracted oil) is a food rich in protein but is also used to produce groundnut paste and flour which is used in many human foods. The seeds or kernels are eaten raw, boiled or roasted. They are made into confectionery and snack foods, or they are cooked as soup and sauces to use with meat and rice dishes. The vegetative residue from the crop also provides excellent forage for livestock.

In South Sudan the crop is widely cultivated across all regions of the country. Particularly in the Lakes and Greater Equatoria States and Northern Bahr-el-Ghazal, the groundnut is an important cash crop. The groundnut is a vital ingredient of most household diets in the majority of communities in South Sudan.

Site selection

The following considerations should be followed when identifying a location to produce ground nuts. Deep, well drained, light-textured, loose, friable sandy loam or sandy clay loam soils should be selected in upland areas to avoid flooding. Heavy (clay) soils are not suitable for groundnut production, neither are higher altitudes where the climate is cooler. The area should be open to allow access by sunlight and should be grown on new or fallowed land to avoid pest and disease infestation.

Land preparation

Land should be prepared early (3-4 weeks before the onset of the rains) so that sowing may take place parallel to the decomposition of organic matter. Crop residues and weeds should be well incorporated into the soil in advance and seedbeds finely tilled. The crop is best adapted to well-drained, loose, friable medium-textured soils. Heavy textures can make it difficult to lift the crop at harvest.

The topsoil should be loose to allow the pegs (on which the fruits are formed) to enter the soil easily. Land should be ploughed and harrowed at a recommended depth. Excessive presence of water in the soil (waterlogging) is harmful and limits the activity of the nitrogen-fixing bacteria.

Selection of planting materials

Seed should always be purchased from reliable and certified seed dealers who are legally recognised by the Ministry of Agriculture and Food Security (MAFS). Farmers should also use their own saved seeds from previous seasons. Healthy and good quality groundnut seeds should be sorted after shelling at harvest time.

Varieties

South Sudan grows two major varieties of groundnut: (1) the creeping (runner) type, a long-maturing type of 120-150 days, and (2) the upright (bunch) type, a short-maturing variety of about 90 days. Varieties should be selected according to their suitability to the farmer's ecological zone. Other criteria to be considered when choosing a variety include yield, resistance to drought and disease, market demand and local preferences. Common groundnut varieties grown by many farmers in South Sudan include:

- The erect (Virginia) type, known as "Mr. Lake" in Lakes State and as "Atomthii" in the other three States of Greater Bahr el Ghazal;
- The bunch type, known as "Jang/ Tongpiny Jang" in Lakes State and as "Atomdit" in the other three States;
- The runner type, known as "Maborgok" in Lakes State, "Atomdit" in the other three States of Greater Bahr-el-Ghazal and "Bongotwan/ Bombom" in Central Equatoria State.

Improved groundnut varieties that have been tested in the Greater Bahr el Ghazal region include:

- Igola I, II and III (100 days to mature)
- Red Beauty (75 days to mature)
- Sodari (Sudan, 100 days to mature)

The Serenut varieties are developed by the National Semi-Arid Resources Research Institute (NaSARRI) Serere Uganda. These varieties are popular among farmers in South Sudan.

- Serenuti II, III and IV (60-100 days to mature)
- Serenuti 5R (red-seeded Uganda Serere, 100-110 days to mature)
- SERENUT 6T (tan-seeded Uganda Serere, 90-100 days to mature)

Recommended Commercial groundnut varieties for Uganda

Variety	Maturity Days	Yield (kg/ha)	Year of release	Potential market use	Other remarks
Serenut 1R	100-110	2500-3700	1998	Confectionery, butter	Virginia, tan
Serenut 2	100-110	2500-3700	1998	Condiment, flour	Virginia, Red
Serenut 3R	90-100	2500-2900	2002	Butter, oil	Spanish, Red
Serenut 4T	90-100	2500-2900	2002	Confectionery, butter	Spanish, Tan
Serenut 5R	100-110	2500-3000	2010	Butter, oil	Virginia Red
Serenut 6T	90-100	2500-3000	2010	Butter, oil, confectionery	Spanish Tan
Serenut 7T	100-110	2500-3700	2011	Confectionery, butter	Virginia, tan
Serenut 8R	100-110	2500-3700	2011	Confectionery, butter, oil	Virginia, Red
Serenut 9T	100-110	2500-3700	2011	Confectionery, butter	Virginia, tan
Serenut 10R	100-110	2500-3700	2011	Butter, butter	Virginia, Red
Serenut 11T	100-110	2500-3700	2011	Confectionery, butter	Virginia, tan
Serenut 12R	100-110	2500-3700	2011	Butter, oil	Virginia, Red
Serenut 13T	100-110	2500-3700	2011	Butter, oil	Virginia, tan
Serenut 14R	100-110	2500-3700	2011	Butter, oil	Virginia, Red

Figure 30: Groundnut varieties
Source: NaSARRI Serere Uganda

Planting time

Planting is done immediately at the onset of the rains (mostly, between April and May). However, planting should be based on the planting calendar of the agro-ecological zone. The groundnut plant is most sensitive to water deficit during the flowering period, followed by the pod formation period if not planted at an appropriate time. In general, water deficits during the vegetative period lead to delayed flowering and harvest, and they can reduce growth and yield.

Planting

Before planting, farmers should conduct a simple germination test by pouring water into a cup containing sample seeds. The seeds should be left to stand for about 5 minutes and then observed. Seeds found to be floating should be collected and discarded.

In South Sudan, planting of groundnuts is normally done by opening holes with hand hoes. The seeds are dropped singly into each hole or into furrows along a row. Seeds selected for planting should be clean, viable and without blemish.

Planting depth is about 5-8 cm depending on the size of the seeds, but in most parts of South Sudan the planting depth is only estimated visually when digging holes. If the farmer is sure of the viability of the seeds being planted, there is only need to place 1 seed. If in doubt, 2 seeds may be sown per hole to account for failure to germinate. The seeds should be covered with a thin layer of soil to protect them from birds and insects. This layer should be pressed gently and firmly onto the seed so as to ensure contact with soil moisture.

Conventionally, groundnut is spaced between 40 x 20 cm and 30 x 20 cm. Groundnut crops are commonly intercropped with sorghum, maize, cassava and sesame in South Sudan.

Seed rate

The quantity of groundnut seeds planted per feddan is about 30-35 kg depending on the variety.

Spacing

Depending on the variety planted and the fertility of the soil, the following spacing is recommended:

- Erect type (Mr. Lake): 25 cm x 40 cm, i.e., 25 cm between plants and 40 cm between rows.
- Bunch type (Jang or Atomdit): 30 cm x 60 cm, i.e., 30 cm between plants and 60 cm between rows.
- Creeping types: 50 cm between rows and 15 cm between plants.

Harvesting

Under rain-fed conditions, good average yields vary from 2-3 tonnes/ha of unshelled nuts under intensive management. Yields respond well to ox-plough cultivation. Under irrigation and intensive management, yields can reach 3.5 to 4.5 tonnes/ha of unshelled nuts. Harvesting starts in August or September but varies according to the variety and time of planting. Generally, harvesting is carried out 90-120 days after planting.

Soil fertility and maintenance

Groundnuts belong to the legume group of plants, which have the ability to generate their own nitrogen through the nodules of their roots. However, the groundnut thrives best with the application of optimum quantities of plant nutrients via organic manure such as cow dung and crop residues, which improve soil fertility.

Being a legume, groundnuts can fix nitrogen from the air, but a pre-planting nitrogen application of 10-20 kg/ha is recommended to ensure good crop establishment. Phosphorus requirements are 15-40 kg/ha and potassium requirements are 25-40 kg/ha. For proper kernel formation and pod filling, 300-600 kg/ha of calcium (Ca) is required at the onset of pod (fruit) formation in the topsoil. Limestone is used when soil acidity needs to be corrected, and gypsum is used when only the Ca level needs increasing. At a pH lower than 6, liming may be necessary to avoid aluminium and manganese toxicity.

Weeds and weed control

In order to achieve maximum economic yield, weeds must be eliminated. Groundnuts are very poor competitors with weeds during the early stages of their growth. Weeding should be carried out at least twice per season depending on soil fertility levels. The first weeding should be done after 2-3 weeks once the seedlings are 10-15 cm high, and the second weeding should be done after 4-6 weeks. Weeding should be done early while at the same time “earthing” up the ridges to allow proper root development and encourage pegging, i.e. the penetration of young nuts through the soil. However, once pegging begins, soil disturbance near the plant should be avoided or kept to a minimum, so as not to interfere with the developing pods. Weeding is done using hand hoes (small maloda) or jembe, but late weeding is only done by hand through the picking of weeds in order to avoid damaging the pegs and tender pods that are developing. Mulch should be applied to the base of the plant during weeding to help conserve moisture.

The most common weeds that affect groundnuts are grasses. Striga does not severely affect groundnut; therefore, farmers are advised to plant bulrush millet, sorghum and maize around groundnuts to starve the weed by denying it food. It is advisable to include groundnut and these cereals in a rotation plan.

Other important agronomic practices

- Crop rotation: Groundnuts should be rotated with cereal crops after 2-3 seasons to avoid the build-up of pests and diseases.
- Intercropping: Groundnuts should be intercropped with cereals or cassava so that available land space is well utilised. Intercropping also fosters symbiotic relations between cereals and pulses.
- Row planting: Planting in rows reduces plant competition with weeds for sunlight, water and nutrients from the soil, hence maximising crop yield.

Pests, diseases and their control

Groundnut pests mostly include white grubs, termites, millipedes, aphids, grasshoppers, thrips and ground leaf miners.

White grub (Holotrichia consanguinea)

White grubs are the larvae of scarab “chafer” beetles. Many species of white grubs are associated with groundnut damage in parts of sub-Saharan Africa and can attack groundnut plants at all stages of growth. They eat the roots and damage the pods of groundnut plants. White grubs feed mainly on the taproots and/or peripheral roots, leading to stunting (reduced growth) or death.

Figure 31: White grubs

Control: Farmers should allow enough time between manure application and groundnut planting. Excessive use of organic manure in groundnut farms increases the incidence of white grubs, especially when manure is applied during the cropping season. Deep ploughing or hand hoe tillage exposes soil pests to desiccation and predators, thus helping to reduce their numbers and minimising the damage they cause.

Termites

Termites are serious groundnut pests throughout Southern Africa and West Africa. Termites attack and invade growing groundnut plants through the roots and stem at ground level, hollowing them out and causing the plants to wilt and die resulting in a reduced crop stand. Scarification of pods is by far the most common type of termite damage at plant maturity, a factor often aggravated by late harvesting.

Figure 32: Termites

Control:

- Farmers should remove residues of previous cereal crops (sorghum, millet and maize). Plant residues left in the field serve as food for termites, which may infest the new crop.
- Planting should be carried out early enough to avoid periods of drought. Moisture deficiency may put a crop under stress and lead to attacks by termites due to compromised resistance.
- Harvesting should be done promptly. The drought and high temperatures that come during the late growing season are conditions that favour termite infestation as well as fungal (A. flavus) infection of pods, leading to aflatoxin formation in seeds.
- The complete destruction of mounds and removal of queen termites are effective control measures against mound-building species (Macrotermes spp.).

Millipedes

Millipedes are among the most economically damaging of groundnut soil pests. They are brown to blackish in colour and curl when disturbed. They attack groundnut seedlings during the first 20 days after planting, feeding on the emerging cotyledons before moving to the root system at the collar region.

Figure 33: Millipedes

Millipedes also attack maturing groundnut plants during pod formation when the pods are still soft. Immature pods from severed pegs are often perforated and thus suffer secondary infection or invasion by rot-causing organisms such as Aspergillus flavus.

Control:

- Early planting and dense, close spacing are effective cultural practices.
- The build-up of aphids and their natural enemies should be monitored and the latter conserved. Ladybirds are reported to be important natural predators of groundnut pests.
- Neem seed or leaf extracts should be used if necessary.
- Groundnuts (and other legumes) should not be cultivated continuously on the same ground.
- Where possible, varieties that are tolerant of or resistant to pests should be used.

Diseases

Groundnut diseases include rosette, leaf-spot and Aspergillus flavus (A. flavus), the latter of which causes aflatoxins. Aflatoxins and leaf-spot pathogens are poisonous to humans. Aflatoxins are one of the most potent and dangerous groups of mycotoxins, produced by certain moulds such as Aspergillus flavus and Aspergillus parasiticus. These moulds grow in agricultural commodities such as tree nuts, peanuts, rice, corn, sorghum, wheat, millet, sesame seeds, sunflower seeds, cotton seeds, chili peppers, etc. and in a variety of spices. Aflatoxins are produced by fungal action during production, harvest, storage and processing.

When moulds start contaminating the commodity, powdery grey-green spores may develop on the surface of the product, and aflatoxins may be produced by the fungi when the kernel moisture is around or above 15%. High ambient temperatures, drought stress and insect injury may contribute to increased aflatoxin contamination.

Figure 34: Aflatoxins

Aflatoxins have been associated with increased liver cancer in interaction with a chronic hepatitis B virus (HBV) infection. They may also interact with other viral infections such as those caused by Epstein-Barr virus. In addition, aflatoxins cause aflatoxicosis and may result in growth faltering and immune suppression in children.

Leaf-spot is induced by fungus. The symptoms are dark spots on the leaves, followed by yellowing and eventual death of the leaves. Rosette is a viral disease spread by aphids. Infected plants will become stunted and bunched, and eventually they will die.

Control:

- Early planting.
- Resistant varieties.
- Close spacing.
- Crop rotation.
- Burying of crop debris.
- Removal of affected plant parts.

Harvesting and storage

Groundnuts mature after 100-120 days depending on variety, soil fertility and ecological conditions. If planting is done in May or June, harvesting is usually in September or October.

Groundnuts are visibly mature when the leaves turn yellow and begin to fall from the plant. To check for maturity, the farmer should uproot at least 2-3 plants at random from different parts of the field and look for the following signs:

- The pod should be completely full and hard;
- A fully mature pod should be light brown to tan in colour and well textured when examined;
- The kernel of mature seed should appear dark when opened.

Groundnuts are ready for harvest when the leaves turn yellow and begin to wilt. Harvesting should be done by hand while making sure the pods stick to the pegs. If the pods are trapped in the soil, hoes can be used to lift them. Farmers should avoid causing mechanical damage to the pods to avoid infection during storage. Harvesting can be done either by direct lifting (pulling out the plant by hand) when the soil is wet or by digging it out using a hand hoe when the soil is dry.

Harvesting should begin when a good number of pods have fully developed and are fairly intact. The maturity of pods is normally achieved when the veins begin to turn yellow and leaf shedding begins.

The method of harvesting groundnuts depends on the specific type grown. Harvesting by hand is more suitable for erect (bunch) groundnut varieties, while runners are usually pulled out using a hoe (maloda). When using a hoe to harvest groundnuts, care must be taken to avoid damaging the pods and seeds.

After harvesting, groundnuts are dried to the required moisture content (7-8%), after which they are sorted, bagged and stored or sold in their shells. Traditional and local storage facilities vary from one community to another and include gunny bags, gourds, pots, tins, baskets, and woven leaves.

For safe storage, it is recommended that farmers adhere to the following:

- Properly dry groundnuts to a moisture content of less than 13%.
- Place groundnuts in packaging that maintains a suitable environment and restricts moisture accumulation and insect or rodent infestation.
- Use new/clean gunny or polybags to store the groundnuts.
- Put only clean, sorted kernels into the bags.
- Avoid placing the bags directly on the floor.
- Avoid heaping groundnuts in their shells on the floor of the storage structure.

• Maintain good storage facilities (which are well-ventilated, dry and of low relative humidity) and take care not to expose produce to moisture during transport and marketing.
• Monitor and control insect and rodent activity during storage.
• Avoid mixing new and old produce.

Marketing and Utilization

Groundnuts are locally marketed in the ten States of South Sudan. They are consumed raw, boiled and roasted. The roasted nuts are mostly processed into paste and butter for sauce. It is common to see small scale groundnut milling machines in all major markets across the country. Groundnut oil is extracted and used in cooking. Some groundnuts are roasted and sold by petty traders as confectionery, while others are taken to bigger markets in Juba, Malakal, Bentiu, Jonglei and Wau by traders where they are sold in bulk.

Figure 35:
Some groundnut products

Cowpea Production
(Vigna unguiculata L. Walp.)

Background

Figure 36: Cowpea pods

Sources indicate that the cowpea (Vigna unguiculata L. Walp.) originates from Southern and West Africa. In South Sudan, cowpea is grown for its leaves and seeds, and it is consumed as a green vegetable. Cowpea is a quick-maturing crop and farmers can start consuming it after 21 days. Cowpea is also an important nitrogen-fixing crop. The seeds can be consumed fresh along with the pods and leaves as a vegetable. Dried seeds are consumed after cooking. The plant can be used as a forage crop or for hay or silage.

In South Sudan the local name of cowpea is lubia and the young green leaves are plucked and eaten as korofo ngette in the Equatorial region. Cowpea leaves contain protein, low glycemic index carbohydrates, prebiotics, fat, iron, calcium, phosphorus, magnesium, potassium and sodium.

Site selection

Cowpea is grown in a wide range of soils but shows a preference for well-drained and friable sandy loam soils, which tend to be less restrictive to root growth. Cowpea can grow in a pH range of 5.6 to 6.5. The crop is tolerant of dry and shady conditions but is highly susceptible to a variety of pests and diseases and does not do well in poorly drained soils. The land must be well-drained to avoid waterlogging. Growth habits of cowpea can be climbing, creeping or erect. Cowpea is important in areas of marginal rainfall, as it is well adapted to dry climates and is suitable for a variety of intercropping systems.

Land preparation

During land preparation, existing fallow weeds, trees and shrubs are cut down manually or slashed. This should be followed by ploughing and harrowing. Land preparation should be done at least 3-4 weeks before planting.

Selection of planting materials

Farmers should select clean seed that is free of pests, diseases and weeds (and preferably drought tolerant). Planting materials can be sourced from farmers' own stock, the market or family and friends.

Varieties of cowpea

The main varieties of cowpea cultivated in South Sudan are Secow 2 W and Secow IT (a short-maturing variety that is ready for consumption in 3 weeks). A seed rate of 25-30 kg/feddan is recommended for harvesting pure grain and vegetable depending on the variety planted. For green manure, a seed rate of 35-40 kg of seed is required.

Planting

Cowpea can be irrigated or planted immediately at the onset of the rainy season. The seed should be planted at a depth of 3-4 cm. Crops sown earlier tend to have elongated internodes and to be less erect, more vegetative and lower yielding than those sown at the optimal time. It is recommended that one seed is planted per hole at 7-15 cm apart or two seeds per hill of 60 cm x 30 cm. If the seed has not come from a certified dealer, a simple germination test can be performed before planting to achieve optimum plant population.

Soil fertility requirements and maintenance

Cowpeas can benefit from organic and chemical fertiliser in depleted and marginal soils, although in South Sudan the need for fertiliser is limited.

Intercropping

Crops that can be intercropped with cowpea include sorghum, maize and other non-nitrogen-fixing crops.

Weed control

Weeds are best controlled by good seedbed preparation or the use of no-till farming, along with timely and thorough manual weeding. This should be done 2-3 weeks after germination. After 6-8 weeks when the canopy closes, weeds should no longer cause a problem for cowpea.

Pest and disease control

Common pests of cowpea are:

- Aphids
- Pod-sucking bugs
- Blister beetles
- Pod borers

Cowpea aphids

Figure 37: Aphids on Cowpods

Aphis craccivora is an important legume pest. Cowpea aphids normally feed on the under surface of young leaves, on young stem tissue and on pods of mature plants. When present in large numbers, they cause direct feeding damage. The plants become stunted, leading to leaf distortion, premature defoliation and the death of seedlings. They cause damage to the hosts and also transmit cowpea aphid-borne mosaic virus.

Pest control methods include the following:

- Planting of resistant varieties.
- Use of clean planting materials.
- Pulling out and burning diseased plants.
- Field hygiene and weeding.

Common diseases of cowpea are:

- Anthracnose.
- Cowpea mosaic (cowpea mosaic comovirus, black-eyed cowpea mosaic virus, cowpea severe mosaic virus and cowpea aphid-borne mosaic potyvirus).
- Damping-off disease.
- Bacterial blight.

Anthracnose

Anthracnose of cowpea is a fungal disease caused by Colletotrichum lindemuthianum. It affects stems, branches and stalks of leaves and flowers. The fungus is more common under wet weather. The pathogen produces brown necrotic lesions on leaves, petioles, stems, and pods. When infected, plants have tan to brown sunken lesions on leaves, with other lesions merging to girdle stems and petioles. Lesions may become covered in pink spore masses during periods of wet weather. Cowpeas affected by anthracnose produce shrivelled seeds of poor quality.

Anthracnose on leaf

Photo credit University of Georgia

Anthracnose on beans

Photo credit Infonet-Biovision

Anthracnose on bean pods

Photo credit Bamac Pty Limited

Figure 38: Anthracnose on beans

To control anthracnose disease farmers should do the following:

- Pull out and burn diseased plants.
- Use resistant varieties.
- Use seed treated with fungicide.
- Intercrop with cereals.
- Practice good field hygiene.
- Crop rotation.
- Use chemicals (pesticides, etc.).

Cowpea mosaic

Cowpea mosaic comovirus is also known as black-eyed cowpea mosaic virus, cowpea severe mosaic virus and cowpea aphid-borne mosaic potyvirus. Field symptoms usually consist of discoloration of the leaves, which show the mosaic pattern, mottling, vein banding, vein chlorosis, vein yellowing, leaf deformation and yellow spots. Affected plants may also show growth reduction.

Figure 31: Damping-off disease of cowpea

Harvesting, drying and shelling cowpeas

The growth habits of cowpeas vary according to whether the erect or semi-erect types are being cultivated. At the time of maturity, leaves will wilt but may not drop off completely. Cowpeas need to be harvested when the seed moisture content is low. When grown for consumption as vegetables, cowpea leaves are picked 4 weeks after planting; this continues until the plant starts to flower.

Farmers should:

- Harvest on time when the leaves are dry to avoid loss due to shattering, mould, and rot.
- Dry the crop on a clean patio or tarpaulin and manually thresh when sufficiently dry.
- Further dry the seed to about 10-12% moisture content for storage.

Storage

The way beans are stored is very important. This will have a significant effect on the quality of the beans and the price consumers are willing to pay for them.

For best outcome, the moisture content of the beans before bagging must be in the optimum range (10-12%). Ensure that stores are clean, and bags are properly stacked. The storage environment must be moisture free.

Figure 31: Hermetic bag

Generally, farmers should:

- Treat seed with a recommended chemical;
- Package and store them in a cool, dry and clean environment;
- Use durable and moisture-proof packaging material to avoid re-absorption of the moisture which can cause pre-germination;
- Use hermetically seal bags

Marketing and utilization

For the cowpea, seed marketing quality is vital so care must be taken during harvest and post- harvest handling. It is crucial to avoid cracking or splitting the seed. The beans are commonly cooked and eaten across the country. The beans are also packed neatly in plastics and can be sold in supermarkets. Cowpea leaves are also sold in nearly all daily markets and at farm gates as fresh vegetables. The leaves are consumed widely in South Sudan.

To attract better pricing, quality is very essential. The East African standard recommends the following:

General requirements for the market include:

- Dried and mature grains
- Well-filled, clean, wholesome and uniform in size and shape;
- Free from substances which render them unfit for human or animal consumption or processing into or utilisation thereof as food or feed;
- Free from abnormal flavours, musty, sour or other undesirable odour, obnoxious smell and discolouration;
- Free from micro-organisms and substances originating from micro-organisms, fungi or other poisonous or deleterious substances in amounts that may constitute a hazard to human health.

Contaminants

Pesticide residues: Cowpeas shall comply with those maximum pesticide residue limits established by the Codex Alimentarius Commission for this commodity.

Hygiene

Cowpeas shall be produced, prepared and handled in accordance with the provisions of appropriate sections of EAS 39.

When tested by appropriate standards of sampling and examination listed in Clause 2, the products shall:

a) be free from microorganisms in amounts which may represent a hazard to health and shall not exceed the limits as stipulated in 104 EAS 217 which are:

i) Yeasts and moulds, colony forming units (cfu) per g max. (Limits 104)
ii) Staphylococcus aureus, cfu per g max. (Limits 103)
iii) Escherichia coli, per g (Absent)
iv) Salmonella, per 25 g (Absent)
be free from parasites which may represent a hazard to health;
not contain any substance originating from microorganisms in amounts which may represent a hazard to health.

Oil Crops

Oilseed Crops are grown primarily for the oil contained in the seeds. Oil palm, soybeans and seed cotton are known as the top three most traded oil seeds, however, sesame is documented as the oldest oilseed crop known to humanity.

Sesame Production
(Sesamum indicum L.)

Background

Sesame (Sesamum indicum L.) is a very important crop in South Sudan and is grown in all regions of the country. Mostly referred to and traded as simsim, benne or nyim, sesame is believed to originate in East Africa and is one of the oldest commercial oil seed crops in the world. Common varieties of sesame colours are black, white and brown. The crop matures in 120-140 days. Sesame indicum L. is an oil seed crop, with oil contents varying between 40% and 60% based on the crop variety.

Figure 41: Sesame pods

The sesame crop belongs to the tropical climatic zone, as it is largely grown in India, China, Myanmar and Sudan. China is the largest producer of sesame in the world, which contributes about 21.4% of total world sesame production. China also has the highest area productivity, about 10 tonnes per hectare on average.

The economic advantages of sesame include:

High nutritional value: sesame has an oil content of 45-50% and a protein content of 44-48%. The oil is clear and edible, with a pleasant taste and a very long shelf life if properly refined. Sesame oil is used in cooking and in preparation of salads. It also finds use in the production of margarine, soaps, pharmaceuticals, paints and lubricants. The residue left after the extraction of oil is known as the oil seed cake which is used as cattle feed. Stalks can be burnt to ashes and used as a tenderiser.

Site selection

Sesame should be grown in well-drained, fertile, sandy loam soil that is protected from animals. Sesame is adaptable to many soil types, but it thrives best on well-drained and medium-textured fertile soil with 5 to 8 soil pH.

Land preparation

Land clearance starts with the removal of shrubs and stumps from the sesame farm. Commonly used tools are hand hoes (jembe, pangas, rakes and axes), while for large-scale production ox ploughs and tractors are used. The crop requires a very fine tilth because of its small seeds, so secondary tillage is vital.

Selection of planting materials

Only viable and certified sesame seeds are recommended for planting.

Types and varieties of sesame seeds in South Sudan

There are two types of sesame native to South Sudan: (i) Black/Grey and (ii) White.

The most widely grown imported variety is Morada, which originated in the Congo and produces higher yields, while also being more resistant to aphid attacks.

- Sesim 2 (Purple at maturity. Maturity is usually 100-110 days after planting)
- Sesim 3 (Green and hairy until maturity. Maturity is usually 90-100 days after planting).

Both Sesim 2 and Sesim 3 are also common in neighbouring Uganda, while in Sudan the Elobeid 1 (an improved cultivar) and Hirhri (a traditional cultivar) are popular.

Preparation of planting materials

Planting requires the availability of seeds and tools. The recommended seed rate for broadcasting is 5 kg/ha, the rate for drilling on flat land is 4 kg/ha, and 3.5 kg/ha when drilling is done in ridges.

Planting

Sesame is often cultivated as the first crop in a rotation, as it requires fertile soil. In this case, grasses must be eradicated since sesame is a poor competitor with weeds. Planting should be done when there is sufficient moisture in the soil. This is should be as early in the rainy season as possible. A seedbed of relatively fine-textured soil is required for the small seeds to grow properly.

There are several cultivation methods:

- Direct sowing in holes, using sticks for support.
- Sowing after narrow strips have been prepared.

A spacing of 30 cm x 10 cm or 30 cm x 15 cm is recommended depending on soil fertility. Drill in rows about 45 cm apart and later thin (at a height of about 5-10 cm) to 15-20 cm within the row.

Mixed broadcasting with other crops

The optimum depth at which to sow sesame is 1.5-2.5 cm. It is important to sow at an even depth to ensure simultaneous and uniform growth of the crop. Smallholder farmers will often sow by hand. Mixing the seed with sand, dry soil, ash or dried, sieved manure or compost can help make seed distribution more uniform. In order to achieve an optimum crop density, unbranched varieties should ideally be spaced at 6-10 cm, and later thinned (once they reach a height of 5-10 cm) to at least 15 cm within rows. Branched varieties should be drilled in rows about 45 cm apart and later thinned (at a height of about 5-10 cm) to 15-20 cm within the row.

Sesame is often sown at the onset of the rains (April-May) along with other crops such as pigeon pea, maize or sorghum. It grows to a height of 1-2 metres. When not being intercropped, it can also be planted in July.

Fertiliser requirements

Organic manure from crop residues, cow dung and goat and chicken droppings can be applied to improve the fertility of the soil. Inorganic fertilisers are not commonly used in South Sudan, but it has been found in the region that sesame does well in environments where good quantities of NPK fertiliser are readily available.

Cultivation of sesame in the South Sudan savannah does not require excessive fertiliser unless the soil quality is very poor. NPK fertiliser is required where soil fertility is low. Two bags (25kg each) of NPK fertiliser (15:15:15) should be sufficient to fertilise one hectare.

Weed control

Weeding should be done once or twice a year to enhance maximum sesame yields. Common weeds of sesame are grasses and other vegetative plants. Traditionally, weeding is done by hand using hoes (maloda) or simply by hand-picking the weeds from the sesame fields. Herbicides are not generally used to control weeds since commercial farming has not yet become common in the country.

Pests, diseases and their control

The most common pests of sesame include the gall midge, web worm, silver leaf fly, cotton aphid, beet army worm, green peach aphid, fire ant, cutworm, bollworm, grasshopper and yellow-striped blister beetle.

Gall midge

Sesame gall midge, caused by Asphondylia sesami Felt, is an important constraint to sesame (Sesamum indicum L.). The adult is mosquito-like and small. They are usually about 4-5 mm long and pale orange in colour. The legs slender, yellowish-brown; forewings transparent, dusky and covered by numerous small grayish hairs. Distal part of halters strongly enlarged. Eye dark, dorsal connected. Antennae long, 14-jointed.

Figure 42: Gall midge

The female lays eggs singly in buds, flowers and developing capsules. The eggs hatch in 2-4 days. The young maggots feed on floral parts and cause malformation of the buds which fail to develop into seeds. The larvae complete their development in 14-21 days and pupate inside the galls. The moths emerge from the galls in 7-12 days. The life cycle is completed in 23-37 days. There are several generations in a year. It is the irritation caused by feeding of larvae which results in dropping of flower buds and formation of gall like buds. These reduce seed yield by up to 100% in susceptible genotypes and under favourable conditions.

Control:

(i) Clip the galls and pick and burn the shed buds.

(ii) Spray 2.5kg of carbaryl 50WP in 625 litres of water per ha.

Web worm of sesame

Figure 43: Web worm of sesame

Webworm, Antigastra catalaunalis Duponchel (Lepidoptera: Crambidae) is the most serious pest on sesame throughout the world. It attacks the crop at all growth stages and causes a significant yield loss. In the early stage of the sesame crop, the larva webs top leaves and feeds within, whereas at maturity, it bores into the capsules and feeds on the contents.

The two natural enemies of the sesame webworm, Hemipimpla spp. and a nematode of the order Mermithid. It was found in Ethiopia that planting sesame early on the onset of rainfall followed with two applications of insecticide (Diazinon 60 EC) at 2 and 4 weeks after emergence was found economical and optimum management option for controlling A. catalaunalis.

Generally, good cultural practices are essential to pest control. Sesame is an excellent rotation crop of cotton, maize, groundnut, wheat and sorghum. It restricts nematodes that attack cotton and groundnut plants and is also an excellent soil builder, as it improves both texture and moisture retention and alleviates soil erosion. Sesame is resistant to drought and tolerant of insect pests and diseases. It is generally a low-cost crop, making it one of the best alternative speciality crops.

Diseases

Diseases which affect sesame include cotton root rot, bacterial leaf spot, bacterial blight and sesame root rot.

Methods of disease control include:

- Treating seeds in hot water (for 10 minutes at 52 °C)
- Cultivating at low humidity and temperature (changing the sowing date if necessary);
- Destroying crop residues;
- Using clean seed of known origin.

Harvesting

Sesame is ready for harvest when the plant has completely dried out. The plants are cut to a height of 10-15 cm, or uprooted before the capsules are fully ripened. The optimum time for harvesting is when:

- The first, lowest capsules turn brown and begin to pop open
- The stem turns yellow;
- The leaves turn yellow and begin to fall off, and blossoming has finished

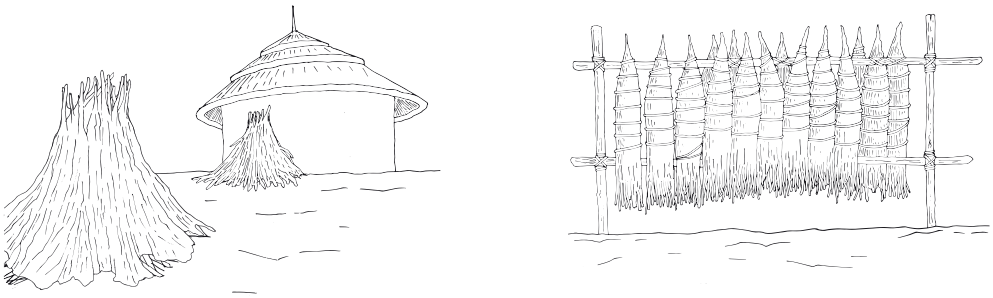


Figure 44: Drying sesame on stake

Sesame should be harvested when about 50% of the capsules have turned from green to yellow. Harvesting should be done without delay to prevent seed loss through shattering, and it should be done by cutting the stems of the plants with sickles. Harvesting by pulling the plants from the root should be avoided to prevent contamination of the seed by sand. After harvesting, the plants should be tied with rope into bundles and stood on a mat or a sheet of tarpaulin until the capsules are fully dried. This prevents wastage of seeds and contamination by impurities compared to simply leaving the capsules on bare ground where they may shatter.

Threshing

Threshing is normally carried out after the sesame has completely dried. The stalks are beaten to open the capsules and release the seeds. Winnowing is done after threshing to separate the seeds from any foreign bodies and residues.

Storage

Sesame is mostly stored in jute and polyethylene bags. Traditionally, it can also be stored in pots, granaries and plastic containers that are tightly closed to suffocate any pests.

Marketing and utilization

Sesame is found in all markets in South Sudan. Although it is mostly produced in small quantities, sesame is traded very actively in all the states and is exported in small quantities to Uganda and Kenya. Sesame is mixed with honey and is sold as hallwa simsim. Bread coated with sesame is sold in the supermarkets. Pasted simsim mixed with olive oil is sold as tahini and is very popular among South Sudanese and the Arabs. Light coloured seeds are considered to yield better quality oil than dark seeds. However, dark coloured varieties have higher oil content than light coloured seeds. White-seeded varieties are preferred when roasted and eaten; they also command a higher price over the dark seeds.

A bottle of sesame oil

Bread garnished with sesame seeds

Figure 45: Some products of sesame

Tubers

Tubers are modified stems that may store starch, as seen in the potato. Tubers are a specialized storage stem of certain seed plants. Tubers are usually short and thickened and typically grow below the soil. Largely composed of starch-storing parenchyma tissue, they constitute the resting stage of various plants and enable overwintering in many species. As modified stems, most tubers bear minute scale leaves, each with a bud that has the potential for developing into a new plant. Starchy root and tuber crops are second only in importance to cereals as a global source of carbohydrates. They provide a substantial part of the world's food supply and are also an important source of animal feed and processed products for human consumption and industrial use. Potatoes and yams are tubers, whereas taro and coco yams are derived from corms, underground stems and swollen hypocotyls. Cassava and sweet potatoes are storage roots and canna and arrowroots are edible rhizomes. All these crops can be propagated by vegetative parts and these include tubers (potatoes and yams), stem cuttings (cassava), vine cuttings (sweet potatoes), side shoots, stolons or corm heads (taro and cocoyam). The principal root and tuber crops of the tropics are cassava (Manihot esculenta Crantz), yam (Dioscorea spp.), sweet potato (Ipomoea batatas L.), potato (Solanum spp.) and edible aroids (Colocasia spp. and Xanthosoma sagittifolium).

Figure 46: Sweet potatoes

Figure 47: Cassava tubers

Cassava Production
(Manihot esculenta)

Background

Cassava (Manihot esculenta) originated in South America and was introduced to the Congo Basin in Africa by the Portuguese. Cassava is a perennial shrub of the family Euphorbiaceae which is grown primarily for its storage roots but also for its leaves that are eaten as a vegetable.

Some of its local names are banda and bafra. There are two main types of cassava: bitter and sweet. The bitter types contain hydrogen cyanide (prussic acid) which is highly poisonous, hence the need to process bitter cassava before it is eaten. The cassava plant is a woody plant with erect stems and spirally arranged, simple-lobed leaves with petioles (leaf stems) of up to 30 cm in length. The edible roots of the plant are usually cylindrical, tapered and may be white, brown or reddish in colour.

Cassava plants can reach four metres in height and are usually harvested 6-12 months after planting, depending on the variety cultivated. In South Sudan, cassava is traditionally grown in the Equatorial States, but it has since spread into all other parts of the country.

Cassava is an important crop for the following reasons:

- Cassava leaves are nutritious and add vitamins and minerals to the diet.
- The stalks can be dried and used as sources of energy.
- Cassava peel can be used for animal feed and mulching.
- Cassava acts as a tenderiser if burnt to ashes.
- The starch can be extracted as an ironing agent.
- Cassava can be used to brew alcoholic drinks.

Site selection

Cassava prefers light soils or deep, well-drained loam soils. It is drought-resistant and can grow in poor soils, but it cannot with stand waterlogging as this causes the tubers to rot.

Planting materials

Cassava is normally planted from stem cuttings taken from a plant which is at least 10 months old. The stem should be healthy and without bruises. A good stem should be at least 30-40 cm in length, with a minimum of 5-7 nodes. A stem is healthy if it is free from insects, pests and diseases and its diameter is not less than 1.5 cm. A stem is fresh if the latex or sap comes out within 3 seconds after cutting.

Varieties

The popular varieties of cassava that are grown in South Sudan are numerous. The released varieties are Akena, PAYE 1 (Nase 17) Sweet, PAYE 2 (Nase 19), PAYE 3 (Nase 18) Sweet and Nase 14. Other common varieties are Sweet Baworoworo, Abbey Ife, SS4, TME-5, TME- 12, TME-14, MM95/0414, Tiara, Karangba, Nasse-1 and Nasse-2. Cassava is primarily grown for its carbohydrates, but protein-rich varieties are now being developed to improve nutrition when consumed. These varieties can currently be sourced from research institutions.

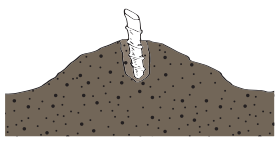
Planting

Cassava stem cuttings can be planted at any time of the year provided there is enough moisture for germination. In the Equatorial States where cassava is very popular, the best time for planting is between April and September as this is when the rains are most regular.

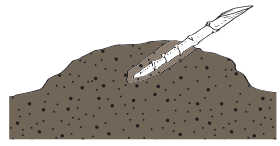
The rows are typically 1-1.5 m apart, and the plants are 1 m apart. With this spacing, there are between 7,000 and 10,000 cassava plants to the hectare.

The orientation of the stem in the soil depends on the maturity of the stem and the soil type. Cuttings are placed according to the direction of the wind and the nodes should be in an upright position.

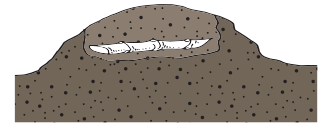
It is common for farmers in South Sudan to place cassava stem cuttings flat (horizontally) in the soil; however, it is recommended that cuttings be pushed into harrowed soil on a mound or ridge at an angle of 45°. Horizontal planting is suited to mature cuttings in loam soils with sufficient moisture. This will lead to the production of many stems.



GUARD AGAINST LODGING
plant vertically in sandy soils with 2/3 of lenght of cutting below soil to produce deeper lying storage roots for anchorage.



FOR EASE OF HARVESTING
plant at an angle in loamy soils to produce more compactly arranged roots.



FOR MULTIPLE STEM PRODUCTION
fully bury the stem cutting to increase stem production. Storage roots are many but they are comparatively smaller in size.

Figure 31: Damping-off disease of cowpea

If planting is delayed, store the stems under a cool and shady place. Storage under such condition is possible up to one month. In storing, make sure that the base of the stem faces the ground.

Planting time

Early planting at the onset of the rains is recommended in Greater Bahr el Ghazal and in most states of South Sudan. This enables the cuttings to receive sufficient moisture to sprout and become well established, thus making them more tolerant of pests and diseases. In the Equatorial States, planting may be done at any time of the year, and it is normal to intercrop cassava with maize, groundnut, and millet as well as with upland rice as a relay crop.

Spacing

The recommended spacing is 1-1.5 m between rows and 1 m between plants and (1.5 x 1 m). For seed multiplication, the recommended spacing is 1 m between rows and 50 cm between plants. Most communities plant on flat, well-ploughed and harrowed land.

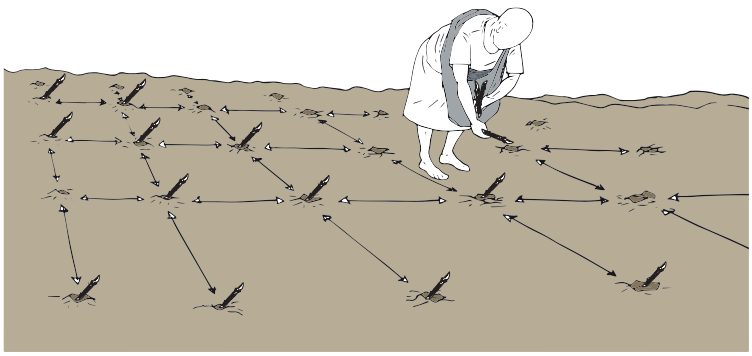


Figure 49: Inter and intra spacing

Planting depth

Planting depth varies according to the type and condition of the soil. Shallow planting in soil where the moisture content is low will result in poor establishment and low yields, while deep planting can make sprouting difficult. Deep planting is advisable in areas prone to attacks by termites.

The following table contains the planting depth for cassava in different soils under varying environmental conditions.

Soil type	Dry	Wet
Sandy	6 inches (15 cm)	4 inches (10 cm)
Loamy	4 inches (10 cm)	2-3 inches (5-7.5 cm)

Gap filling

Any plants that have died must be replaced within the first month after planting. Plants replaced later than this may fail to catch up due to shading by taller, healthier plants.

Fertilizer

Cassava can do reasonably well without the use of inorganic fertiliser, but it responds particularly well to fertiliser application. Application of NPK 10:10:20 at 260 kg per hectare should be done three months after planting. Potassium (K) is essential to the development of the root. The yield of cassava falls greatly when the soil lacks potassium fertilizers. If the farmer applies fertilizers and looks after his plantation well, the yield of cassava could reach 25-65 tonnes per hectare.

Weed control

Cassava is a slow-growing crop and is thus susceptible to weed competition, especially in the first 1-4 months of growth before the canopies are formed. When cassava is a solitary crop, it is best to weed the cassava farm 3-4 times per season (starting 3-4 weeks after planting).

Cultural control, which is the most commonly used method among small-scale producers, includes hand weeding using small hoes (maloda and jembe). Care must be taken not to disturb the root or to cause bruises through which the crop may become infected by disease.

Chemical control (i.e. the use of herbicides) on cassava farms is not very common in South Sudan as only small areas are currently cultivated. Herbicides are only effective if applied on time and in the appropriate amount; therefore, the use of herbicides is recommended only when the cassava field is too large to be weeded culturally. Diuron, alachlor and floumetron have been found to be effective as pre-emergent herbicides. For information on quantities, farmers should contact their extension agent or refer to the instructions issued by the manufacturer of pesticides.

Common pests

Cassava is often affected by termites, green mites, white flies, variegated grasshoppers, porcupines, rats, bush rats, wild pigs, monkeys, moles, domestic animals and human theft.

Common diseases and disease control

Common diseases of cassava include cassava mosaic, brown streak, bacteria blight and root rot. The common disease control measures practised by farmers in South Sudan are crop rotation, roughing, timely weeding, field hygiene and the use of resistant or tolerant varieties. For cassava mosaic, the most effective measure is to plant improved varieties that are resistant to the disease.

The most common methods of pest control include the use of traps or nets, fencing, scaring off pests or destroying their natural habitats. Pesticides are used only as a last resort when the need overwhelms the farming community.

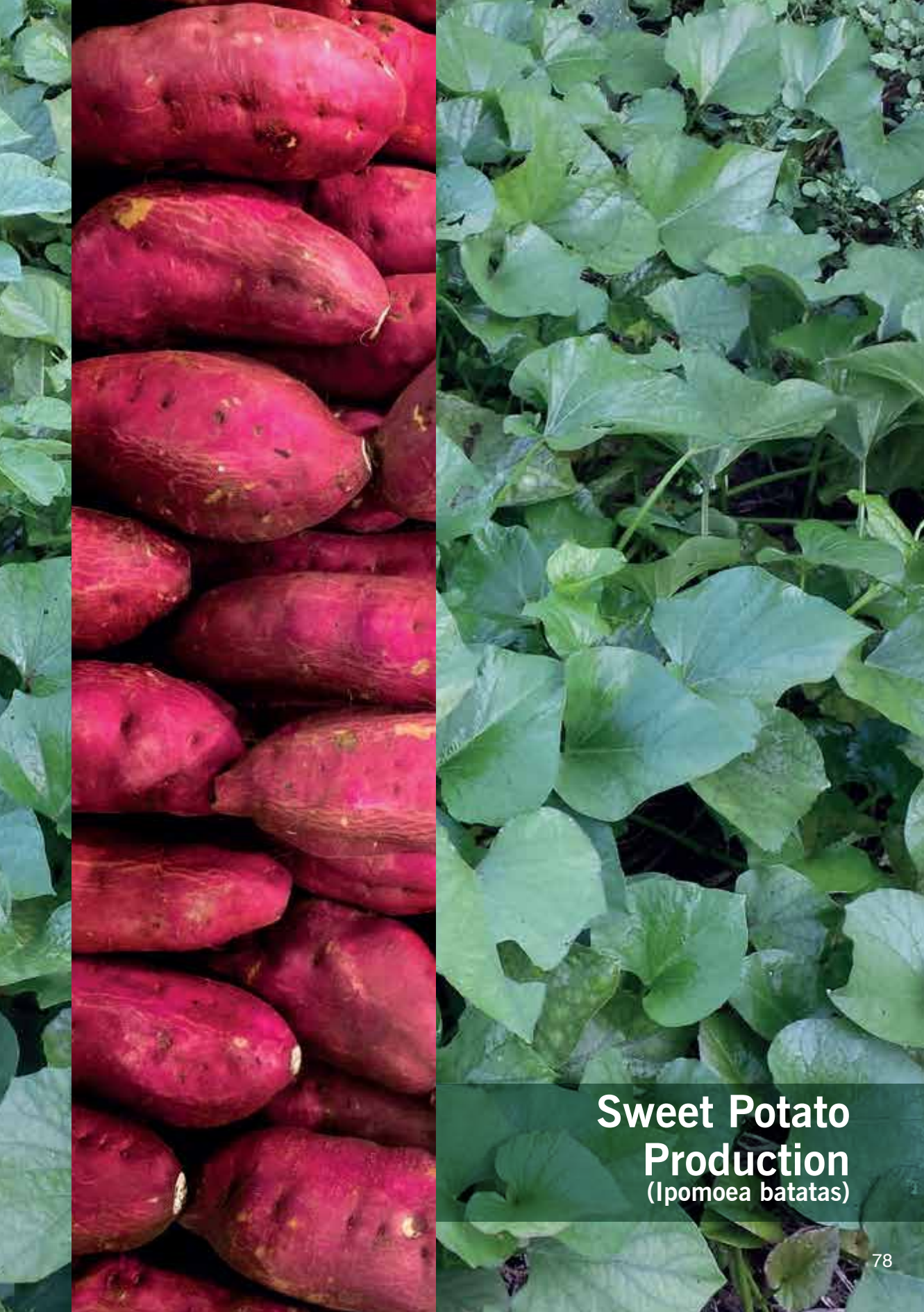
Harvesting

Cassava is usually ready for harvesting about a year after planting, depending on the variety grown. Some early-maturing varieties may be ready for harvesting within nine months. On most smallholder farms, cassava tubers are harvested by hand-pulling or digging. The roots should be dug up carefully to prevent damage.

Cassava roots are highly perishable and quick to rot. Therefore, they are usually sold in the market as soon as they are harvested. It is a common practice to keep the tubers in the soil until the farmer is ready to take them to market. The life of the root tuber can also be extended by processing it into other forms. Cassava can yield up to 12.5-15 tonnes per hectare without the application of fertiliser. When fertiliser with adequate potassium (K) content is supplied, cassava can yield up to 20-35 tonnes per hectare depending on the variety planted.

Marketing and utilization

Cassava is sold locally as fresh tubers and leaves in most markets in South Sudan. Sweet varieties are eaten fresh, boiled or roasted, while bitter varieties are cut into chips, soaked in water for 3-5 days, which is vital to reduce the cyanide poison. It is then dried and milled into flour, which is sold in bags across the country. If properly packed and kept in a dry environment, cassava flour may be stored for a long time. Cassava cuttings are also sold on the local market to generate income for smallholder farmers. Cutting multiplication, bulking and selling, particularly of improved varieties, is becoming an area of specialisation of some producer groups.



Sweet Potato Production
(Ipomoea batatas)

Background

Sweet potato (Ipomoea batatas) is native to Central and South America, but is cultivated throughout the world. It is highly suited to many of the local growing conditions in East Africa. In South Sudan, sweet potato (bambe or kayata) is commonly grown in the Greater Equatorial region and on a very limited scale in the Greater Bahr-el-Ghazal region.

Figure 60: Sweet potatoes

Development partners are currently distributing sweet potato cultivars rich in beta carotene, which are an excellent source of essential vitamins.

Global and continental production level

Sweet potato is the potato of the tropics. It is a tough crop, able to grow in arid conditions and with little demand for either water or fertilizer. Sweet potato ranks as the world's seventh most important food crop, principally because of its versatility and adaptability. Sweet potato is a co-staple in East Africa. It is a tough crop, able to grow in arid conditions and with little demand. In many other countries it is an important secondary crop grown for an expanding fresh market. Africa's top producers are Uganda (1.7 million t), Rwanda (980,000 t), Malawi (960,000 t) and Kenya (725,000 t). Sweet potato was ranked the second most important root crop after cassava. Sweet potato is a subsistence crop grown by smallholder farmers on pieces of land of less than 0.4 ha. Cultivation is performed mostly by women.

Site selection

Well-drained, sandy loam soil is preferred, and heavy clay soils should be avoided as they can restrict root development, resulting in cracks and poor root shaping. Sweet potatoes grow very well in tropical and subtropical climates and they are very sensitive to cold weather. They grow best at temperatures in excess of 25 °C (77 °F) in well-draining, loamy soil with a pH of 5.6–6.6. Sweet potatoes should be planted in full sun and require plenty of space as the vines will spread over large areas.

Planting material

Disease-free planting materials (usually fresh vine cuttings or sprouts from tubers often called "Slips") can be purchased from research stations or farmers (it should be fresh and disease free). Crops are bulked in a nursery bed to provide enough cuttings for commercial planting.

Vine cuttings should be about 30-40 cm in length with approximately 8 nodes and should only be taken from crops that are mature enough to provide this material.
Seedbed preparation

Sweet potatoes are grown on raised beds or mounds. This provides developing roots with loose, friable soil to expand to their potential size and shape without restriction, while also allowing for adequate drainage. Mounds should be about 30 cm high and 40 cm wide at the base. The main requirement is that the developing roots should remain below the soil within the hill.

Planting of cuttings

Cuttings should be inserted into the mound at an angle of about 45° as this promotes uniform root development. The cutting should be inserted about halfway with 3-4 nodes visible. The recommended plant spacing is 30 cm between cuttings (or 330 cuttings for every 100 metres of row). Cuttings must be watered during or immediately after planting.

Varieties

Most of the sweet potato varieties grown in Africa are diverse landraces, selected by farmers for adaptation and taste. White, cream or yellow-fleshed varieties are the norm, and orange-fleshed varieties are still relatively rare.
The popular types of sweet potato grown in South Sudan are:

- Osukut (early maturing, high-yielding, sweet and highly marketable)
- Araka red (early maturing, high-yielding and tolerant of Cylas spp.)
- Araka white (early maturing, high-yielding)
- Yellow-fleshed sweet potato
- Orange-fleshed sweet potato

Nutritional benefit of orange-fleshed sweet potatoes (OFSP)

Figure 51:Orange-fleshed sweet potato.
Photo credit: Live Science

From a nutritional perspective, the orange-fleshed sweet potato ranked first among all vegetables. The orange-fleshed sweet potato possesses the characteristic of an attractive sweet taste and is particularly eye-pleasing to children because of the yellow to orange colour.

The orange-fleshed sweet potato is a good source of non-digestible dietary fibre, minerals, vitamins and antioxidants. It also has anti-carcinogenic properties and attributes that prevent cardiovascular disease (CVD).

Weeds and weed control

Weeds are only likely to cause a problem early in crop growth before vigorous vine growth covers the beds as plants become established. Sweet potato is a very active creeping plant that usually interlocks and covers the soil surface quickly. Since weeds compete with crops for nutrients, light, water and space and may also host insect pests, farmers must ensure that weeds and their root systems are either removed or deeply buried during land preparation. Unwanted plants should be removed wherever found. Weeding should be done before the sweet potato vines cover the soil, with hand weeding done twice, at three and six weeks after planting.

Pests and Diseases

Pests

Sweet potatoes are commonly affected by a range of pests including termites, aphids, beet army worms, sweet potato weevils (Cylas puncticollis), caterpillars of the sweet potato butterfly (Acraea acerata), millipedes, porcupines, rats, bush rats, wild pigs, monkeys, moles, domestic animals and human theft.

Sweet potato weevils

The full lifecycle of sweet potato weevils takes just over a month. Adult weevils feed on leaves, the underground storage roots (tubers) and the vines of sweet potatoes. Most of them are active during the night, which makes it more difficult to detect their presence. It is most destructive during the larval stage. They demonstrate concealed feeding habits, which makes it quite difficult to control their population. Their infestation normally causes 20-50% of damage in most commercial plantations.

A symptom of infestation by sweet potato weevils is yellowing, cracking and wilting of the vines, but a heavy infestation is usually necessary before this is apparent. Damage by weevils can be recognised by the holes in the vines or the tunnels in the tuber when you pull them up from the soil. Attacked tubers become spongy and brownish to blackish in appearance.

Figure 52: Sweet potato weevil on sweet potato
Photo credit: International Potato Centre

Crop rotation and inter-cropping are two of the preventive measures that can deliver a high level of effectiveness. Field sanitation is another prevention method that will work. Get rid of infested vines and decaying vegetation within the plantation. Proper timing of planting and harvest will also be essential.

Diseases

Alternaria leaf spot & leaf and stem blight (Alternaria spp.)

Alternaria is caused by a fungus called Alternaria bataticola. Manifestation of alternaria (also called Leaf petiole and stem blight disease) varies among varieties. It often appears as brown lesions on leaves with concentric rings resembling a target; lesions are usually restricted to the older leaves and may be surrounded by a yellow halo. Small grey-black oval lesions with lighter centres may occur on stems and leaf petioles and occasionally on leaves. Stem and petiole lesions enlarge and often coalesce resulting in girdling of the stem; defoliation may occur. A. bataticola attacks the whole vine (leaves, petioles and stems) throughout the crop cycle.

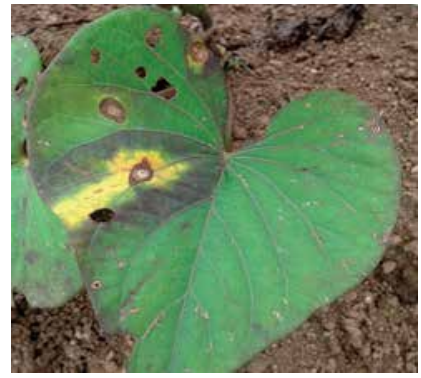


Figure 53: photo showing random scatter of dark brown lesions with concentric rings and yellow halo on leaves of sweet potato by Plant Village

The management and control of alternaria could be addressed through cultural and chemical approaches. The selection and breeding of resistant or tolerant varieties is the main cultural method of managing the disease, together with cultural practices of crop hygiene, involving the destruction of the infected crop debris. Chemical control is not an appropriate method of managing this disease.

Sweet potato chlorotic stunt virus:

Sweet potato virus disease is a disease complex caused by two viruses: sweet potato chlorotic stunt virus (SPCSV) and sweet potato feathery mottle virus (SPFMV). The symptoms are severe stunting of infected plants, stunting, distorted and chlorotic mottle or vein clearing of the leaves. It is confirmed that SPCSV enhances the accumulation of SPFMV.

Black rot (Ceratocystis fimbriata):

Other diseases may result in sweet potatoes rotting after a harvest. Black rot, caused by Ceratocystis fimbriata, not only causes rotting but gives the sweet potatoes a bitter flavour. Small, roundish, dark brown spots are the first signs of black rot. These spots then enlarge and change hue with visible fungal structures apparent.The symptoms of black rot include stunted plants, wilting plants, yellowing plants, dropping leaves, plant death and circular brown-black patches of rot on tubers.

Figure 54: Ceratocystis black rot of sweet potato
courtesy Plant Village

The disease can be managed by using disease-free seed material. Sweet potato should not be planted in sites where sweet potato has been grown during the previous 3-4 years. Transplant material should be collected from plants by making cuts above-ground. Seed material should be treated with an appropriate fungicide prior to planting

Harvesting

Sweet potato roots are ready for harvesting 3-8 months after planting, depending on the variety. If the crop is harvested too early the roots will not be fully developed. If left for too long in the soil, the roots may become fibrous, thus reducing yield and increasing rot.

Figure 55:
Photo showing harvest of sweetpotatoes

Most farmers conduct piecemeal harvesting. This involves moving around the field looking for cracks in the mounds and ridges, which farmers perceive to be indicative of a sizeable root. They remove a selection of larger roots then heap soil over the remaining smaller roots to allow continued bulking. This practice involves harvesting small quantities at a time and normally starts as early as two months after planting for some varieties. Longer-maturing varieties are usually more suited to the piecemeal method than early maturing varieties, which have storage roots that mature around the same time.

Storage

During the storage of sweet potatoes, rot-causing organisms such as rhizopus fungi can infect damaged roots and spread to other roots on contact. The best method of control is prevention, i.e., avoiding skin damage and discarding damaged roots. Roots should also be dried before packing.

Optimum storage conditions are 14-16°C in a high-humidity cool store. Storing sweet potatoes below 10°C may cause damage due to chilling, while storing above 16°C can lead to excess weight loss and sprouting.

Sweet potatoes can be preserved by slicing and drying the chips, which can then be pounded into flour if desired. Some varieties can also be used to feed animals such as rabbits, guinea pigs and shoats.

Marketing and utilization

Sweet potatoes are sold locally as fresh tubers or dry chips (muterere) in most markets across South Sudan. Sweet Potatoes are also used in making Jams, Sweet Potato Hotcake, Sweet Potato Drinks, Sweet Potato Flour, Sweet Potato Donuts, Sweet Potato Fritters and Sweet Potato Bread. Sweet potato vines can also be sold as planting materials to other farmers as a source of income.

Vegetables

Vegetables are the edible product of an herbaceous plant. These are often products from plants with a soft stem, as distinguished from the edible nuts and fruits produced by plants with woody stems such as shrubs and trees. Vegetables can be grouped according to the edible part of each plant: leaves (lettuce), stalks (celery and asparagus), roots (carrot), tubers (potato), bulbs (onion and garlic) and flowers (broccoli). In addition, fruits such as tomatoes, cucumbers, squash, pumpkins, and capsicums and seeds such as peas and beans are commonly considered vegetables. All parts of herbaceous plants eaten as food by humans, whole or in part, are generally considered vegetables.

Tomato Production
(Solanum lycopersicum)

Background

Tomato (Solanum lycopersicum) originated in South America and has since spread all over the world where it is cultivated on homesteads, in small gardens and on large-scale industrial farms. The tomato is one of the most important, popular and widely grown vegetables in the world ranking second after the potato.

Figure 56: Photo showing tomatoes

Global production exceeds 70 million metric tonnes annually. The tomato is a member of the botanical family Solanaceae, which includes edible plants such as the potato, pepper, tobacco, Irish potato and aubergine. Tomatoes are a good source of minerals and vitamins, especially vitamin C and carotenoids, which are consumed throughout the world fresh and in processed products.

In South Sudan, the tomato is produced at both small and medium scales for consumption and income generation. Tomatoes are an important source of vitamins and an important cash crop for both smallholders and medium- scale commercial farmers. Tomatoes are used in cooking as a flavour enhancer and thickener. They are always in high demand for fresh consumption and processing.

Tomatoes will do very well under a wide range of agro-ecological conditions. They can be grown under irrigation, in greenhouses or in hydroponic conditions, and some varieties also do well under rain-fed agriculture. Tomatoes grow best in temperatures of 20-27°C. Fruit development will be poor when average temperatures exceed 30°C or fall below 10°C. Tomatoes prefer well-drained soils, as they are sensitive to waterlogging, and they do best with 7-19 hours of sunlight per day.

Depending on the variety and technology used, the general growing phases of tomatoes are:

7-10 days for germination.

4-6 weeks from emergence to transplanting (plants should be transplanted when they are approximately 10-12 cm tall).

4-6 weeks from transplanting to first flowering.

4-6 weeks from first flowering to the first ripening of fruit.

10-15 weeks for the harvesting period.

Site selection

Tomatoes gives good results when grown in well-managed, sandy loam soils and heavy, clay loam soils that are free of a hardpan. However, the best results are obtained from deep, well-drained loams. The soil should be rich in organic matter and plant nutrients, with an optimum soil pH value of 6-7. It is good practice for farmers to avoid planting tomatoes alongside other solanaceous crops such as pepper, tobacco or aubergine because these crops share common insect pests and diseases. As such, it is important to rotate crops within the field.

Land preparation

Proper land preparation is necessary to loosen soil and break any hardpan or compaction. Farmers should ensure deep digging and the preparation of soil to a medium tilth. Land preparation should include the incorporation of a reasonable quantity of farmyard manure (such as cattle or poultry dung) into the soil in order to improve its structure, fertility, texture, aeration and capacity for water retention.

The soil should be sterilised by exposing pests and weeds to sunlight. This can be done by burning dry stalks inside the soil or piling them on top of the seedbed before planting. This should reduce the population of nematodes and other soil-borne diseases of tomato. In soils that have low pH, lime can be applied to increase the pH. For alkaline soils, gypsum can be used to reduce soil pH and levels of sodium.

Nursery practices

When cultivating solanaceous crops such as tomato, it is recommended that farmers start with a nursery. Here, crops are provided with the care and conditions that will develop strong seedlings able to withstand harsh conditions in the field. A nursery seedbed will be of one of two types, depending on the season. In the dry season (during which most tomatoes are grown in South Sudan), seedbeds should be slightly sunken to increase water retention during watering. During the rainy season, the beds should be raised and flat, and shelter should be provided from heavy downpours.

Nursery soils should be free of stones or stumps and should be prepared to a fine tilth using hoes and garden forks. The nursery beds should be shaded and lightly covered with mulch to further reduce moisture loss and keep weeds in check. It is important to keep the beds clean and free of weeds.

Nursery beds of tomato should measure approximately 1 m x 1.5-3 m. The length of the bed may vary as necessary and convenient. If the soil is prone to nematodes, it may be sterilised in the nursery by heating it in bags or by burning dry plant residue on top of the nursery bed.

Near the end of the time in the nursery, seedlings need to be hardened off in order for them to adjust to field conditions. This is done by gradually reducing the amount of water and shade provided to the seedlings. This should be done 6-9 days before transplanting.

Seed rate

About 250 g of seed (approximately 70,000 seeds) is required to produce enough seedlings to plant one hectare of an indeterminate variety. For one hectare of a determinate variety, 125 g of seed is required. Seeds should be sown at a depth of 0.5 cm.

Planting/transplanting

Seedlings raised in nurseries are transplanted to the field. They are usually ready to be transplanted 3-4 weeks after sowing, when they have developed 3 true leaves, and they should be transplanted into moist soil. The seedbeds should be irrigated after sowing, and this should be done regularly until the seedlings reach a height of 5-7 cm or are about 1 month old. Transplanting is best done in the evening or very early in the morning to avoid strong sunlight.

Varieties

Most tomato seeds planted in South Sudan are imported. Common varieties grown by farmers, especially in the dry season, are Roma VF, Ronita, Roma VFN, Piacenza and Tengeru 97. All of these are plum-shaped, fleshy, of an intense red colour, excellent for processing and with the capacity for long storage and travel. The Roma VF variety is also resistant to verticillium and fusarium, and Roma VFN is resistant to verticillium, fusarium and root knot nematode.

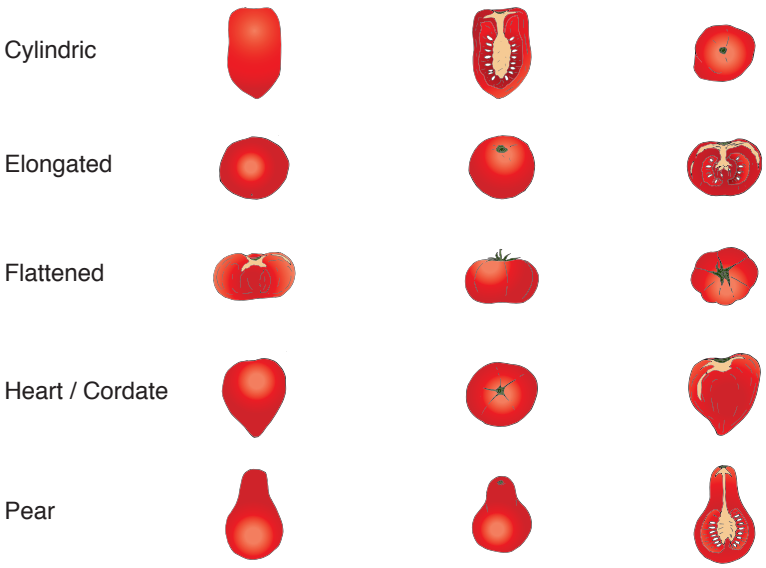


Figure 57: Tomatoes and their shapes

Spacing

Tomato spacing is determined by variety, soil fertility and the availability of soil moisture. Tomatoes usually thrive best when spaced at 60 cm x 45 cm. Yields of 75-100 tonnes/ha are possible.

Staking

This is the practice of supporting the tomato plant to protect it from breaking due to strong winds and/or the weight of the fruit. Staking is done when the plant has completely established itself and is almost flowering. Stakes approximately 4 feet long and 0.75 to 1 inches square are placed between every one or two plants depending on the tying system that is employed. Stakes are usually driven about 12 inches into the ground. An additional stake can be supplied at the end of each section to strengthen the trellis.

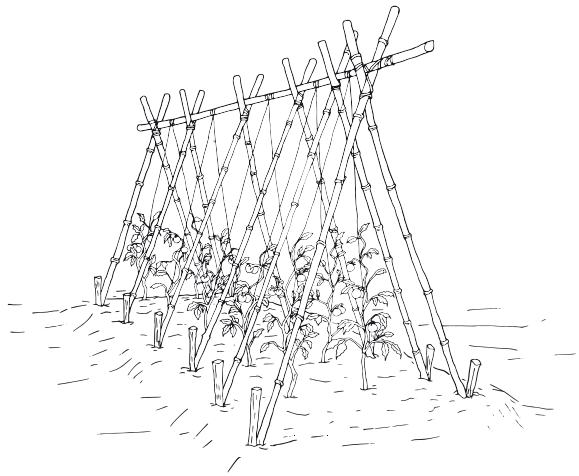


Figure 58: Staking tomatoes

Stakes should be inserted immediately after transplanting to minimise damage to the root system. It is therefore important to collect the stakes before transplanting.

When staking, plants should be tied prior to any of them lodging. The first string is usually placed about 10 inches above the ground, with subsequent strings placed about 6 inches above the previous one. Some varieties may be tied as many as three or four times. In Lakes State, tomato plants are also tied to fence sticks around the garden.

Pruning

Side shoots (laterals), old or diseased leaves, branches and overshadowed lower leaves should be removed by hand. Following formation of the first fruit cluster of mature green tomatoes, all lower, older leaves should be removed to enable ventilation and the dispersion of food to the fruit. Flowers should be pruned to 5-6 per cluster for medium to large fruits.

Fertiliser application

Tomatoes are heavy feeders of plant nutrients, including nitrogen, phosphorus and potassium (NPK), and as such respond well to organic fertiliser. The amount of fertiliser applied is influenced by the fertility of the soil, the season and the cultivar. Besides using organic fertiliser, farmers are advised to use compost, farmyard manure, green manure and liquid manure (slurry and plant tea).

Irrigation

Irrigation is critical to tomato production, especially in the dry season. Most farmers in South Sudan will move their farm closer to a river or stream during this period. It is important to supply sufficient water at critical times, such as immediately after sowing or transplanting. However, care should be taken because heavy irrigation after a long dry spell without prior light irrigation results in cracking of the fruit.

Weed Control

The crop stand should be kept free of weeds at all times. Weeds compete for soil nutrients, space, water and sunlight, and are also vectors of disease. Hand weeding of tomato fields is recommended. Mechanical cultivation should be shallow and should not be done too close to the plants to prevent damage. Hand hoeing is also practised.

Common pests and diseases

Pests

The tomato is often affected by pests such as the whitefly, leaf miner, red spider mite, cutworm, aphid, thrip, African bollworm and birds.

Thrips

Thrips are very small, slender insects that are best seen with a hand lens. Mature western flower thrips are 0.06 inch (1.5 mm) long, while onion thrips are slightly smaller at 0.05 inch (1.3 mm) long. The most distinctive characteristic of thrips is two pairs of wings that are fringed with long hairs. Adults are pale yellow to light brown in colour. Immature stages have the same body shape as adults but are lighter in colour and are wingless. Thrips are a common pest found in gardens. They damage plants by sucking their juices and scraping at the fruits, flowers and leaves. Plant leaves may turn pale, splotchy and silvery and then die. Injured plants are twisted, discoloured and scarred.

Thrips

Photo credit: Planet Natural

Thrips damage on tomato fruit.

Photo credit: T.A. Zitter, Cornell University

Thrips injury on leaves

Photo credit: Laidback gardener

Figure 59: Photo showing Thrips damage on tomatoes

To control thrips, use cultural practices such as removing weeds and grass from around garden areas and eliminating alternate hosts. During hot weather, weeds dry up and the insects migrate to more attractive plants. Thrips lay eggs inside plant tissue and the pupae feed on plant juices. Thrips also lay eggs in unopened buds making it difficult to control the insect. Thrips also spread plant viruses; for example, tomato thrips and western flower thrips spread the tomato spotted wilt virus. Use dry mulch material and clean up crop debris in the garden, especially onion leaves after harvest. Avoid as much as possible planting tomatoes next to onions, garlic, or cereals, because high thrips numbers often build up on these crops.

African bollworm (Helicoverpa armigera)

African bollworms are destructive and can put a dent on the profit margin of tomato farmers if not checked. The larva (caterpillar) is the most destructive stage of the pest. It feeds on leaves, growing points, buds, flowers and fruit, causing heavy losses. A single caterpillar can attack several fruits/pods. These caterpillars bore circular holes through pods or fruits and feed on their internal contents. They feed with their heads and foreparts inside and the rest of the body outside. These holes also serve as entry venues for pathogens.

Figure 60: Damaged tomato fruits by African bollworm
Photo credit: Mogga Michael VSF – SUISSE

Chemical methods of control have been found to be very effective in controlling and managing African bollworms. Farmers should seek advice from the nearest country office of the Ministry of Agriculture. LEGACY 5% EC at a rate of 10 ml/20 L or Pentagon 50EC at a rate of 8-10 ml/20 L of water.

Cultural practices such as crop rotation with non-host plants, maintaining field hygiene and ensuring proper weed management will also minimise attacks of the bollworm. A properly weeded farm will ensure that the worms do not find hiding places among weeds.

Mealybugs (Planococcus citri)

Mealybugs are soft-bodied, wingless insects that often appear as white cottony masses on the leaves, stems and fruit of plants. They feed by inserting long sucking mouthparts, called stylets, into plants and drawing sap out of the tissue. Damage is not often significant at low pest levels. However, at higher numbers they can cause leaf yellowing and curling as the plant weakens. Feeding is usually accompanied by honeydew, which makes the plant sticky and encourages the growth of sooty moulds.

Retarded tomato plant by Mealybug.

Photo Credit: Mogga Michael VSF – SUISSE

Mealybugs on tomato stem. Photo credit:

Christina Shanthi De Silva

Retarded tomato plant by mealybug.

Photo Credit: Mogga Michael VSF – SUISSE

Figure 61: Mealybugs on tomato plants

Do not over water or over fertilize – mealybugs are attracted to plants with high nitrogen levels and soft growth. Neem oil is an organic pest deterrent, as it disrupts the growth and development of pest insects and has repellent and anti-feedant properties. Best of all, it is non-toxic to honeybees and many other beneficial insects. Mix 30 ml/3.8 L (1 oz/1 gallon) of water and spray every 7-14 days, as needed.

Tomato leaf miner (Tuta absoluta)

Leaf miner adults are small, black-and-yellow flies. The female leaf miner lays about 260 cylindrical eggs. Their colour varies from creamy white to bright yellow, darkening in the embryonic phase and becoming almost black near eclosion.

The first instar larvae are whitish to yellowish after emerging. They mine inside the leaf, stem or fruit. In the second to fourth instars they become greenish with a black band behind the head.

Figure 62: An adult leaf miner

Figure 63: Blotch-shaped mines in the leaves

Figure 64: Larvae inside the tomato fruit

The most distinctive symptoms of damage by the tomato leaf miner are the blotch-shaped mines in the leaves. Caterpillars prefer leaves and stems, but they may also occur underneath the crown of the fruit and even inside the fruit itself. Fruits can be attacked as soon as they are formed. In case of serious infection, leaves die off completely. Mining by the caterpillar causes malformations, and damage to fruit allows fungal diseases to enter, leading to rotting fruit before or after harvest.

Management of tomato leaf miners

The tomato leaf miner is a very challenging pest to control. It almost crippled the young tomato industry in northern Nigeria in 1997-1999. Effectiveness of chemical control is limited due to the insect's nature of damage as well as its rapid capability to develop resistance to insecticides. Sex pheromone traps are used as an early detection tool. Mass trapping as well as lure and kill application of pheromones have been found to be effective to mass capture of adult leaf miners. Integrated pest management (IPM) strategies are being further developed to achieve appropriate management of tomato leaf miners.

Biological control agents

1. Predatory capsid bugs (Nesidiocorus tenuis and Macrolophus pygmaeus) target the eggs of the tomato leaf miner.

2. Bacillus thuringiensis mainly targets larvae.

3. Mixed cropping with African marigold (Tagetes spp.) minimises root-knot nematode damage acting as a trap crop. In tomatoes, marigold or cucumber is commonly used as a trap crop for every 15 rows of the main crop to attract the tomato fruit borer. Other instances where marigold has been used as a trap crop are in potato and rice against nematodes and snails, respectively.

Figure 65: Tomato mixed crop with African marigold

Physical control methods

1. Clean the area of old fruits and plants.
2. Close greenhouse ventilation openings with insect netting.
3. Use tomato leaf miner sticky traps for monitoring and mass trapping of adults.
4. Use a delta trap together with pheromones for scouting and monitoring the adults.
5. Use a Tutasan water trap together with pheromones for mass trapping of the adults.

Compatible insecticides

1. Azadiractin (neem seed extract) acts as a contact and systemic insecticide against tomato leaf miners.

Diseases

Common diseases of tomato are blight (early and late), damping-off disease, bacterial wilt, bacterial canker, bacterial speck, leaf spot, powdery mildew, end rot and anthracnose.

Control methods for diseases

Cultural methods include crop rotation, appropriate weeding, optimum spacing, fencing, removal of infected crops and field hygiene. Mechanical methods may be used to control insect disease vectors by scaring the insects away, trapping, picking or crushing them and destroying their habitats. Biological methods use resistant varieties and preserve natural predators of pests such as birds, wasps, ladybirds, praying mantises, etc. Chemical control involves the use of various chemicals to limit both pests and disease.

Signs of nutrient deficiencies in tomatoes

Phosphorus deficiency in tomato leafs

Chlorine deficiency in tomato leafs

Nitrogen deficiency in tomato leaves

Figure 66: Photo showing nutrient deficiencies

Harvesting

Most smallholder farmers use a combination of field picking “pinks” (tomatoes that have begun to change colour) and bulk harvesting mature green tomatoes. Generally, the time and method of harvesting depends on the distance to the market and the storage capacity of the variety cultivated.

The end-use of the product and the distance to the market will determine when to start harvesting. Tomatoes intended for processing are harvested once they are fully mature. Fruit intended for shipment over a long distance is harvested before this stage, while crops for local markets are picked later.

There are six distinct stages of picking depending on the intended market:

- Green stage
- Breaker stage
- Pale yellow (turning stage): the fruit will last a week or more before ripening depending on the cultivar.
- Pink stage: at this stage the fruit will ripen in 4 days or more.
- Light red stage: at this stage the fruit will ripen in one or two days.
- Ripe: the fruit will be ripe or firm and should be marketed or used immediately.

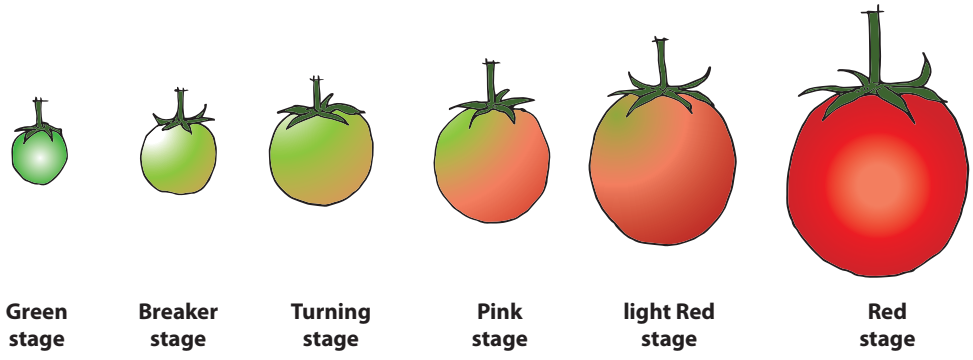


Figure 67: Stages of picking tomatoes

Tomatoes for the fresh market are harvested by hand while those intended for processing purposes are harvested mechanically, especially in developed countries. It is recommended that picking be done early in the morning.

Grading

Tomatoes are graded according to size, colour and quality. Fruit of good quality must be succulent, well-shaped and uniform in size and colour. It should also be free of diseases, cracks, blemishes, foreign matter or spray residue.

Packing

Tomato fruits (especially high-grade fruits and/or those intended for specialised markets) are packed in trays, wooden boxes or cartons. Lower-grade fruits are packed separately.

Storage

Storage conditions are dictated by the stage of ripeness of the fruit. In general, tomatoes should be stored in a cool, dry place.

Marketing and utilization

Tomatoes are sold fresh to communities and in local markets. Most of the tomatoes purchased are eaten as a salad ingredient by households and at hotels. There is a large demand for tomatoes in the major cities of South Sudan where markets are numerous and the human population is higher.

Okra Production
(Abelmoschus esculentus)

Background

Okra (Abelmoschus esculentus) is a vegetable crop of the family Malvaceae. Okra is mostly called bamia in South Sudan. It is a stout, erect annual herb that may grow up to four metres tall depending on the variety. It has spirally arranged leaves with leaf blades up to 50 cm in diameter with each leaf possessing 3-7 lobes. Okra is believed to have its origin in Africa (most likely East Africa) and today is widely distributed across the tropics, sub-tropics and warmer portions of the temperate regions.

Nutritionally, Okra is a good source of vitamins C and A, B-complex vitamins, iron and calcium. It is also low in calories and a good source of dietary fibre.

Site selection

Figure 68: Young Okra

Okra will grow well in a variety of soil types but thrives particularly well in well-drained loam soils. The plant is best adapted to a climate with a long, warm growing season and grows best at a maximum average temperature of 35 °C with a minimum average of 18 °C.

Varieties

The common varieties of okra that are cultivated in South Sudan are:

- Pusa sawani: This is a high-yielding variety that is tolerant of vein mosaic. It grows to 2-2.5 m tall and has long pods (18-20 cm) that are dark green, smooth and have 5 ridges. This variety is mainly imported.

- Clemson spineless: This variety grows to 1.2-1.5 m in height and has pods that are about 15 cm in length, green and moderately ridged. It is also known as ladies' fingers. It is an improved variety, and the seeds are mainly imported.

- White velvet: This is a medium-height variety that can grow to 1.5-1.8 m. Pods are 15-18 cm in length, slender, tapered, smooth and creamy white.

- Local varieties: These include Khartomia, Turang per, Thou amaal and Amilaak baar. They are known by several different names depending on the ethnic group that cultivates them.

Land preparation
Soil is prepared 2-3 months before planting, and it is recommended that farmers allow any crop residues and organic matter in the soil to decompose before okra is planted. Early land preparation also permits weed seeds to germinate, thereby allowing early cultivation to destroy young weeds before planting. Soils should be prepared to a fine tilth.

Planting
In South Sudan, okra is established by direct sowing in the field. To facilitate speedy germination, okra seed should be soaked in water overnight before planting. About 3 kg of seed is required per feddan. The seed rate should be 8-9 kg per hectare, and the planting depth should be about 1.5 cm.

Spacing
This should be 45 x 45 cm, 50 x 30 cm or 60 x 15 cm for inter-row and inter-plant spacing, depending on the variety, soil moisture content and soil fertility.

Fertilization
Inorganic fertiliser and natural sources of plant nutrients such as compost, manure tea and plant tea (e.g., tithonia for foliar feed) are commonly used. Well-composted manure should be applied at the time of planting at a rate of 20g/plant. Additional compost or manure is needed during the vegetative period. Manure and plant tea can be fed to the plants via a drip irrigation system to avoid excessive use of labour.

Weeds and weed control
Common weed species that affect okra in many parts of South Sudan include annual grasses such as crabgrass and goose grass; perennial grasses; broad-leaf weeds such as sickle pod, annual morning glory and common cocklebur; and nut sedge.
When the okra and weeds are small, tilling with a rolling cultivator (on medium-sized farms) will kill most small weeds. Where weeding is done manually, as is the case among most smallholder farmers in South Sudan, local tools such as hoes and maloda should be used. Farmers should avoid throwing too much soil directly against the okra stems because doing so can increase the incidence of stem rot. The first weeding should be carried out 2-3 weeks after planting.

Pests and diseases
Common pests of okra include the cutworm, cotton seed bug, African bollworm, spiny bollworm, spider mite, thrips, tobacco whitefly, root node nematode, aphid, flea beetle, grasshopper, leaf miner, flower beetle, cotton stainer and stink bug. Common diseases include damping-off disease, early blight, powdery mildew, bacteria blight, black mould, and fusarium wilt.

The common disease control measures practised by farmers include crop rotation, roughing, timely weeding, field hygiene and the use of resistant varieties. The most common methods of pest control include the use of traps or nets, fencing, scaring off pests or destroying their natural habitats. Chemicals are sometimes used as a last resort.

Harvesting

Most varieties of okra grown in South Sudan are ready for picking 45-55 days after planting. Bud-like pods begin to form about 4-6 days after flowering. Pods are harvested when still tender and once they have attained a length of 7-15 cm, depending on the variety and market requirements.

The crop will bear pods for several months under ideal conditions, especially when mature pods are picked regularly. Pods must be picked about 4-5 days after flowering when about 4 inches in length, before they mature and toughen.

Figure 69: Fresh Okra

Under conditions in South Sudan, harvesting normally continues for 45 days after the first harvest. Regular picking every 1-2 days is essential to ensure pods comply with the size prescribed by the market. Okra should not be harvested when it is raining or when the soil is excessively wet since excess moisture can induce mould development on the pods and the cut petioles.

Storage

The most common way of preserving okra in South Sudan is by drying and grinding it into powder.

Okra deteriorates rapidly after harvesting and is normally stored only briefly before being marketed or processed. Large quantities are canned, frozen or brined. Okra has a very high rate of respiration at warm temperatures and must be promptly cooled after harvest in order to reduce the pod temperature and minimize subsequent deterioration. Okra that is in good condition can be stored satisfactorily for up to 10 days at 7-10° C. Toughening, yellowing and decay are rapid at higher temperatures. A relative humidity of 90-95% is desirable to prevent shrivelling.

Marketing and utilization

Fresh okra pods decay quickly and should be marketed within a day of harvesting. However, okra can be harvested, sliced, dried and ground into powder to extend it shelf life. Dried okra chips and powder are popular among many households in South Sudan where they make soup with them.

Figure 70: Dry sliced okra

Kale Production
(Brassica oleracea L. var. acephala)

Background

Kale (Brassica oleracea L. var. acephala) is mainly grown for home consumption and sale in local markets. It is thought to originate from a domestication process that occurred either in the Mediterranean area or in the European northwest. It is a popular vegetable crop in South Sudan commonly known as sukuma wiki. It is known to be a valuable source of vitamins and minerals as well as a source of cash for small-scale farmers in rural and peri-urban areas. The crop can be either rain fed or irrigated. It requires an optimum mean temperature of 15-18 °C for growth and leaf development and a maximum temperature of 24-28 °C. It grows well in a wide range of soils of adequate moisture and fertility. To maintain growth, kale requires a constant supply of moisture and should, as a general rule, receive a minimum of 2.5 cm of water per week.

Brassicas also include crops such as cabbage, covo, rape, viscose and cauliflower. As such their agronomic practices are similar.

Site selection

The land should be located near a water source and should be raised off the ground in order to avoid waterlogging. Kale thrives in well-drained, light-textured loam or sandy clay soil. The recommended seed rate is 2kg per acre.

Land preparation

Nurseries

Kale seedlings are first raised on a nursery bed before transplanting. The nursery bed should measure 1 m x 1.5-3 m to allow for easy nursery management. A furrow should be dug using a stick and the seed drilled into the furrows. The furrows should be covered with light soil and grass and then watered.

Seedbeds

Land should be prepared well in advance of transplanting. Field operations should be avoided when the land is wet. This will help to prevent the spread of disease from plant to plant and minimise the movement of infested soils within and outside the field. The field should be free of weeds.

Figure 71: Watering on kale farm

Transplanting

Seedlings should be transplanted when they have grown to 5-10 cm in length and have 2 or 3 leaves. Transplanting should be done early in the morning or late in the evening when the sun is low. The seedlings should be planted at a depth of 2-3 cm with a spacing of 45 x 45 cm between row and plants. After transplanting, other management practices such as watering, application of organic manure and weeding should be carried out.

Weeding

Weeding should first be done within 1-2 weeks of planting and then repeated as necessary to avoid competition for nutrients, water and space. Weeding is also done to reduce the incidence of pests and disease.

Pests and Diseases

Pests

The most common pests of kale include aphid, sawfly, cutworm, diamondback moth, leaf miner and thrips (T. tabaci and Frankliniella spp.). Seed-borne diseases such as black rot, black leg, black spot and ring spot are common.

Diseases

Fusarium wilt (yellows) Fusarium oxysporum f. sp. Conglutinans

The first sign of yellows on kale is a lifeless, yellowish green colour overall, but often more noticeable on one side of the plant. A lateral warping or curling of the stem and leaves occurs. The lower part of the leaf blade adjoining the petiole or midrib wilts and dies first, resulting in a curve in the midrib. The lower leaves turn yellow first, and then symptoms move to the upper leaves. With time, the yellow turns brown, and the tissue becomes dry and brittle.

Figure 72: Fusarium oxysporum f. sp. Conglutinans on leaves and stem

The fungus enters the plant mainly through the young rootlets, although wounds made in older roots at transplanting time may offer entrance pathways also. Fusarium penetrates the young roots, migrates directly to the water vessels, and finally progresses up the stem into the leaves. The rate of development depends upon temperature.

Control: Since the yellow fungus can live free in the soil for many years and has several other characteristics that differ from most other vegetable disease fungi, the conventional controls such as rotation, seed treatment, fungicide sprays, and destruction of crop refuse are of little value once the fungus has established itself on a farm or in a specific field. Then the use of resistant varieties is the only control.

Verticillium wilt (Verticillium dahliae and V. longisporum)

Vertcillium wilt commonly affects most herbaceous crops (annuals and perennials). This wilt is caused by a soil-borne fungus called Verticillium dahlia and Verticillum longisporum. Initial symptoms of verticillium wilt include sudden yellowing of foliage, typically first appearing on one side of a plant. These leaves then wilt and die.

Vegetables infected with verticillium cannot be cured and will eventually die. However, one can extend the life of infected plants by fertilizing and watering them properly.

Figure 73: Effect Verticillium dahliae and V. longisporum on leaf and stem

Do not repeatedly grow crops that are highly susceptible to verticillium wilt in the same area of your garden each year. Try to rotate highly susceptible crops with other less susceptible crops. Also, try to plant vegetable varieties that are resistant to verticillium wilt.

White rust (Albugo candida)

Albugo is a water mould or oomycete, a fungus-like organism. Albugo survives in soil, plant debris and infected seed.

The main symptom of white rust on kale is the deposition of pustules which originate from powdery spores on the leaves, stems and flower stalks.

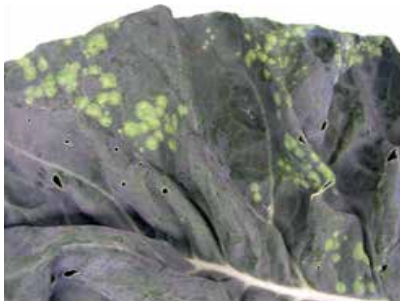


Figure 74:
Photo showing effect of white rust

White rust prefers cool, moist conditions and a temperature of between 13 °C and 25 °C. It thrives well when humidity is around 90% and rain is frequent.

The spores require only two to three hours of free water on the plant surface at the correct temperature to germinate. The pustules are usually found on the underside of the leaf, and may develop singly or in concentric rings. Once the spore has penetrated the plant cells, it will take 6-21 days, depending on the temperature, for the pustules or blisters to appear. This cause the leaves to twist, wither and die.

Figure 75:
Effects of Albugo candida on leaves

Cultural control

The most important way of managing this disease by cultural methods is to use good quality seed, practice long crop rotations and remove debris after harvest.

Before planting:

Use seed that is of high quality and certified free from albugo.

Make nurseries far from production areas and remove weeds.

Check seedlings in the nursery and remove infected plants.

Remove volunteer brassicas and weeds from the production areas.

During growth:

Irrigate for short periods early in the day, use wide row spacing and plant in the direction of prevailing winds so the leaves dry rapidly.

Maintain appropriate crop nutrition (particularly adequate potassium and phosphorus) to reduce susceptibility of plants to the disease.

After harvest:

Remove crop debris (capable of harbouring oospores) and burn or plough in.

Rotate with non-brassica crops for at least 3 years.

Chemical control:

If fungicides are needed in the field, do the following:

Apply fungicides early, before the disease is serious.

Alternate protectant products (e.g., copper, mancozeb) with systemic products (e.g., metalaxyl, phosphorus acid) to prevent the development of resistant strains of the oomycete.

Blackleg

This is a serious cabbage disease caused by the fungus Leptosphaeria maculans (Phoma lingam). Symptoms of blackleg usually appear as oval, sunken, light brown cankers, often with a black or purple margin, near the base of the stem. The canker enlarges until the stem is girdled and the plant wilts and dies. Severely infected plants are stunted. Infected plants eventually wilt and turn dull blue-red. With black leg, plants may suddenly collapse due to stem deterioration.

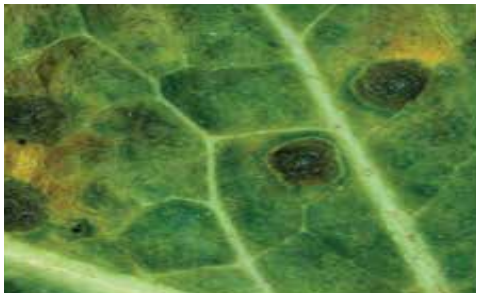


Figure 76: Leaf lesions may appear as (a) grey circular spots containing many small black dots or (b) white to brown spots with many tiny black dots in the centre

Photo credit: L. Tesoriero

Figure 77: Stem and stalk develop sunken brown to purple lesions which eventually turn black and split.

Photo credit: L.Tesoriero

Controlling blackleg disease

- Avoid wet soil. Blackleg is most destructive in wet soil.
- Diseased leaves should not be fed to farm animals if manure is to be used on crucifer fields.
- Plant tolerant/resistant varieties where available. Check with seed dealers.
- Plough the diseased crop residue under the soil immediately after harvest.
- Practise a 4-year rotation since the fungus remains alive in soil for at least 3 years.
- Properly weed production fields.
- Use certified, disease-free seed since blackleg is seed borne (i.e., carried on and in the seed).

Marketing and utilization

Mostly eaten fresh as salad and sold in small bunches. They can be seen in all majormarkets in South Sudan.

Amaranth Production
(Amaranthus spp.)

Background

Amaranths comes from Greek word for "unfading", and common names for A. caudutus include love-lies-bleeding. Amaranth belongs to the family Amaranthaceae.

Amaranth is a very popular leafy vegetable in South Sudan and in many parts of tropical Africa. Vegetable amaranths are probably the most widely eaten boiled greens throughout Africa's humid lowlands. During the production season, amaranth leaves provide some African societies with as much as 25% of their daily protein. In parts of West Africa the tender young seedlings are pulled up by the roots and sold in town markets by thousands of tons annually. Amaranth leaves provide a secure food supply for millions. The leaves and stems make excellent boiled vegetables with a soft texture, mild flavour and no trace of bitterness. Globally, Asians are known to be among the largest consumer of this vegetable.

Figure 78: Amaranth plant

Nutrition

Amaranth is sometimes considered a superfood with seeds that have a much higher content of the minerals calcium, magnesium and iron compared to most grains, especially maize, which are low in these minerals. Amaranth also contains the amino acid lysine, which is typically obtained from eating meat. Amaranth seeds are also high in potassium, zinc and vitamins B and E. They can contain over 20% protein depending on the variety.

Varieties

There are a few variants of amaranth grown in South Sudan. The majority of them are local and usually with green leaves and white fluffy heads. However, there are also varieties with red heads and green leaves. They are both found in the market, but the most common is the variety with white heads.

Improved varieties include Burgundy (Amaranthus hypochondriacus), Love-Lies-Bleeding (Amaranthus caudatus), Plainsman (Amaranth hypochondriacus and Amaranth hybridus) and Joseph's Coat (Amaranthus tricolor).

Soil requirements

Amaranth performs best in very rich soils (e.g., loam to sandy loam soils) with high organic matter and good water-holding capacity, but it can grow on a wide range of soil types and moisture levels. Seedbeds must be well drained and located outdoor with minimal shade. The soil pH should be 4.5 to 8.

Planting and plant spacing

The most common method of amaranth propagation is by sowing seeds. The seeds are usually very tiny and typically germinate in 3-4 days. They respond very well to proper spacing. They are often planted by direct seeding, broadcasting or by drilling the seeds. Normally, the small black or cream seed is broadcasted very thinly (a seeding rate of 2 g per m2) on prepared beds. The tiny seeds are covered with a thin layer of soil to a depth of less than a centimetre. The seed may be sown in nursery beds and subsequently transplanted to the field as seedlings.

A seed rate of 2-3 kg per hectare is recommended for direct drilling. If planted in a nursery, farmers should use 0.75 kg seeds per hectare and transplant when seedlings are three to four weeks old. Transplanted seedlings should be spaced at 20 x 20 cm, giving a plant population of 200,000 to 250,000 seedlings per hectare. For optimum plant population and with the right fertility, up to two million seedlings per hectare may be planted. This can be achieved if seedlings are planted at 10 cm (between rows) x 5 cm (between plants).

Fertilisation

Nitrogen is very good for development of leaves; therefore, amaranth responds very well to the generous application of nitrogen fertilizers (e.g., NPK) for good growth.

Weed and weed control

Farms must be clear of weeds because amaranth does not compete well with weeds. Early weeding should be practiced, ensuring that plots are cleaned by hand weeding (uprooting) or by hoes if crops are planted in lines and have the right spacing. There are also wild cultivars (pigweed) of amaranth, which usually have thorns. Farmers should avoid mixing them with cultivated varieties and should destroy them whenever they are found on the farm because they serve as hosts for pests.

Harvesting

Amaranth, like all vegetables, is perishable so it must be harvested fresh when plants are succulent and at their prime before becoming woody. The leaves are best harvested in the morning when they can be taken directly to the market or sold at the farm gate to attract better prices.

The plants grow rapidly and may be harvested when they reach a height of 30-60 cm. Although the whole plant can be uprooted, most are cut back, which increase leaf harvest and encourages lateral growth. As many as 10 weekly harvests have been reported.

If the entire plant is harvested, a garden plot of 10 m2 can yield 20-25 kg of vegetables on a well-managed farm. If the leaves and lateral shoots are picked individually several times over, the same small plot can average 30-60 kg total yield. On a per-hectare basis, vegetable amaranth yields are generally in the range of 4-14 tonnes/hectare fresh weight. However, harvests as high as 40 tonnes per hectare have been reported.

Figure 79:
Harvesting and selling vegetable at her farm in Lakes State

Harvesting the seeds

Seeds are ready when the leaves drop and the head can be gently rolled between the thumb and fingers. If the seeds fall out readily, then it is time to harvest. If the weather is wet, cut the stalks and hang them to dry over a clean sheet. After they dry, give them a good shake. Each flower spike yields 113-227 grams of seed.

Figure 80: Amaranth seeds and heads

Amaranth flowers are usually ready for harvesting after two months. By this time the head/flowers have a yellowish colour. Place the heads on a sheet (preferably tarpaulin) and remove the seed by rubbing gently with hand, by enclosing the seed heads between cloths and treading on the top without shoes on, by beating the seed heads inside of a bag or by beating seed heads together over a cloth. If the heads are not fully dried, lay them inside bags with heads down and leave them in the shade to finish drying.

Dry the grains for two days. When dried, thresh to remove the chaff from the grain. The chaff can be used as a fertiliser in the garden or mixed with maize bran and fed to poultry birds.

Pests and diseases

Amaranthus species are affected by a host of pests. Since the leaves are the most eaten part of the crop by households, any damage to the leaves reduces their value. There are many leaf-chewing pests which can cause an enormous damage to the leaves. The most common pests affecting amaranths in South Sudan are:

1. Amaranth weevils (Linxus truncatulus)
2. Grasshoppers (Zonocerus variegatus)
3. Leaf rollers (Sylepta derogate), which attack leaves by rolling them, resulting in defoliation.
4. Leaf miner (Hymenia recuriblis)

To control pests of amaranth, farm hygiene is important. A well-kept farm is the most effective means of controlling the breeding sites and spread of pests. Pesticides should be applied only if it is extremely necessary. In such cases, Vetox 85 or Sevin may be sprayed. For instance, Servin can be sprayed every two weeks at the rate of 1 g per litre of water. Do not pick and eat leaves for 3-4 days after you spray pesticides. It is important that farmers strictly follow the instructions on the insecticide packaging and also consult their extension staff at the Ministry of Agriculture for guidance.

Common amaranth pests

Amaranth weevils (Linxus truncatulus)

An attack on amaranth by amaranth weevils can result in stunted, twisted plants and cankers on the stems and branches. In India, Kenya and Mexico, amaranth weevils are considered important pests, and in many other countries it is a potentially important pest due to the increased popularity of amaranth as a fast-growing, nutritious vegetable. The impact of these weevils is increased by their ability to spread Fusarium species that cause stem and branch decay and cankers.

Figure 81: Amaranth hypolixus larvae
Photo Credit: Lucid Central.Org

Figure 82: Amaranth stem weevil

To detect weevils in amaranth, look for plants that are stunted, wilted or deformed. Slit open the stems to find the tunnelling larvae in galleries filled with frass. Look for the adults on the foliage.

To control amaranth weevils, remove wilted crops, do not plant close to host crops like the wild amaranth plants and keep the farm clean. For chemical control, spraying neem solution and Malathion is reported to be effective against the adult weevil, but it may be not effective against the larvae already inside the tunnel.

Leaf miners (Hymenia recuriblis)

Adult leaf miners are small (1.8 mm), yellow-and-black flies that are about the same size and shape as fruit flies. These are small insects whose maggots make long, slender, white mines (tunnels) in leaves. They have a habit of feeding within leaves or needles, producing tunnelling injuries. Severely mined leaves may turn yellow and drop. If seedlings are mined they become stunted and eventually die.

Figure 83: Leaf miner leaving patches on the leaves

Control

- A natural enemy of leaf miners are several species of parasitic wasps, which attack and destroy the larvae in the mines. Parasitic wasps (Dacnusa sibirica, Diglyphus spp., and Opius pallides) might be not only practical but incredibly effective too.
- Handpick and destroy mined leaves. Insecticides are not very effective for leaf miner.
- Whenever necessary spray the crop with neem products.

Common diseases of amaranth

- Stem rot (Choanephora cucurbitarium)
- Damping off (Phythium aphanidermatum and Rhizoctonia solani)
  Spraying Diathane M45 at 20 g/10 litre of water every two weeks has been found to be effective. Once sprayed, it is advisable not to harvest the crop for three to four days after spraying.

Figure 84: Root rot of amaranth

- Root-gall nematodes: Amaranth is susceptible to root gall nematodes. Nematodes are microscopic worm-shaped invertebrates that parasitise plants by eating the roots. This is the bump or gall you may see on plant roots. Well-aerated soils and use of tolerant or resistant seed varieties can minimize the impact of root-gall nematodes.

Marketing and utilization

Leaves are eaten as cooked greens and served as side dishes called dodo or gwedeng-weden. The grain is milled into flour, which is used in baking cakes and bread and is popular for making amaranth porridge. The grains can also be roasted and used in confectioneries or added to the surface of bread to increase the nutritional value and aesthetic appeal for better pricing. Amaranth seed bars are made by adding honey in the same way sesame bars (alawa simsim) are made. It is said to be more palatable because it lacks the bitterness of sesame. Amaranth seed oil is also gaining popularity as a potential export commodity.

Figure 85: Some products from amaranth seeds

Egg Plant Production
(Solanum melongena)

Background

Egg plants are grown worldwide and are very popular for their often-purple fruits used in cooking. Also known as aubergine and guinea squash, eggplant is a perennial and can grow up to one meter high. It is believed to have been domesticated in Asia where the wild relative (Solanum incanum) still exists. This crop is in the Solenaceae family along with tomatoes and potatoes. World production of eggplant in 2001 was almost 23 million tonnes from 1.4 million hectares of land. Asia is the main producer, in particular China (53% of the world production), India (28%) and Turkey (4%).

Figure 86: Purple fruit egg plant

Africa represents less than 4% of the world's production of eggplant, with well over 90% of it occurring in northern Africa.

Eggplant fruits have the following composition per 100g of edible portion: water 92.9g, energy 64kJ (15 kcal), protein 0.9g, fat 0.4g, carbohydrates 2.2g, fibre 2.3g, Ca 10mg, P 16mg, Fe 0.3mg, carotene 70µg, thiamin 0.02mg, riboflavin 0.01mg, niacin 0.1 mg, folate 18µg and ascorbic acid 4mg.

Varieties

The fruit is creamy-white, yellow, brown, purple or sometimes almost black. Common varieties include Black Beauty, Florida High Bush, Early Long Purple, Ravage and Long Purple. African Garden Eggs (Solanum aethiopicum) are a very close substitute.

Figure 87:
Garden eggs (Solanum aethiopicum)

Soil requirement

Eggplant requires evenly moist soil to ensure the best and fastest growth. The best pH for eggplant is from 5.5 to 6.8. It will grow in most soils but will perform best in well-drained soil rich in organic matter. The soil should be light and well prepared. Prepare the planting beds with aged compost and side dress eggplants with compost tea every 2-3 weeks until the fruit has set. Do not overwater or allow the soil to dry out. Mulch around the plants to retain soil moisture and an even growing temperature.

Planting and plant spacing

Seedlings are kept in the nursery until they have developed 5-7 leaves and are then planted in the open or in a greenhouse at a spacing of 100 x 50 cm between rows and plants. With proper nursery management the seed requirement is about 300 g/ha, but farmers often use more. A first watering at the base of each plant is necessary just after transplanting. Afterward, the frequency of irrigation depends on the soil type, season and cultural practices. The ideal transplant is a seedling with three to four true leaves, stocky, disease free and without flower buds.

Fertilization

Eggplant is a heavy feeder, and it remains in the field for a relatively long period of time. Therefore, nutrient depletion of the soil occurs quickly, and fertilizer and manure requirements are large for high yields. Fertilizing should be adapted to local soil fertility, rainfall conditions and technical skills of the growers. Requirements of N, P and K are larger than for tomato.

In tropical Africa, fertilizer recommendations for intensive production of eggplant may include 45-50 t of farmyard manure, 50-300 kg N, 25-100 kg P and 30-200 kg K per hectare. Apply farm yard manure, phosphorous and potassium before planting. The nitrogen content of the soil should not be too high to avoid the young eggplant developing excessive foliage to the detriment of fruit production.

Weed and weed control

Eggplant is slow to become established and cannot compete with aggressive weeds. Weeds also harbour insects and diseases. Weeding can control weeds if done immediately when they are observed.

Harvesting

Harvesting must be done regularly, two or three times per week. The fruit is harvested immature, before seeds begin to enlarge and harden. Fruit should be picked when they are firm, and the colour is bright and shiny. Eggplant fruit becomes pithy and bitter as it reaches an over-mature condition. The eggplant fruit grows on a sturdy stem, but the fruit stalks can be removed with knife or secateurs. To obtain fruit that keeps well it is best to harvest at dawn or in the early morning. Fruit harvest can be expected in 100-150 days from seed and 70-80 days from the time of transplanting. Average yields of 40-50 t/ha from open field production in 4–5 months are possible.

Grading: Eggplant fruits are sorted by size (small, medium, and large) and culls are removed.

Storage and preservation: Whole eggplant will keep in a well-ventilated place for up to 1 week at 50 °F; it is best not to refrigerate eggplant. It can be frozen or dried.

Pests and diseases

Eggplant is susceptible to fungus and bacterial diseases. Intercrop it with beans or other nitrogen-fixing crops. Do not plant with or immediately after tomatoes or corn to reduce the incidence of bacterial wilt and nematodes.
Pests: Shoot and fruit borers, broad mites, aphids, cutworms, white flies, flea beetles, potato bugs, spider mites and tomato hornworms.

Shoot and fruit borer (Leucinodes orbonalis and Euzophera perticella)

Fruit and shoot borers can be very destructive. Larvae bore in terminal shoots and young fruits, feeding on the inside. Larvae also bore plant stems, killing the plant.

Figure 88: Shoot borers and Fruit borers

Control: To control fruit and shoot borers, remove affected fruits and shoots from the field. Destroy plant residues after harvest. Plough the field deeply and practice appropriate crop rotation. For chemical control, spray Rogor-40, but the manufacturer's recommendations must be strictly followed.

Whiteflies (Bemisia tabaci)

Whiteflies feed on the leaves of eggplant by sucking the plant's sap. Whiteflies are vectors of the mosaic virus reported to occasionally affect eggplant in West Africa. Large populations cause leaves to turn yellow and sometimes fall off the plants.

Figure 89: Adults and immature stages of the cabbage whitefly (Aleyrodes proletella).
© A. M. Varela, ICIPE

Figure 90: Adults whiteflies
Photo Credit: Pakagrifarming

Control:

- Keep eggplant fields free of weeds.
- Use yellow sticky traps to monitor their levels.
- Use water sprays.
- Avoid use of broad-spectrum insecticides since they reduce natural enemies.
- Use neem products to reduce populations.
- Spray thiacloprid (CALYPSO SC480®) for chemical control measures.

Common diseases

Bacterial wilt (Ralstonia solanacearum): The most important soil-borne disease is bacterial wilt causing the wilting of branches, followed by wilting of the whole plant. Its incidence can be reduced by good rotations.

Fruit rot (Phytophtora parasiticas): this causes rotting of fruits forming dark brown circular patches.

Verticillium wilt: (Verticillium albo-atrum)

Figure 91: Verticillium wilt

Verticillium wilt causes stunting and wilting of plants. Leaves turn yellow along the margins and later turn brown and wilt. A lengthwise cut of the infected stem shows dark-brown discoloration in the vascular tissue.

The recommended practices for controlling verticillium wilt are practicing crop rotation with non-solanaceous crops, using resistant varieties and soil sterilization.

Root-knot nematodes (Meloidogyne spp.): Root-knot nematodes are common soil pests that affect plants. They can provoke severe galling on the root system as well as withering, wilting and severe growth reduction of the aerial part of the plant.

Control: Plant disease resistant varieties when possible, and practice crop rotation and mixed cropping. Keep the garden clean from debris; diseased plants should be removed immediately before the disease spreads to healthy plants. Protect plants against soil borne disease by rotating crops. Do not plant eggplant families in the same location two seasons in a row.

Figure 92: Root-knot
Photo Credit: A.M Varela,icipe

Marketing and utilization

Eggplant fruit is usually picked when they are full, fresh and shiny. They are sold in vegetable markets.

Common farm tools and machinery in South Sudan

Machete
also called Panga

Axe

Sickle

East African hoe

Jembe or maloda,
the traditional hoe

Metal ox/donkey-drawn plough

Wooden ox-drawn plough

A tractor

Figure 93: Common farm tools

Common crop extension approaches, methods and institutions

There are many extensions approaches and methods used in South Sudan. Many of these are delivered jointly by extension workers from government ministries (Livestock and Fisheries, and the Ministry of Agriculture) and non-governmental organizations guided by the National Agriculture and Livestock Extension policy (NALEP) of South Sudan. The most common approaches in use are:

1. Training and Visit (T&V) System
2. Farmer Field School (FFS), Agro-Pastoralist Field School (APFS), Fisher Folk Field School (FFFS) Pastoralist Field School (PFS), Pastoralist Livelihood and Education Field School (PLEFS);
3. Group approach (extension group/production group/marketing group, etc.)
4. Outreach approach (with a whole range of methods like lead farmers/farmer promoters, demo plots, farmer field days, farmer demonstrations, mass awareness campaign and others)
5. Community-Based Approach (extension delivered by community-based extension workers)
6. Farmer-led extension approach (extension through lead farmers and collaboration between individual farmers)
7. Block farm model (blocks of often more than 100 farms having a central demo plot and being serviced by a community-based extension worker)

Common extension methods

Demonstrations

Farmers like to see how a new idea works, and what effect it can have on increasing their crop production. Both purposes can be achieved by means of a farm demonstration. A good, practical demonstration is an invaluable method in extension work. The demonstration is a particularly powerful method to use with farmers who do not read easily. A demonstration will give such farmers the opportunity to observe, firsthand, the differences between a recommended new crop practice and traditional practices. The strength of the demonstration should lie in its simplicity and its ability to present the farmers with concrete results.

There are two principal types of demonstration used by extension agents: method demonstration and result demonstration.

Method demonstration

Method demonstrations basically show farmers how to do something. In the method demonstration, the farmer is shown step-by-step how, for example, to plant seeds in line, to do weeding, etc. The agent will probably be dealing with farmers who have already accepted the practice being demonstrated, but who now want to know how to do it themselves.

The main advantage of the method demonstration is that the extension agent can explain simple farming skills to many people, thus increasing the impact of his extension work. Moreover, as farmers can participate, there is a greater chance that they will benefit from the demonstration than if they were passively hearing it in a lecture.

Result demonstration

The main purpose of a result demonstration is to show local farmers that a particular new recommendation is practicable under local conditions. Comparison is the important element in a result demonstration: comparison between line planting and broadcasting, between poor seed and selected seed, or between use of fertilizer and no fertilizer. "Seeing is believing" is an age-old expression, but one appropriate to a result demonstration. Until a farmer has seen the results of, for example, introduction of a new crop variety, he will not be convinced by the agent's recommendation. By showing tangible results of a new practice recommended by the extension service, the agent can help to create confidence among the farmers and can greatly encourage them to try the practice themselves.

A result demonstration is an ideal way to present to farmers a comparison between traditional and new practices. It can also help to establish confidence in more scientific farming methods and increase the farmers' confidence in ideas originating from research stations. It shows proof of the value of a new practice. A result demonstration is also a useful tool that an agent can use to establish confidence among farmers in a new area.

Field days

Field days are usually opportunities to hold method or result demonstrations on a slightly larger scale and are usually run in a more informal and less structured manner. The purpose is often to introduce a new idea and a new crop, and to stimulate the interest of as many farmers as possible. Experimental stations or other government centres may be used for field days, but it is more usual and profitable for them to be held on the land of a local farmer. There is a greater chance of making an impact if the field day is held on a farmer's land, and if the farmer plays a part in running it and explaining the purpose.

Tours

Farmers like to visit farms in other counties to see how they work, what they grow and what kinds of problems the farmers there are facing. A tour is a series of field demonstrations on different farms or at different centres, and it can often attract a lot of interest from local farmers. The tour should give local farmers a chance to see how other farmers cultivate their land, and to exchange ideas and experiences with them. It is important, therefore, that the area to be visited be in some way similar agriculturally to that of the visiting farmers.

Farmer Field Schools

The basic principle of Farmer Field Schools (FFS) is to provide an opportunity for farmers to test new varieties and methods under local conditions but without risking their food security. Extension options can be visualised as a continuum between very prescriptive top-down approaches, like a seed company demonstration plot, to farmer-led research and farmer-farmer approaches. FFS are extension-led or farmer-led, or something in between. Extension-led FFS are more top-down, with farmers following a syllabus designed by extension staff based on seasonal activities.

Farmer-led FFS are intended to help farmers run their own trials and research projects to develop solutions to their local problems, for example participatory variety selection trials. NGOs and governments tend to prefer Extension-led FFS as these provide greater control over the crops and methods taught; they also fit better with log frames and annual work plans.

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Common adaptation of approaches

As implementers gain experience from their field operations, they are seen to make efforts for improvements to their services by combining approaches and adapting them to suit local conditions. Following are some common such adaptations:

- FFS is commonly integrated with group & individual farmer's production plots.
- For broader targeting, it is common to use a mix of FFS and outreach approach.
- Most often, Village Savings and Loans Associations (VSLAs) are established within FFSs or other groups.
- Farmer group approach (extension groups & producer groups) is incorporating FFS participatory methods.

Examples of what has worked

Asked which extension approaches and methods have worked well in their projects, implementers' comments can be summarized as follows:

- FFS is considered a good entry point for empowering communities and creating the desired group cohesion that is so important for extension to succeed.
- FFS is a great stimulator for setting up structures for marketing as it promotes the establishment of networks with representatives from different FFS groups.
- A mix of outreach approaches and FFS is common and works well.
- There is extensive experience with fusion of FFS and VSLA which was promoted as the core approach under SORUDEV.
- Community-Based Approach with lead farmers works well as they become role models creating and strengthening community ownership of introduced technologies
- Block farm extension (with a central demo plot & a CBEW serving all farmers in a block) is a promising effective model considering one extension worker can cover a big number of farmers situated close together.

Challenges

Following are some of the challenges mentioned by implementers:

- All ESPs claim to use FFS and PFS, but this is often not properly done due to insufficient training of facilitators.
- The FFS approach needs very good facilitators – failure to get competent facilitators changes the approach as a curriculum cannot be followed.
- FFSs needs highly motivated farmers – possibly from already existing groups.
- FFSs ought to be discovery-based which is difficult to achieve with vulnerable groups who are often unable to focus on research as their minds are preoccupied with numerous problems affecting their families.
- FFSs cannot work where there are fresh conflicts and in areas where farmers are seasonally displaced by floods.
- The traditional FFS was found not relevant for the majority of the target group (SS agro-pastoralists) – but is now being adapted (broadened) to suit prevailing conditions.
- It is difficult to introduce demand-driven extension in communities suffering from dependency syndrome (a very big step).
- There is confusion concerning participatory approaches and methods to be used in extension – operational guidelines are available for FFS, PFS and PLEFS but not for the other commonly used extension approaches mentioned (e.g. group approach, outreach approach, community-based approach, farmer-led extension approach and block farm model).

Training institutions

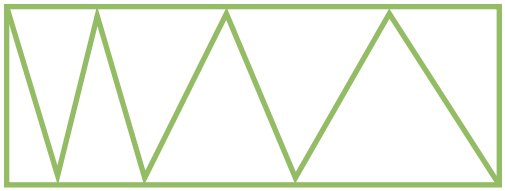
There are many institutions and centres of learning in South Sudan. In some of them courses on Animal Sciences and Livestock Management and related disciplines are offered leading to the award of Bachelors and Masters Degrees and PhDs in universities such as University of Upper Nile, University of Bahr el Gazal, University of Juba, Catholic University and the John Garang University of Science and Technology.

Summary of husbandry practices for the cultivation of all vegetables

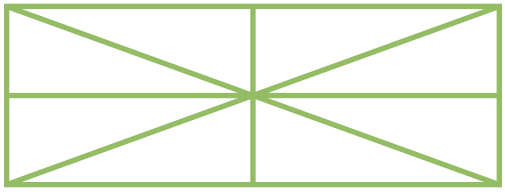
Select	Select a suitable site
Use	Use recommended varieties
Follow	Follow approved nursery practices
Ensure	Ensure proper land preparation
Apply	Apply the correct amount, right time, right place, right methods and type of fertiliser
Transplant	Transplant at the correct time and spacing
Control	Control weeds
Use	Use recommended pest control measures
Harvest	Harvest regularly and on time

Identify destructive pests quickly and take action. Scouting is a method for observing and identify pests once you notice infestation. Examples of sampling techniques include the zigzag, multi-bisectoral and 'W' patterns

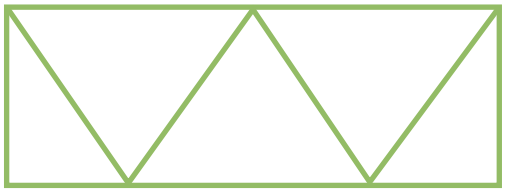
Figure 1. Examples of scouting patterns



Zigzag pattern



Multi-bisectoral pattern



W pattern

Fertilizers

A fertilizer is any material, organic or inorganic, natural or synthetic, which supplies one or more of the chemical elements essential for the plant growth. Fertilizers are applied to replace soil nutrients for proper plant growth to the soil after they have been depleted.

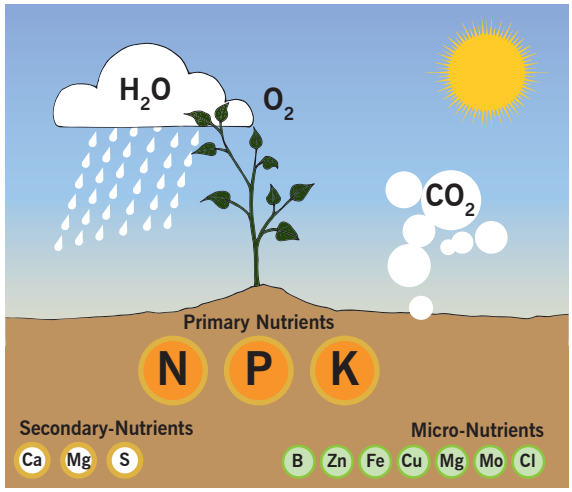


Figure 94: Soil nutrients

Aside from the three non-mineral essential nutrients (Hydrogen, Carbon and Oxygen) needed by plants, nutrients are classified as macronutrients and micronutrients. The macronutrients can be further divided into primary and secondary. The three basic primary nutrients are nitrogen, phosphorus and potassium. The secondary nutrients are magnesium, sulphur and calcium, which plants require in smaller quantities. The micro-nutrients are boron, manganese, zinc, copper, iron, chlorine, nickle and molybdenum.

Fertilizers are either organic or inorganic. Most organic fertilizers originate from animal manures – either from the faeces and urine of livestock animals or from the faeces of poultry, alone or mixed with bedding material (e.g., farmyard manure, cow dung and chicken litter). They are also made through composting and green manuring. Organic fertilizers increase the organic matter content of the soil, promote the reproduction of microorganisms and change the physical and chemical properties of the soil. Inorganic fertilizers are chemical fertilizers that contain nutrient elements for the growth of crops made by chemical means.

The primary purpose of fertilizer is not to feed the plant but to enable it to more readily absorb the nutrients present in the soil. A substance is considered as a fertilizer when it contains as least 5% in total of nitrogen, phosphorous, potassium, magnesium and/or sulphur in a form that promotes plant growth. Fertilizers work best when provided to growing plants at the time they need them using an appropriate method or technology.

When managing fertilizers, consider the following four “Rs”: Use the right amount of the right type of fertilizer at the right place and at the right time.

Nitrogen (N):
Nitrogen in fertilizers enhances the growth of the plants. Nitrogen is essential for plant cell growth and chlorophyll. It gives plants their green colour and is needed to form protein. All parts of a plant need nitrogen for growth—the roots, leaves, stems, flowers and fruits. A lack of nitrogen causes the lower leaves to turn yellow and the whole plant to turn pale green. On the other hand, too much nitrogen could make a plant only produce leaves, which is good for leafy vegetables, for instance, but could affect pod and seed formation in others. At high dosage nitrogen could even kill plants.

Phosphorus (P):
Phosphorus is needed for cell division and to help form roots, flowers and fruit. Phosphorus deficiency causes stunted growth and poor flowering and fruiting. Phosphorus must be dissolved in water to be taken up by plants. The phosphorus present in the fertilizers helps in the faster development of roots and formation of seeds in the plants.

Potassium (K):
Plants need potassium for many of the chemical processes that allow them to live and grow. A potassium shortage shows up in various ways, but stunted growth and yellowish lower leaves are common symptoms in many plants.

Magnesium (Mg):
Magnesium is absorbed as the Mg2+ ion and is mobile in plants, moving from the older to the younger leaves. Deficiency symptoms include slow growth and leaves turning pale yellow, sometimes just on the outer edges. New growth may be yellow with dark spots. To correct magnesium deficiency in soil, use dolomitic lime when lime is needed; use soluble sources of magnesium when lime is not needed. The most common soluble sources of magnesium to use as fertilizer are magnesium sulphate (containing 10% Mg and 14% S, also known as epsom salt), sulphate of potash magnesia (containing 11.2% Mg, 22% S, and 22% K2O, commercially sold as K-Mag), and magnesium oxide (containing 55% Mg, also known as magnesia).

Sulphur (S):
Sulphur is a secondary nutrient needed in fairly large quantities by most crops. It is an essential building block in chlorophyll development and protein synthesis. Symptoms of sulphur deficiency cause new growth to turn pale yellow with older growth staying green. Growth is stunted. The leaves appear pale green to yellow. The plants are spindly and small with retarded growth and delayed fruiting.

Other sources of sulphur are rainfall and fertilizers that contain sulphur. Some readily available sources include ammonium sulphate (21% N and 24% S), potassium sulphate (50% K_20 and 17.6% S), gypsum (32.6% CaO and 16.8% S), and zinc sulphate (36.4% Zn and 17.8% S).

Calcium (Ca):

Calcium is a secondary plant nutrient. Calcium is essential for plant growth and needed in large quantities. It normally exists in the soil and is taken in by plants through transpiration. The primary function of calcium in plant growth is to provide structural support to cell walls. Soluble calcium is available as the Ca2+ ion. It is needed for peanuts at pegging time and for peppers and tomatoes to prevent blossom end rot. Deficiency symptoms are new leaves that are distorted or hook shaped; the growing tip may die. When calcium is deficient, new tissue such as root tips, young leaves and shoot tips often exhibit distorted growth from improper cell wall formation. Blossom end rot of tomatoes is a classic case of calcium deficiency. Without proper levels of calcium, the shelf life of fruits such as cantaloupes and tomatoes can be reduced significantly.

Soil pH

The pH of a soil refers to how acidic or alkaline the soil is. The letters “pH” mean “potential hydrogen.” The availability of nutrients is directly affected by soil pH. If the soil’s pH is too high or too low, some nutrients become insoluble, limiting the availability of these nutrients to the plant root system.

Figure 95: pH Test Strips

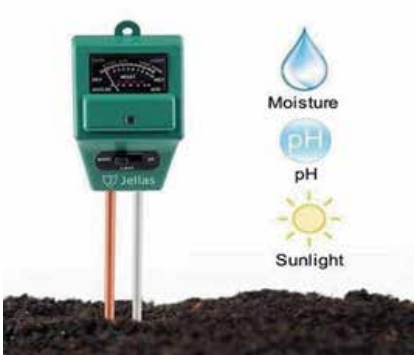
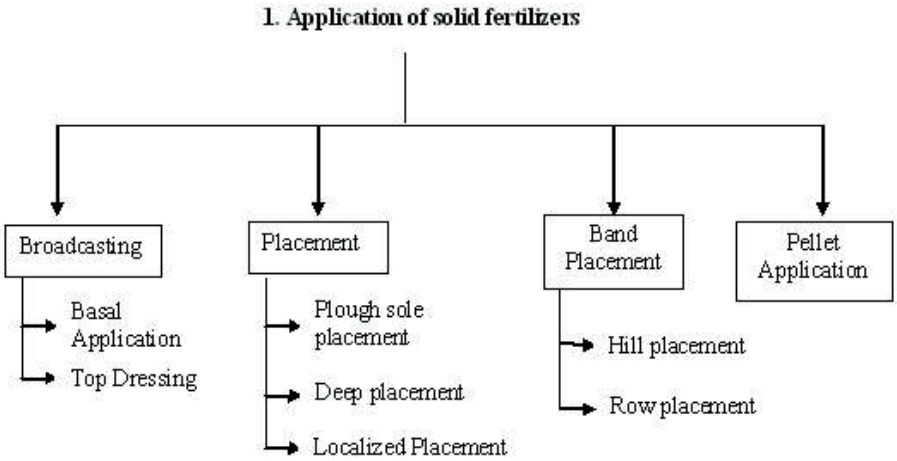


Figure 96: pH Test Meter

The acidity-alkalinity scale ranges from 0 to 14. Soils are referred to as being acid, neutral or alkaline, depending on their pH levels. A pH of 7 is neutral, while a pH lower than 7 is acidic, and a pH higher than 7 is alkaline (basic).

Application of fertilizers

Fertilizers can be applied using the following methods depending on whether it is in a solid or liquid form.



Organic fertilizers

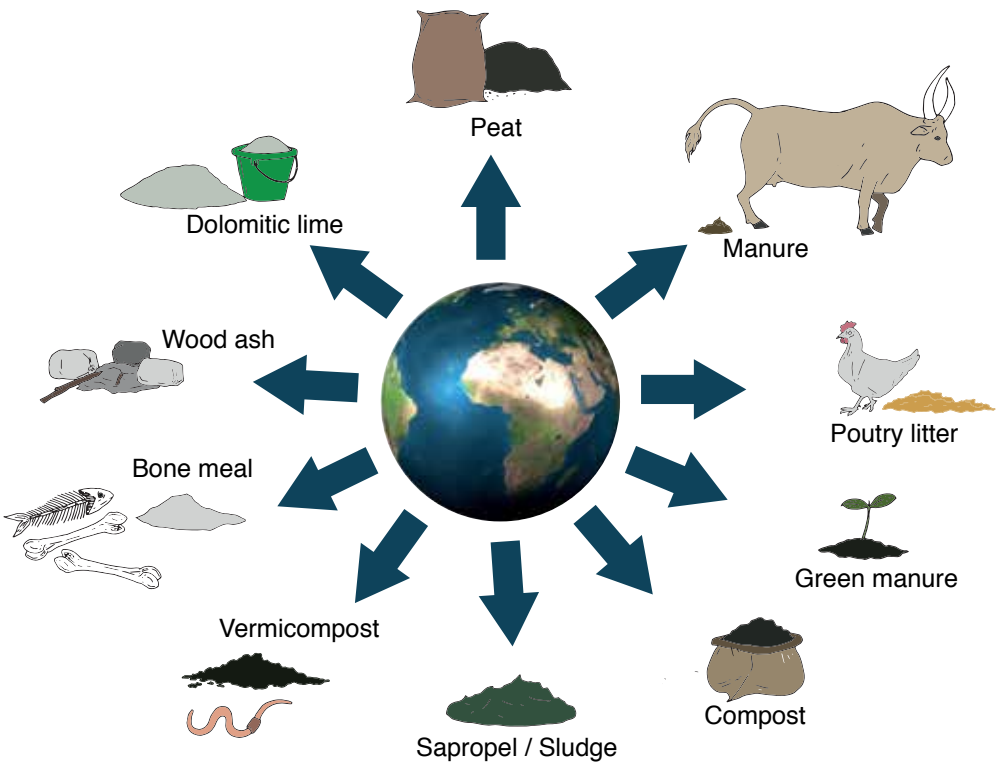


Figure 97: Sources of Organic fertilizer

Suggested outline for training by extension agents

Topic:
Clearly state the topic you intend to cover during this session.

Objectives:
Start with "at the end of the topic, the trainees should be able to…" and list what you want them to have learned by the end of the session.

Facilitation method:
State here the type of facilitation method you intend to use. There are many methods, so be specific and chose the method that is most effective (this is not limited to lectures, demonstrations, field work or role playing). Remember that you could use a combination of methods.

Duration:
State the time required to carry out the training. Remember to be brief and precise and not to waste the participants' time. They may lose interest if the training takes too long, and you should not rush your lectures due to limited time. Pick an appropriate time for training. Remember that your trainees will usually be adults, who have competing needs for their time so be sure to be creative, get straight to the point and make your points clearly.

Materials for training:
List all the required materials, training aids and possible equipment to be used in the training. Be sure to use illustrations as much as you can, especially if your trainees are without formal education.

Content:
List the specific concepts and knowledge that will be part of the training (such as common diseases of sheep and goats).

Resources:
State the sources of the information you are delivering. This is useful to provide further reading for the trainees as well as a reference. Resources can include technical guides (such as this one), textbooks and other publications.

Organic fertilizer

How to make good compost

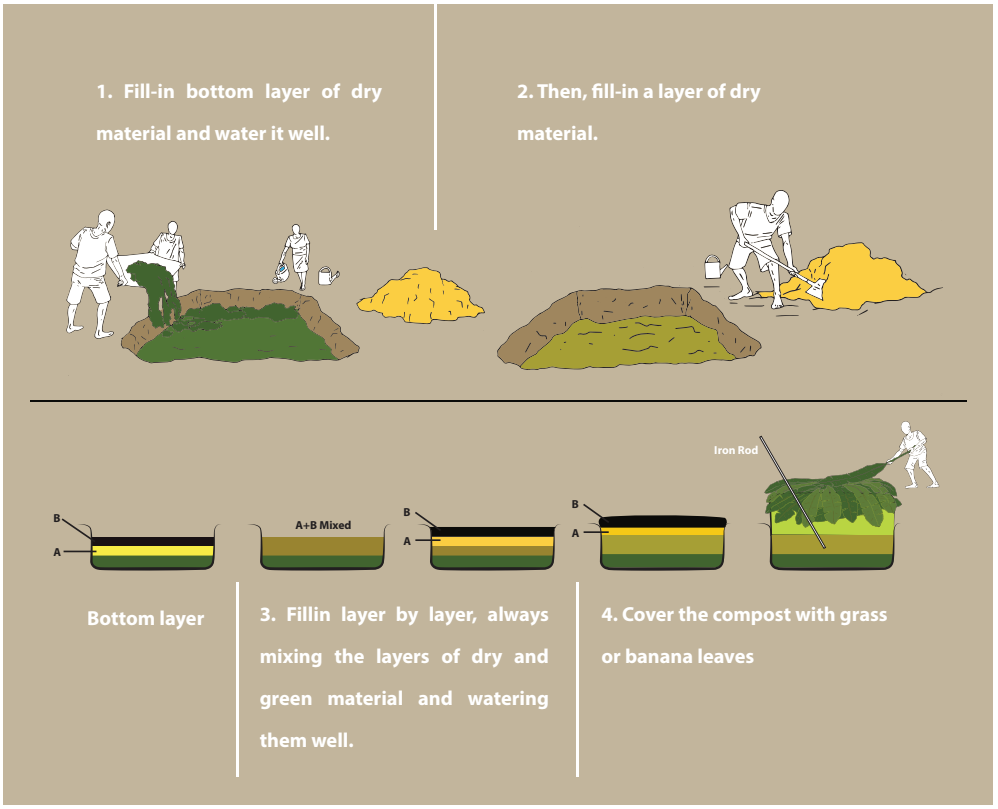


Figure 98: Steps in making good compost

Composting is the process of transforming fresh organic matter (animal manure, food wastes, green wastes, agricultural residues, etc.) into stable humus-like substances. Composting is carried out by microorganisms (bacteria and fungi). The microorganisms degrade organic matter to produce carbon dioxide, water and energy.

Importance of compost in soil and plant growing media

1. Adds to the amount and type of nutrients in the soil.
2. Increases organic matter content.
3. Improves soil structure which decreases soil density and increases permeability of water, air content and water storage.

To make compost, materials are heaped together as described in the illustration above to maximize the biological activity. As bacteria multiply and feed on the material, they respire and generate heat. This heat encourages growth of more bacteria which causes the bacteria population to grow and decomposes the materials. The heat can also kill weed seeds and human pathogens. Compost can be completed in 3 weeks to 3 months, depending on the materials used.

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