Good Quality Seed Production Guide

for smallholder farmers

A Field Guide for Extension Workers in South Sudan

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Prepared by Omotayo Daud' Alabi

Agriculture Extension Specialist at the Technical Assistance (TA) for Increased Agriculture Production of Smallholders in South Sudan implemented by AESA with funding from the European Union.

Illustrations & layout by Steve Gitonga

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Foreword

Food and nutrition security and poverty reduction are a priority of our government. The Ministry of Agriculture and Food Security and the Ministry of Livestock and Fisheries are mandated to ensure that the people of South Sudan produce sufficient food to feed themselves and to export.

We have developed the National Agriculture Livestock Extension Policy (NALEP) and the Comprehensive Agriculture Master Plan (CAMP) through which many projects will be implemented across the country.

The Ministries at national and state levels are challenged by limited resources and weak capacity of community based extension workers, particularly at the county and payam levels, even though these are the staff that meet and advise our farmers on a daily basis. Increased production and productivity issues are crucial if we are going to ensure that crop farming and livestock rearing, on which our smallholder farmers and families depend, is improved. Input availability and advisory services are core to achieving this objective.

We highly value and appreciate the support and efforts made by our development partners and the UN agencies, particularly the support from the European Union to develop this extension guide to be used by our extension workers in the country.

The process of developing this guide was rigorous, and the facilitation was thorough. I am assured that just as the earlier three guides (crops, livestock and general guidelines) were written, this guide on seed production is composed in a language that will be understood by our extension staff and experts in seed production in different agricultural zones of the country. This is a very useful resource to move forward our commitment to extension and advisory services.

I am delighted that this booklet will now be used across the country.

Hon. Onyoti Adigo Nyikwec
Honourable Minister of Agriculture and Food Security
The Republic of South Sudan

Preface

This guide is the fourth in the series of extension guides produced for agricultural extension workers to support production and productivity of the South Sudanese farmers. It is produced for the use of extension staff and seed producers in the country. Due to the level of technical information and detailed explanation of terms and processes involved in seed production, we believe it is a very useful handbook and reference material from which simpler materials for community training can be drawn.

This booklet was reviewed extensively by the Ministry of Agriculture experts in research, crops and seed; development partners, NGOs and UN agencies including the Agricultural Technical Working Group of the Food Security Cluster; and academic scholars. Throughout this period, the material was pretested in many communities, and at each review stage we checked and improved on the gaps, clarity, accuracy and the relevance of the content.

The technical information in this booklet is from the experience of South Sudanese farmers, extension staff and development partners implementing food security projects. Additional information was sourced from materials developed by the government, NGOs, FAO, UNIDO and academic, research and agricultural training institutions across Africa, especially from the East African subregion.

The European Union through the South Sudan Rural Development (SORUDEV) Programme funded and facilitated the production of this booklet.

'Tayo Alabi

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Abbreviations

Abbreviation	Meaning
°C	Degrees Celsius
EUD	European Union Delegation
FAO	Food and Agriculture Organization
FEWS NET	Famine Early Warning Systems Network
HESSREP	Harmonised East African Seed Standards, Regulations and Procedures
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITA	International Institute for Tropical Agriculture
ISTA	International Seed Testing Association
DNA	Deoxyribonucleic acid
KM	Kilometres
REC	Africa's Regional Economic Communities
mm	Millimetres
GMO	Genetically Modified Organism
MT	Metric Ton
N P K	Nitrogen Phosphorus Potassium
Pp	Plant Population
NGO	Non-Governmental Organization
MAFS	Ministry of Agriculture and Food Security
OPV	Open Pollinated Variety
UNIDO	United Nation Industrial Development Organization
WVI	World Vision International

Measurements used

1 hectare = 2.47105 acres
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

Introduction

Geography, climate and livelihoods of South Sudan

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. The vast majority of people live in the rural areas. The common farming system is split in two broad categories: (1) pastoralist and (2) agro-pastoralist. 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. Pastoralist communities refer to the population 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.

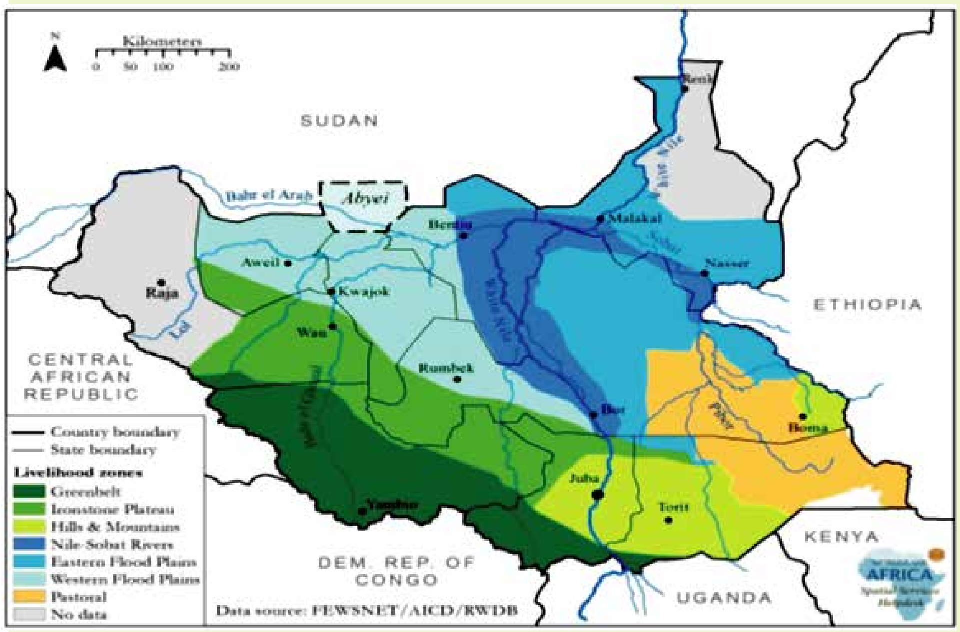


Figure 1: Agro-ecological zones of South Sudan. Source: FEWS NET, accessed 2018.

The agro-ecological zones and the old states which constitute them 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).

Figure 2: South Sudan livelihoods zones. Source: FEWS NET, accessed 2018

Most farming activities are at subsistence and small holding level, and are mostly rain fed, with approximately 78% of households reliant upon crop farming and animal husbandry as their main source of livelihood. Out of the total land mass of 644,329 km2, more than half is estimated to be arable.

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. The northern areas are dryer and experience more frequent drought, while there is abundant annual precipitation in the south and southwest areas (Fig. 3). Served by many tributaries, the White Nile River is the main source of fresh water and an important source of water for the Sudd Wet Land. 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.

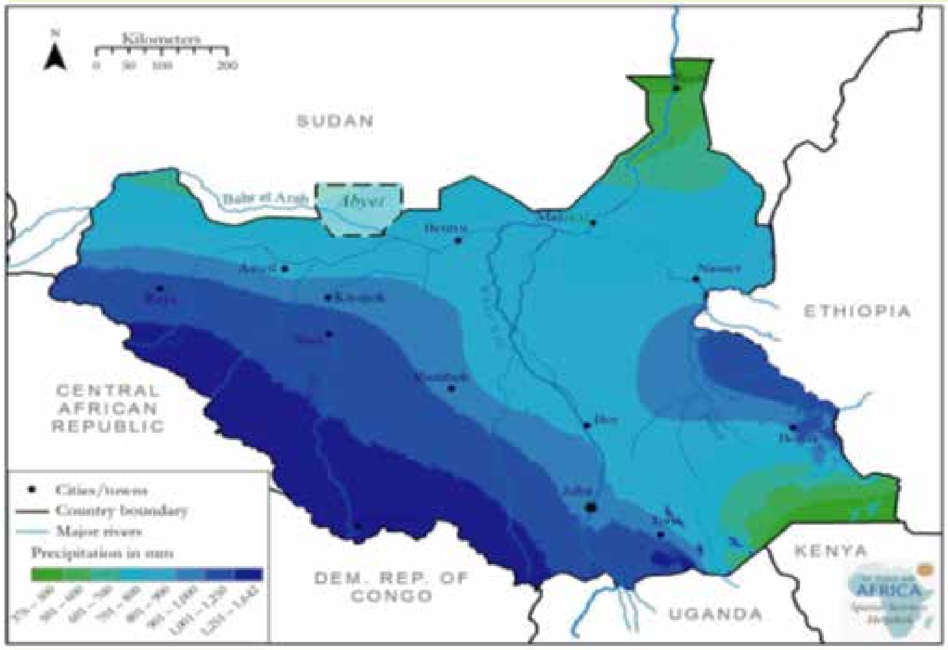


Figure 3: Annual rainfall distribution map of South Sudan. Source: World Bank 2013: The Rapid Water Sector Needs Assessment and a Way Forward

The rainfall pattern along the agro-ecological zones influences the crop grown and the operation timings of different agronomic practices undertaken by farmers. Figure 4 illustrates a typical seasonal calendar for cropping operations across the agro-ecological zones. 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.

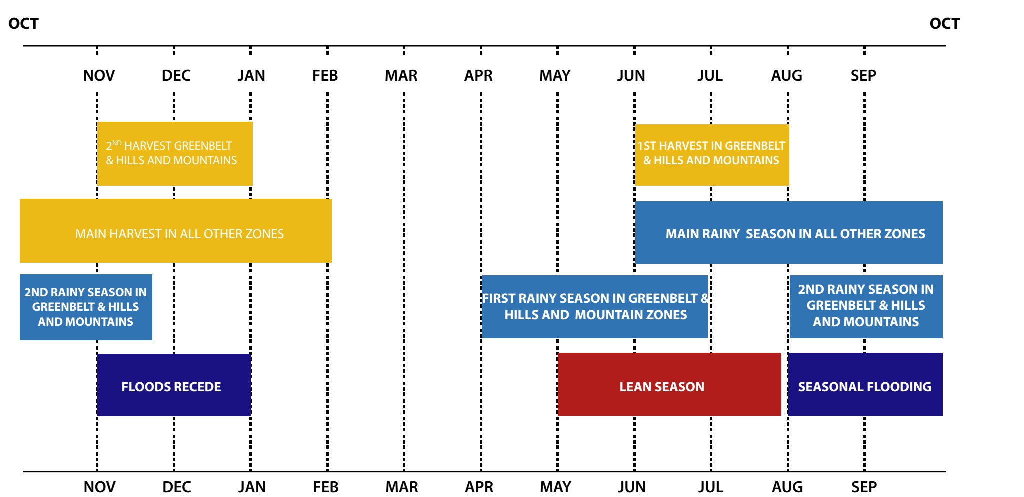


Figure 4: South Sudan typical seasonal calendar across agro-ecological zones. Source: FEWS NET, accessed July 2018.

The seed situation in South Sudan

The South Sudan land mass of 644,329 km2 is massive. The country is bordered by six countries with very close affinity and cultural linkages. The countries bordering the Republic of South Sudan are Sudan, Ethiopia, Kenya, Uganda, Democratic Republic of Congo and Central African Republic. The borders are long and largely unmanned which allows free movement of people, and as a result it is not unusual to find different varieties of seeds indigenous to a group of people moving freely from neighbouring countries into South Sudan. All of these add to the confusion faced by farmers in selecting appropriate seeds and accessing the right type, quantity and quality of seeds. Development partners (NGOs and international organizations) working in seed production also assist in procuring and moving seeds within the country or from across the border for cultivation by smallholder farmers.

As most of the seeds sown by farmers in South Sudan are from traditional sources the imported seeds from neighbouring East African countries such as Uganda, Ethiopia, Kenya and Sudan augment the seed stock. However, the majority of the seeds imported from the same region may not be entirely suited to the specific agro-ecologies of South Sudan. Notwithstanding, some of the imported seeds have been used over time and are now trusted by farmers. For many of the imported seeds there are complaints of loss of viability, low vigour and outright failure by the time they reach the farmers. Despite this, many of the seed stocks and references to varieties of seeds that are used in this manual are from the old Sudan and from the neighbouring countries.

Currently, less than 10% of available land is under cultivation, therefore the potential for investment and return on agricultural investments for all South Sudanese (and investors) is massive given the varied agro-ecological zones and rainfall pattern. The minimal level of cultivation and low crop productivity are attributed in part to inadequate farming knowledge, low uptake up of technology, inadequate farm inputs such as farm machinery and tools, limited extension services and lack of access to good quality seed.

Specific challenges in accessing quality seed include lack of distinction between seeds, grains or pulses, as well as an absence of a formal seed system, with the popular traditional seed system being largely uncoordinated. Additionally, despite seed being the most important input of any crop production system, the seed stock grown by farmers in South Sudan is lacking in quality and not necessarily the most improved. Some of the seeds are either wild traditional varieties (heirloom) or very old open pollinated variety stocks which were released over twenty years ago. However, as these varieties have been planted continually over many seasons and over a long period of time, the genetic characteristics of the seeds could be eroding. Therefore, seed is among the first considerations toward ensuring food security for conflict affected farmers or small holder farmers and rural populations of South Sudan.

This guide on certified seed production techniques provides information and simple explanations of basic methods to increase the understanding and skills needed for producing good and certified quality seeds for smallholder farmers. It is primarily intended for use by front line crop extensionists and seed producers in South Sudan.

Government policies on seed production in South Sudan

Current legislation on seed production

Seed production, seed certification and formal seed marketing at scale are only just beginning in South Sudan. Though plant breeding and adaptive research are ongoing by the Ministry of Agriculture and a few NGOs such as World Vision and AGRA, the agricultural research institutes including the National Research Institute are weak due to absence of funding, lack of required manpower, low motivation, derelict physical infrastructure and general prevailing insecurity across the country. In addition to this, there are a limited number of reputable private seed producers and companies.

To address these issues, the Republic of South Sudan is in the process of approving a National Seed Bill. The draft produced in 2012, revised in 2013, is currently awaiting approval. The bill integrates the Harmonised East African Seed Standards, Regulations and Procedures (HESSREP). HESSREP contains a comprehensive framework for development of the seed sector, and is part of the legal and regulatory reform in the region. It is also a significant component in the harmonization of standards created by Africa's Regional Economic Communities (REC). When in operation, the bill will lay the laws and regulations for governing seed systems in the country. The department of research in the National Ministry of Agriculture and Food Security is responsible for regulating seed production in the country.

Seed certification

Certification is an important part of an approval process of seed production particularly in the formal seed system. It is a little less essential in the traditional seed system, but even there peer approval and recommendation of high performing seeds are often sought by farmers. Seed certification is a quality assurance (in the form of a certificate) given after a seed lot is inspected, graded and tested by an authorized body. For seed certification to be granted, there is a long set of required protocols including farm inspections by staff from the inspecting agency at specific intervals throughout the production cycle, from processing to bagging. In most countries these certificates are issued by the responsible government institutions. The certificate is a guarantee that seeds are true to type, free of contaminations, high in purity, high in germination, high in vigour and are largely pest and disease free. The seed certification process provides seed producers a seal of approval for high quality seed production while at the same time assures buyers of quality seeds for planting, which is the first step toward improved yield and increased profit.

Seed inspectors and supervisors

The process of seed certification can be divided into the following four phases: Verification of seed source; field inspections; sampling and testing of processed seed; tagging and sealing of seed containers.

Seed inspectors are usually from government institutions like the Ministry of Agriculture and Food Security, Research institutes and/or seed certification boards. Increasingly, private seed producing companies have trained and equipped their seed inspectors to work with and monitor seed producer farmers. On some occasions these inspectors are referred to as seed extension specialist, with certified specialisation as an agronomist or crop production, being trained in seed handling and inspection. Seed inspectors work under the supervision of seed supervisors, and their role as seed inspectors is to ensure compliance to all agreed seed production protocols. They are expected to report on crop growth and progress as they work with the farmers through the seed production stages: pre-planting, sowing, flowering, pre-harvest, harvesting and post-harvest. In some cases seed inspectors are mainly involved at receiving centres where they accept or reject seed consignments brought in by farmers. Field production records from seed producers must meet quality specifications of both the company and government certifying agency.

There are a number of government infrastructures supporting seed research in the country. Under the Ministry of Agriculture and Food Security are:

1. Yei Basic Research Centre and Seed Laboratory
2. Palotaka Basic Seed Centre and Seed Processor
3. Halima Research Station and Seed Laboratory
4. Wau Soil Laboratory

These centres are currently under rehabilitation. When completed they, along with the University of Juba, will be designated centres for research and training for seed inspectors and supervisors.

Role of extension agents in good quality seed production

The primary role of extension agents in the production of good quality seeds is advisory. Unlike formal systems, farmers within the informal system of seed production rarely follow strict protocols required for producing good quality seeds. This is because the informal seed system does not require that seed produced follows a strict certification process which is often controlled by the government.

Since seed is an essential input for increased production and productivity, if all agronomic practices are followed (along with sowing of good quality seeds), chances are that yield will be better, food stock at the household level will increase and income from sales of surplus produce will provide the needed cash for the farming household.

As a result, the effectiveness of the visitations and advisory messages passed to farmers by the frontline extension agents is crucial. In facilitating two-way communication where information is given and feedback is received or physically observed, face-to-face interaction with seed producing farmers has been found to be useful to increase the rate of compliance and adoption of improved agronomic practices. Methods such as demonstrations plots, farmer field schools and farmer-led approaches are encouraged. These allow for extension worker observations, side by side evaluations of practices, trial of new varieties and opportunities for learning by doing. These methods and approaches are very commonly utilized as a means of passing information, building capacity and advising farmers. There are inherent challenges of poor communication, bad access to most of the farms, low number of extension staff to farmers and low incentives to extension workers. All of these could be overcome through proper extension management and a national agriculture development programme.

In many instances, the extension agents also help to ensure that the quality of seeds produced is good and acceptable based on seed purity. This helps farmers in the informal system transition into the formal seed systems where they can be part of a seed production group or individually become contract seed farmers.

The 'Quality Declared Seed' system

Quality Declared Seed (QDS) refers to a form of quality assurance that was created to reduce the burden of rigorous conventional seed certification, while retaining the basic characteristics of external quality assurance. It thereby increases access to quality seed for smallholder farmers. An obvious advantage of QDS compared to self-control is the introduction of a truly external quality assurance mechanism that provides a clear incentive for seed producers to be rigorous and methodical about the quality control of their seed.

The process of certifying seeds may be laborious and hard to achieve in situations of conflict and fragility. Often these situations present periods of diminished infrastructure and limited human expertise, yet the vast majority of people caught in the conflict zones or emerging from the conflict are farmers who require seeds for planting because they obtain most of their sustenance and livelihood from farming.

To improve the quality of seed being offered for sale in countries where human and physical resources for quality control are limited, FAO has introduced the Quality Declared Seed system which makes use of resources already available in seed production organizations. The system is designed to provide quality control during seed production which is less demanding on government resources than seed certification, but is adequate to provide good quality seed both within countries and in international trade. Part I of Quality Declared Seed outlines the general guidelines applicable to all crop species. Part II deals with guidelines on individual crop species by category: cereals, food legumes, oil crops, forage crops (both grasses and legumes), industrial crops and vegetable crops. Annex IV of this manual presents a guiding note from World Vision's experience in South Sudan with relevant examples in the East African subregion.

Infrastructural needs for seed production systems

Whether in a formal or semi-formal seed production system there is a need for proper planning and a well thought out process. The creation and establishment of proper facilities to handle seed is essential in setting up a proper seed system. The requisite facilities must receive priority attention such as:

- An organization with sufficient technical expertise, administrative freedom, management efficiency and adequate funding.
- Access to modern harvesting and threshing equipment. This should include processing plants with seed drying capability, adequate covered space for labour saving features and capacity to match production targets.
- Modern seed testing laboratories.
- Seed stores designed to keep ambient humidity and temperature within safe seed storage limits.
- Modest foundation seed farms.
- Dependable transport for seed movement.
- Seed technology research support.
- Capacity, knowledge and on farm infrastructure to cope with involvement of contract seed growers in producing quality seeds at an economic cost.
- Elaborate seed market network.

Seed and planting material production protocol

The seed production process or protocol starts with proper identification of the seeds bearing a clear scientific name, the origin of the seed distribution and the description of how it was produced. The protocol for the production of planting materials, including seeds from a clean planting material source, should include the following:

- Field facilities and equipment
- Source of material, including positive selection
- Field requirement
- Field inspection
- Agronomic practices such as isolation, rotation and negative selection
- Harvesting and handling
- Post-harvest treatments
- Storage and transport
- Quality standards for the supplied product

Stages for seed field inspection

Seed inspection is needed to ensure that field standard dedicated to seed production include site selection, isolation, requirements, spacing, planting ratio, border rows, access, agro climatic information of the area including related plant health issues. It is suggested that field inspection is planned properly and scheduled to take place at the following stages of crop growth: Pre flowering, Flowering, Post flowering, Pre harvest, and harvesting stages:

Pre flowering stage to verify if planting seeds are from an approved source and planted according to instruction such as planting ratio, verify isolation distance and advise on timely action, and to guide seed growers on off-type plants, pollen shedders, shedding tassels, diseased plants, weed plants timely removal and establish frequency of roguing and review with the seed grower the prescribed standards and their application.

Flowering stage, this should be carried out when more than 50% plants are flowering. At this stage review the actions of pre flowering stage, check the effectiveness of roguing, very isolation distance for acceptance or rejection, verify if recommended agronomic practices are been followed and caution the seed grower if crop is liable for rejection.

Post flowering stage, is the stage to verify the effectiveness of roguing, isolation and general condition of the crop. In the case of self-pollinated crop facing rejection, the inspector should request permission for re-inspection from farmer if explain to the seed grower the need for her/him to pay special attention to save the seed field from rejection.

Pre harvest stage: at this point the inspector should look out for those factors and development in the field that were not apparent earlier, verify varietal purity, instruct growers on rouging based on ear, seed, chaff characters such as colour, shape, size and maturity; guide farmers on the correct method of harvesting, sorting, drying and threshing. Discuss arrangements put in place for drying and processing; and estimate yield from the seed field.

Harvesting stage: the inspector should verify if crop from any rejected area has been adequately separated. Verify particularly in the case of hybrids seed production, if the male rows have been removed from the field.

Much as joint planning and participatory assessment by seed inspector/seed extension personnel and the farmer is encouraged, however, field inspection meant to verify those factors which can cause irreversible damage to the genetical purity or seed health should be conducted without prior notice to the seed producer. In all cases, field inspection report and feedback should be shared with the seed producer.

Attributes of good quality and certified seed

Using good quality and certified seed at all times is very important. In farming, seed is a critical input to enhance production and productivity. Seed is the first input required for crop farming. When good quality seeds are planted, chances are that yield will be higher. Evidence and experience from farmers have shown that planting good quality seed has many advantages including:

- Good quality seed can increase yield significantly and in some cases could double yield. If yield is increased significantly, there will be more food, and farmers will make more money from selling surplus.
- Good quality seed reduces the amount of weeds on the farm.
- With good quality seeds farmers are more likely to have uniform crops growing together which makes it easier for farmers to undertake other cultural practices such as thinning, weeding, fertilizer application, harvesting and many more.
- Good quality seed also protect the farmer from crop diseases. This is possible because some diseases are introduced by seeds that are already infected. Planting such seeds exposes farmers to introduced seed-borne diseases.
- Planting good quality seeds makes economic sense because the seeds will germinate and have the vigour to succeed. It is a waste of time and valuable resources including family labour for farmers to clear land, prepare it and sow seeds that have very low germination rates or fail to germinate at all.

Distinction between seeds and grains

A grain is a small edible fruit, usually hard on the outside, harvested from grassy crops. Grains grow in a cluster on top of a mature grass plant such as maize, corn, wheat, oats, rice and barley. Because grains are generally grown by many farmers at varying scales, they are considered staple crops, which are the number one energy providers worldwide. It is important to understand that nearly all plants possess a means of regeneration. They all have propagation means such as seeds and other planting materials.

In this guide, the word seed is used to specify quality seeds used for planting that have the ability to grow into a full plant naturally or as nurtured by the grower. It is important also to note that though many seeds, grains or nuts will germinate when planted, they may not necessarily grow into what a farmer wants or may not necessarily lead to good yield.

Table 1:
Summary of differences between grains and seeds

Grains for consumption	Seeds for planting
A grain is a fusion of the seed coat and the fruit	A seed is an ovule containing an embryo
Grains are harvested for food	Seeds are planted to grow plants
Grains provide food from the fruit part	Seeds mainly provide food from embryo parts
Grains require no specific temperature	Seeds must be kept at a specific temperature which will allow them germinate and grow
A grain can still be eaten when the embryo is dead	A seed will not germinate if planted when the embryo is dead
A grain need not be viable and cannot be sown as seed by farmers	A seed must be viable, vigorous and should be physically and genetically pure
A grain usually needs no certification for consumption	A seed must have passed through quality checks and be certified
A grain should never be coated with fungicides or any chemical	A seed should be coated with seed dressing chemicals such as fungicides to protect it from pests
Grains should never be converted to seeds	Seeds can be converted to grains and consumed provided they are not coated with poisonous chemicals
Knowing a grain pedigree is not necessary	The pedigree of seeds are very essential to trace their initial breeder seeds

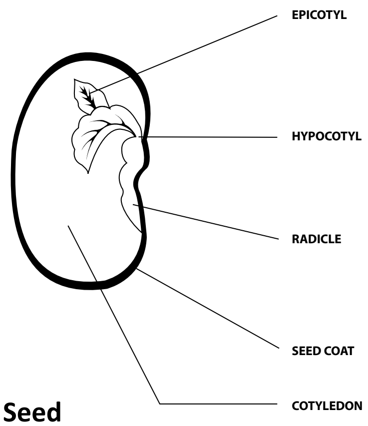
For example, most of the imported popcorn grain sold in our local supermarkets will not germinate if planted because they have been exposed to conditions that make their embryo completely dormant or dead. Yet we make lovely fluffy popcorn from them. This illustrates that they are useful as a grain for consumption, but not seed for planting. In contrast, many of the vegetable seeds marketed are in vacuum sealed packets to properly preserve them so that they can be sown to produce a crop.

Other planting materials

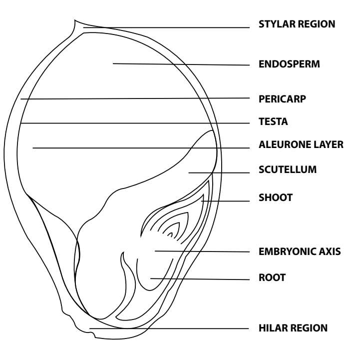
As mentioned above, a seed is usually planted to produce another plant. However, seeds are not the only materials from which other plants grow. Examples of other planting materials produced through asexual or vegetative propagation methods are from growing parts of an already growing plant or crop. These are called vegetative parts. Examples of vegetative parts are stem cuttings, vines, roots, stalks, leaves, buds, tubers, corms, rhizomes, bulbs and others. Examples of crops that are vegetatively propagated are: potato, sweet potato, yam, cassava, sugar cane and cocoyam.

Pollination and fertilization

A seed is defined as an embryonic plant covered in a seed coat, often containing some food. It is formed from the ripened ovule of plants after fertilization. The embryo grows from the zygote while the seed coat grows from the ovule rind. Figure 5 illustrates the parts of a dissected seed.



Cowpea Seed



Sorghum Seed

Figure 5:
Cross-section Illustration of seed parts.

In sexually reproducing plants, seed formation begins with the growth of flowers, followed by pollination and fertilization. The flower is the sexual reproduction organ in plants, and consists of both male and female reproduction organs of the plant. The male parts of the flower are called the stamens, which consists of anthers held up by filaments. Pollen grains, which are the male sex cells, are produced in the anthers. Female sex cells are produced in ovaries, which are contained in the ovule. The stigma collects the pollen grains for the fertilization. Fertilization can take place through cross-pollination or through self-pollination.

Brightly coloured petals and nectar attract insects to the flower in order to enhance the pollination. In cross-pollination an agent such as an insect and wind are important in moving pollen grains from one plant to the stigma of the other. Self-pollination, on the other hand, refers to a type of pollination wherein the pollen from the anther is transferred to the stigma of its own flower. Flowers that carry out self-pollination are hermaphrodites. Self-pollinating plants have smaller flowers that are unscented. Examples of plants produced through self-pollinating include wheat, barley, oats, rice, tomatoes and potatoes.

The main difference between pollination and fertilization is that pollination is the deposition of pollen grains from the anther to a stigma of a flower whereas fertilization is the fusion of the haploid gametes, forming a diploid zygote. In breeding, fertilization could be assisted or carried out by scientists through a process known as mastication.

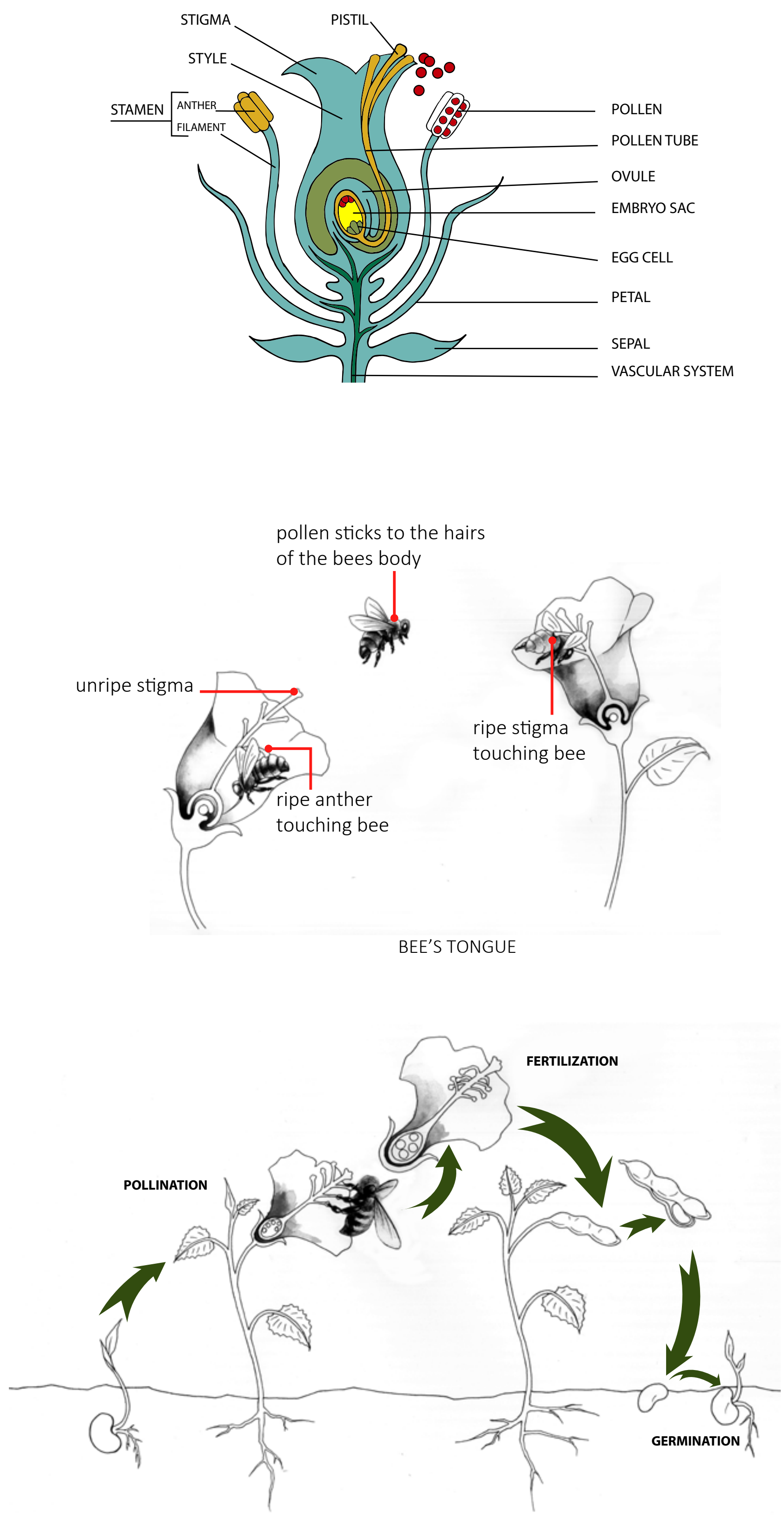


Figure 6:
Illustration of pollination and fertilization of plants.

In their natural setting, traditional or wild plant varieties are pollinated through natural agents such as wind or insects. From the pollination activities, male and female parts of the plants cross, fertilise and produce fruits, grain heads, cobs, etc., from which we derive seeds. In nature not all seeds are collected and planted by humans because the natural cycle encourages fruits to drop when they are mature (e.g. windblown tree branches that drop fruit).

The fallen fruits rot, and over time the seeds in them germinate when the conditions are conducive for growth, with adequate moisture and heat.

For instance, in many parts of South Sudan, this is still the case with mangoes and neem trees. Other pollination agents include birds, water and mammals such as primates, bats and rodents.

Examples of self-pollinated crops are: rice, wheat, barley, pea, cowpea, groundnut, tomato, soya bean.

Examples of common cross-pollinated crops are: maize, millet, okra, alfalfa, cabbage, cauliflower, amaranth, onion, carrots, radish, and watermelon.

Examples of crops that are often self but could also be cross-pollinated are: sorghum, cotton, green gram, egg plant and pepper.

Common sources of seeds

The common practice among subsistence and smallholder farmers in South Sudan is to access seeds through the following ways:

1. Own seeds, usually from the seeds they store from their harvest.
2. Gift from other farmers and relatives including trade by barter.
3. Seed fairs, which is a type of recollection system.
4. Purchase from agro dealers and open markets, especially for vegetable seeds.
5. Zakat, an obligatory alms giving system to the poor and needy amongst Muslims.

Type of seed

Generally, there are three types of seed, namely breeder, foundation and certified seed.

Breeder seeds

These are new varieties of seeds which are the result of breeders' efforts in crossing varieties with specific and desirable qualities. Breeder seeds are carefully produced by highly skilled scientists in a controlled environment usually in research institutions, education centres or specialised seed companies. As a result, breeder seeds have the highest genetic purity level (100%). Breeder seeds are expected to be pure and match the breeder's description in terms of character and identity. Every commercially produced seed batch should be traceable to the breeder seeds. Breeder seeds are usually registered when released by the Variety Release Committee, research institute or by a government approved breeding programme.

Foundation seeds

Foundation seeds are the direct result obtained by growing breeder seeds. Foundations seeds are certified seeds often produced under the supervision and control of the breeder or releasing institution.

Certified seeds

Certified seeds are produced from the breeder and foundation seeds having followed a set of strict seed production protocols and supervised by seed inspectors. The protocols are established by the releasing institutions or government agencies responsible for seed release in the country. For seeds to be accepted as certified, they must have high germination percentage and vigour, be very clean and maintain the genetic purity and identity of the variety as described by the breeder. These are the seeds primarily planted by large scale farmers and increasingly demanded by small holder farmers.

Types of seed varieties

There are also different seed varieties, most of which are from plants growing in the wild and identified through natural selection, or which could be a product of the breeding in the lab, experimental fields, research plots or farmers' fields. Seed varieties are categorised broadly as land races, open pollinated, hybrid, F1 hybrid and biologically modified seeds

Land races (traditional varieties)

Land races are seed varieties that are indigenous to many locations and areas. They are often indigenous to zones or regions in which they are used. In South Sudan, there are many sorghum varieties believed to be wild and indigenous as the origin of Sorghum is partly traced to this region. Land races could also be improved seed varieties that were introduced many years ago, that have completely adapted to the local environment and for which many generation of farmers may not remember when they were first released. In most cases these seeds are often called by local names and have local characteristics to the extent that farmers trust and are often attached to them. These are also called farmers' seeds. Many of the traditional seed varieties depend on natural selection in the fields. Here farmers look for desirable qualities which could include vigour of growth, colour, disease free or tolerant, speed of growth and whether they are pest free or tolerant to pest attack.

Open Pollinated Varieties (OPVs)

These are varieties of seeds produced by controlled natural processes through pollinating agents such as wind, birds or insects. With open pollinated seeds, the natural processes are controlled to ensure that pollen grains from a specific male plant variety are deposited on a similar female plant variety through winds, birds and or insects without contamination. The only difference is that it occurs in a controlled environment in the field which is often isolated (read more about isolation below).

In the wild there is no way of controlling how many pollen types from a male plant land on a female plant. Even though seasons could be clear, nature also has its own risks of either starting earlier or coming late in the year. Therefore the outcome of any cycle of fertilization is unknown and the products from such fertilisation processes cannot be predicted, thus making the fertilisation sequence tricky. Therefore, in open pollination, farmers and agriculturists control the cross-pollinating process so that two of the same varieties of plant are guided to cross through natural agents.

The key aspect in guaranteeing proper control is to ensure isolation and to have the skills for selecting seeds with vigour and the characteristics desired by farmers. When this happens and it is successful, the result of the cross-pollination is that the plants are naturally mixed but very similar. The seeds originating from this guided process are called and marketed as open pollinated varieties or OPVs. Experts skilled in working with farmers or on research farms have produced good seeds by proper isolation. There are OPVs that are high yielding, and many are either tolerant or resistant to a set of pests and diseases.

Table 2:
Open pollinated varieties of sorghum, maize and rice that have been officially released in South Sudan.

The advantage of OPV seed is that it will produce the same type of plant as its parent, even if the plant gets pollinated by a different representative of the same variety. Yield is usually a lot higher than those of the wild varieties and, even more important to smallholder farmers, is that the OPV seeds can be collected by farmers, processed, stored, planted, harvested and planted again over a relatively long period (between 3-5 years) if the conditions are right and the seeds are well handled. Many varieties of open pollinated sorghum, maize and rice seeds have been officially released in South Sudan (Table 2).

Sorghum	
Macia	Open pollinated
Sesso I, II, and III	Open pollinated
Kari mtama 1, 2	Open pollinated
Wad Hamad	Open pollinated
Gadam El Hamam	Open pollinated
Maize	
M45	Open pollinated
KDV4	Open pollinated
Longe 4	Open pollinated
Longe 5	Open pollinated
Rice	
For Uplands	
NERICA 1	Open pollinated
NERICA 4	Open pollinated
NERICA 10	Open pollinated
DKAP-27	Open pollinated
For Lowlands	
NERICA L-1	Open pollinated
NERICA L-2	Open pollinated
Komboka	Open pollinated
Wita 9	Open pollinated
Supa 1052	Open pollinated

Hybrid seeds

Hybrid seeds are increasing in popularity across Africa and in the East African region. Unlike the open pollinated varieties, seeds are described as “hybrid” when a plant variety is developed through a specific and carefully controlled cross of two parent plants. Usually, hybrids are produced by the cross-pollination of male with the female parts of parents of the same species. The selected crop varieties could be inbred lines like the open pollinated. In other words the difference between a “hybrid” seed and an open pollinated seed is that in hybrid varieties the pollination of the two plants from the same species are guided, directed and controlled to cross by human intervention.

Table 3:
Maize seed varieties that have been officially released in South Sudan.

The yields from hybrid varieties are much higher than the open pollinated types, although hybrids require a relatively higher input. Hybrid seeds can be shared as farmers' seed over a shorter period of time before it begins to show decrease in yield. Note that not all hybrids seeds can be kept by farmers for replanting. Six varieties of maize have been officially released in South Sudan (Table 3).

Maize	
KH500-44A	Hybrids
KH500-22A	Hybrids
Longe 6H	Hybrids
Longe 10H	Hybrids
GRENNGOLD (SC0923)	Hybrids
MAXIM (SC719)	Hybrids

Genetically modified seeds

These are seeds that result from modification of genetic cells and organisms. This work usually takes place under a very highly scientific laboratory, and is rarely the type of process in which subsistence or smallholder farmers will be involved. In these labs scientists modify the DNA of seeds to manifest their desired characteristics, which then takes prominence in the germ plasm. This involves cell slicing and could be extremely successful at completely altering cell composition of any seed type both in the lab and when they multiply them for commercial farming. Though there is no policy against the use of GMOs in South Sudan at the moment, the promotion of genetically modified seeds is discouraged by development practitioners mostly because it may require significant inputs to be successful, most of which the small scale farmer cannot afford. An unintended consequence of having GM seeds is the fact that there could be pollen contamination which may drift with wind, rendering open pollinated seeds ineffective over time. It should be noted that the use of genetically modified seed is currently banned as MAFS is still debating guidelines for its utilization.

Plant population

Crops thrive and perform better when they are provided with adequate space that enables them to stretch out to sunlight and when they are allowed sufficient space for root development, which means there is a reduced competition for soil nutrients and the water essential for proper growth.

The space required by a plant depends on the size (both height and width) of the plant at full development stage. In addition, the space a crop is planted will also depend on whether it is sole cropping, mixed cropping or a plantation crop, and whether it is rain fed or under an irrigation system. Therefore, there are specific plant populations or plant densities for various crops. Table 4 below provides spacing requirements and plant populations for selected crops.

Table 4:
Plant density recommendation for selected crops under mono-cropping and rain fed conditions.

Crops	Plant Spacing	Plant Population per hectare
Maize	0.3m x 0.6 m	50,000
Sorghum	0.4 m x 0.40 m	100,000
Cowpea	1.0 m x 1.2 m	50,000
Cassava	1.0 m x 1.0 m	10,000
Soybean (Glycine max Merill.)	0.75 m x .05 m	266,700

Formula for calculating plant population:

$$\text{Plant population} = \frac{10{,}000\ m^2}{\text{Product of spacing between plants (m) x spacing between rows (m)}}$$

How to calculate plant population per hectare

1. The plant population of any field is given by multiplying the spacing between plants with the spacing between the rows.
2. The total area of a hectare is 10,000 square metres.
3. Divide 10,000 by the result of multiplying the between plant spacing and the between row spacing as given in as shown below

$$\text{Plant population} = \frac{10{,}000\ m^2}{\text{spacing between plants (m) x spacing between rows (m)}}$$

An example

If the between plant spacing of tomatoes is 30 cm and between row spacing is 90 cm, what is the plant population per hectare?

1. First convert cm to m
   30 cm = 0.3 m, 90 cm = 0.9 m
2. Multiply between plant spacing and the between row spacing
   0.3 m x 0.9 m = 0.27 m^2
3. Divide area of 1 hectare by 0.27 m^2
   10000 m^2 / 0.27 m^2 = 37,037
4. Therefore the plant population of potatoes per hectare is 37,037.

You can do this for most crops to determine the plant population.

Figure 7:
Calculation for determining plant population.

Steps for producing good quality seeds

Producing good quality seed starts with a complete understanding of the protocol guiding production. The quality of seeds to be produced thus begins from the choice of seeds, the agro-ecological condition, the treatment and the cultivation practices the seed stock is subjected to. Often farmers see and could be attracted to the seeds in packages but the actual quality determination starts from the field. A poorly grown seed will do no good to a farmer who will depend on it for providing food for his family and from which s/he hopes to earn an income.

Soil type and climate

Different crops require different types of soils. But most cereal crops thrive best in light- to medium-textured soils with a tolerable level of acidity/alkalinity, measured in pH. Maize prefers pH in the range of 6.0 to 7.2, although sorghum can tolerate a soil pH of 5.0 to 8.5. Groundnuts grow best in slightly acidic soils with a pH of 6.0 to 6.5, but a range of 5.5 to 7.0 is acceptable. Overall, the soil you choose should preferably be well aerated and drained for most cereal crops.

Basic agronomic practices for most cereal crops

For ideal growth of crops we need to understand soil types, soil acidity/alkalinity measured by pH level and level of soil fertility. We also need to consider climatic conditions such as rainfall, precipitation, amount of sun shine and recent unpredictability of weather conditions. In addition to soils and climate, it is important to carry out appropriate agronomic practices.

A few of the agronomic practices common to cultivation of annual crops such as cereals and pulses are described and illustrated below (Table. 5). This can be very useful when cultivating cereal for seeds. Agronomic practices for seed production should consider the following:

Adequate isolation especially for OPVs and hybrids; Proper land preparation to ensure that seeds are planted in weed free land; Spacing and number of seeds per hole to ensure that the right plant population is obtained which very much determines the performance of the plant; Timely weeding, be it mechanically or chemically. Timeliness means whenever weeds have emerged, this should be determined by the farmer which depends on the type of weeds, time of planting (whether there were no weeds when planting); Rouging; that's the removal of off-types (diseased, infested or weak/bad looking plants) to minimize contamination; and Harvesting; right timing and the handling to ensure that seeds are harvested after physiological maturity is attained and partial drying occurred already. Proper handling is to minimize contamination and reduce losses

It is important to pay special attention to the isolation distances discussed in the subsequent section.

Sorghum is an example of a staple cereal crop grown by most farmers in South Sudan and in the tropics where it is well exposed to sunshine. It is also widely grown in temperate regions and at altitudes of up to 2,300 m. Well drained soil is preferable and areas of land that are waterlogged must be avoided. Preparation of land should be done as early as possible at the start of the rains.

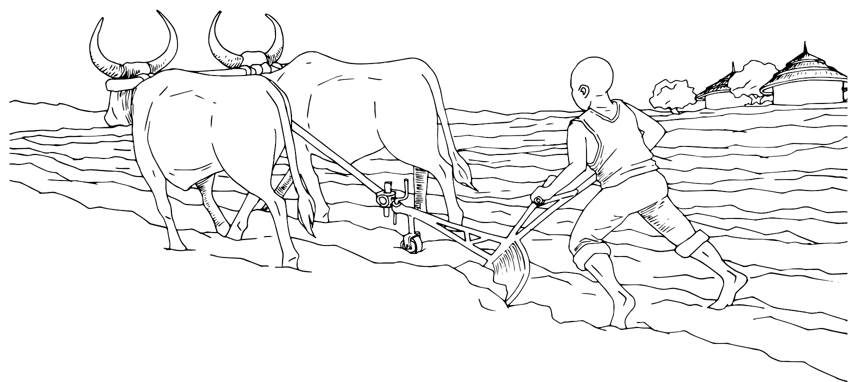
Site Selection

When selecting a site for seed cultivation, it is important to choose areas that are safe from animals and theft, and which are well suited to animal traction (ox ploughing), especially if there is a desire to expand the area under cultivation. To ensure the production of pure seed lots there may also be the need to isolate your farm either by space or by time depending on the crops grown by your neighbours.

Land preparation

This is mostly the removal of undergrowth and felling of some trees. It is advisable to undertake two separate types of tillage for land preparation: a general primary tillage and a secondary fine seedbed preparation.

The tools commonly used by smallholder farmers in South Sudan are hoes (maloda/pur) and the ox plough (pur weng), while tractors are used for land preparation by large-scale farmers. For commercial purposes and on large-scale tractors implements such as disc ploughs, harrows and ridgers are used.



Sowing of suitable seed variety

Seeds should be free of physical damage, pest infestation and disease, and should be adequately dried before being stored in a clean and well-ventilated area. Farmers are encouraged to procure their seeds from the reliable seed suppliers and to use certified seeds where available. Seeds should come from a stock kept in good condition in order to preserve their viability.

Row planting is the preferred method because it ensures optimum plant population, higher yields and the development of good quality grains. Seeds are planted or placed at a shallow depth of approximately twice the size of the seed.

Irrigation

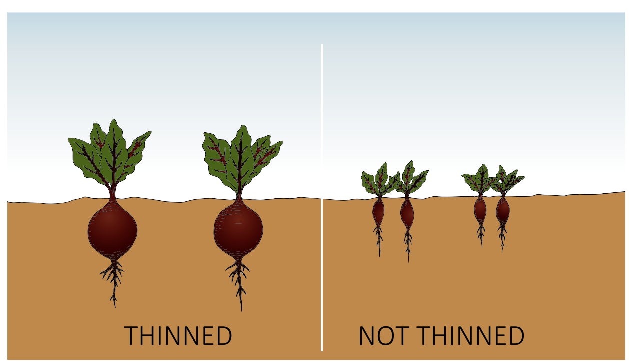
This is the application of water to the crops. In South Sudan, rainfall provides water naturally and most farmers wait on the rains for main season cultivation. In the dry season, planting is done near water sources which could be along the river banks, reservoirs or open wells. Not many farmers grow dry season sorghum, but maize is becoming common. Water is brought using watering cans and in some cases through treadled or motorised pumps.

Weeding

For most annual crops, timely weeding is recommended. On small holder farms this is done using hand hoes (maloda and jembe) with wooden handles. For sorghum it is advisable to weed twice (by the third and sixth week).

Thinning

Thinning is carried out at the same time as hand weeding (1-3 weeks after emergence) and when soil is moist, or at intervals during the crop cycle, particularly where the removed plants are used to feed livestock. Thinning determines the space a plant is allowed to grow. For good growth plants need space to flourish.



Roguing

This refers to the removing/ destroying undesirable plants which are affected by pests and diseases in order to prevent infestation/ infection to other plants in the field. An undesirable plants may be plants of another cultivar or different genetic or off type. It should be noted that Roguing of undesirable plants from fields intended for seed certification prior to field inspection is very important.

Harvesting and harvesting techniques

For seeds, harvesting is best done when crops are fully matured and the fruits are drying. On small holder farms we encourage that seed bunch is reasonably dry on the crop before harvest. Further drying will be needed to reach the 15% moisture content for good storage and to be processed into seeds.

Cereal crop pests

Common pests in the field that notably affect cereals are the fall army worm (Spordoptera frugiperda), birds and grasshoppers. Fall army worm has been reported to have a devastating effect on plant population and yield which may result in food shortages in the areas where they are prevalent. Apart from applying the appropriate pesticide, good agricultural practices such as timely planting, timely weeding, spacing, use of manure and fertilizers to ensure that plant stay healthy, farmers are also advised to scout for the egg masses and caterpillars and destroy them. Intercropping maize or sorghum with beans, cowpeas, ground nuts or soybeans can help reduce the spread. The use of collective, area-wide management rather than farmers acting individually is important to prevent spread from one farm to the other. It is also important to avoid moving an infected plant to a non-infected area.

Figure 8:
Identification markers of the fall army worm (Spordoptera frugiperda)

Common diseases affecting sorghum

A notable disease that affects sorghum is smut which attacks at the seed development stage. The selection of very clean and healthy seeds that are free of disease can help to reduce the incidence of smut. 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. Stem borer disease is also very common, but can be controlled effectively by ensuring good field hygiene, regular weeding and the destruction of host crops. Other diseases of sorghum include anthracnose and leaf blight.

Understanding growth stages of sorghum and maize

Growth stages of crops vary from crop to crop. For the purpose of understanding the process for most cereal crops the example used here is of Sorghum, which is commonly grown by farmers across South Sudan. The growth of Sorghum is spread over 9 stages, from emergence until physiological maturity, as listed below and illustrated in Figure 9.

Stage 0. Emergence
Stage 1. Three-leaf stage
Stage 2. Five-leaf stage
Stage 3. Growing point differentiation stage
Stage 4. Final leaf visible in the whorl stage
Stage 5. Boot stage
Stage 6. Half bloom stage
Stage 7. Soft dough stage
Stage 8. Hard dough stage
Stage 9. Physiological maturity stage

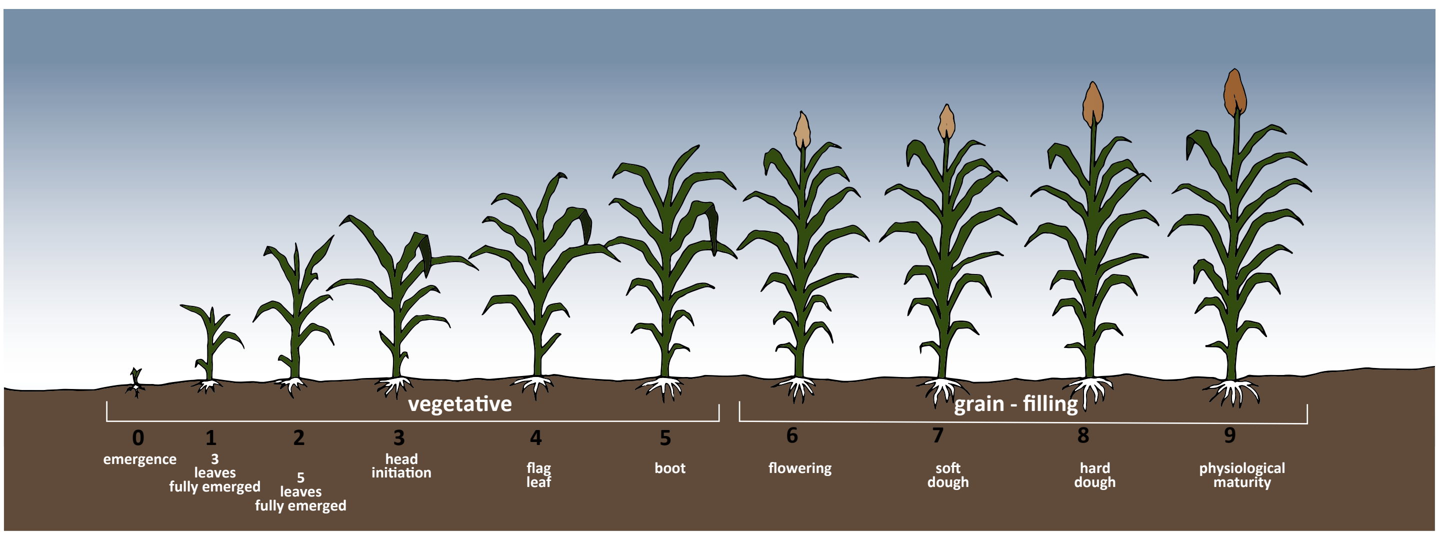


Figure 9: Growth stages of sorghum

The time required to reach each stage depends both on the type of seeds and the environment in which it is growing. The time and stages presented are for comparative purposes only. They will change for the same variety at the same location if the planting date was changed or if results from two seasons were compared. Other factors such as soil fertility, insect or disease damage, moisture stress, plant population and weed competition may also affect both the timing of developmental stages and the plants' condition at each stage of development.

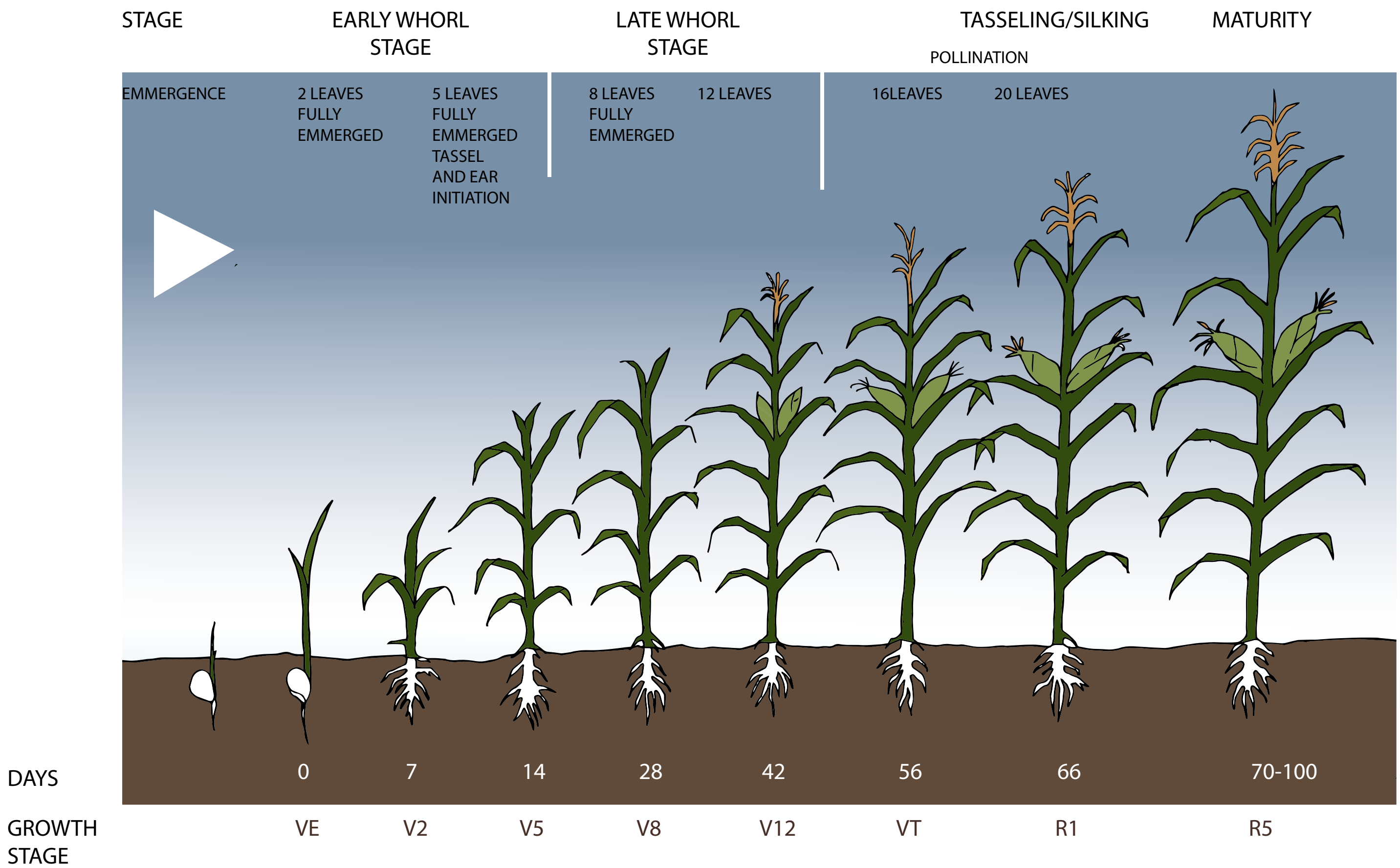


Figure 10: Maize growth stages

Isolation by time and by space

It is important to note that not all crops are pollinated by insects such as bees. The vast majority of grain-producing crops are pollinated by the wind. This happens when pollen is carried by wind and deposited on another individual of the same or a similar variety. It is therefore important that farmers producing certified seed should ensure that their field has sufficient distance from any neighbours' field growing the same type of crops.

For instance, the most convenient way to grow sorghum is in a field where farmers around you have maize or millet. Some crops such as the groundnut are self-pollinating, so it requires a shorter isolation distance. The rule is to not grow a crop meant for seed close to a crop of the same variety in order to avoid contamination and cross-pollination. The recommended Isolation distance is shown in Table 6 below.

Crop Type	Isolation distance (m)	Date of sowing	Seed rate (kg/ha)	Plant spacing (cm)	Depth of sowing (cm)	Plants per stand
Maize	400-600	June/July	20-25	75 x 50	3-5	2
Sorghum	200-400	June/July	10-15	75 x 40	3-4	2
Rice	5-10	June/July	40-50	25 x 25	2-4	4-5
Millet	200-400	June/July	3-5	75 x 50	2-3	2-3
Soybean	5-10	June/July	40-50	75 x 20	2-3	5-6
Groundnut	5-10	June/July	35-40	75 x 25	3-5	2
Cowpea	5-10	July/August	25-30	75 x 20-50	3-5	2

Table 6: Field isolation distance and sowing requirements for seeds farms. Adapted from PROSAB IITA 2008.

Figure 11 below shows the planning of farm location and the surrounding farmer plots to reduce cross pollination to its minimum. A field of maize seed should be isolated from neighbouring maize fields by 400-600 m in all directions.

Apart from ensuring distance, an alternative way of ensuring that isolation takes place is to plant crops meant for seeds at a different time in the season. Research shows that if you delay planting by a couple of weeks when other farmers around you have already planted, your crop is likely to produce clean seeds because it will come into maturity a little later than surrounding crops. However, depending on the season and arrival of rains, and the unpredictable season in recent times, extensionists and farmers consider delayed planting as impractical, especially where irrigation facilities are minimal or nonexistent. As an alternative, planting a crop type different from the crops grown by neighbouring farmers has proved an excellent strategy that ensures very good isolation and curbs the problem of contamination.

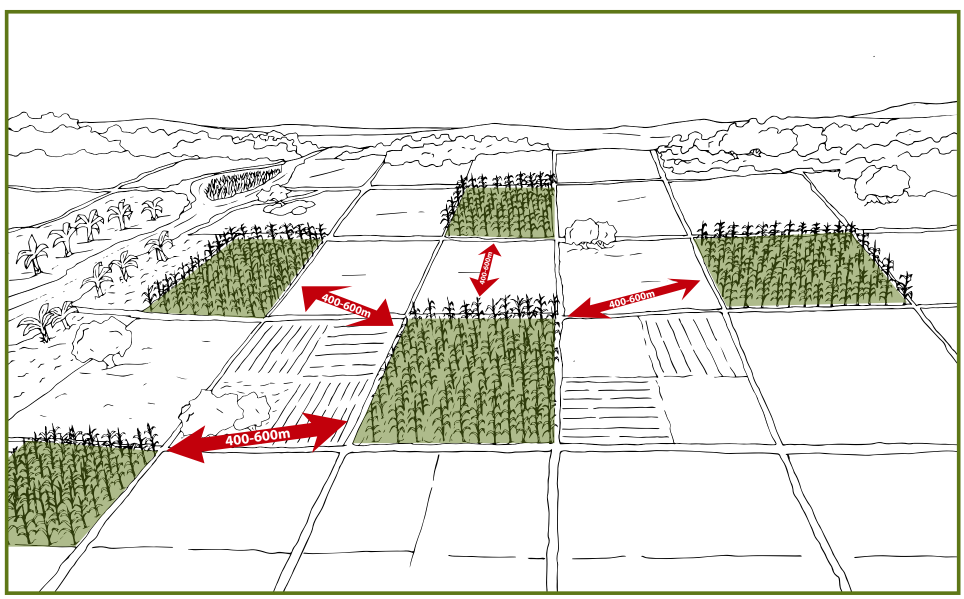


Figure 11: Illustration of isolation distance requirements for maize seed farms from neighbouring maize fields. Source: IITA Guide to Certified Seeds Production in Borno State.

Characteristics of seed quality

Seed quality is perhaps the most important aspect of seed production, acquisition and use. A bad seed or seed lot is not only a waste of money, it is a waste of time and it brings mistrust among farmers, seed producers and seed sellers. Bad quality seed affects the entire crop production value chain. Even more important is that bad quality seed with low germination power or count can discourage farmers from purchasing them especially where efforts are being made to introduce improved seed varieties.

There are four basic attributes of seed quality to consider:

1. Physical qualities of the seeds in a specific seed lot
2. Physiological qualities observed as germination and vigour of seeds
3. Genetic quality, which relates to specific genetic characteristics of seed variety
4. Seed health, which refers to the presence of diseases and pests within a seed lot

These attributes and their realisation is what farmers here describe as "seed purity".

Physical characteristics

Observing physical characteristics of seeds is an important first step of checking and determining whether a seed lot is good or not. We use our senses of seeing, touching and feeling to determine the quality of the seed. At this stage farmers should look at:

- Seed width
- Seed length
- Seed weight (if too light they could be empty or full of chaff)
- Seed shape (comparing them to what is desired and what you think it should be)
- Surface texture (mostly of the coat, if is it coarse or smooth, cracked or wrinkled)
- Colour (Are the seeds the desired colour? Is the colour artificial? Is this what the market wants?)
- Has it been affected by too much moisture or exposed to too little sunlight? (If it is affected by moisture it could be mouldy and even smell bad).

Based on Quality Declared Standards (QDS) of FAO, good quality cereal seeds should have 13-15% moisture content, legumes at 10% or below and vegetable seed at 8% or below.

Physical seed moisture content test using teeth or a salt jar

Farmers in many regions in South Sudan test seeds by attempting to crack the seeds with their front teeth. They do this to determine how dry or wet the seeds are. A very dry seed is usually harder to crack, which means that it is probably having lower than the required 15% moisture content.

Another simple method is to shake a sample of grain with dry salt in a clean dry glass jar for several minutes. If the salt sticks to the sides of the glass jar, it means the grain moisture content is above the safe moisture content level. If the jar surface is clear of salt, it means the grain is dry enough to be put in storage.

It is important to note that these methods are not scientific and are prone to many inadequacies. There are simple moisture meters nowadays that can be used to read seed moisture content either in the laboratory or on the farmstead.

Figure 12: Description of physical seed moisture tests.

Additionally, from physical examination it should be possible to see and confirm that seeds are free from contaminants such as weed seeds, other variety of seeds, inert material which are not of plant origin such as plastics, papers, metal and so on. It is also possible to identify damaged seeds and seeds that are not of desired size, which could indicate that they are not fully formed if they are small.

Physiological characteristics of seeds

This examination refers to the observation of germination percentage as well as the vigour with which seeds germinate when tested under a potentially stressful condition. While the physical characteristics examine visual seed aspects, these checks examine the performance of the seed. In other words, it checks how the seeds will germinate when sown. With this test it is possible to make a preliminary judgement about how rapidly the seed will grow in real field conditions. Most farmers and practitioners in the field often look only at the germination percentage or germination count, ignoring the observation of vigour. It is important to note that a seed with a high germination rate can have poor vigour, and that seeds with initially high vigour rate can deteriorate over time due to storage conditions and the transportation system used.

Phytosanitary characteristics of seeds

Since seeds are biological they can be affected by diseases which may be caused by microorganisms such as bacteria, fungi and viruses or caused by other organisms such as pests. Unlike physical examination, it is not always easy for small scale or subsistent farmers to spot these when they examine seeds because most of them are invisible to the naked eyes (microscopic), with the exception of mould.

Figure 13: Groundnut seeds contaminated by aflatoxin (left) and disease free (right). Source: UNIDO post-harvest training manual.

Determining Viability and Vigour of Seeds

Other than observing moulds some of which are colourful and feeding on the outer coat of seeds, many disease-carrying seeds cannot be easily detected. For instance, tomato seeds are known to carry fusarium, root nematodes and verticillum pathogens which cannot be seen but can grossly damage seeds or plants when sown. Therefore, this characteristic of seed quality should be taken very seriously. Unfortunately, these can only be undertaken in laboratories by experts.

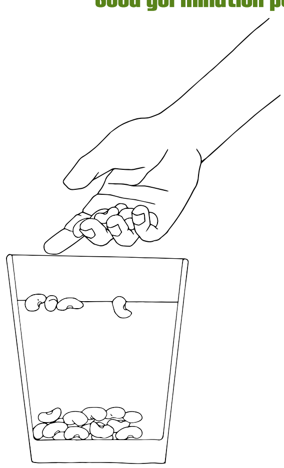
Seed viability testing

Viability testing describes the various type of tests run to determine what percentage of the seed lot will yield acceptable seedlings. This is important because the test will help farmers know how much seed to sow to obtain the desired plant stand per area under cultivation. The other aspect of viability is the determination of the seed lot vigour.

Determining seed germination percentage

1. Seed viability test using water and a bowl

Farmers frequently use this old method, and the majority of smallholder farmers have come to trust it. This method uses the weight and density to determine viability by placing seeds in water, then observing the percentage of seeds that settle at the bottom of the bowl versus the seeds that float on top of the water. The logic is that floating seeds are unfit for planting because they are too light or infested by weevils.



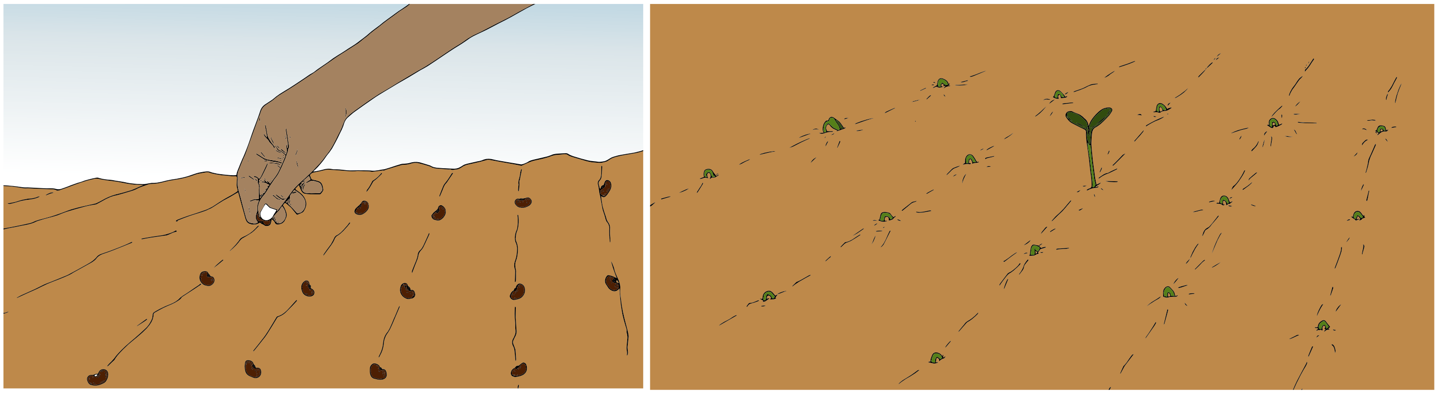


Figure 14:
Illustration of in-soil germination test.

2. Seed germination test using plate method

In this case, farmers take a few seeds (usually 100) and place them on a plate with moist tissue paper or in sow them in the soil on a small area suitable for a pre-nursery (Fig. 14). The plate is then covered. If it is in the soil, the seeds are sown with water sprinkled to ensure that the soil is moist. With both methods, the seeds are left undisturbed for a few days (4-5 days). In South Sudan where temperature is relatively moderate, germination is expected to be fast. On the fifth day, the plate is opened and the number of germinated seeds is counted.

To calculate the germination percentage, divide the number of seeds that germinated by the number of seeds you sow, then multiply by 100.

$$\% \text{ germination} = \frac{\text{number of seeds germinated}}{\text{number of seeds sown}} \times 100$$

Figure 15:
Calculation for determining seed germination percentage.

Seed vigour testing

Seed vigour is described as the sum total of those properties of the seed which determine the level of activity and performance of the seed or seed lot during germination and seedling emergence. Determining seed vigour is very important because it cannot be easily detected by physically examination, yet it is one of the most important factors of good quality and certified seeds. It is seed vigour that determines the potential for rapid, uniform emergence and development of normal seedlings under a wide range of field conditions

Vigour tests can help predict:

- Rate and uniformity of seed germination and seedling growth
- Field performance, including extent, rate and uniformity of seedling emergence
- Performance after storage and transport, particularly the retention of germination capacity

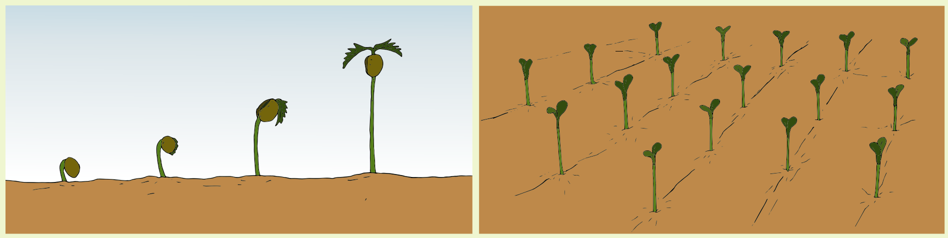


Figure 16: Stages of seed growth (left) and examples of seeds germinating in the nursery (right).

Vigour testing is not a substitution for germination testing. Both are tests of seed viability, but they measure different sides of that coin. A germination test tells you what percentage of your seed lot will start to grow under ideal conditions. A vigour test, on the other hand, is an indicator of how that seed will perform under less than perfect environmental conditions, taking into account the seeds' genetic constitution, size, physiological maturity, and any effects related to production and storage the previous year.

Seed vigour testing measures two properties of a seed lot. These are:

1. Emergence: Describes the percentage of seedlings that developed normally and rapidly under cold conditions.
2. Vigour: This is the percentage of seedlings that have reached the minimum criteria to be considered high vigour.

The benchmark for a high vigour seed lot is 80% emergence and 60% vigour. Expected field performance falls between the vigour and emergence values under a wide variety of field conditions, and it is significantly better when field conditions are ideal.

Seed vigour testing could be classified into direct and indirect testing. Direct testing methods are those in which an environmental stress expected in the field is reproduced in the lab and the percentage and rate of seedling emergence is recorded (e.g. cold test). Indirect testing methods are those in which other characteristics of the seed, which have proved to be correlated with an aspect of field performance, are measured (e.g. respiration rate, conductivity test).

The benchmark for a high vigour seed lot is 80% emergence and 60% vigour. Expected field performance falls between the vigour and emergence values under a wide variety of field conditions, and it is significantly better when field conditions are ideal.

There are several vigour testing methods which could range from simple to a slightly more complex method. Examples of vigour testing methods are:

- Seedling growth rate test
- Accelerated aging test
- Controlled deterioration test
- Electrical conductivity test
- Potassium leakage
- Computer imaging
- Tetrazolium test

For the purpose of this manual the seedling growth rate test, the accelerated aging test, and tetrazolium test are described because of the practicality and relative ease of doing this in a field or adaptive research condition.

Seedling growth rate test

This test is closely related to the standard germination test (described in the previous section) and is useful to figure out field planting potential under optimal or near ideal conditions.

Seeds are planted under optimum conditions and are allowed to grow for an extended period of time, usually several days past the typical germination period. The seedlings are evaluated by their growth characteristics such as stem length, leaf development or root branching.

The measurements determining strong or poor vigour are highly dependent on the particular cultivar being tested. Some varieties of lentil, for example, may naturally be longer than others. It means seed analysts have to get very familiar with a lot of different growth characteristics.

Cold germination test

Cold germination tests assess the seedlings' ability to withstand low temperature stress (5-7 °C) typically experienced in early spring planting. This test helps you better assess early season risk. In other words, if test results show the seed is susceptible to cold stress, you can adjust your seeding dates accordingly. The cold test can be carried out in the following forms:

- Tray method
- Shoe box method
- Rolled towels method
- Saturated cold test

The cold germination test results are reported in two categories:

o Emergence is the percentage of seedlings that developed normally and rapidly under cold conditions.

o Vigour is the percentage of seedlings that have reached the minimum criteria to be considered high vigour.

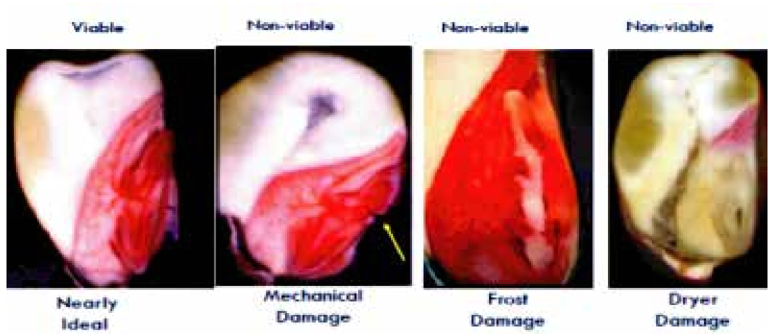
Cold tray test

The tray test is the oldest method of determining seed vigour and germination. The testing steps are as follows:

- Place one sheet of CCP on each tray and add 1100 mL of water
- Place trays in a cart overnight at 10 °C in the cold room.
- Plant 4 samples per tray. Press down seeds.
- Add 4:1 sand/soil mixture.
- Move cart to 10 °C cold room (without light) for 1 week.
- Move cart to 25 °C with exposure to vertical lights to rear of cart.
- Evaluate samples on day 5-7 according to AOSA Rules.

Tetrazolium test

The tetrazolium test is an important method providing fast assessment of seed physiological quality. Test can be used to determine viability as well as vigour. The tetrazolium vigour test measures vigour indirectly, and therefore treats vigour as an intrinsic property of the seed. This is usually carried out in a laboratory by qualified scientists.



The use of tetrazolium is to determine which seed tissues are alive and have the potential to germinate under optimum conditions. Tetrazolium is a colourless chemical that reacts with living cells and stains them red. Tetrazolium tests are particularly good for detecting heat-damaged seed as this kind of damage creates a unique staining pattern. With a tetrazolium test it is possible to detect the very early stages of heat damage. Mechanical damage to the seed embryo and sprouting can also be assessed with tetrazolium. Tetrazolium salt (2, 3,5-triphenyl tetrazolium chloride) used in the test is colourless, but it reacts with hydrogen released during respiration to form water-insoluble formazan (the red colour seen). Seeds must be imbibed prior to testing to initiate metabolic pathways of respiration. When the test is completed, it allows for evaluation of the staining patterns of critical areas of the embryo. This test is useful in a wide range of species.

Figure 17:
Example results of a tetrazolium test.

Seeding rate

Seeding rate refers to the quantity of seeds required to sow your field or plot size, which is partially determined by the purpose of the crop (i.e. for pasture or other uses) and the farm cropping practice you plan to use (i.e. mono-cropping or mixed cropping). The knowledge of seeding rate helps you to decide the amount of seeds you need to buy for your farm. Usually seeds are packed in grams or kilograms depending on the sizes of the seeds. Since seeds are an essential input for farming, it is important to know the actual quantity of seeds that you need to obtain the correct plant population and to be able to budget appropriately.

Seeding rate, therefore, is defined as the number of seeds planted per hectare (ha) to ensure normal density of sprouts and a maximum yield. The seeding rate is expressed by the number of germinating seeds and the weight of the seeds (kg). It is determined by considering plant requirements for feeding space, the purpose of cultivation (grain, silage), soil fertility, climatic conditions and other factors. The seeding rate may differ for the same crop. The seeding rate for crops raised for silage is higher than that for crops raised for grain.

To calculate the seed rate for most of the common annual crops grown by farmers there are two methods explained and advised.

First method: Calculation based on plant population and number of seeds per kilogram

You first need to know how many seeds of each crop are contained in a kilogram. The most accurate way of calculating this is to weigh out a 100 g sample of the seed and count it. Multiplying the number by 10 will give the number of seeds per kilogram. Otherwise, you can use Table 7 below as a rough guide.

Table 7: Estimated number of seeds per kilogram

Crop	Number of seeds per kg
Maize	2,860
Sorghum	44,000
Groundnuts	1,540
Beans	3,960
Cowpeas	4,040

Second method: Calculation based on seed weight and likely establishment

To find the kilograms of seed needed per hectare, simply divide the number of seeds needed (the desired plant population per hectare) by the number of seeds/kg. Multiply this times the size of the field in hectares to get the total kilograms of seed required.

For this method, first determine the type of crop you want to grow, and identify the desired plant population per square metre (m2).

Secondly, you will need to know the weight of one individual seed in milligrams (mg).

Thirdly, you will need to have an idea of the "likely establishment" rate of the seeds expressed in percentage. Utilize Table 8 below that shows the likely field establishment rate from a range of sowing densities and two laboratory germination percentages.

Figure 18: Steps in seed processing

Table 8: Likely field establishment rates based on laboratory germination and sowing density.

Laboratory germination (%)	Target plant population per m^2	Likely establishment (%)
95	50	95
	100	**90**
	200	80
	400	60
85	50	85
	100	80
	200	70
	400	50

The formula to determine seeding rate is as follows:

$$\text{Seed rate (kg/ha)} = \frac{\text{target plants/m}^2 \times \text{seed weight (mg)}}{\text{likely establishment (\%)}}$$

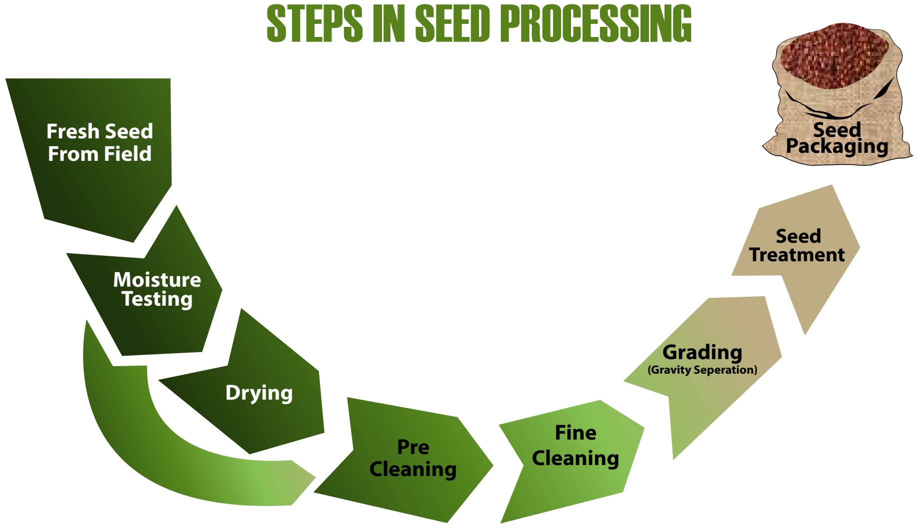
For example: for a target population of 100 plants/m2, an average seed weight of 35 mg and a laboratory germination test of 95 percent, the seed rate = 100 x 35/90 or 39 kg/ha (check the first table for likely establishment percent).

For a plot size of 10 m x eight rows (at 20 cm spacing), or 0.0016 ha, the weight of such seed (35 mg) to sow per plot is 62 g.

Seed quantity required = 39 kg/ha x 1,000 x 0.0016 ha

Seed processing

STEPS IN SEED PROCESSING



Seed processing is a post-harvest activity. It is a process that involves the preparation of seeds for market and for farmers' use by removing all unwanted materials from a seed lot. Seed processing is very crucial for certification, and it is important for attracting good prices in the market. The process ensures that seeds are separated from inert materials, common weeds seeds, noxious weed seeds, deteriorated seeds, damage seeds, other crop seeds, other varieties of seeds and off-size seeds.

Figure 19: Maize cobs tied for drying

There are various levels of processing. Simple or basic seed processing can be done by small holder farmers in a less complicated situation, while industrial level seed processing requires a highly mechanised system of seed processing. Industrial processing is often done through the use of specialised equipment and can be highly scientific.

Table 9 below illustrates simple seed processing practices utilized by small scale farmers in South Sudan and across the African subregions.

Seed cleaning by winnowing

Winnowing is a basic technique of cleaning dry seeds. It ensures that seeds are cleaned based on their differences in specific gravity. It is usually done by hand using a tray or a fanner. It is best done where there is wind. The seeds, along with chaff, are allowed to drop from a height of several feet (about shoulder level of an adult) with the wind blowing. As they drop with the wind blowing gently through them, the seeds are separated from chaff and other light unwanted materials. With some skill and the wind, the clean seeds will fall closer onto a sheet, tarpaulin, mat or container while the chaff will fall further away because seeds are heavier than the chaff.

Grading and sorting of seeds

Seeds are further made cleaner through grading and sorting. This stage involves the use of at least two sieve sizes, with one slightly larger than the other. The two sieves are placed over each other. The first will allow anything smaller than the desired seed size to pass through, while the other will hold the seeds with the larger size.

Seed dressing

Seed dressing is use of fungicides or antimicrobials for coating the seeds before sowing. Dressing is a first protection treatment that is a basic and cheap way to fight pathogens that are in the soil or that have been relocated with seeds. Seed dressing is the most common method of seed treatment. The seed is dressed with either a dry formulation or wet treated with a liquid formulation of the seed treatment chemicals. Dressings are applied both industrially and on-farm. See Annex III for the required conditions for seed treatment in an FAO-supported intervention.

Fundamental seed processing steps include:

- Receive the seeds from the field, including aggregating or bulking.
- Dry the seeds. Drying is necessary to ensure the right moisture content.
- Pre-cleaning. During the pre-cleaning process, undesirable elements such as large impurities, sand, thin grains and weeds are to be separated. During this process it is important for the cleaning to eliminate heavy impurities, such as stones, metallic particles and other foreign bodies from the seed products.
- Fine cleaning. This removes all off-types and ensures phytosanitary conditions are met as much as possible. At this stage the seeds are further examined to pick out mould and seeds that shows diseases on their coats.
- Sorting and grading into sizes. This ensures that the seeds are not too large or too small, indicating that they have just enough food to sprout.
- Treatment. At this point seeds could be further dried, aired and in many cases coated with approved agro-chemicals that have an anti-microbial or fungicidal active ingredient. Seed dressing happens at this stage.
- Packaging. Bagging in the right bag types ensures adequate aeration or complete vacuum.
- Storage. Seeds are then transported and stored in a pest free shelter on pallets away from the walls to avoid moisture. From the store, seed will proceed to market.

Methods of seed dressing

Seed treatment describes both products and processes. Using specific products and techniques can improve the growth environment for the seed, seedling and young plant. There are many types of seed dressing, which can either be drying techniques to avoid moisture content in the seeds or wet techniques in which the seeds are soaked in the nutrients and vitamins solution. Seed coating is another type of seed dressing where colours are applied to the seeds to save them from the birds. These colours make them invisible to the birds. Seed pelleting is a type of seed dressing in which the shape of the seed is changed to enhance the plant handling.

Benefits of seed dressing

- It is useful for uniform establishment and growth of the crop.
- It enhances the seed germination process.
- Seed dressing is better than foliar or soil application of treatment chemicals.
- Protection is provided for seed germination and seedlings against the soil borne insects. It also controls the soil insects.
- Plants can withstand adverse conditions like low or high moisture levels.
- It prevents the plants from acquiring and spreading plant diseases.

It is vital that farmers invest in getting their seed dressed before sowing as it will help them obtain better yields.

Seed cleaning and dressing cannot be undertaken single-handedly as it requires use of modern techniques and adequate time. Since farmers may not be in the position to invest substantial time in such processes, it is vital to seek assistance from a reputed seed cleaning and dressing agency.

Identifying good quality certified seeds

Merely looking at a seed stock cannot assure a farmer of the quality of a seed as we have said in the previous section. However, good quality seeds which have been certified by the authority will be accompanied by a label with:

- Name of seeds (written in bold letters)
- Variety of the seeds
- Year of production
- Expiring dates of seeds (most times printed)
- Phytosanitary certificate, including the certification and batch number, usually printed in bold on the labels
- Germination percentage clearly indicated

Seeds packaging and storage conditions

Packaging is necessary to facilitate handling and storage of seeds, comply with any legal requirement, preserve viability and seed quality, make presentable product for selling and maintain variety and lot identity. There are three critical factors that affect grains in storage whether they are kept as seeds or are for consumption. These are temperature, moisture content and relative humidity. All three factors affect the quality of seeds in storage because they may produce the right conditions for pests and diseases to grow.

Temperature: Storage insects and mould thrive within an optimal temperature range between 25-34 °C for most storage insects, and between 15-30 °C for the development of mould. Above or below this range, the development of these threats to the stored products is limited and the losses are negligible.

Please note that while high temperatures could be fine for seeds for consumption, seeds for planting will be physiologically damaged when exposed to a very high temperature.

Figure 20:
Seed packaging and storage facility.

Moisture content is described as the quantity of water bound in the grain kernels, expressed as a percentage by weight of the grain or seed sample. The moisture content of dry grain ranges from 6-15% depending on the type of grain. Moisture content is a determining factor in the proliferation of mould and storage pests.

Relative humidity is the percentage of water vapour in the air between the grains, and represents the equilibrium between the humidity of the air and the moisture content of the grain. If the relative humidity exceeds 65%, mould and storage insects can develop, and stored grains and seeds are susceptible to deterioration.

> The lower the temperature, relative humidity and moisture content are, the lower the risk of grain damage and reduction of the germination capacity.
>
> It is best to harvest fully matured crops and dry them well before storage.

Traditionally in South Sudan, seeds are stored by subsistence farmers and small holder farmers in five ways: household granaries, gourds, bags, metal storage bins and the hermetic bags (double-line bags, Fig. 21).

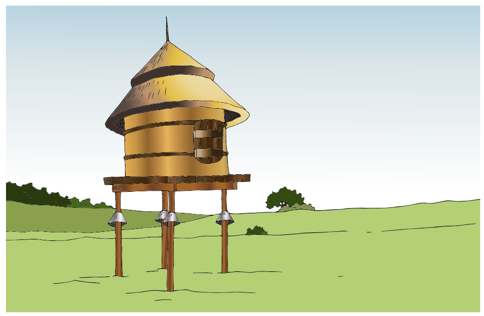
Additionally, seeds can be stored in improved storage bins (silos) made out of galvanised metal sheets. Silos come in different sizes and scales. Some are highly mechanised and monitored scientifically to ensure the balance between moisture, relative humidity and temperature. Small metal silo bins (including recycled oil drums) which can hold 100-3,000 kg of grains or pulses, are developing as an efficient and low-cost storage system suitable for small-scale farmers. These silos are loaded from the top, and once they are closed they are inaccessible to rodents or insects. They can also be properly sealed against water leaks. They are normally covered, raised from the ground and placed in a well-ventilated place to control both temperature and humidity.

Figure 21:
Hermetically sealed bags. Source: UNIDO post-harvest training manual.

Figure 22:
Traditional household granary in South Sudan (left) and improved grain silos (right). Source: World Vision South Sudan.

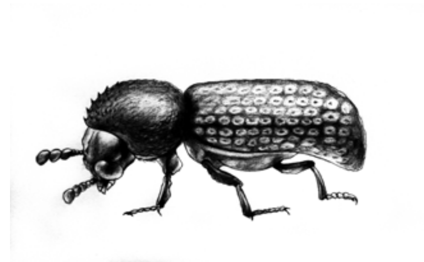
FAO's work on post-harvest losses and seed storage shows that although hermetic bags are recent, they can be effective for storing most seeds. These hermetically sealed bags or cocoons are available in various sizes (50 kg to 300 MT), and they offer an interesting alternative to traditional storage. The hermetic bags work on the principle that grains release carbon dioxide which rapidly replaces the oxygen in the sealed container. Once oxygen is exhausted, the pests die and fungi cannot spread.

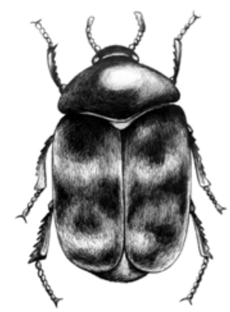
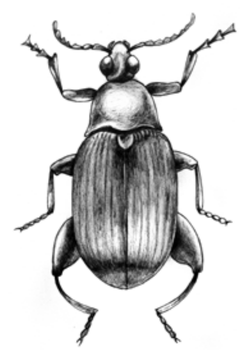
Common storage pest of selected crops and how they can be identified

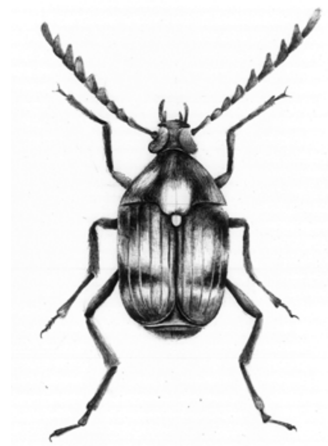


Crop Type	Common storage pests	Images
Maize (Zea mais)	***Maize weevil (Sitophilus zeamais Motschulsky).*** Maize weevil, also called greater grain weevil is the most common pest of stored maize in most African countries. Attack may start in the mature crop when the moisture content of the grain has fallen to 18-20%.	
	Larger grain borer (Prostephanus truncatus (Horn)) Adults are black or brown and cylindrical in shape, heads face down. Slightly larger (3 to 4 mm) than the lesser grain borer. Posterior end of the elytra slope back with two strong lateral ridges with sharp edged corners. Larvae are grub-like with poorly formed legs and are less mobile as they mature. Primarily affects maize but also affects dried root crops, bamboo, rattan, cassava, wheat, sorghum, dried sweet potato. They will bore into, but does not feed on, cowpea, cocoa, haricot, coffee, rice	

Table 10:
Common storage pests of selected crops, including description and identifying characteristics.

Crop Type	Common storage pests	Images
Sorghum (Sorghum bicolor)	***Larger grain borer (Prostephanus truncatus (Horn)*** Adults are black or brown and cylindrical in shape, heads face down. Slightly larger (3 to 4 mm) than the lesser grain borer. Posterior end of the elytra slope back with two strong lateral ridges with sharp edged corners	
Millet (Pennisetum glaucum [L.] R. Br.)	*Larger grain borer (Prostephanus truncatus (Horn)* Adults are black or brown and cylindrical in shape, heads face down. Slightly larger (3 to 4 mm) than the lesser grain borer.	
Rice (Oryza sativa)	***Rice weevil (Sitophilus.oryzae).*** These are a storage pest that bores into the grains and grinds the interior soft content of the grain;	
	Termites These are ants which affect rice both in the fields and in the store	

Crop Type	Common storage pests	Images
Groundnut (Arachis Hypogeal)	***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.	
	Khapra beetle (Trogoderma granarium) Adults are small (2-3 mm long and 1-2 mm wide), brownish in colour with a smooth oval shaped body. There are 3 transverse bands (markings) of pale colour hairs on the wing covers. Eggs hatch into small hairy larvae that can grow up to 7 mm long, are reddish brown in colour and darken as they mature.	
	Groundnut bruchid, Caryedon serratus (Olivier). Coleoptera: Bruchidae The adult is a brown beetle, about 4-7 mm long and 5 mm wide with prominent large hind legs (Fig 1). A single gravid female lays 20-30 creamy white eggs (1 mm long), which are glued to the surface of roundnut shell or kernels	
	Red flour beetle, Tribolium castaneum (Herbst) Coleoptera: Tenebrionidae. Red flour beetles attack stored ground-nuts and other grain products The adults live for several months and are strong fliers. The female lays eggs in cracks of the testa or on the damaged portions of the kernel to enable the young grub to feed on the kernel directly.	

Crop Type	Common storage pests	Images
Cowpea (Vigna unguiculata)	***Cowpea bruchids (Callosobruchus spp.)*** They are the most common and widespread insect pests in storage. Adults are 2 to 3.5 mm long. They are major pests of pulses (cowpeas, pigeon peas, soybean, green gram and lentils). They attack both pods in the field and seeds in storage. They attack nearly mature and dried pods. Infested stored seeds can be recognised by the round exit holes and the white eggs on the seed surface. Post-harvest losses are highly variable, but losses can be over 90%.	

Control of major storage pests

While adults are the signs of an infestation, merely killing them is not sufficient and cannot be the solution. Infested seed lots and bags must be found and destroyed. Identification of the pest can provide clues on where to look, but some of these insects can live on a wide range of materials. Disposal of infested materials is the best way to eliminate the problem. After treatment, good sanitation and proper storage are key to preventing future problems. Three main types of storage pest control are recommended based on the field experience and research of FAO, UNIDO, other implementing partners and scientific journals.

Physical control: Insects in stored grain can be controlled by manipulating the physical environment or applying physical treatments to the grain and insects. The variables defining the physical environment that are usually controlled are temperature, relative humidity, grain moisture content or relative composition of atmospheric gases in the intergranular air. Physical treatments include mechanical impact and physical removal as well as physical barriers preventing the entrance of insects such as abrasive and inert dusts, ionizing irradiation, light and sound.

Fumigation: Fumigation is a method of pest control that completely fills an area with gaseous pesticides to suffocate or poison the pests within. It is utilized for control of pests in buildings, soil, seed and grain produce. It is also used during processing of goods to be imported or exported in order to prevent transfer of exotic organisms. Fumigants are chemical compounds in gaseous form that enter the body of insects through the spiracles. Where seeds are observed to be infested with insects in store or in transit, they should be fumigated using an appropriate chemical and, as most of the smallholder farmers are already practising, by applying chillies to seed lots if stored in small containers or sacs.

Microbial control: Synthetic chemical insecticides provide many benefits to food production and human health, but they also pose some hazards. In many instances, alternative methods of insect management offer adequate levels of pest control and pose fewer hazards. One such alternative is the use of microbial insecticides that contain microorganisms or their by-products. Microbial insecticides are especially valuable because their toxicity to non-target animals and humans is extremely low. Compared to other commonly used insecticides, they are safe for both the pesticide user and consumers of treated crops.

Annex 1: Complete List of Seed Varieties Officially Released for Use in South Sudan

1.0	Cereal crops	Varieties	Classification	Agro-ecological zones	Potential seed source
1.1	**Sorghum**	Macia	Open Pollinated	Ironestone, flood plain, arid, hill & mountains, and parts of green belt	Kenya/ Uganda/South Sudan
		Sesso I, II, and III	Open Pollinated	Ironestone, flood plain, arid, hill & mountains, and parts of green belt	Kenya/Uganda/South Sudan
		Kari Mtama 1, 2	Open Pollinated	Ironestone, flood plain, arid, hill & mountains, and parts of green belt	Kenya/South Sudan
		Wad Hamad	Open Pollinated	Ironestone, flood plain, arid, hill & mountains, and parts of green belt	South Sudan/Sudan
		Gadam El Hamam	Open Pollinated	Ironestone, flood plain, arid, hill & mountains, and parts of green belt	South Sudan/Sudan
1.2	**Maize** (hybrids)	KH500-44A	Hybrid	Green belt, hills and mountains and ironestone zone	Kenya
		KH500-22A	Hybrid	Green belt, hills and mountains and ironestone zone	Kenya
		Longe 6H	Hybrid	Green belt, hills and mountains and ironestone zone	Uganda
		Longe 10H	Hybrid	Green belt, hills and mountains and ironestone zone	Uganda
		GRENNGOLD (SC0923)	Hybrid	Green belt, hills and mountains and ironestone zone	Zmbabwe
		MAXIM (SC719)	Hybrid	Green belt, hills and mountains and ironestone zone	Zmbabwe
	Maize(OPV)	M45	Open Pollinated	Green belt, hills and mountains and ironestone zone	Kenya/Uganda
		KDV4	Open Pollinated	Green belt, hills and mountains and ironestone zone	Kenya
		Longe 4	Open Pollinated	Green belt, hills and mountains and ironestone zone	Uganda
		Longe 5	Open Pollinated	Green belt, hills and mountains and ironestone zone	Uganda/South Sudan

		Longe 5	Open Pollinated	Green belt, hills and mountains and ironestone zone	Uganda/South Sudan
1.3	**Rice** (Uplands)	NERICA 1	Open Pollinated	Green belt and ironestone zone	South Sudan/Uganda
		NERICA 4	Open Pollinated	Green belt and ironestone zone	South Sudan/Uganda
		NERICA 10	Open Pollinated	Green belt and ironestone zone	South Sudan/Uganda
		DKAP-27	Open Pollinated	Green belt and ironestone zone	South Sudan/Mali
	Rice (Lowlands)	NERICA L-1	Open Pollinated	Flood plain and Nile and Sobat River	Uganda/Ivory Coast
		NERICA L-2	Open Pollinated	Flood plain and Nile and Sobat River	Uganda/Ivory Coast
		Komboka	Open Pollinated	Flood plain and Nile and Sobat River	Uganda
		Wita 9	Open Pollinated	Flood plain and Nile and Sobat River	Uganda
		Supa 1052	Open Pollinated	Flood plain and Nile and Sobat River	Uganda/Ivory Coast
2.0	**Oil crops**	**Varieties**	**Classification**	**Agro-ecological zones**	**Potential source**
2.1	**Sesame**	Sesame 1	Open Pollinated	Ironestone, flood plain, semi-dry areas and parts of green belt	Uganda
		Sesame 2	Open Pollinated	Ironestone, flood plain, semi-dry areas and parts of green belt	Uganda
2.2	**Sunflower**	Black /white stripped	Open Pollinated	Ironestone, flood plain, semi-dry areas and parts of green belt	Uganda/Kenya
		Black	Open Pollinated	Ironestone, flood plain, semi-dry areas and parts of green belt	Uganda/Kenya
2.3	**Groundnuts**	Serenut 2	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	Uganda
		Serenut 4	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	Uganda
		Serenut 4T	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	Uganda

		Red beauty	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	Uganda/South Sudan
		Sodari	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	Sudan
		Berbedi	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	South Sudan
		Mr Lakes	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	South Sudan
		Manipintar	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	Zambia
		MaKulu Red	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	Zambia
		Agar	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	Sudan
		Berit	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	Sudan
		Igola	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	Uganda
		YEIPA1 (SVG 99031) TAN	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	Uganda/South Sudan
		YEIPA 2 (SVG 99064) RED	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	Uganda/South Sudan
		YEIPA 3 (Serenut 5) RED	Open Pollinated	Ironestone, flood plain, arid areas, hills and mountains and green belt	Uganda/South Sudan
3.0	**Pulses**	**Varieties**	**Classification**	**Agro-ecological zones**	**Potential source**
3.1	**Cowpeas**	Secow 2W	Open Pollinated	Ironestone, flood plain, semi-dry areas and parts of green belt	Uganda

		Secow 1 T	Open Pollinated	Ironestone, flood plain, semi-dry areas and parts of green belt	Uganda
		AGRAC-116	Open Pollinated	Ironestone, flood plain, semi-dry areas and parts of green belt	South Sudan/Nigeria
		AGRAC-216	Open Pollinated	Ironestone, flood plain, semi-dry areas and parts of green belt	South Sudan/Nigeria
		AGRAC – 316 (Mabior bor)	Open Pollinated	Ironestone, flood plain, semi-dry areas and parts of green belt	South Sudan
3.3	**Beans**	Rosecoco	Open Pollinated	Green belt and ironestone zone	Kenya
		K132	Open Pollinated	Green belt and ironestone zone	Uganda
		French beans	Open Pollinated	Green belt and ironestone zone	Kenya
		NARO bean 1	Open Pollinated	Green belt and ironestone zone	Uganda
		NARO bean 2	Open Pollinated	Green belt and ironestone zone	Uganda
		NABE 15	Open Pollinated	Green belt and ironestone zone	Uganda
		NABE 17	Open Pollinated	Green belt and ironestone zone	Uganda
3.4	**Soya beans**	Maksoy 1 N	Open Pollinated	Green belt and ironestone zone	Uganda
		Maksoy 2 N	Open Pollinated	Green belt and ironestone zone	Uganda
		Maksoy 3 N	Open Pollinated	Green belt and ironestone zone	Uganda
		Namsoy 4N	Open Pollinated	Green belt and ironestone zone	Uganda
4.0	**Roots & tubers**	**Varieties**	**Classification**	**Agro-ecological zones**	**Potential source**
4.1	Cassava	TME 14		Green belt, H&M and ironestone	Uganda/South Sudan
		Akena		Green belt, H&M and ironestone	Uganda
		PAYE 1 (Nase 17) SWEET		Green belt, H&M and ironestone	Uganda
		PAYE 2 (Nase 19) SWEET		Green belt, H&M and ironestone	Uganda
		PAYE 3 (Nase 18)		Green belt, H&M and ironestone	Uganda
		NASE 14		Green belt, H&M and ironestone	Uganda
		TME 14		Green belt, H&M and ironestone	Uganda

5.0	Vegetables	Varieties	Classification	Agro-ecological zones	Potential source
5.1	**Amaranthus**	White Elma		Ironestone, flood plain, semi-dry areas and parts of green belt	Kenya/Uganda
5.2	**Tomatoes**	Money Maker		Ironestone, flood plain, semi-dry areas and parts of green belt	Kenya/Uganda
		Cal J		Ironestone, flood plain, semi-dry areas and parts of green belt	Kenya/Uganda
5.3	**Carrots**	Nantes		Ironestone, flood plain, semi-dry areas and parts of green belt	Kenya/Uganda
5.4	**Onions**	Red Creole		Ironestone, flood plain, semi-dry areas and parts of green belt	Kenya/Uganda
		Bombay Red		Ironestone, flood plain, semi-dry areas and parts of green belt	Kenya/Uganda
5.5	**Kales/Collards**	Georgia		Ironestone, flood plain, semi-dry areas and parts of green belt	Kenya/Uganda
5.6	**Watermelon**	Crimson Sweet		Ironestone, flood plain, semi-dry areas and parts of green belt	Kenya/Uganda
		Charleston Grey		Ironestone, flood plain, semi-dry areas and parts of green belt	Kenya/Uganda
5.7	**Eggplants**	Black Beauty		Ironestone, flood plain, semi-dry areas and parts of green belt	Kenya/Uganda
5.7	**Cabbage**	Copenhagen		Ironestone, flood plain, semi-dry areas and parts of green belt	Kenya/Uganda
		Drum head		Ironestone, flood plain, semi-dry areas and parts of green belt	Kenya/Uganda
5.9	**Okra**	Clemson Spineless		Ironestone, flood plain, semi-dry areas and parts of green belt	Kenya/Uganda
		Pusa Sawani		Ironestone, flood plain, semi-dry areas and parts of green belt	Kenya/Uganda

Annex II: Seed Distribution Pathways for ZEAT BEAD 2 and SORUDEV SSR

Background

In the past ten years the European Union rural development programmes in South Sudan within the national NEAT programme of the Government of South Sudan funded several food security projects including substantial road rehabilitation. These were aimed at strengthening the capacity of farmers and increasing resilience of vulnerable and smallholder farmers in the rehabilitation and recovery process. The core programmes were the FSTP, Pro-Act, SORUDEV, SORUDEV-SSR and ZEAT BEAD (1&2). The design and implementation of these programmes were grounded on the geographical context of the country based on:

A. Farmer identification process

IPs identify poor farming households using a clear selection and vulnerability criteria

They shall:

- Keep a detailed farmer registration list with criteria of selection and gender.
- Keep the village, boma and payam names and coordinates.
- Fill the information into the official project database www.ciissouthsudan.org.
- Identify the seed type and varieties required by the farmers. (The crop names, variety and characteristics of seeds required must be clear. This must be cross-checked with the MoA departments of crops, crop protection and extension services at each state and county level).

B. Farmer capacity building process

IPs commence capacity building training on agronomic practices

They shall:

- Start with capacity gaps in understanding of current agronomic practices and nutrition.
- Train and orient their extension and community development officers in extension methodologies (FFS, lead farmers, groups, etc.). Decide at this point if a demonstration field is needed and do not confuse this with FFS.
- Using this information, develop and commence training of farmers in a structured manner.

C. Seed procurement process

IPs procure improved and certified seeds for distribution to vulnerable and smallholder farmers.

They shall:

- Do a mapping of all seed companies where good quality improved and certified seeds can be purchased. This should be done ahead of time because it takes time to identify the seeds providers that operate in the country, personally verify and check references (including from FAO) and check approval of the national Ministry of Agriculture.

• Use a very clear guideline on seed procurement that clearly lists the quality and conditions of seed purchases. QDS standards suggest that good quality cereal seeds should have 13-15% moisture content, legumes at 10% or below and vegetable seed at 8% or below.

• Determine the quantity of seed required by each farmer to launch seed procurement. This can be calculated though simple multiplication. For instance, if each farmer requires 3 kg of sorghum, and the target number of farmers is 3,000, then the quantity needed is 3 x 3,000 = 9,000 kg of seed.

• It is very important to check the EU general conditions for procuring goods and services on PRAG. Please note the thresholds for single procedure, negotiated advertisement in the country. The threshold for purchasing overseas is often based on total value of the commodity. It is also very important to check the government of South Sudan regulations guiding importation, tariffs and tax exemptions.

D. Procuring foundation seeds for seed producer groups

IPs shall assist seed producer groups to import foundation seeds according to the required policies for importation.

There is a clear difference between "improved certified seeds" distributed to farmers and the "foundation seeds" that will be distributed to seed producer groups.

The IP again should map sources of foundation seeds. At this point in South Sudan there are very few companies or institutes producing foundation seeds. Therefore it is not unusual to source this from neighbouring countries. In the case of sorghum and millet, the research institute in Sudan has bred Bushana and Ashana varieties of sorghum and millet, respectively, which could be obtained very easily. Similar varieties could be available in Uganda, Ethiopia or Kenya. IPs should follow very strict guidelines for importing seeds and for moving seeds across country borders. Based on the old Sudan regulations, and pending the finalization of the Seed Act in South Sudan, guidelines include:

1. Only companies registered with Seed Administration are allowed to import crop seeds.
2. To get a preliminary import permit for the importation of seeds, the registered company must following these rules of procedure:

a. Submit a written application on the company's letterhead with a signature and stamp. The letter must show the crop variety intended to be imported, seed class, quantity, the purpose for import and the port of entry.

b. Present a pro forma invoice from the exporting company or its branches.

c. The application to import field crops should be only for the registered varieties released by the Variety Release Committee. Imports of vegetable seeds are exempted from registration.

d. Pay the assigned fee

e. After presenting the preliminary import permit to the Office of the Undersecretary of Agriculture and paying the assigned fee, a phytosanitary import permit (Form No. 10) will be issued for the importer permitting the company to import the seeds within 45 days.

E. Working with the seed producer groups

IPs shall identify existing cohesive and strong farmer groups with clear interest in producing seeds or already producing seeds for sale.

A decision should be made on the number of seed producing groups that will exist. It should also take into account the number of farmers making up the group and whether they will have a single group farm or individual group members' farms. Understanding logistical and material situations required are equally important.

- IPs shall assess the farmers' understanding and knowledge of seed production checking if they understand the difference between "grain" and "seed".
- IPs shall conduct training on agronomic practices of the essential seed production techniques, seed processing, packaging, storing and marketing. There are publications by FAO, EUTA and many others that can be referenced.
- Seed production requires a significant time investment, and it will make sense for IPs to have dedicated extension staff to work with the producer groups.

Annex III: Required Conditions for Seed Treatment in an FAO-Supported Intervention

At the seed treatment facility:

- The pesticide products applied must be cleared by FAO's Plant Production and Protection Division and must be registered with the relevant national authority in the country/countries concerned.
- The company providing the pesticides has to declare that they are observing the FAO Code of Conduct on Pesticide Management, especially its provisions on labelling, as well as packaging and transport of pesticides.
- Users of pesticides applied as seed treatment must adhere to the necessary precautionary measures described on the product labels (e.g. wearing a protective mask, goggles and gloves).
- The treatment of seeds must be done in an appropriately equipped facility that ensures full containment of the pesticides.
- Users of seed treatment equipment should be provided with suitable application equipment and instructed on calibration, use and cleaning of the equipment.
- Treated seeds must be dyed an unusual and unpalatable colour to discourage consumption.
- All packages containing treated seeds must be clearly marked "Not for human or animal consumption" and with the skull and crossbones symbol for poison.

At the point of use of the treated seeds:

- Those handling treated seeds should be informed that the seeds are treated with pesticides, which can have toxic effects on their health, the health of others and on the environment.
- Handlers should be advised to wear clothes that fully cover their body (long sleeves, long trousers/skirt and closed shoes), and the distribution kits should include gloves and dust masks with instructions on their use. Handlers must wash themselves and their clothes after handling the seed.
- Packaging from treated seeds should not be reused for any purpose.

Annex IV: Compilation of World Vision South Sudan Experience and Guiding Note on Quality Declared Seeds

Acknowledgement: The notes, figures and pictures in this summary are taken from Effective Seed Quality Assurance, ISSD Africa, Synthesis Paper and the FAO Guide on Quality Declared Seed Systems (2006)

Introduction

Quality assurance is an important aspect of seed production and marketing. Seed producers or seed traders distinguish themselves from grain producers or grain sellers by offering quality seed in response to the demands of the seed client. External quality assurance is often seen as the centrepiece of the seed sector, therefore when aiming to strengthen seed sector functioning, the automatic response is to improve seed certification systems. It should be noted that there is little evidence of well-functioning seed certification systems in sub-Saharan Africa, however the system of independent seed certification is not the only option for improved quality assurance.

Alternative quality assurance mechanisms

Internal & external quality control

Internal quality control refers to the measures that seed producers take to ensure that the seed they produce meets their own minimum standards. Every seed producer, whether informal or formal, practices some form of internal quality control. External quality assurance refers to an independent or semi-independent inspection of the quality of the work done by a seed producer. External quality assurance has as such no influence on the quality itself; it only verifies whether a certain quality standard is met.

Improving internal quality control by seed producers could be made a more deliberate part of seed sector interventions. Judging from case studies, seed producers could benefit from clear, pragmatic crop-specific quality control protocols for the management of their seed crop. Such quality management protocols should not only specify norms, but they should also assist seed producers in following specific steps in crop management and administration during the production season. As a result, seed producers would be better able to monitor the quality of their seed crop, respond with specific cultural practices in a timely manner and downgrade their seed if necessary. Better monitoring of the seed crop will also deter seed producers from inviting inspection services to check a crop that is clearly not within the norms, thus avoiding costs to the seed producer as well as to the seed certification body.

The value of external quality assurance

It must be acknowledged that seed is often produced and traded without external quality assurance mechanisms. It is therefore valid to question what the added value of external quality assurance actually is. External quality assurance is first and foremost a service for seed clients, who can rely on it when judging the quality of the seed they intend to buy and use. As their own productivity depends on the quality of the seed they buy, an additional safeguard that the seed they purchase is of good quality is appreciated by farmers. It was also agreed that farmers would likely be willing to pay for external quality assurance under three important conditions:

1. The additional cost of external quality assurance is modest compared to the profits they could obtain from the crop;
2. They are convinced of the rigour of the external quality assurance; and
3. There is a clear difference in the yield potential of quality seed produced by a seed producer and their own seed.

Alternatives to classical seed certification systems

In the desk study, the African case studies and the experts' debate, a number of alternative models for certification were identified and discussed. Table 1 provides a schematic overview of different quality assurance mechanisms identified and their advantages and disadvantages as perceived.

Table 1:
Seed quality assurance mechanisms

System	Advantage	Disadvantage	Example
Self-control	Cheap and simple; based on reputation protection	Subjective; cannot be controlled; difficult to market off-farm; little incentive to be consistent; no check on the knowledge of the local seed producer	South Sudan
Truthfully labelled	Cheap; based on reputation protection; full private sector control over logistics	Requires ethical entrepreneurs; only works where a company wants to protect its reputation; responsibility with seed buyers to make a prudent choice	State seed trade in India
Group control	Internal organization of inspection; cheap	Not independent; sensitive to internal group politics	Burundi & Uganda
Quality Declared Seed (QDS)	Local inspection; independent; relatively cheap	Often limited laboratory testing; largely field-based observations	Uganda & Tanzania
Certification	Least opportunity to cheat; fully independent	Requires complex logistics; centralized laboratory testing; requires full-time inspectors	Formal system in most countries

Quality Declared Seed

Quality Declared Seed (QDS) refers to a form of quality assurance that was created to reduce the burden of rigorous conventional seed certification, while retaining the basic characteristics of external quality assurance and increasing access to quality seed for smallholder farmers

The leading principle of QDS is that quality assurance is organized locally, through individual self-control or through group-based mechanisms as described above. The national seed inspection services only routinely check a random sample of seed producers to assess whether the local quality assurance mechanism is functioning properly. The standards the seed producers need to adhere to under QDS can be adapted to the local situation.

An obvious advantage of QDS compared to self-control is the introduction of a truly external quality assurance mechanism that provides a clear incentive for seed producers to be rigorous and methodical about the quality control of their seed.

Options for improving QDS

- Institutionalization of QDS in the national seed regulations
- Development of realistic minimum quality parameters
- Development of local inspection capacity
- Development of local laboratory testing capacity and local laboratory testing protocols
- Support for local labelling and marketing of QDS seed

Figure 1:
Maize seed produced in South Sudan under self-quality control.
Source: Effective Seed Quality Assurance, ISSD Africa, Synthesis Paper.

Recommendation for team composition

The quality inspection team structure is recommended to be as described in table 2.

Table 2: Quality inspection team structure.

Member title	Inspection team role
State DG for Agriculture or his delegate	Chair person
Director or inspector for agriculture - State	Member
Head of County Agriculture	Member
One Agronomist from Research or University	Member
WV Agronomist/Manager	Member

Procedure to follow for Quality Declared Seed

The inspection team will do two rounds of inspection using an objectively prepared evaluation sheet for scoring.

Round 1: at vegetative stage to see the planting techniques, crop management, ways of controlling pest and disease and rogueing off-types (any overly tall or short plants or those with different colours).

Round 2: before harvest to see the performance of the crop and sample check any pest or disease infestation, and to check how the group prepared to do the sorting, transport and storage etc.

Other tasks of the inspection team may be to:

- Suggest the packing and labelling methods.
- Facilitate market linkage in the operational area by dealing with other FSL project implementing partners.
- Facilitate a seed expo so as to create public awareness on how the seed quality was rated and declared so as to motivate farmers to given more attention to quality in the next season.
- Assess the price of seed in the local market and project the selling price for different levels of quality declared seeds.
- Contact seed companies and NGOs at local and national levels to contract the QDS seed at a high pre-arranged price. WVSS will not sign the contract but only facilitate the meeting of buyers and sellers.
- Conduct a germination test one month before sales to determine germination %.

Seed multiplication group evaluation forms

Table 3: Evaluation form on the vegetative phase of growth. (The rating will be a score of 1 to 5, with 5 = very good and 1 = not good.)

s/n	Name of the group	Crop	Planting standard (line planting & spacing)	Isolation (geographic or planting time)	Crop management (harrowing, weeding, etc.)	Pest & disease control	Total score

Table 4: Evaluation form during harvest.

s/n	Name of the group	Crop	Crop management (weed control, etc.)	The situation of the yield	Pest and disease control	Group plan for harvest, sorting, grading and storage	Total score

Table 5: Summary sheet of field evaluation and categorizing the seeds/groups in to three levels.

s/n	Levels of QDS	Description of the different levels in declaring the quality of the seed	Farmer groups and the type of crop in this category	Remark
1	Level 1			
2	Level 2			
3	Level 3			

Joint committee recommendation of prices for different level of quality declared seed

Table 6: Price recommendation of crops for sale during harvest season.

s/n	Type of crop grown for seed	Market price for 1kg of seed in the area, during harvest	Quality declared seed level based on filed observation & evaluation			Remark
			Level 1	Level 2	Level 3	
	Sorghum					
	Groundnuts					
	Maize					
	Beans					
	Cassava					

Table 7: Price recommendation of crops for sale in April adding time value with proper storage.

s/n	Type of crop grown for seed	Market price for 1kg of seed in the area- close to planting period	Quality Declared Seed Level Based on filed observation & evaluation			Remark
			Level 1	Level 2	Level 3	
	Sorghum					
	Groundnuts					
	Maize					
	Beans					
	Cassava					

Annex V:

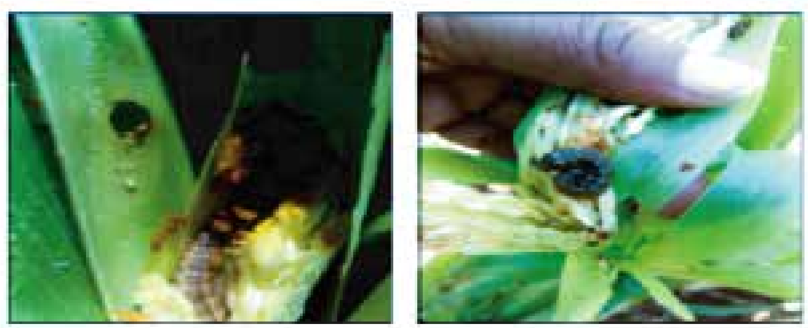
Fall Army Worm Stages of Growth in Pictures

Egg mass on lower leaf

Young Larvae (caterpillars) maize plant whorl

Advanced larva stage and its frass (excreta)

Typical FAW damage on maize



Typical FAW damage on maize tassels

Source: Status of the Fall Army Worm (FAW) in Kenya

Annex VI:
FAO Emergency Farm Kits for Farmers

The Food and Agriculture Organization of the United Nation (FAO) is a major player in supporting farmers and the people of South Sudan. FAO emergency operations are critical especially during the period of emergency when the government's capacity to support farmers and the large vulnerable population is often weak. This is a critical part of their mandate. Along with NGOs and CBO partners, FAO in South Sudan has demonstrated their commitment to support farmers through the distribution of assorted seeds, tools and fishing kits, often referred to as emergency livelihood kits.

The organisation's experience in supply chain management enables the procurement of seeds in the subregion and across the world. The stringent guidelines and instructions for Quality Declared Seeds which are followed for sourcing good quality seeds are referenced globally. The presence of FAO on the ground enables their staff and partners to deliver seeds directly to farmers with the objective of either helping the beneficiaries replace their lost seeds or augmenting the little seed stock they have left as a result of the war, displacement or migration.

Figure 1: FAO distributed seeds. Source: http://www.fao.org/emergencies/fao-in-action/stories/stories-detail/en/c/232311/

References

Besancon, Thierry Besancon et.al. (2018) Sorghum Growth and Development. USA: Department of Crop Science North Carolina State University.

CIMMYT (International Maize and Wheat Improvement Center) 2018. Fall Armyworm in Africa: A Guide for Integrated Pest Management, First Edition. USA: CIMMYT.

David Leonard. 1981. Traditional Field Crops. USA: Peace Corps' Information Collection & Exchange (ICE)

Difference between Seeds and Grains. 2010. DifferenceBetween.net. Accessed on line February 2019

Eric A. Kueneman 1995. "Optimizing plant population, crop emergence and establishment." FAO Publication. www.fao.org/3/y5146e/y5146e07.htm accessed June 2018.

FAO 1993. "Quality declared seed: technical guidelines for standards and procedures FAO plant production and protection." Paper 117. 1993 186pp ISBISBN 92 5 103278 5. Rome: FAO. Publications Department, FAO Via delle Terme di Caracalla 00100 Rome, Italy

FAO 2010. Seeds in Emergencies: A technical handbook. Seed and Seed Quality for Emergencies Appendix 14. Reprinted 2011

FAO. 2014. Appropriate Seed and Grain Storage Systems for Small-scale Farmers: Key Practices for DRR Implementers. Italy. FAO Publication.

Government of Sudan 2007: Procedure Import and Export of Seeds, Sudan. Khartoum

Hampton, J.G. and Tekrony, D.M. (1995). "Handbook of Vigor Test Methods". 3rd Edition, ISTA, Zurich, 117. Zurich: International Seed Testing Association (ISTA). Editors: Hampton, J. G.; TeKrony, D. M

Hybrid Crop Science Knowledge Zone India. n.d. (accessed online September 2018). http://cybridindia.com/Knowledge-Zone

I.Y. Dugje, I.Y. and J.E. Onyibe, J.E. (2004). : IITA Guide to Certified Seeds Production in Borno State, Nigeria. Ibadan: Published by IITA Prosab Project

ISU 2013. H8-Seed Vigour Ttesting. USA. IOWA State University Publication.

Joshua A. and Singh A (1982)."Technology of seed production and certification in Nigeria. Moor Plantation Ibadan. Nigeria: Published by Akinola Brothers. Pp 9,12,53,54

Katrin Kuhlmann 2015; Harmonizing Regional Seed Regulations in Sub-Saharan Africa: A Comparative Assessment. Part of a series of Syngenta Foundation's Seeds2B initiative

Nordby D. 2004. Pocket Guide to Crop Development: Illustrated Growth Timelines for Corn, Sorghum, Soybean, and Wheat., USA: University of Illinois Extension Service. 2004.

Optimizing plant population, crop emergence and establishment http://www.-fao.org/3/y5146e/y5146e07.htm.

Prutskova M. G. 2010, “Seeding Rate.” The Great Soviet Encyclopaedia., 3rd Edition (1970-1979). Farlex, Inc PA 19006 USA.

Ranga Rao GV, Rameshwar Rao V and Nigam SN. 2010. Post-harvest insect pests of groundnut and their management. Information Bulletin No. 84. Patancheru 502 324, Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. ISBN 978-92-9066-528-1. Order code IBE 084. 20 pp

Seed Dressing and Its Advantages. 2018. USA Walco Seed Cleaning.

Shackley, B.J. 2000. “Crop management”. In The Wheat Book -principles and practice, edited by W.K. Anderson & J.R. Garlinge, eds. The Wheat Book -principles and practice, pp. 137-145. Australia: Agriculture Western Australia. , Bulletin 4443. Australia

Shadia E. Abd El-Aziz., 2011. “Control Strategies of Stored Product Pests”. Journal of Entomology, 8: 101-122.

Sharma H C, Ashok S Alur, et.al. 2007. Management of sorghum and Pearl Millet Pests in Bulk storage. Global Theme on Crop Improvement. International Crops Research Institute for the Semi-Arid Tropics, Patancheru 502 324, Andhra Pradesh, India: 20 pp

Small footprintfamily (unknown) accessed online July 2018 “The Difference Between Open Pollinated, Hybrid and GMO Seeds”. Accessed July 2018. Original article at: https://www.smallfootprintfamily.com/hybrid-seeds-vs-gmos#ixzz5XJP6obYo.

Stahr, Michael. 2014. Cold Testing Options in Vigor Testing of Seeds. USA: Iowa State University Seed Lab.

UNIDO. 2015. Post-Harvest Training Manual South Sudan. ZEAT BEAD Project UNIDO

World Vision South Sudan. 2017. Seed Adaption Trials. PowerPoint Presentation Quarterly Review Meeting. Juba South Sudan. QRM (2017)

World Vison South Sudan. 2018. Adaptive Research Protocol Report. Juba South Sudan: World Vision South Sudan. (2018)

Xueping, Wua. 2012. “The Influence of Different Seed Dressing Treatments on Wheat Seedlings Growth under Water Stress Conditions.”

South Sudan Rural Development Programme