Soil Health Strategies for Sorghum Systems in Kenya

A Training of Trainers Field Manual

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About Excellency in Agronomy

The Excellence in Agronomy (EiA) Initiative offers a new model and research culture, seizing these opportunities to deliver agronomic gain at scale by facilitating efficiencies through globalized networking and aligning research and development (R&D) priorities with demands from scaling partners through context-specific Use Cases. It utilizes standardized analytics and decision support approaches in partnership with non-CGIAR Advanced Research Institutes (ARIs) and builds on Use Cases involving multi-actor partnerships. The vision of success of EiA is to deliver by 2030 agronomic gain for millions of smallholder farming households in prioritized farming systems, with emphasis on women and young farmers for measurable impact on food/nutrition security, income, water use, soil health and climate resilience. EiA's delivery pathway is through facilitating the delivery of agronomy-at-scale solutions, including development and technical/user-experience validation and the co-creation and deployment of gender- and youth-responsive solutions to smallholder farmers via scaling partners; Enabling the creation of value from big data and advanced analytics through the assembly and governance of data and tools, application of existing analytics and solutions for specific use cases, supply of information on climate impacts, inclusivity and sustainability of agronomic solutions; and national agricultural research system capacity strengthening; Driving the next generation of agronomy-at-scale innovations by addressing key knowledge gaps and facilitating innovation in agronomy research through engagement with partners, and Nurturing internal efficiencies for an agile and demand-driven agronomy research and development community through internal organization and external partnerships for prioritization, demand mapping and foresight.

About the Technologies for African Agricultural Transformation

The Technologies for African Agricultural Transformation (TAAT) is a major continent-wide initiative designed to boost agricultural productivity across the continent by rapidly delivering proven technologies to millions of farmers. TAAT aims to double crop, livestock, and fish productivity by expanding access to productivity-increasing technologies to smallholder farmers across Africa. TAAT brings together partners drawn from the Consultative Group on International Agricultural Research (CGIAR) Centres, and other Advanced Agricultural Research Institutes to work in consortium with the National Agricultural Research and Extension Systems (NARES), Ministries of Agriculture, the private sector, farmers' cooperatives and not-for-profit organizations involved in agricultural development to deploy agricultural innovations at scale with a focus on: Eliminating extreme poverty; Ending hunger and malnutrition; Turning Africa into a net food exporter, and Positioning Africa at the top of agricultural value chains. The developmental objective of TAAT is to rapidly expand smallholder farmers' access to high-yielding agricultural technologies that improve their food production, assure food security and raise rural incomes. This is done through three principal mechanisms: Creating an enabling environment for technology adoption by farmers; Facilitating effective delivery of these technologies to farmers through a structured Regional Technology Delivery Infrastructure, and Raising agricultural production and productivity by identifying and deploying strategic interventions that include improved crop varieties, animal breeds, and fingerlings.

About Diageo

Diageo is a global leader in beverage alcohol with a collection of more than 200 outstanding brands sold in more than 180 countries around the world. Every year Diageo produces more than 240 million equivalent units of their brands, from more than 150 manufacturing sites in 30 countries. Their annual revenue last year was more than £12.7B ($17B). Diageo owns Johnnie Walker and Smirnoff, two of the world's four largest international spirits brands by retail sales value. Diageo is a high performing business that is sensitive to consumer, community, and societal needs. Its ambition is to be one of the best performing, most trusted and respected consumer product companies in the world. Diageo is also the mother company to East African Breweries Limited (EABL) which itself includes: Kenya Breweries Ltd., Uganda Breweries Ltd., Serengeti Breweries Ltd. and East African Maltings Ltd. Its environmental, social, and governance (ESG) agenda "Society 2030: Spirit of Progress" defines its 10-year action plan to help create a more inclusive and sustainable world. To achieve that ambition, Diageo needs to make sure it is doing business the right way, from grain to glass. That means thinking about the long-term value and impacts it creates, and the risks and opportunities of its operating environment and business model. It is committed to promoting a positive role for alcohol, to championing inclusion and diversity, to preserving the natural resources on which its long-term success depends on, and to making a positive contribution to the communities in which Diageo lives, works, sources, and sells. As part of its "Society 2030: Spirit of Progress" smallholder farmers come under target #24: "Provide all of Diageos's local sourcing communities with agricultural skills and resources, building economic and environmental resilience (supporting 150,000 smallholder farmers)". Diageo's smallholder strategy aims to deploy smallholder programs which provide the required training and inputs needed to improve yields, crop quality and ultimately income for the farmers.

At the heart of this approach is the recognition that partnerships with farmers are the most effective way to promote sustainable farming practices and secure local supply networks. Likewise, building a network of technical and implementation partners to support Diageo in the delivery of these targets and programs is crucial. This is where this collaboration between Diageo and International Institute of Tropical Agriculture (IITA) comes in. This collaboration aims to support at least 20,000 sorghum smallholders across eastern and western Kenya by July 2023 by providing training on topics to include soil conservation and regenerative agricultural practices which can reduce the need for external inputs, control pests naturally and promote strong yields through healthy soils. This partnership begins with a training of trainers in eastern and western Kenya in May 2023.

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List of Abbreviations

CA	Conservation agriculture
GAPs	Good agronomic practices
ISFM	Integrated soil fertility management

Acknowledgement

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Forward

Healthy soil is soil with capacity to sustain soil biodiversity while maintaining water and air quality and supporting human health. For this reason, healthy soil is the foundation of a productive and sustainable environment. Such soil can support different types of plants and living organisms that conduct critical functions in the soil. Living organisms are important in recycling crop nutrients and making them available to growing plants, managing crop pests and diseases, building soil structure, conserving moisture and ultimately increasing crop yields.

Soil becomes unhealthy when one or several of its components i.e., living organisms, nutrients, air, water, and structure starts reducing or degrading. In as much as attaining high yield is important, there is need to ensure the productivity of fields is sustained with minimal effects on the environment. This can be achieved through employment of field management strategies that not only promote increased yields but also support the existence of diverse living organisms and that are resilient to changing climate.

Understanding the key characteristics of healthy soil, such as good structure, nutrient richness, pH balance, water retention, organic matter, and carbon storage is essential in agriculture, gardening, or landscaping. In this manual, we will explore the key principles and discuss benefits of promoting soil health. By employing practices outlined in this manual, you can manage the health of your soil for a long period and enjoy associated benefits.

Information in this guide is presented in a simple and concise way that is easily understood by diverse audience. This makes it a useful resource for extension staff and other stakeholders providing agricultural support services to local farmers.

Brain storming

- Have the audience define soil health in their own perspectives.
- Have the audience list some soil health promoting practices being conducted by farmers in their area.

What is soil health?

A healthy soil is dark in color, soft in texture due to presence of organic matter and has visible living organisms such as earthworms. Think of soil like a town with a well-established administration that has tall buildings and thousands of people conducting different functions. Some are producing raw materials, others cooking food, others supplying different products, others cleaning houses and streets, others are security persons etc. In short, everyone is busy supporting a certain role. This is how a healthy soil works.

A dark soil with growing plants and some visible living organisms

Why a Healthy Soil?

A healthy soil can meet its needs with little or no support. Take for example forest soil; nobody goes to the forest to apply fertilizers for trees to grow. But they grow anyway!

Healthy farms can also produce crops with little fertilizer needs from outside source. This is because farms can supply their nutrient needs if soil health is maintained. Only 10-40% of applied nitrogen fertilizer is taken up by crops but much of it is derived from microbial associations. However, 60% is lost to the environment through different pathways. Application of nitrogen fertilizers inhibit the ability of certain soil organisms to fix nitrogen from the atmosphere. Therefore, maintaining a healthy soil could really save cost for farmers.

Healthy soils can withstand different challenges such as floods, heat waves and drought and still produce food. This is because the different functions within the soil are active and functioning properly. To be able to conduct different functions, some key soil health principles should be put in place.

Principles of Soil Health

A healthy soil can be identified by the five principles indicated below:

1. Has maximum soil cover
2. Experiences minimum disturbances
3. Supports existence of maximum biodiversity
4. Presence of plants
5. Integrates livestock

Maximizing soil cover: use different materials to help provide cover to the soil. Crop residues and weeds are not trash, rather, they can be left on the surface of the soil to provide cover against adverse conditions such as:

- **Soil and nutrient erosion:** this happen when strong winds blow over bare land carrying away soil particles in form of dust. In addition, the direct impact of rain drops detaches particles of the rich topsoil. Water that flows over the soil surface i.e., runoff, then carries away detached soil and the nutrients if not able to infiltrate
- **Soil temperatures:** like any other living organism, soil requires cover from solar heating. Too much heating of the soil threatens the life of living organisms in the soil resulting in their death or reduced capacity to function. Heating increases water loss through evaporation and transpiration which limits plant's ability to access nutrients from soil
- **Weeds:** Like other plants, weeds require access to sunlight and free germinating space. Ensuring maximum soil cover reduce the ability of weeds to germinate and allows crops to grow with minimum competition for light and nutrients.

A crop field with maximum crop cover by crop residues and lablab cover crop

Minimizing soil disturbance: you can achieve this by reducing tillage activities which disrupt important soil processes. Reasons why you should avoid disturbing the soil include:

- Tillage destroys soil pore system that acts as channels for water infiltration reducing runoff. Intact soil pore system also provides airflow to support functions by living organisms
- Living organisms burrow the soil and makes tunnels that they use for their movement. In addition, they build their habitat or houses which are destroyed when soil gets disturbed. Millions of living organisms also die due to physical killing or exposure to solar heating during tillage process
- Healthy soil such as forest soils have a good structure with particles that stick together to form small balls called aggregates. Aggregates acts as a store for moisture, soil carbon and organic matter which acts as food for living organisms and source of plant nutrients.
- Tillage destroys soil structure by splitting aggregate particles which exposes organic matter to heavy feeding by living organisms. This depletes the stored organic matter and causes loss of associated nutrients and increases the rate for soil moisture loss
- Splitting large aggregate particles results in development of finer particles. Fine particles create a cement layer on soil surface i.e., crusting, that prevents percolation of rainwater. If the fine particles are deposited on the plough layer, they compact forming a hard pan which prevents water percolation to deep soil layers and prevents penetration of plant roots to deep soil layers
- Tillage results to incorporation of organic residues which results in loss of soil cover. Incorporating residues increase their breakdown and decomposition by living organisms.

- Tillage increases soil erosion through blowing of dust in the air and detachment of soil particles after structure destruction. The particles are easily eroded by runoff water.

- The process of soil disturbance is labor and intensive. Reducing disturbance will save on use of fossil fuel which pollutes the environment resulting to unhealthy soil.

Maximizing biodiversity: biodiversity refers to the different kinds of plants and living organisms that depends on the soil. Maintaining a large biodiversity of plants ensure plants exploit nutrients from different soil layers and living organisms derive food from diverse sources. Biodiversity can be maximized through the following methods:

- Crop rotation is a cropping system where different crop types are alternated in different seasons. Cereal crops such as sorghum and maize are planted in one season and alternated with legume crops such as beans, cowpea and pigeonpea in subsequent season

- Intercropping is the integration of cereal and legume crops on the same piece land and within the same season. The two crop types are either planted within the same row or ridge i.e., intercropping, or in different rows/ridges i.e., strip cropping

- Diversity of living organisms that are visible or not visible in the soil can be increased by minimizing soil cover and minimizing soil disturbance

- Crop diversification provides food and habitat for insects that help to reduces instances of pest attack on food crops and enhance pollination increasing crop yields. This helps to save on chemical use for pest control.

A soil with a rich diversity of plants that exploits nutrients from different soil layers avoiding competition

Soil needs Plants: Plant roots are important for supporting essential soil functions such as feeding the living organisms in the soil. While legumes develop structures that house the process of biological nitrogen fixation called nodules, certain bacteria conduct the actual function of fixing of the nitrogen. Other

Functions of roots in promoting soil health include:

- Living roots are known to secrete some sugars as they continue to grow. These sugars are used as important part of diet for majority of living organisms in the soil
- Helps in cycling of crop nutrients. Some roots can penetrate into deeper soil layers to get nutrients deposited there and pump them back to the top layers through their biomass
- Soil with rich crop root biomass benefits as the roots wears out and die. Dead roots become organic matter which enriches soil with organic carbon to feed the living organisms. Organisms break down organic carbon releasing nutrients that are taken up by other living roots
- Organic matter from old dead roots helps to build soil structure after decomposition by living organisms into soil

A beneficial association between plants and microbial organisms enhancing access of nutrients

Integration of Livestock: livestock are essential drivers of soil health. This is because of the critical role they play on nutrient cycling. Some of the ways in which livestock helps in promoting soil health include:

- Breakdown of plant residues into smaller particles
- Produces manure or dung that can be composted to enrich soil organic matter and produce rich organic fertilizers
- Application of manure generated from livestock helps to increase diversity of specific types of living organisms in the soil.

A farm with crops and animals to meet different soil health needs

Assessment One

- ❖ List five components of soil health
- ❖ Indicate how each of the component can be achieved by a local farmer.

Visual diagnostic of Soil Health

A visual diagnosis to identify a healthy soil is possible through examining the soil and growth patterns in vegetative parts of crops.

Watch out for some of these visual indicators of soil health:

- Color of the crop: Dark green coloration of a crop is a good indicator of a healthy soil. Deficiency of different nutrients is usually displayed by changes in color of plant leaves

- Crop yield: Reduction in yields is a factor linked to different growth variables, however, poor yield despite good rainfall could be a sign of poor soil health

- Living organisms: reducing numbers or absence of living organisms like earthworms in the soil is an indicator of unhealthy soil. Living organisms reduces when organic matter which forms an important source of their feed decreases. Soil becoming either acidic or alkaline and improper handling of agro-chemicals can also affect the number of living organisms.

- Soil color: an organic matter rich soil is dark in color. As the organic matter content in the soil starts reducing, the dark color fades off.

- Soil hardness: healthy soils are soft and less resistant to penetration. Soil has visible granules called aggregates which acts as store for soil organic matter. Aggregate particles also allow passage of air and water in the soil. As soil continue to lose its fertility, it starts hardening and becoming more resistant to penetration. Breakage of aggregates leads to blockage of soil aeration channels and inhibits infiltration of water hence negatively affecting growth of crops and activities of living organisms.

- Weeds: Weeds such as wondering jew and amaranth are indicators of healthy soil, However, presence of poverty grass, Mexican marigold or striga (witch weed) is a sign of unhealthy soil. Striga grows in nitrogen impoverished soils and its population continue increasing as the fertility of the soil continues to decrease.

A sorghum field infested by Striga; an indicator of poor soil health. Photo credit: TAAT Clearinghouse, 2022

Visual Soil Assessment (VSA)

An intact block,15 cm deep, 20 cm thick and 20 cm wide are obtained from a soil pit (30×30×30 cm in size) and put on a plastic bag. Depending on soil type, the blocks are dropped a maximum of three times from 0.5 m height (sandy soils) and 1 m height (clay soils). Key soil quality indicators such as soil texture, soil structure, soil porosity, number and colour of soil mottles, soil colour, earthworms, soil smell and potential rooting depth are then assessed. Scores for each individual indicator are given by comparing the soil with reference photographs as described in the manual (Shepherd, 2009). Each indicator is scored as visual soil (VS) of 0 (poor), 1 (moderate), 2 (good), or in-between (0.5 = moderately poor and 1.5 = moderately good) in respect to reference photos. The scores for each attribute are then weighted and summed up to derive a final overall score for soil structural quality (Shepherd, 2009). Weighting factors of 1, 2 or 3 as suggested by Shepherd, (2009) are used. Soils with a sum of visual scores ranking <20 have a poor soil quality, and soils with values >37 have a good soil quality. Values between these ranges are of a moderate soil quality.

SCORE CARD

VISUAL INDICATORS TO ASSESS SOIL QUALITY UNDER CROPPING

SOIL INDICATORS

Land owner: Land use:
Site location: GPS ref:
Sample depth: Topsoil depth:
Soil type: Soil classification:
Drainage class (p. 73): Date:

Textural group: (upper 1m) ☐ Sandy ☐ Coarse loamy ☐ Fine loamy ☐ Coarse silty ☐ Fine silty ☐ Clayey

Moisture condition: ☐ Dry ☐ Slightly moist ☐ Moist ☐ Very moist ☐ Wet

Seasonal weather: ☐ Dry ☐ Wet ☐ Cold ☐ Warm ☐ Average

Visual Indicators of Soil Quality	Visual Score (VS) 0 = Poor condition 1 = Moderate condition 2 = Good condition	Weighting	VS Ranking
Soil texture (p. 70)		× 3	
Soil structure (p. 71)		× 3	
Soil porosity (p. 72)		× 3	
Number and colour of soil mottles (p. 73)		× 2	
Soil colour (p. 74)		× 2	
Earthworms (Number =) (p. 76) (Average size =)		× 3	
Soil smell (p.78)		× 2	
Potential rooting depth (mm) (p. 80)		× 3	
Surface ponding (p. 82)		× 3	
Surface cover and surface crusting (p. 84)		× 2	
Soil erosion (wind/water) (p. 85)		× 1	
SOIL QUALITY INDEX (Sum of VS rankings)			

Soil Quality Assessment	Soil Quality Index
Poor	< 20
Moderate	20 – 37
Good	> 37

Visual Evaluation of Soil Structure (VESS)

Block extraction is same as in VSA as explained above. In this method, resistance of contrasting soil layers is considered. The assessment of the soil blocks includes manual break down of aggregates by hand and assessing the individual criteria, i.e., ease of breaking aggregates, size and appearance of aggregates and visible porosity. One overall score per block is then assigned based on an integrated appreciation of the individual criteria (Guimarães et al., 2011). The blocks of soil are scored on a scale from structural quality (Sq)1 to Sq5 with score 1 as best. Scores are fitted between structural quality categories when the soil block has the properties of both. The overall score of the 30 cm soil block is determined by multiplying the score of each layer by its thickness and dividing the product by the overall depth (Pulido Moncada et al., 2017). Soils with scores of 1–3 have acceptable condition of soil structure whereas those with scores of 4–5 have a limiting condition and require change of management.

Table 1. Comparison of VSA versus VESS

VSA	VESS
Evaluates several soil attributes	Evaluates soil structure
Considers a soil block as a whole	Considers contrasting layers in each soil block
Soil block dropped	Soil block broken into aggregates by hand

Soil structure evaluation under VSA

VESS Score Card

Visual Evaluation of Soil Structure

Soil structure affects root penetration, water availability to plants and soil aeration. This simple, quick test assesses soil structure based on the appearance and feel of a block of soil dug out with a spade.
The scale of the test ranges from Sq1, good structure, to Sq5, poor structure.

Equipment:
Garden spade approx. 20 cm wide, 22-25 cm long.
Optional: light-coloured plastic sheet, sack or tray ~50 x 80 cm, small knife, digital camera.

When to sample:
Any time of year, but preferably when the soil is moist. If the soil is too dry or too wet it is difficult to obtain a representative sample.
Roots are best seen in an established crop or for some months after harvest.

Where to sample:
Select an area of uniform crop or soil colour or an area where you suspect there may be a problem. Within this area, plan a grid to look at the soil at 10, preferably more, spots. On small experimental plots, it may be necessary to restrict the number to 3 or 5 per plot.

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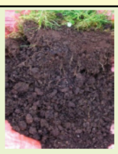
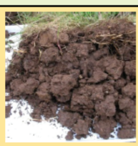
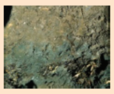
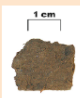
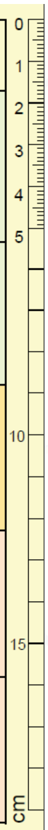
Method of assessment:

Step	Option	Procedure
Block extraction and examination		
1. Extract soil block	Loose soil	Remove a block of soil ~15 cm thick directly to the full depth of the spade and place spade plus soil onto the sheet, tray or the ground
	Firm soil	Dig out a hole slightly wider and deeper than the spade leaving one side of the hole undisturbed. On the undisturbed side, cut down each side of the block with the spade and remove the block as above.
2. Examine soil block	Uniform structure	Remove any compacted soil or debris from around the block
	Two or more horizontal layers of differing structure	Estimate the depth of each layer and prepare to assign scores to each separately.
Block break-up		
3. Break up block (take a photograph - optional)		Measure block length and look for layers. Gently manipulate the block using both hands to reveal any cohesive layers or clumps of aggregates. If possible separate the soil into natural aggregates and man-made clods. Clods are large, hard, cohesive and rounded aggregates.
4. Break up of major aggregates to confirm score		Break larger pieces apart and fragment it until a piece of aggregate of 1.5 - 2.0 cm. Look to their shape, porosity, roots and easily of break up. Clods can be broken into non-porous aggregates with angular corners and are indicative of poor structure and higher score.
Soil scoring		
5. Assign score		Match the soil to the pictures category by category to determine which fits best.
6. Confirm score from:		Factors increasing score:
	Block extraction	Difficulty in extracting the soil block
	Aggregate shape and size	Larger, more angular, less porous, presence of large worm holes
	Roots	Clustering, thickening and deflections
	Anaerobism	Pockets or layers of grey soil, smelling of sulphur and presence of ferrous ions
	Aggregate fragmentaion	Break up larger aggregates ~ 1.5 – 2.0 cm of diameter fragments to reveal their type
7.Calculate block scores for two or more layers of differing structure		Multiply the score of each layer by its thickness and divide the product by the overall depth, e.g. for a 25 cm block with 10 cm depth of loose soil (Sq1) over a more compact (Sq3) layer at 10-25 cm depth, the block score is (1 x 10)/25 + (3 x 15)/25 = Sq 2.2.

Scoring: Scores may fit between Sq categories if they have the properties of both.
Scores of 1-3 are usually acceptable whereas scores of 4 or 5 require a change of management.

16 Oct 2012

Structure quality	Size and appearance of aggregates	Visible porosity and Roots	Appearance after break-up: various soils	Appearance after break-up: same soil different tillage	Distinguishing feature	Appearance and description of natural or reduced fragment of ~ 1.5 cm diameter	
Sq1 Friable Aggregates readily crumble with fingers	Mostly < 6 mm after crumbling	Highly porous Roots throughout the soil			 Fine aggregates		The action of breaking the block is enough to reveal them. Large aggregates are composed of smaller ones, held by roots.
Sq2 Intact Aggregates easy to break with one hand	A mixture of porous, rounded aggregates from 2mm - 7 cm. No clods present	Most aggregates are porous Roots throughout the soil			 High aggregate porosity		Aggregates when obtained are rounded, very fragile, crumble very easily and are highly porous.
Sq3 Firm Most aggregates break with one hand	A mixture of porous aggregates from 2mm -10 cm; less than 30% are <1 cm. Some angular, non-porous aggregates (clods) may be present	Macropores and cracks present. Porosity and roots both within aggregates.			 Low aggregate porosity		Aggregate fragments are fairly easy to obtain. They have few visible pores and are rounded. Roots usually grow through the aggregates.
Sq4 Compact Requires considerable effort to break aggregates with one hand	Mostly large > 10 cm and sub-angular non-porous; horizontal/platy also possible; less than 30% are <7 cm	Few macropores and cracks All roots are clustered in macropores and around aggregates			 Distinct macropores		Aggregate fragments are easy to obtain when soil is wet, in cube shapes which are very sharp-edged and show cracks internally.
Sq5 Very compact Difficult to break up	Mostly large > 10 cm, very few < 7 cm, angular and non-porous	Very low porosity. Macropores may be present. May contain anaerobic zones. Few roots, if any, and restricted to cracks			 Grey-blue colour		Aggregate fragments are easy to obtain when soil is wet, although considerable force may be needed. No pores or cracks are visible usually.



Group Assessment two

- List six visual indicators of soil health.
- Indicate the major differences between VSA and VESS.

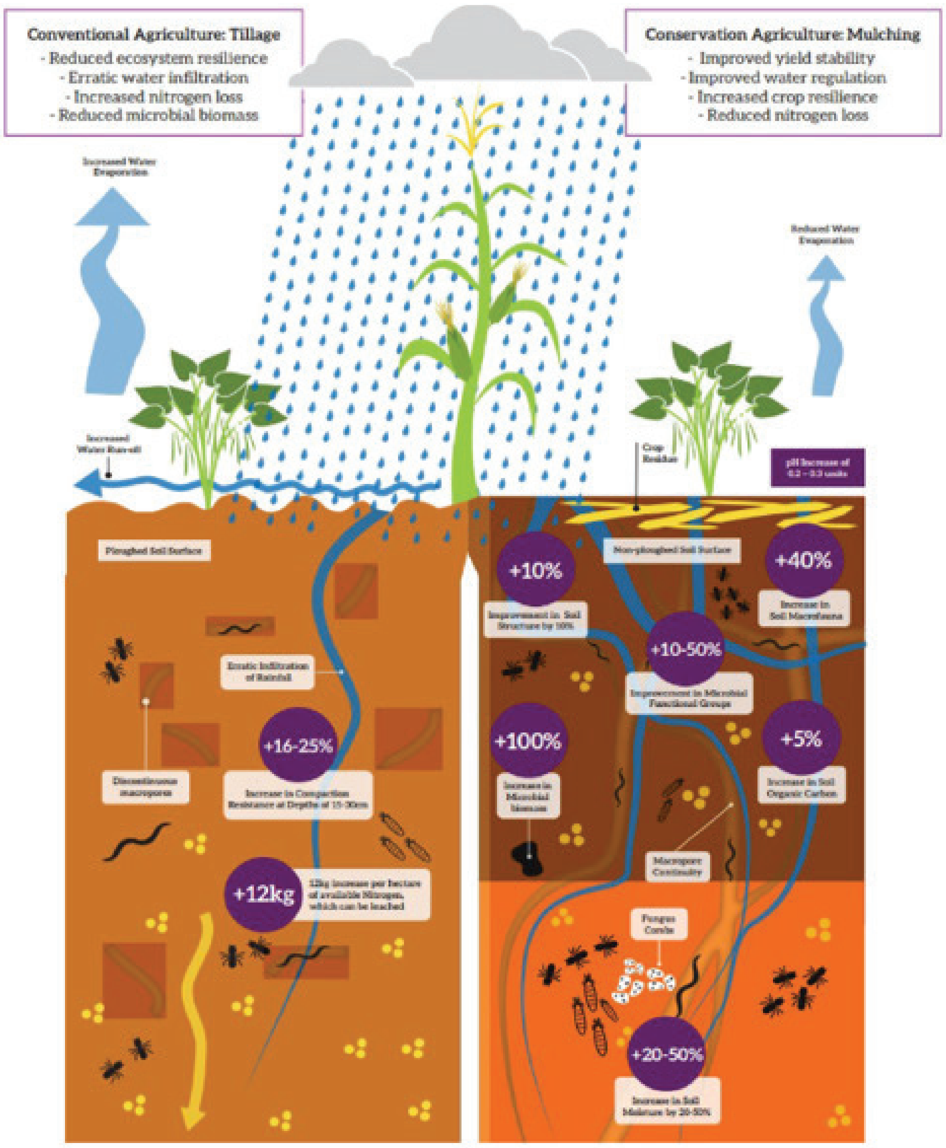
Avoid the harmful effects attributed to conventional tillage by adopting conservation agriculture (CA). Conservation agriculture involves reduced disturbance of soil, maintaining at least 30% of permanent soil cover and crop rotations. Reduced soil disturbance controls destruction of soil structure and damage to home for the living organisms.

Good Agricultural Practices for Promoting Soil Health in Sorghum Systems

Some technologies promoting soil health of sorghum systems are explained below.

Conservation Agriculture

- Use of crop residue mulch or cover crops such as groundnut, green grams, cowpea and lablab help to regulate soil temperatures and surface water flow after rains by encouraging rainwater infiltration.
- Residue from sorghum and/or cover crops also decompose and is converted into organic matter that acts as source of food for living organisms in the soil and nutrients for the crop.
- Cultivate sorghum under cereal-legume rotational cycles rather than continuous cropping to avoid build-up of pests and diseases. The legume phase helps to break pest and disease cycles. Integrating legume rotations in sorghum systems also help to improve soil fertility through fixation of nitrogen derived from the atmosphere. Fixation of nitrogen from the atmosphere reduces the amount and cost incurred to purchase fertilizers during top-dressing.



Soil health benefits under conventional tillage relative to conservation tillage. Photo credit: Kihara et al., 2020

Integrated Soil Fertility Management

This refers to a soil fertility management practices that include proper use of fertilizer, organic inputs and improved varieties, combined with GAPs (i.e., proper spacing, timely plating, weeding, pest and disease control etc.) on how to adapt these practices to local conditions. The aim of ISFM is to maximize use efficiency of the applied nutrients and increasing crop productivity.

Inorganic fertilizers: these are nutrients that are in chemical form which are mainly manufactured from the industries. Inorganic fertilizers are applied as a 'First Aid' for unhealthy soil to help it support crop growth. However, they are not a lasting solution to improving the health of the soil. You are advised to combine inorganic fertilizers with organic fertilizers to promote lasting soil health.

Organic fertilizers: these are fertilizers whose main source is the plants. These types of fertilizers can provide crop nutrients at controlled levels and for a long period of time. They also act as food for living organism by increasing soil carbon and organic matter levels, helps to improve soil structure, regulate soil pH and conserve soil moisture. Some organic fertilizer types include:

- Farmyard manure: manure from composting of animal dung
- Compost manure: manure from composting crop residues
- Crop residues: Remains of crops after harvest that are left in the farm to decompose forming rich organic matter
- Biochar: Partially burned organic material from unwanted plants such as invasive weeds or plants applied on soil to improve soil carbon content and moisture holding capacity.

Biochar from partially burnt wood fuel from cooking area

- Biofertilizers: Biofertilizers are natural and eco-friendly nutrient sources like nitrogen-fixing bacteria, mycorrhizal fungi, rhizobacteria, foliar sprays and plant extracts. They are perfect alternatives to synthetic fertilizers because they help improve soil structure, nutrient availability, and plant resistance to pests and diseases. Their integration into field management practices promotes sustainable and healthy soil ecosystems while reducing the negative environmental impacts associated with chemical fertilizers.

- Vermiculture: Refers to use of earthworms to break down organic matter into nutrient-rich castings. The practice improves soil structure, increases water retention, and regulates nutrient release avoid flushes to the environment. It is a sustainable natural method that fits a variety of settings ranging from small-scale gardens to large-scale agriculture. The practice promotes soil health while reducing dependency on synthetic fertilizers and pesticides.

Improved seed varieties: these are seeds that have been improved to help in increasing crop yields. Improved seeds are also bred to resist growth challenges such as pest and diseases and drought. Improved seeds are also efficient utilizers of nutrients compared to local seeds.

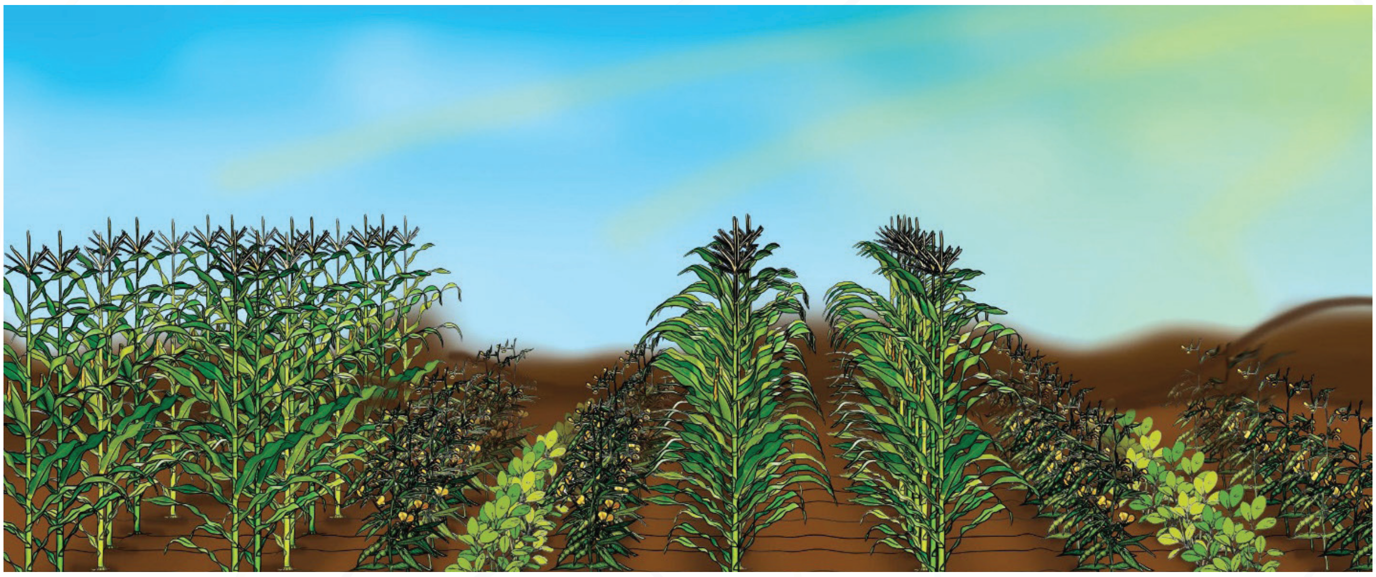
Intercropping: Sorghum crop can be planted either as a sole crop or as an intercrop with other crops. The process of cultivating crops of different kinds is called crop diversification. Crop diversification helps to reduce chances of total crop loss in case the prevailing weather does not favor sorghum production. Use improved intercropping innovations such as MBILI and Mbili-Mbili developed to optimize the economic returns as well as promote soil health through crop diversification

- Do not intercrop sorghum with cereal crops such as maize and millet because they have same growth pattern as sorghum and draws growth resources at the same time resulting in unhealthy competition. They also suffer from same pests and diseases which would increase the intensity of attack

- Intercrop sorghum with leguminous crops such as cowpea, pigeonpea, lablab, groundnuts or fodder crops such as desmodium. legumes have different growth patterns reducing potential competition for growth resources

- Leguminous crops also improve soil fertility through nitrogen fixation. For example, a pigeonpea intercrop can fix up to 20 kg per acre of nitrogen depending on the agroecological conditions

- Retain residues from the intercropped legumes which are rich in nitrogen to helps in improving soil fertility and structure.



Mbili-Mbili technology showing integration of a cereal crop with two species of legumes

Agroforestry

Agroforestry is a practice where trees are integrated in agricultural production i.e., in crop and animal production. Trees can be planted on farm boundaries or inside the farm. When planted along farm boundaries, trees can help to break strong weeds which may cause lodging of sorghum crop reducing its production. Leguminous agroforestry trees such as sesbania and calliandra can be planted on strip across sorghum field and pruned at the end of the cropping season.

- Prunings from leguminous agroforestry trees are important source of nitrogen, organic matter, and help to conserve moisture in the soil
- Apply prunings on the surface as mulch or chop into pieces and burry them in the soil during land preparation to improve soil organic matter
- Use prunings as supplementary fodder for the livestock to avoid complete removal of sorghum residues during crop harvest
- Apply prunings from leguminous trees in crop fields to provides food for living organisms. These prunings help to quicken the breakdown of the hardy sorghum residues and avail nutrients to subsequent crops
- Roots from agroforestry trees fix nitrogen from the atmosphere without competing with cultivated crops
- If the field is susceptible to soil erosion, plant agroforestry trees along the vulnerable areas to help hold the soil.

Select agroforestry trees that are not preferred as nesting sites by birds. This is because birds could be a potential threat to sorghum crop. However, birds can be controlled by regular pruning of trees

An agroforestry system with integration of trees, crops and livestock. Source: Duguma et al.

Pit Cultivation

Pit cultivation is a climate resilient strategy for crop production in dry areas. Small pits are dug and applied with well composted manure or other organic matter to improve soil fertility and increase moisture conservation. Multiple sorghum seedlings can then be planted in the pit, depending on the size of the pit. Examples of pit cultivation methods include:

- **Zai pits:** a hole measuring 1.5 m × 1.5 m with a depth of 30 cm is dug using a hand hoe. Topsoil from 0-15 cm is separated from that of 15-30 cm. Topsoil is mixed with fertilizer and manure and returned to half-fill the pit. Bottom soil is piled on the lower side to trap runoff water into the pit. Several sorghum plants are planted in the pit.

- **Ngolo pits:** has similar dimensions as Zai pit, however, dry crop residues are chopped and layered along the edges of the pit. Topsoil is evenly spread on the residues, leaving a small hole known as 'ngolo' at the center. Sorghum is planted at the edges of the pit while ngolo pit is left to harvest and conserve rainwater

Zai pit (left) and ngolo cultivation pit (right) supporting different types of crops. Source: Wafula et al. (2022)

In-Situ Water Harvesting

- Contour bunds: are small molds of soil (upto 50 cm high) that are heaped across the slope to act as barrier for holding runoff and ensure controlled infiltration of water in the field. Construct a series of contour bunds at closer intervals if your field is on a steep slope to reduce the erosive force of runoff water. To reinforce the bunds, soil can be mixed with stones or agroforestry trees such as gliricidia (G. sepium), leucaena (L. leucocephala) and forages like napier planted to provide quality forage.

A sloping field with a napier strip planted to reinforce a contour bund

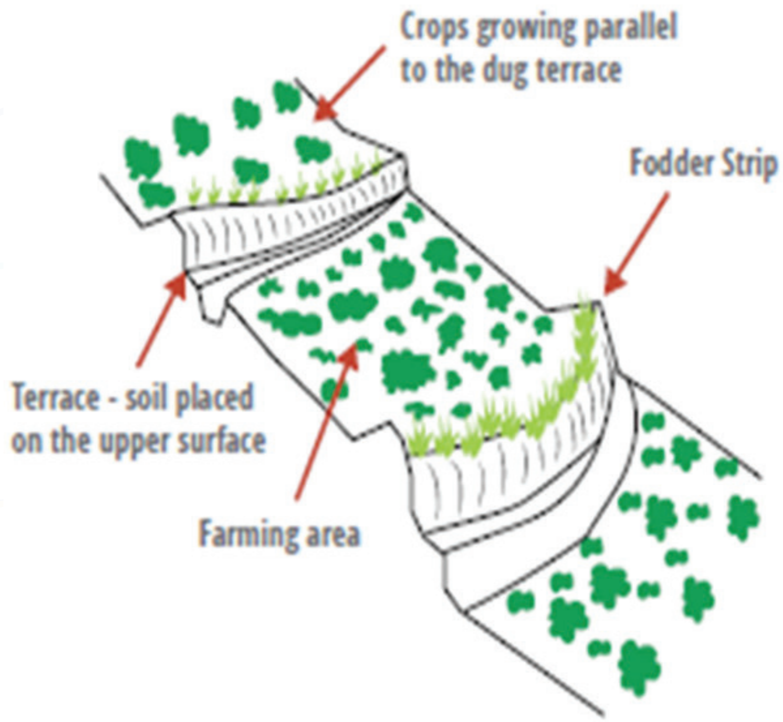
- Terraces: Terraces are deep furrows that are constructed across the slope with the aim of controlling soil erosion by runoff water. Terraces can be dug, and soil placed on the upper “Fanya Juu” or lower “Fanya Chini” side of the slope. Placing soil on the upper side of the slope enhances water infiltration and deposition of eroded soil in the portion of land adjacent the terrace. Placing soil on lower side of the terrace allows collection and conservation of run-off water inside the terrace. The soil bund on either the upper or lower side of the terrace can be stabilized by planting grass strips, forage crops such as napier or agroforestry trees.

- Retention ditches: These are shallow furrows that are constructed across the slope for holding run-off water. Like their name suggests, they collect and retain water until it slowly seeps in the soil. Retention ditches are ideal for semi-arid areas to help conserve much of the water that is lost through surface runoff.

- Cut-off drains: Cut-off drains are furrows that are constructed across the slope for harvesting surface runoff water from the farm and safely directing it away from the field. Retention ditches are used to collect water from cut-off drains in fields where there are no water channels to safely direct the water.

- Infiltration pits: These are a series of pits that are dug across the slope to collect runoff water and allow its seepage into the soil. The pits can be as wide as 2 m squared and up to 1 m deep. The number of pits in a field are determined by the amount of runoff they are intended to collect. Once full, a small furrow is dug to channel overflow from one pit to another.

- Water pans: These are small dams that are sunk in the field to collect water from the different water harvesting structures. The size of the pan is determined by the size of the field and availability of labor. In highly permeable soils such as sandy soils, a polythene liner can be used to prevent rapid water loss through percolation. Agro-forestry tree such as calliandra are also planted around the pan to create a macro-climate that prevents water loss through evaporation. Water collected in the pan can be later irrigated to the crop during the dry period.



A sloping field with terraces constructed and reinforced with forage grasses

Assessment Two

- ❖ List different strategies that can be used to promote soil health.
- ❖ Indicate soil health promoting strategies applied by farmers in your area.
- ❖ Identify and explain which soil health promoting strategies can be introduced in your area to promote soil health.

Challenges Affecting Sorghum Production

Sorghum is known to be the 'camel of the crops' because of its ability to withstand drought while providing food security solutions in a period of changing climate. The crop is cultivated in marginal areas while 85% of arable land in Kenya is committed to maize and beans cultivation. Potential to adapt to harsh weather conditions and presence of unsatiable market provides a great opportunity for sorghum cultivation in the country.

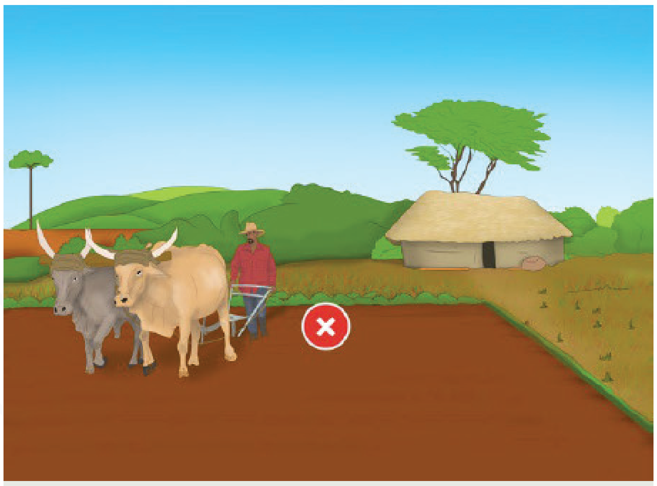
With the increase in degradation of cultivated land and accelerated interest of promoting drought tolerant crops, the future of sorghum enterprise as a contributor of food security, income earner and poverty alleviator continues to brighten. This creates need for more investment in avail sorghum production knowledge to farmers and other relevant stakeholders. This can help to improve sorghum yield form the current 1.2 t ha^{-1} to a potential yield of 2.5 t ha^{-1}.

Agronomic Practices for Sorghum Production

Land Preparation

Select a field that is not isolated from other sorghum fields. Isolated fields are vulnerable to attack by birds which are a big threat to sorghum production. Prepare your land early enough to ensure it does not coincide with other essential field activities such as planting. Consider the following practices during land preparation:

- Sorghum requires a fine tilth to allow uniform germination, so make sure large soil clods are reduced to sizable level through harrowing
- If conducting tillage, ensure land is ploughed deep enough (at least 20 cm deep) to break a stiff layer forming about 15-20cm from the surface called hard pan
- Avoid tilling your land when the soil is moist. Tilling moist soil encourages formation of hardpan especially where heavy machinery like tractors or animal ploughs are used
- If your field is slopping, conduct tillage activities across the slope and not along the slope. Tilling the land across the slope prevents removal of nutrient rich soil from the upper side of the slope to the bottom areas.



Tilling the land along the slope (up and down) is a bad practice that encourages soil degradation.

Tilling the land across the slope is a good practice that controls land degradation.

Seed Selection

Ensure timely selection of sorghum seed to plant to allow enough time for sourcing enough materials. This will allow you to test for seed ability to germinate i.e., seed viability. If 10 grains are planted in a container or seed bed, at least 8 of the grains should germinate. Sorghum variety to be planted is determined by the following factors:

- Agro-ecological conditions of the area
- Seasonal weather predictions
- Resistance to potential threat such as pests and diseases
- Intended use of the produce

Certified hybrid seeds have higher yields than both the local and recycled seeds. Recycled seeds harbor high concentration of pests and disease-causing pathogens from the previous season's infestation. If recycled seeds are the only available option, get seeds that are free from pest and diseases from a clean field. Consider the following steps while choosing recycled seeds:

- The field you intend to get seeds should have has a pure sorghum variety, avoid fields with mixture of varieties
- In the middle of your field, select plants with large and healthy panicles
- Air dry the panicles to remove excess moisture. Avoid over drying the grains
- Cut off the edge of the panicle to eliminate small grains
- Thresh the panicle and winnow to obtain clean seeds
- Remove any damaged or broken grains
- Dress the seeds with appropriate pesticides and store in a dry and well aerated place
- Do not replant recycled seeds for more than three seasons since their productive capacity is drastically reduced.

Choose sorghum varieties that are suitable for your area. Sorghum varieties with late maturity characteristic are suitable for areas or seasons characterized by higher rainfall while early maturity varieties are recommended for seasons and areas receiving low rainfall. Some common sorghum varieties and their suitable growing areas are provided in the table below

Table 2. Sorghum varieties and areas suitable for their cultivation

Sorghum variety	Phenological characteristics	Ecological conditions	Suitable areas	Uses	Potential yield (bags/acre)
Gadam	Grain white in color, Semi-dwarf to average height, early maturity (85-95 days),	Low rainfall semi-arid areas, Warm mid-highlands	Mwingi, Makueni, Machakos, Kitui, Tharaka, Mbeere, Kilifi, Tana River , Marsabit, Moyale and Kajiado	Brewing industry	14
Seredo	Medium height, spreading tillers, dark brown color, early maturity (110-120 days), resists birds attack	Wet lowland regions	Busia, Kisumu, Homabay, Kakamega, Siaya and Lower eastern Kenya	Human food and poultry feed	12-16
Serena	Medium height, straight erect tillers and narrow leaves, compact conical head, brown grain, short maturity (90-110 days), resists bird damage	Semi-arid areas	Tharaka, Kitui, Mwingi, Makueni, Machakos, Kakamega, Busia, Homabay, Kisumu, and Siaya	Human food and poultry feed	8-10
KARI Mtama-1	Tall variety, has two straight tillers, short duration (90-120 days), large and white grain, tolerant to aphids and stalk borer attack, Vulnerable to attack by birds	Semi-arid areas	Tharaka, Mbeere, Kitui, Mwingi, Makueni, Machakos, Marsabit, Moyale Kilifi, Tana river, and Kajiado	Human food and poultry feed	17
Ikinyaruka DP	Long duration maturity (8 months)	Dry high lands and High Potential areas		Human food	14
E 6518	Brown grain, Long duration maturity (8 months)			Human food	12-17
E 1291	White grain			Human food	10-15
Sila	White sweet tasting variety. Disease tolerance. Short growing period. Flowers at 65 days. Matures at 3-3.5 months. Water stress resistant It's a dwarf variety, standing at about 1 meter (for easy management) Resistant to leaf blight, rust, and ergot fungi. Low in tannin content, high in malting content.			Human food, brewing industry	12-18
Advanta's Hybrid Sorghum 23012	White variety. High yielding, drought tolerant, early maturing and suitable for brewing.			Brewing industry	

Planting

Dry plant your seeds few days before or immediately after rainfall onset to maximize the utilization of the soil moisture. Make shallow furrows, about 5 cm deep, using ox-drawn plough or hand hoe. Ensure that planting furrows runs across the slope to control soil erosion on slopping fields. Consider the following tips during planting:

- Timely planting ensures the crop develops at the same time as that of other fields to avoid infestation by pests and diseases
- Plant early maturity varieties if sowing has been delayed
- Plant between 3 to 4 seeds per planting station to achieve a good planting density
- Place seeds at a depth of between 2.5 to 4 cm if the soil has enough moisture content or 5 cm if dry planting
- In case it's too late to plant but soil moisture can allow seed germination, substitute sorghum with drought tolerant varieties legumes such as cowpea or lablab

Late planting of crop is a poor agronomic practice. It increases chances of crop failure and exposes crop to pest and disease attack.

Thinning

Sorghum germination starts on the 5th day where the number of plants per station are reduced to 1, a week after germination. The process of minimizing plants per planting station is called thinning. Consider the following tips during thinning of the sorghum crop:

- Thinning should be done on moist soil and when plants are young to avoid shock on the seedling.
- Consider removal of seedling that are weak, deformed, or diseased to give way for the growth of the healthy ones.
- Healthy thinned seedlings can be replanted in stations where seeds did not germinate.
- Replanting of thinned seeds is done if soils are moist and preferably in the evening to avoid shock on the transplanted seedlings.
- The lower leaves of the seedling being transplanted are cut off to reduce water loss.

Spacing

Achieving the correct plant density is an important indicator of the expected sorghum yield. Consider the following spacing depending on your agroecological zone and preferred cropping system

Table 3. Different sorghum spatial arrangements guided by agro-ecological conditions and cropping systems

Agro-ecological are	Cropping system	Spacing
Low rainfall areas/season		90 cm x 15 cm
High rainfall areas/season	Sorghum monoculture systems	75 cm x 20 cm
	Sorghum single row alternate intercrop system	90 cm x 20 cm
	Sorghum with double rows of intercropped legume	120 cm x 20 cm

An extension staff advising farmers on proper plant spacing

Assessment Three

- ❖ Why is it important to consider they type of variety to plant in your field.
- ❖ List types of sorghum varieties suitable for your area.
- ❖ What guides the spacing of plants in your field.

Soil Fertility Management Practices

Supply the right nutrients to sorghum to attain optimal yield. You can achieve this through application of inorganic and organic fertilizers.

Inorganic Fertilizers

These are plant nutrients produced in the industry. Macro-nutrients are fertilizers required by plats in large quantities and include nitrogen, phosphorus, and Potassium.

- Apply the Right type of fertilizer in the Right amounts at the Right time, in the Right place to achieve yield increases of between 40% to 120%.
- Place fertilizers at least 5 cm away from seeds, or base of plant to avoid burning effect.
- Applying fertilizer on each planting station saves between 25% to 50% of fertilizer lost through broadcasting method.

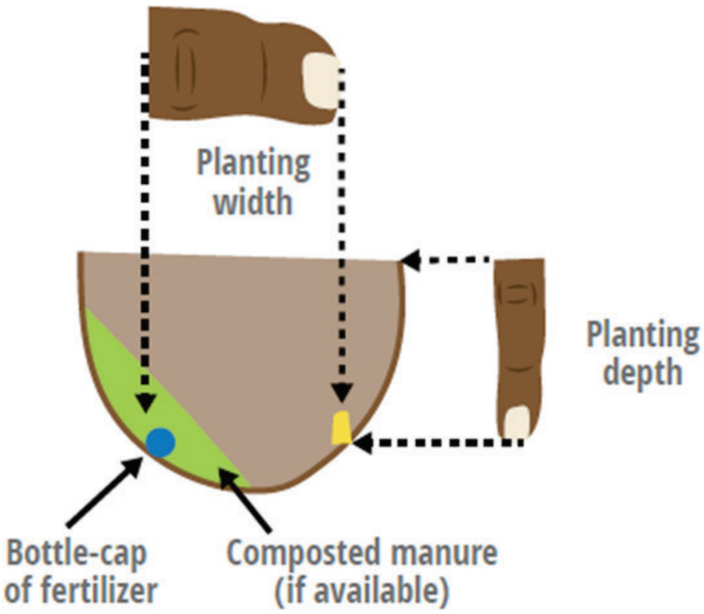


Illustration of proper application of manure and fertilizer in a planting station

Fertilizers rich in phosphorus are applied during planting. These fertilizers include

- Di Ammonium Phosphate (DAP)
- Triple Supper Phosphate (TSP)
- Single supper Phosphate (SSP)
- NPK among others.

These fertilizers help in root development of the young crop. A 50 kg bag of NPK (17:17:17 or 20:20:20 or 23:23:0), MEA Mazao (10-26-10 + Ca + Micronutrients), and Mavuno Basal (10-26-10 + Ca + Micronutrients) or 25 kg of DAP (18:46:0) per acre supplies the right amount of phosphorus to sorghum.

- ❖ Use a bottle top full of fertilizer for each planting station to provide the right amount of nutrient required for sorghum growth.
- ❖ The fertilizer can also be applied along planting furrows and thoroughly mixed with soil before seeds are sown.

Fertilizers rich in nitrogen are applied when the crop has reached the height of the knee. These fertilizers help to enhance vegetative growth of the crop. These fertilizers include Urea, CAN and YARA. A 50 kg bag of CAN i.e., one bottle top per planting station, provides the right amounts of nutrient for an acre of sorghum crop.

Application of micronutrient fertilizers such as Zinc (2-4%) is recommended to promoted growth and grain filling of the panicle. Zinc Sulphate (general purpose grade) can be mixed with top-dressing fertilizer and applied when the plants have attained between 4 to 5 leaves.

*You are recommended to apply fertilizers when the soil is moist.

Organic Fertilizers

Organic fertilizers are crop nutrients derived from plants. These organic fertilizers include farmyard manure, compost manure, animal droppings and crop residues. Organic fertilizers improve soil organic matter which promotes crop growth and activities of living organisms in the soil. Application of organic fertilizers also helps to improve soil structure, capacity of the soil to conserve moisture, plant's ability to utilize nutrients and reduce severity of some problematic weeds such as striga (Striga hermonthica).

- A ton of manure can provide upto 28 kg of nitrogen and 11.2 kg of phosphorus
- Two tons of well decomposed manure per acre can significantly increase sorghum yield
- Manure should be broadcasted in the field before ploughing and incorporated into the soil during land preparation

- If the quality of manure low and insufficient for broadcasting in the field, apply it along the planting furrows and mix it with soil before sowing your seeds

- Exposing manure to direct heating by the sun promotes nutrient loss in the air

- Frequency of manure application is as important as application of the resource. Split application of large heaps of manure into different plots at regular intervals

- Smaller regular splits are more efficient than a one-time application followed by several seasons of waiting before another application is done.

Lime Application

Some soils may not respond to fertilizer application. Increase in soil acidity makes applied fertilizer to be inaccessible to crops resulting to low or total yield loss. Soil analysis can help to determine the acidity level of your soil. Apply lime to reduce the acidic effect of the soil. Frequent application of well composted manure reduces soil acidity, in case lime is inaccessible.

Soil Salinity

Fields in semi-arid areas are prone to waterlogging during the rainy period while subsequent heating results in deposition of salts. Salt deposition on soils has a negative influence on water and nutrient uptake resulting in reduced sorghum yields. This problem is common in sorghum growing areas such as Taveta, Kiboko and Kibwezi. Frequent manure application can help to reduce soil salinity.

Weed Management

Weeds are a major threat to sorghum production due to their negative effect on yields. Elimination of weeds reduces competition for light, nutrient and soil moisture and destroys habitat for pests and diseases that destroys the young crop. Initial weeding is recommended 2 to 3 weeks after germination. For proper weed management, two weeding phases are recommended. Always manage weeds before they develop seeds. In case your field is infested by striga weed, practice intercropping or rotation with legume crops such as cowpea, groundnut, soybean, and sesame or forages such as desmodium to suppress the weed through Push-pull mechanism.

Pest and Disease Management

Control pest and diseases whose effect results in significant yield and income loss. Some of the major sorghum pests include fall army worm, millet head miner, shoot fly, aphids, cut worms, stem borers, termites, leaf hoppers, chafer grubs, bollworms among others. Use integrated pest management (IPM) strategies involving biological, cultural and inorganic pest control methods to reduced losses induced by pest attack. Timely pest attack diagnosis is one of the important control strategies to overcoming pest damage.

Cultural methods of pest control include:

- Use of seeds that are resistant to pests
- Scaring away pests like birds or by avoiding planting sorghum in isolated fields
- Rotation with legume crops to break pest cycles
- Early planting to avoid attacks by fall army worm, stock borers, sorghum smut and stem streak,
- Timely thinning of sickly plants to destroy habitats and breeding grounds for pests
- Destroy any pest affected plants and do not leave it in the field
- Using GAPs, such as fertilizers and conducting timely weeding reduces expenses on agrochemicals.

Inorganic control measures include use of chemicals such as Loyalty for chafer grubs, Cypermethrin for aphids, Dipterex for stem borers among other insecticides. Consult an agricultural extension staff for advice on the best chemical control immediately you notice incidences of pest attack.

Similar cultural and inorganic measures applied to pest can also be used to control losses attributed to disease attack.

Table 4. Common diseases affecting sorghum crop and their control

Disease	Symptoms	Control
Downy Mildew	White greyish ash on lower side of leaves	- Early planting -Avoid flooding of field -Apply Ridomil gold and Tata master
Damping off	Reddish-purple or yellowish-brown spots	-Seed dressing with Gaucho, Poncho, Moncerene fungicides
Leaf rust	Red to dark brown elongated raised bumps on leaves releasing spores	-Early planting, -Rotation with legume crops-Ploughing in crop residues -Spray Mancozeb, Carbendazim or azoxystrobin based fungicides
Sorghum leaf blight	Elliptical reddish lesions on older leaves	-Spray ortiva or copper-based fungicides -Use resistant varieties like Serena and Gadam
Copper spot	Circular lesions expanding from midrib to leaf edges	-Rotation with legume crops -Plant seeds from certified sources
Sooty stripes	Reddish brown or tan stripes on leaves	-Rotation with legumes crops
Head Smut	Black mass of spores on the panicle	-Crop rotation with legumes, thiamethoxam -Early planting, destroy affected plants -Seed dress with Metalaxyl and difeno-conazole based products -Spray Propinazole or Cyproconazole based fungicides or copper-based fungicides at panicle development stage
Charcoal rot	Reddish water-soaked lesions on the roots that later turn black	-Top dress with potassium rich fertilizer -Plant resistant varieties like KARI Mtama 1, Gadam and Seredo -Spray Copper oxychloride on affected crop
Sorghum anthracnose	-Oval reddish- orange to purple lesions development from lower to upper leaf surface -Water-soaked stalks/stem	-Destroy affected plants -Crop rotation with legumes -Seed dressing with thiram or captain

Adapted from Esilaba et al. (2021)

Dressing seeds with pesticides to avoid attack during storage.

Crop field invaded by destructive fall army worm

Harvesting

Harvesting of sorghum vary depending on the variety planted. Ensure timely harvesting to reduce loss or deterioration of the grain. Put the harvested panicles in clean containers to prevent contamination with soil which reduces grain quality.

Ensure sorghum grains are dry to prevent excessive damage on the grain during threshing. Threshing can be done manually by piling dry panicles on a clean surface and hitting them with a stick, using a mechanized thresher or allowing draught animals to trample on the panicles. Place threshed grains on clean tarpaulin, mat or cement slab to dry in case they are not dry by the time threshing is conducted. Properly dried grains have the following characteristics:

- Produce a cracking sound when pinched with fingers or when a handful of grain is tossed in the air
- They are brittle upon biting with teeth
- If a handful of grain is put in a dry bottle and mixed with some dry table salt, the salt does not stick on the surface of the bottle after settling for about 15 minutes

Testing of dry grain through biting and pinching. Source: Esilaba et al (2021)

Beware of grain infestation by mycotoxins such as Aflatoxin which is caused by lack of proper seed drying. Aflatoxin makes sorghum unfit for human consumption. Aflatoxin infested grains are poisonous and should not be fed to livestock or used for brewing.

Proper drying of threshed grain on clean mat (left) and improper drying on bare ground (right). Source: Hodges and Stathers (2012; left) and Michael Kinyua (right)

Winnowing helps to eliminate chaff, debris and other foreign materials to obtain clean grains. Sort to remove grains that are damaged and broken during threshing process. Such grains reduce the quality of the produce which depreciates their market value.

Dust clean grain with Actellic gold before storage to prevent contamination and damage by pests. You can also preserve them in hermetic (PICs) bags to improve shelf life. PICs bags are additional remedy for insect pests' control but may not prevent attacks by destructive rodents such as rats.

Consider the below storage practices to ensure quality of grains during storage

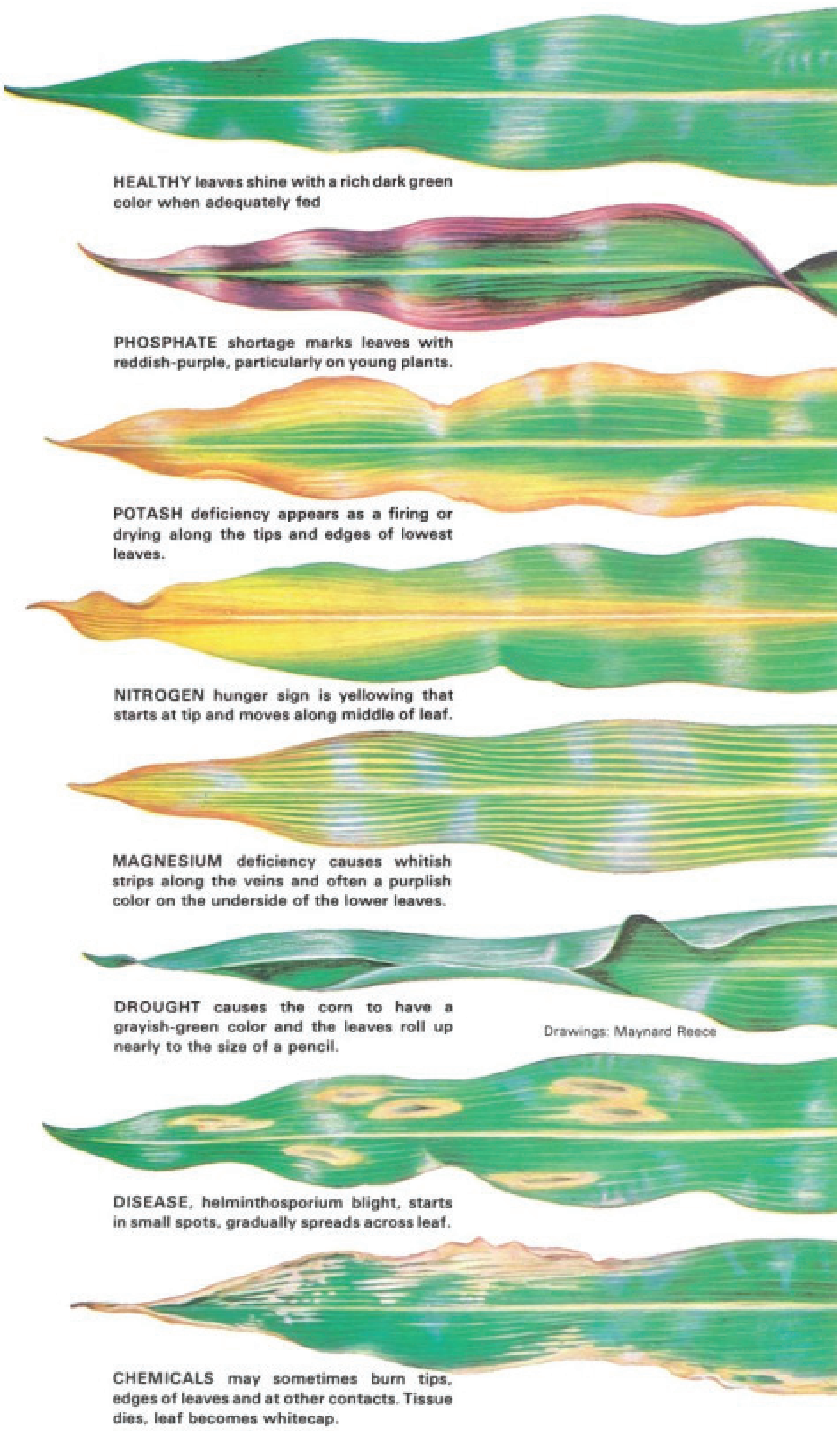
- Avoid mixing harvested grain with grain from previous harvests
- Ensure bags are placed away from the walls and not in direct contact with the soil
- Clean the store and ensure proper ventilation
- If storing the grain for a long time, frequently dust the grains to improve shelf life
- Stored grain can also be placed out in the sun occasionally to reduce moisture accumulation and to destroy storage pests
- If unable to access chemical pest control during storage, mix grain with dried leaves of Mexican marigold, Tephrosia, Neem or other locally tested pest control strateg

Assessment Four

- ❖ Explain the importance of mixing inorganic and organic fertilizers
- ❖ Discuss why ensuring the right moisture of the grain is important.
- ❖ List some common pest and diseases and the best control method used in your area.

Visual Limiting Nutrient Deficiency Diagnosis in Sorghum Crop

Use the below diagnostic aid to guide in detecting stress emanating from nutrient deficiency, drought, and diseases in your sorghum field.



Nutrient deficiency in sorghum crop. Drawing: Maynard Reece

Manure Composting

A well-composted manure for application in either small or large sorghum fields can be obtained through pit and heap compost preparation methods. Follow below tips to produce a well composted manure:

1. Gather any organic material available to you. Such materials include poultry droppings, cattle dung, vegetable residues, kitchen wastes, and maize stubble, weeds, grass etc. Avoid using food leftovers, painted wood, bones and other toxic materials such as dry cells or agro-chemicals.

2. After gathering enough organic materials separate the dry and coarse materials from the green materials

    a. Spread the dry/coarse material (such as sorghum residues and dry grass) evenly at the base to about 0.5–1 foot. For quick action by micro-organisms and turning the heap, chop the materials into smaller pieces before layering

    b. If materials are dry, moisten by sprinkling water but if succulent do not wet

    c. Make a layer of fresh and moist (green) material such as leaves, green grass and weeds, do not sprinkle water

    d. Add a layer of fresh manure of about 5–10 cm thick

3. Continue adding more layers in the same arrangement as described above. The layers should make a gentle slope such that the middle is higher than the side until the heap is 1–1.5 metres

4. Drive few ventilation sticks into the heap to help in testing the level of heating and testing if the heap is decomposing well

5. Cover the compost heap to prevent direct heating by the sun. Direct heating causes loss of nutrients in the air. If rained on there is excessive wetting that slows composting process.

6. Turn the materials on monthly basis by mixing all the layers. Sprinkle water when turning to make materials moist, but not wet.

7. Check for compost maturity by removing the ventilation stick. Bad smell indicates a problem with decomposition. Matured compost is darkish brown in color and can be mistaken with soil.

Proper layering without stepping (left) and improper layering while stepping on composting materials

The type of materials used determine the length of composting process. To meet a greater compost demand in your field, make a series of heaps to help generate ready manure at different times. The manure can be properly stored for application at the right time of the year.

Assessment Five

- Discuss the procedure of preparing a good compost manure.
- Indicate why it is important to apply a well composted manure.
- Why is it not advisable to compost materials such as painted wood, bones, food left-overs, glasses, and residual drugs.

Overcoming the Challenge of Produce Market Volatility

Crop produce prices are quite volatile a situation that is attributed to increased commodity supply during the harvest period. Brokers and middlemen also exploit farmers through purchase of the produce at low prices and later selling to buyers at higher prices. The following strategies can be used to overcome market volatility challenge:

- Hoarding the grain: store your grain until prices have stabilized. Integrating livestock in farming system can provide an alternative source of income, if sold during this period.

- Working in groups: join a common interest group or local cooperative that aggregates farm produce and sell it directly to buyers without involving brokers. You can negotiate for better prices if selling a large consignment of grain relative to small packages as individual farmer. Other benefits of working as a group include:

    - Increased interaction, fertilization of knowledge and learning new innovations from peers

    - Improved services by local agricultural extension

    - Improved access to agricultural credits, inputs, mechanization, subsidies, and funding

    - Builds and strengthens social capital

A farmer group receives agricultural input supplies from a project

Produced and Developed for KBL