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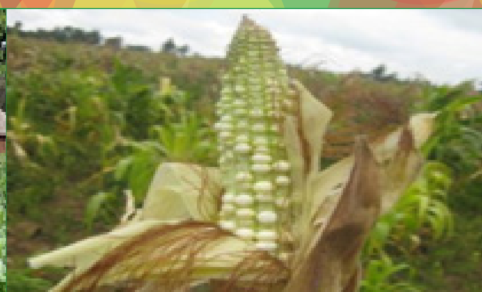
KALRO Kenya Agricultural & Livestock Research Organization

THE KENYA CEREALS ENHANCEMENT PROGRAMME - CLIMATE RESILIENT AGRICULTURAL LIVELIHOODS (KCEP - CRAL) WINDOW



Farmers' Extension Handbook Cereals and Pulses

SUPPORTED WITH FUNDS FROM EU AND ASAP

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Disclaimer

The information presented in this manual is for advisory use only. Readers using the manual should verify details that relate to their agro-climatic zones from their area agricultural extension officers.

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We also thank the researchers, farmers and stakeholders who participated in the project for their support in setting up trials, collecting and processing the data and thus generating large amounts of knowledge and information that KCEP-CRAL has packaged and shared through scientific papers, in seminars and in reports among others. The support of technical officers, laboratory personnel, administrative and support staff is also appreciated as it contributed to the success that the project achieved.

FOREWORD

Kenya Agricultural and Livestock Research Organization (KALRO) is one of the key partners in the Kenya Cereals Enhancement Programme - Climate Resilient Agricultural Livelihoods Window (KCEP-CRAL) Programme funded by the European Union (EU) and implemented by the International Fund for Agricultural Development (IFAD). KALRO participation in this programme is based on proven experience and expertise in agricultural research. Within the programme, KALRO handles the research component, conducting on station and on farm trials, develops farmer recommendations together with training materials for extension staff and service providers and conducts the training. The implementation of KCEP-CRAL is in thirteen (13) counties namely Nakuru, Nandi, Trans Nzoia, Kakamega, Bungoma, Kitui, Tharaka-Nithi, Embu, Machakos, Makueni, Taita Taveta, Kwale and Kilifi.

KCEP-CRAL focuses on the three leading rain-fed cereals (maize, sorghum and millet) and associated pulses (beans, green grams, cowpeas and pigeon peas). The programme's overall objective is to contribute to the reduction of rural poverty and food insecurity of smallholder farmers.

Through this Handbook, the programme will provide a comprehensive guide to extension officers, service providers and lead farmers on how to successfully produce cereals and pulses in Kenya. The Handbook is a useful training and reference material for extension officers and other stakeholders seeking to enhance the capacity of farmers, increase commercialization for food security and promote gender inclusion and participation along the commodity value chains.

Initial lessons learnt in this project indicate that enhancing the capacity of the extension staff and service providers has improved uptake of new technologies for dry land farming. It has opened up more land for farming through use of conservation agriculture in areas that hitherto were not under agriculture. Besides easing the pressure on previously arable land, farmers in the project areas have been trained to use alternative disease and pest management regimes using Integrated Disease and Pest Management and Push pull technologies for persistent pests of economic importance.

On behalf of KALRO, I am grateful to the European Union for supporting this project through the IFAD and KCEP-CRAL of the Ministry of Agriculture, Livestock, Fisheries and Cooperatives (MoALF&C). I also appreciate the excellent coordination of the whole process by the KCEP-CRAL Secretariat led by Dr Anthony O. Esilaba, MoALF&C and other partners, scientists in participating centres, Knowledge, Information and Outreach Unit team and secretarial staff. It is my hope and desire that in using this Handbook, the expectations of all stakeholders will be met.

Eliud K. Kireger, (PhD, OGW)

DIRECTOR GENERAL, KALRO

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ABBREVIATIONS AND ACRONYMS

AEC	Anion Exchange Capacity
AN	Ammonium Nitrate
AS	Ammonium Sulphate
Ca	Calcium
CA	Conservation Agriculture
CAN	Calcium, Ammonium Nitrate
CEC	Cation Exchange Capacity
CO_2	Carbon Dioxide
CSA	Climate Smart Agriculture
DAP	Di-Ammonium Phosphate Fertiliser
FAB	Farming es Business
FYM	Farm Yard Manure
GHGs	Greenhouse Gases
Ha	Hectare
IPM	Integrated Pest Management
ISFM	Integrated Soil Fertility Management
K	Potassium
K_2O	Potassium Oxide
KALRO	Kenya Agricultural and Livestock Research Organization
KAT	Katumani
Kg	Kilogramme
M66	Machakos 66
MLND	Maize Lethal Necrosis Disease
MOP	Muriate of Potash
N	Nitrogen
Na	Sodium
Na_2CO_3	Sodium Carbonate
$NaHCO_3$	Sodium Bi-carbonate
NPK	Compound Nitrogen, Phosphorous Potassium fertiliser

P	Phosphorous
P_2O_5	Phosphatic
PICs	Perdue Improved Cowpea Storage
RWH	Rain Water Harvesting
SALs	Semi-arid Lands
SOP	Sulphate of Potassium
SSP	Single Super Phosphate
SWC	Soil and Water Conservation
TSP	Triple Super Phosphate
UTEO	Winnowing Trays

OVERVIEW

The agriculture sector is important to Kenya's economy. It contributes 33% of the country's Gross Domestic Product (GDP) directly, 27% of GDP indirectly and accounts for 65% of export earnings. It also provides livelihood for most of the Kenyan population through employment opportunities to the rural population and 40% of the country's total population. Agriculture contributes Kenya's food security through production, distribution and availability of safe, and nutritious food. It is a large and complex sector, many public, parastatal, non-governmental and private players. It is a fully devolved the function of the County Governments in ensuring food security. Apart from food production, the Agricultural sector is the main driver of non-agricultural economy within the country comparing manufacturing, building/construction, transportation, tourism, education and other social services.

Despite the important role played by Agricultural sector in the Country's' economy, its growth and stability has been continuously affected by many factors. Climate change potentially is one of the greatest challenges particularly within farming communities. Climatic risks, marked by increased recurrence of droughts, floods, rainfall variability (pattern, timing and intensity), increased mean surface temperature and famine that erode livelihood opportunities and community resilience. Other sources of risks include declining water resources, soil fertility and, increased pests and diseases. Sustainable agricultural production calls for adoption of approaches that sustainably increase agricultural productivity and incomes while adapting and building resilience to climate change, and reducing greenhouse emissions. These approaches include: Climate Smart Agriculture (CSA), conservation agriculture (CA) and agroforestry among others.

Continued supply of nutrients required by plants in correct forms and quantities require soil health management achieved through application of inorganic fertilisers, organic farmyard manure, compost, plant residues and practicing crop rotation. In a nutshell, this is applying integrated Soil Fertility Management (ISFM) or Sustainable Soil Management (SSM). Within the Sustainable Development Goals, soil fertility/health maintenance is of economic, social and environmental importance because it supports healthy plants and livestock growth leading to adequate food provision and healthy individuals. The resultant healthy crops and livestock generate income when sold as well as income from employment opportunities in the production, value addition and marketing phases.

Farmers should strive to conduct their farming with a business orientation geared to the market. However, farming is certainly a risky business, depended upon the factors of production, domestic prices, changes in foreign markets and climate change and variability. To succeed in farming business, just like any other business, several crucial principles should be applied. This calls individual farmers to develop a passion because only passion can take the entrepreneur far into any business including farming. Without passion, one cannot last in farming; commitment to continuous learning. Applying business methods such as record keeping, benefit–cost analysis, marketing skills, group management skills, gender considerations and good communication skills can greatly improve the efficiency of farming. Understanding farm records and record keeping as well as marketing dynamics especially for cereals and pulses is very important.

The cereals covered in this hand book comprise of maize, sorghum and millet. **Maize** is a staple food and contributes about 65% of daily per capita cereal consumption, 35% of total dietary energy and 32% of total protein consumption. It is an important source of carbohydrate, protein, iron, vitamin B, and minerals. It serves both as subsistence and commercial crop. It grows on an estimated 1.4 million hectares comprising 25% large-scale and 75% smallholder farmers. Maize accounts for more than 20% of the total agricultural production and 25% of agricultural employment. However, its production has been decreasing due to climate change and variability. **Sorghum** is a drought tolerant crop that plays an important role as a food security crop in semi-arid areas (SALs) of Kenya. It has an extensive root system which makes it very efficient at extracting any water from the soil. It can survive drought conditions for weeks by rolling up its leaves and thus decreasing water loss through the leaves. It is a high-energy, nutritious food, suitable for consumption by all. It is particularly recommended for children, lactating mothers, convalescents and the elderly. The grain has high levels of iron and zinc, hence may be used to reduce micro-nutrient malnutrition. **Millet** on the other hand is an important food security crop in semi-arid lands of Kenya. It fits well in popular local recipes such as *Ugali* and *Uji*. In recognition of its nutrition value and frequent maize crop failures, the Government of Kenya is putting more emphasis on production of millet to mitigate food and nutritional security.

The pulses covered include beans, green grams, pigeon peas and cowpeas. **Bean** is the most important pulse in Kenya ranking second to maize in importance. The crop provides cheap protein source, rich in essential amino acids such as lysine which is found in fewer quantities in maize and other grains. Despite its importance, production over the years has majorly remained at subsistence level with limited commercialization. Optimal production has continuously been limited by poor agronomic practices such as use of uncertified seeds, poor soil health management practices, poor pest and disease management practices and climate change effects. **Green gram** is an erect annual plant which grows to a height of 60-70 cm tall. It is often cultivated in rotation or relay with cereals and consumed as whole seeds boiled with cereals such as maize or sorghum and occasionally in stews. **Pigeon pea** is a perennial legume that is highly adapted to dry environments. It can grow to 12 ft. tall, but usually only reaches 3 to 6 ft. It has very deep roots which enables it to take up nutrients and water from lower subsoil layers. **Cowpea** ranks second to beans in importance as vegetable protein food crops. It is mainly grown as a green leafy vegetable in Western Kenya and for grain in the dry lands of Eastern, Coast and Nyanza regions. The grain is rich in protein content of up to 30%, including micronutrients such as iron and zinc. Despite its importance, its yields have remained either low or stagnant due to low soil fertility, poor agronomic practices, pest and diseases and poor postharvest management. These aspects of production are poised to be addressed by increased awareness created by this Project.

1. CLIMATE AND AGRICULTURE

The impact of climate change and variability on Kenya's agricultural sector is of great concern to policymakers, researchers, development partners, farmers and other stakeholders. It is a big threat to achieving food security. This handbook presents improved ways on adapting agricultural production systems to climate change indicators, namely, increased temperatures, unpredictable rainfall, and extreme climatic occurrences. The effects of climate change and variability are characterized by increased frequency of droughts and floods, changes in weather patterns, high rainfall intensity and increased incidence of pests and disease outbreaks. Below find pictures of these effects on crop production systems.

Increased land degradation due to climate change

Increased water scarcity

Increased pests and disease incidence

Decreased crop yields

Increased incidence of floods

Decreased crop yields

1.1 What Causes Climate Change and Variability?

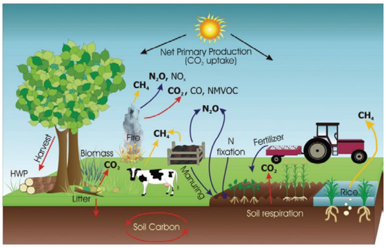


Figure 1.1: Causes of climate change in agriculture

- It is largely linked directly and indirectly to human activities
- Carbon dioxide remains the major greenhouse gas that contributes to climate change
- The major agricultural activities linked to climate change include land clearing and burning plant biomass for farming, charcoal burning, conventional tillage, poor manure handling, and inappropriate use of agro-chemicals, among others (Figure 1.1).

1.2 Climate Smart Agriculture (CSA)

Climate Smart Agriculture (CSA) comprises agricultural practices and techniques that are aimed at sustainably increasing agricultural production and system resilience while reducing greenhouse gas emissions. Additionally, CSA aims to achieve food security and broader development goals under a changing climate and increasing food demand. Consequently, CSA practices are made to suit three main pillars: increasing agricultural production and incomes, enhancing resilience (adaptation) of livelihoods/ecosystems and reducing GHG emissions. This handbook describes key approaches that conserve the soil, rain water, soil nutrients and stabilize land production. The approaches are based on three principles; minimum tillage, permanent soil cover and crop rotation.

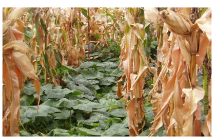
1.3 Characteristics of climate smart farms (Climate-smartness indicators)

- Soil and water conservation structures or measures to increase ground cover and use little water

Figure 1.2: An integrated climate smart farm

- Use of manure and compost to decrease use of chemical fertilizers
- Promotion of agroforestry (crops and trees) systems i.e. trees and crops coexist and benefit from each other
- Integration of perennial and annual crops
- Diversification of farm enterprises
- Readiness of a farm plan (Figure 1.2, Table 1.1 and 1.2).

Table 1.1: Different agricultural practices under CSA pillars

Adaptation -Build resilience and the capacity of agricultural and food systems to adapt to climate change	Mitigation- Seek opportunities to reduce or remove greenhouse gases food security and development goals	Productivity- sustainable increase in agricultural productivity and incomes
		
Agronomic practices • Improved crop variety, Crop rotation, green manure, Multiple cropping, Intercropping, Alley cropping, Relay cropping, Contour strip cropping, ridging and IPM Nutrient Management practices • Mulching • Improved fallows • Manures	Livestock management practices • Improved feeding, Animal breeding or upgrading, and use of fodder banks • Farm production adjustments such as diversification and intensification **Agro-forestry practices** • Use of trees in Agricultural systems • Use of boundary/hedges or tree /contour planting	Food and nutrition security in the face of climate change • Food and Nutrition security (Availability) • Enough food is accessible to everyone everywhere - phisically and economically (Access) • Food is properly utilized (right quality and diversity) (Utilization)
• Composting • Careful use of fertilizers Weed Management practices	• planting windbreaks, Woodlots **Tillage and Residue Management practices** • *Reduced tillage*	Income generation measures • Establishment of fruit and tree nurseries
• Cover crops • Appropriate crop intercropping	• Zero tillage • *Residue Management*	• Sell of fruit and tree seedlings
		

1.4 CSA Practices and their Benefits

1.4.1 Conservation Agriculture

What is Conservation Agriculture? – It is a method of farming system that conserves, improves and uses natural resources more efficiently through sustainable intensification (integration) of locally available resources.

1.4.2 Principles of Conservation Agriculture

A. Minimum soil disturbance - The farmer tills the soil as little as possible or disturbs the soils as little as possible. The soil should only be dug where the seed, fertilizer and manure are placed when sowing. Some of the benefits of minimum soil disturbance include improved soil water infiltration, build-up of soil organic matter, reduced cost of tilling the land, reduced soil degradation etc.

B. Permanent soil cover – a farmer uses crop residues, cover crops, tree biomass to provide maximum soil cover. The cover crops include cowpeas, velvet beans, soya beans, common beans. Some of the benefits of permanent soil cover include reduced soil erosion, more water sinking into the soil, suppresses emergence of weeds, organic residues improve organic matter content and soil nutrient status.

C. Crop diversification - growing several crops on the same land through crop rotation or intercropping systems. Some of the benefits include improved soil fertility, reduced pests and diseases, increased income,

1.4.3 Benefits of conservation agriculture

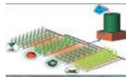
A. Economic – saves resources like finances; controls pests and diseases; reduces risks of crop failure; increased farm output and incomes; improved soil water management; reduced labour use etc.

B. Environmental – improved soil health; reduced greenhouse gas emissions and water use; improved water infiltration etc.

C. Agronomic - Increase in soil organic matter – good soil environment for crop development.

Table 1.2: Examples of CSA Practices and benefits.

CSA PRACTICE	BENEFITS	PHOTO
Agroforestry	• Provides a buffer against the effects of climate change • Provides alternative income streams to the farmer hence reduces potential on-farm income risks • Reduces soil erosion • Windbreaks and more building materials	

CSA PRACTICE	BENEFITS	PHOTO
Irrigation and Drainage systems	• Drip irrigation systems promotes efficient water use • Increase crop production efficiency • Irrigation provides crops/fodder production throughout the year • Well-designed water channels reduce soil erosion and improve plant water access.	  
Water harvesting and conservation measures(*terraces/ bunds, Zai pits)*	It is the harnessing of rain (road runoff) or ground water • It retains water and conserve moisture/ fertility • Rehabilitation of barren/crusted lands • Controls soil erosion	
Improved soil management measures	• Improve soil fertility • Contributes to sustainable land management • Increases crop productivity and improves agrarian livelihoods.	
Crop diversification and seed/varietal selection	• Merges crop/seed variety with local climatic conditions • It spreads farmer production and income risks • It reduces household inability to cope with weather or market shocks • It brings benefits in terms of pest management and soil quality, etc.	
Weed/control management	• Use of shallow weed scrapper or herbicide application have minimal soil disturbance • Use of cover crops manages weeds and enhance soil stability • Prevent weeds from flowering	
Improved Livestock management measures	• Includes improved feeding, rotational grazing, Fodder crops, Grassland restoration/ conservation, Manure treatment, Improved livestock health • Increases farm productivity and household incomes	

1.5 Soil and Water Conservation Measures

Soil conservation is the prevention and reduction of the amount of soil lost through erosion.

Water conservation is a way of tapping as much water as possible and storing it in tanks or reservoirs.

1.5.1 Principles of soil and water conservation

a) Make effective use of soil water reserves

b) Use rainwater effectively

c) Take measures to avoid run off

d) Reduce water losses through drainage

1.5.2 Benefits of soil and water conservation

a) Minimizes the risk of crop/production failure during droughts, intra-seasonal droughts and floods

b) Reduces water erosion, improves water quality, water infiltration and retention, all of which should lead to higher and less variable yields.

c) Controlling soil erosion improves crop and pasture yields.

d) Conserving water makes it available for crops, livestock and domestic use over a longer period.

e) They increase the value of the land.

f) More and better livestock fodder is available.

g) Increases water use efficiency.

1.5.3 Common Soil and Water conservation technologies

a) Field level practices: Bench terraces, Check dams, Contour bunds and hedgerows, 'Fanya juu' terraces, Planting Pits/Zai pits, Katumani Pits, Stone lines, Trash lines, Grass strips, Grassed waterway, Retention ditches, Cut-off Drains, Mulching and Cover crops.

b) Landscape level practices: Agroforestry, Wind breaks/shelter belts, woodlots, Riparian vegetation buffer strips. Large flows are diverted and either used directly or stored for supplementary irrigation.

1.6 Integrated Soil Fertility Management (ISFM)

ISFM is a set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions, aiming at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity. All inputs need to be managed following sound agronomic principles of ISFM.

1.7 Gender in Climate Smart Agriculture

It is important to recognize and adequately address the particular needs, priorities, and realities of men, women and youth to equally benefit them in the design and application of any CSA practice. For example, women and youth typically have less access than men to assets, knowledge and resources. They do not have the same capacity to take up new climate-smart practices for improved climate change resilience. A clear understanding of gender dynamics will therefore lead to significant improvements in the lives of smallholder farmers as well as achieving more sustainable results (Figures 1.3a & b).

Figures 1.3a & b: Gender roles

2 INTEGRATED SOIL FERTILITY AND WATER MANAGEMENT

Soil is the most valuable and widespread natural resource. However there is a general decline in land productivity due to declining soil fertility arising from continuous mining of soil nutrients and inappropriate farming practices. For sustainable agriculture production there is need to aim at achieving high yields per unit of land while at the same time conserving soil resources.

2.1 What is soil?

To a farmer: soil provides the medium where plants grow.

To an Agronomist: soil is unconsolidated layer of the earth's surface that consist of mineral or organic material, air, water and living organisms that supports plant growth..

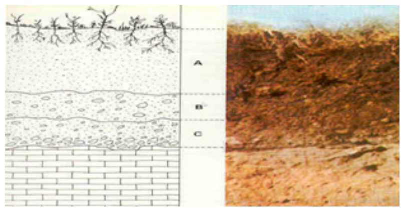


Figure 2.1: Soil Profile

2.2 Soil Composition

Soil is composed of mineral particles from weathered underlying rocks, plants and animals residues (organic matter), living organisms, air and soil water. The relative amount of each component within a given soil determines the properties of the soils in that area.

2.3 Soil Properties

Soil properties are divided into physical, chemical and biological.

2.3.1 Soil physical properties

Soil physical properties includes: texture, structure, bulk density, porosity, consistence, depth/horizonation and colour (Figure 2.1).

Soil texture is the proportions of sand, silt and clay within a soil. This results into textural classes such as sand, loam, clay loam, clay, and silt among others.

Soil structure refers to the arrangement of primary soil particles/ aggregates into secondary aggregates. A well-structured moist soil contains about 50% of solid material by volume and 25% each of air and water.

Bulk density is an indication of soil compactness while porosity is the ratio of the volume of the pores to the total soil volume and is inversely related to bulk density.

Consistence is the ability of soil to resist rapture or deformation. It is a good indication of whether the soil is loose, soft, hard, sticky, firm or friable under different moisture levels and it helps in making decisions on use of farm implements.

Soil horizonation refers to soil depth. Depending on soil formation and climate, some soils are shallow and others very deep. This properties determine the ability of soils to provide water, nutrients and good environment for plant growth and yield. They are also used to show land that has been suffering waterlogging conditions as well as favourable construction sites.

2.3.2 Soil chemical properties

Soil pH, Cation Exchange Capacity (CEC), Anion Exchange Capacity (AEC) and Buffering Capacity (BC) are some of the most important chemical properties.

- Soil pH, Cation Exchange Capacity (CEC), Anion Exchange Capacity (AEC) and Buffering Capacity (BC) are some of the most important chemical properties. **Soil pH** is a measure of acidity or alkalinity of a soil. The pH for acidic soil is below 5.5 while alkaline soils are above 7.5. A pH range between 6.5- 7 is the best because most plant nutrients are available for most of the crops and soil organisms to thrive.
- Cation exchange capacity **(CEC)** is the ability of soils to maintain adequate cations (positively charged ions such as potassium, calcium etc. in the soil solution while anion exchange capacity (AEC) is the ability of soil to maintain adequate anions (negatively charged ions e.g. nitrates, sulphates etc.) in the soil solution. This properties determines whether the soil is fertile or infertile.
- Organic matter or manure application is important because it contributes to improvement of all soil properties namely texture, structure, porosity, water holding capacity, adds nutrients to the soil leading to improved soil CEC and AEC and regulates changes in pH because manure is a strong buffering agent.

2.3.3 Biological properties

Soils contain a wide range of soil organisms (fauna and flora). These organisms include micro-organisms (e.g. bacteria, fungi, protozoa and nematodes), macro organisms (e.g. spiders and springtails earthworms and termites) and plant roots. These organisms are important in provision of nutrients through breakdown and decomposition of organic matter as well as loosening soils for root penetration.

2.4 Traditional soil fertility indicators

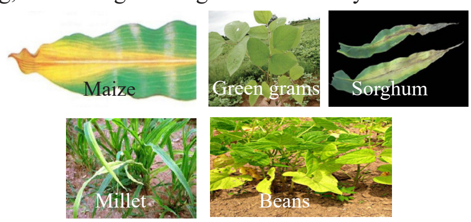
A fertile soil can be identified using local indicators.

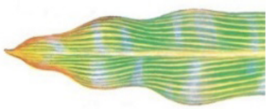
- Structure – a soil with big clods indicates a fertile soil
- Weed species associated with either a poor or a fertile soil e.g. the grassy weed called poverty grass (*Rhynchelytrum repens)* occurs in very infertile soils
- Dominance of certain weed flora (e.g. *Commelina benghalensis*, *Bidens pilosa, Galinsoga parviflora, Commelina diffusa* and *Amaranthus* spp.) imply high fertility
- Dominance of soil fauna (e.g. earthworms) also imply high fertility.

2.5 Plant nutrients and their roles on crop production

Plants require 17 elements to grow well and complete their life cycle. Some of these elements are obtained from the air such as carbon and oxygen while others such as hydrogen and oxygen are obtained from water and the rest (Nitrogen, Phosphorus, Potassium, Calcium, Sulphur, Magnesium, Zinc, Molybdenum, Boron, Iron, Cobalt, Manganese, copper and Nickle) are obtained soil. The concentration of these elements within a given soil is depended on soil type and fertility management levels. Lack of adequate proportions of this nutrients within a given soil leads to poor crop establishment or growth resulting to poor yields (Table 2.1 and Figure 2.2).

Table 2.1: Function of the various plant nutrients and resultant deficiency symptoms

Nutrients	**Functions and deficiencies**
Major Nutrients	
Nitrogen	**Function** - Formation of chlorophyll. - Plant Vegetative growth. - Proteins synthesis.
	Deficiency symptoms - Yellow discoloration of leaves from midrib towards margins. - Stunted growth leading to poor yields. **Excess N symptoms** Excess lodging, excess vegetative growth and low yield. 
Phosphorus	**Function** - Development of the root system. Seed and fruit formation **Deficiency symptoms** Stunted growth and purpling of leaves/stem from margin towards midrib. Plants slow to ripen, remaining green. Fruits may be misshapen, grain is poorly filled  Sorghum/Millet Maize

Nutrients	Functions and deficiencies
Potassium	• Tolerance to moisture stress. • Improves the quality of fruits, vegetables, and grains. • Early ripening of crops. • Resistance to diseases **Deficiency symptoms** Stunted growth and outer edges of leaves becomes yellow or reddish, becoming brownish or scorched and dead (edge necrosis); leaves wilted. Lodging.   Maize Beans
Secondary Nutrients	
Calcium	**Function** • Improving the cell structure and fast division of plant cells, leading to faster growth **Deficiency symptoms** • Young leaves yellowish to black and curved or cupped (brown spots). • Plants appear to wilt. • Fruits may appear rotten (tomato). • Roots are malformed   Maize beans
Magnesium	**Function** • Chlorophyll *formation* • Phosphate metabolism, Biological N fixation, plant oil and fat formation, iron utilization. **Deficiency symptoms** • Yellowing of leaves between veins while veins remain green. Leaf margins turn red- brown- purple. Symptoms start from lower leaves.   Maize Beans
Micronutrients	
Zinc	**Function** - Chlorophyll formation - Enzymes activation.

Nutrients	Functions and deficiencies
	Deficiency symptoms Stunted growth. Broad bands of white bleached-stripped tissues on each side of the midrib in maize and yellowing of lower leaves that develops into bronze or brown colour.
	   Sorghum Beans

2.6 Important nutrients sources

Plant nutrients can be obtained from organic amendments such as organic matter and in-organic sources such as chemical fertilizers.

2.7 Organic amendments

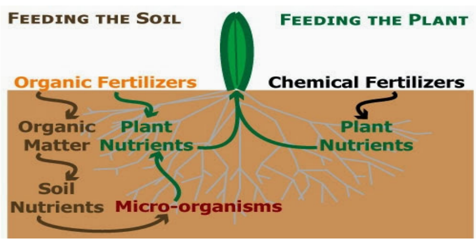


Figure 2.2: Source of soil nutrients

Organic amendments refers to any material that is part of or originated from living organisms. They include farmyard manure, compost, green manure, chicken manure, urban waste, sewage.

2.7.1 Characteristics and benefits of manure

- Main source of organic amendments and also supply macro, and micronutrients.
- Provision of soil nutrients
- Buffering soil pH to avoid instant changes on application of alkaline or acidifying inputs.
- Enhances water-retaining capacity
- Creates favorable conditions for soil micro-organisms
- Improves soil structure and consistence.
- Unlike inorganic fertilizers that provide nutrient immediately, manure has to decompose first to release nutrients.

2.8 In-organic sources

In-organic fertilizers or mineral/chemical fertilizers are manufactured products that contain minimum of one plant nutrient that is essential for plant growth. They are concentrated sources of essential nutrients in a form that is readily available for plant uptake.

2.8.1 Characteristics of chemical fertilizers

- Rich sources of plant nutrients but don't contain organic matter.
- When exposed to the atmosphere, tend to cake by absorbing moisture therefore need proper handling and storage.
- Nitrate-based fertilizers (such as ammonium nitrate) can become explosive in nature if not stored properly.
- Majority provide one or two plant nutrient, such as nitrogen (N), phosphorus (P), or potassium (K).
- Show a quick response and become available to plants immediately on application.

2.8.2 Classification of in-organic/chemical fertilizer products

Common inorganic fertilizers are marketed as either straight or compound fertilizers. For example:

Nitrogenous (N): Ammonium Nitrate (AN), Ammonium Sulphate (AS), Urea and Calcium Ammonium Nitrate (CAN), NPK.

Phosphatic (P_2O_5): Single Super Phosphate (SSP), Triple Super Phosphate (TSP), NPK

Potassium oxide (K2O): Muriate of Potash (MOP), Sulphate of Potash (SOP), NPK.

Apart from the above mentioned, many varied brands with different combinations of both macro and micro elements are available in the market.

2.9 Soil fertility degradation and amelioration

Soil fertility degradation is the loss of the capacity of soil to supply nutrients in adequate amounts. Common causes of soil degradation include continuous removal of plant residues (nutrient mining), soil acidification, salinization, sodicification, erosion, leaching, poor tillage practices, urbanization, pollution, and loss of organic matter.

2.9.1 Nutrient mining

The amount of nutrients removed through cropping depends on type of crop grown, part of crop harvested, stage of growth at harvest and level of nutrient replenishment overtime. Nutrient mining problem can be corrected by cultural methods such as leaving crop residues in the farm or application of organic and inorganic fertilizers. Nutrient expert tool can also be used in the management of nutrient mining.

2.9.2 Soil acidity

Causes of soil acidity include acidic parent material, leaching of base cations and continuous nutrient mining through crop removal, use of acidifying fertilizers such as ammonium rich fertilizers, acid rain and industrial emissions e.tc. Acidification leads to unavailability of some essential nutrients such as phosphorus for plant uptake and abundance of other nutrients such as micronutrients leading to toxicity. Some important soil macro and microorganisms also do not thrive well in acidic soils leading to poor soil biological processes hence low fertility levels. Soil acidity can be corrected through liming with pure calcium carbonate or dolomitic lime, application of wood ashes and manure/organic matter.

2.9.3 Soil compaction

Occurs as a result of poor tillage methods such as ploughing and hoeing which result in the formation of hard pans or hard plough layer leading to poor water, air and root penetration. Corrective measures include; sub soiling and ripping to break the impermeable plough-pan, avoid ploughing when the soil is very wet. In addition, mulching and addition of manures improve soil structure in compacted soil.

2.9.4 Soil erosion

Soil erosion is one of the major causes of land degradation in Africa which causes washing away of top fertile soils leading soil compaction, poor water infiltration rates and poor fertility levels hence poor crop yields. Corrective measures include, increased vegetation, use of embankments, contour cultivation, strip cropping, use of cover crops and conservation tillage

2.9.5 Salinization and sodicification

Salinization and sodicification refers to accumulation of salts in soils. This is caused by original mineralogy of the soil, over application of base fertilizers, and /or poor movement of salts within the soil because of lack of adequate moisture in dry lands. Accumulation of salts leads to occlusion of some important nutrients such as phosphorus hence making them unavailable for plant uptake and also abundance and toxicity of other nutrients/ salts such as calcium or sodium with their carbonates and bi carbonates which leads to burning of plant roots or hindering some important soil organisms from thriving.

2.9.6 Leaching

Leaching is carrying away of soil nutrients beyond the reach of crop roots. It is very common in areas with high rainfall intensity (>30 mm/day) and in coarse-textured sandy soils (>35% sand). Corrective measures include application of manures and nutrient replenishment.

2.10 Soil Fertility Evaluation

Continuous maintenance of good crop yield requires regular soil fertility maintenance. The fertility maintenance is done through regular fertility status evaluation which is carried out through soil or plant tissues sampling and analysis.

2.10.1 Soil sampling and basic soil parameter measurements

What to consider when undertaking soil sampling i.e. identifiers of soil fertility;

- Topography, soil types, soil colour
- Land degradation intensities,
- Sharp physical discontinuities (e.g. rocky outcrops),
- Land-use history or distance from the homestead and livestock facilities.

2.10.2 Frequency of soil sampling and number of samples

- New land- done yearly for first few years until you understand the soil.
- Cultivated land- every 2-3 years, unless concern for environmental problems.
- Sample at least one month before onset of rains to provide enough time for analysis/amendments.
- Number of samples is normally determined by type of anticipated enterprise, land physical attributes and observable diversity. Agronomists normally recommend one composite sample per 2.5 acres or 1Ha or at least one composite sample per acre for uniform land. The composite samples are then taken to the laboratory for analysis (Figure 2.3).

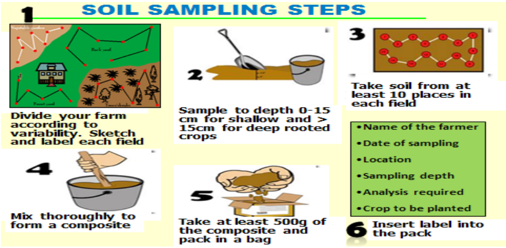


Figure 2.3: Steps in soil sampling

2.10.3 Soil analysis reports

- When the soil is analyzed in a credible laboratory, soil analysis report is always provided.
- The soil test reports contain values that indicate specific nutrient levels in the soil. The levels are either indicated as low, moderate, adequate or high. A summary of these levels implies availability of low, moderate or high fertility. Soil fertility replenishment recommendation is then provided based on the report and the intended crop to be grown.

2.11 Soil Degradation, its Causes and Management

Soil degradation is the decline in soil quality as a result of improper land use activities such as inappropriate agricultural intensification and farming practices, intensive grazing and unsustainable urban or industrial expansion. It involves the decline of the soil's physical, biological and chemical quality. It can be the loss of organic matter, decline in soil fertility and structural condition, erosion, adverse changes in salinity, acidity or alkalinity, and the effects of toxic chemicals, pollutants or excessive flooding. Soil degradation may occur naturally, due to climate change or human activities.

2.11.1 Causes of soil degradation include physical, chemical and biological factors

a) Physical Factors

Physical factors such as rainfall, surface runoff, floods, wind erosion, tillage, and mass movements result in the loss of fertile top spoil thereby declining soil quality.

b) Soil erosion

Soil erosion refers to the wearing away of a land's topsoil by the natural physical forces of water and wind or through forces associated with farming activities such as tillage (Table 2.2). Soil erosion occurs through a number of ways that include water and wind erosion.

Table 2.2: Types of erosion

Sheet and rill erosion	**Rill erosion** occurs when runoff water forms small channels as it concentrates down a slope. These rills can be up to 0.3m deep. If they become any deeper than 0.3 m they are referred to as gully erosion.	**Scalding**
Sheet erosion occurs when a thin layer of topsoil is removed over a whole hillside paddock—and may not be readily noticed.		Scalding can occur when wind and water erosion removes the top soil and exposes saline or sodic soils.
		

Gully erosion	**Stream bank erosion**
Occurs when runoff concentrates and flows strongly enough to detach and move soil particles. Gullies may develop in watercourses or other places where runoff concentrates. In cultivation or pastures, advanced rill erosion can develop into gully erosion.	When clods of these soils are exposed to water, they readily break down into individual particles of sand, silt and clay which are easily removed as water moves through the subsoil. The major cause of stream bank erosion is the destruction of vegetation on river banks (by clearing, overgrazing, cultivation, vehicle traffic up and down banks or fire) and the removal of sand and gravel from the stream bed.
	

c) Chemical Factors

This is the reduction of soil nutrients due to alkalinity, acidity, water logging or removal of nutrients through crop harvests. The chemical factors are mainly alterations in the soil's chemical property that determine nutrient availability.

d) **Biological Factors**

Biological factors refer to the human and plant activities that tend to reduce the quality of soil. Some bacteria and fungi overgrowth in an area can highly reduce microbial activity in the soil through leading to decreased organic matter breakdown, decomposition and availability of nutrients within soil for plant uptake hence reduced crop yields.

e) **Deforestation**

This is the removal of trees and crop cover exposing soil minerals to adverse weather effects. Vegetation cover promotes binding of soil together and soil formation, hence when it is removed it considerably as affects soil health. It also reduces landscapes carbon sequestration ability.

f) **Misuse or excessive use of fertilizers and chemicals**

Excessive use and the misuse of pesticides and chemical fertilizers kill organisms that assist in breaking down and decomposing organic matter to increase soil fertility. It also kills beneficial soil organisms that kill soil pests.

g) **Industrial and Mining activities**

Industrial and mining activity destroys crop cover and releases various toxic chemicals such as heavy metals (mercury) into the soil thereby poisoning it and rendering it unproductive. It also releases toxic effluents and material wastes into the atmosphere, land, rivers, and ground water that eventually pollute the soil. Industrial and mining activities degrade the soil's physical, chemical and biological properties.

h) **Improper cultivation practices**

Improper tillage on agricultural lands breaks up soil into finer particles, which increase erosion rates. It also exposes soil organisms and organic matter to the surface leading to fertility lose. Shallow cultivation leads to soil pan that hinders root penetration.

i) **Urbanization**

Removes the soil's vegetation cover, compacts soil during construction, and alters the drainage pattern. Most of the runoff and sediments from urban areas are polluted with oil, fuel, and other chemicals. Increased runoff from urban areas also causes a huge disturbance to adjacent water sheds by changing the rate and volume of water that flows through them.

j) **Overgrazing**

Overgrazing destroys surface crop cover and breaks down soil particles, increasing the rates of soil erosion which affects soil quality.

2.12 Soil and Water and Management Practices

Soil water management can be defined as active involvement in controlling soil water content at an optimal state for all given purposes, including environmental needs. An optimal state is often a compromise between competing uses and needs to account for long-term sustainability of the soil water system.

The line between soil and water conservation (SWC) and rainwater harvesting (RWH) technologies for crop production is very thin. SWC can be described as activities that reduce water losses by runoff and evaporation, while maximizing in-soil moisture storage for crop production, but the same could be said of RWH. The two are differentiated by the fact that under soil and water conservation, rainwater is conserved *in-situ* wherever it falls, whereas under water harvesting, a deliberate effort is made to transfer runoff water from a "catchment" to the desired area or storage structure.

2.12.1 Principles of rainwater harvesting and management

- Harvesting and storage increases the availability of water in the drier seasons.
- Develop structures such as contour ditches, terracing, pits and bunds to reduce run-off and increase water availability for crops.
- Reduce water lose in the soil by adding organic matter in the form of compost, manures or plant residues.

  There are two types of rain water harvesting i.e. *in-situ* and *ex-situ*.

2.12.2 Soil and Water Conservation Technologies)

Rainwater harvesting for infiltration, also known as ***in-situ*** water harvesting, is a practice in which rainwater uptake in soils is increased through the soil surface, rooting system and groundwater. Structures for in-situ water harvesting include:

- **Contour - bunds and hedgerows –** Stone or earthen walls built across a slope to prevent runoff. The aim is to concentrate moisture into the ridge and furrow area where the crops are planted.
- **Bench terraces -** a series of beds which are more or less level running across a slope at vertical intervals, supported by steep banks or risers (walls or bunds). They are designed to reduce soil losses; promote permanent agriculture on steep slopes and intensive land use.
- ***Fanya juu* terraces -** constructed by excavating soil and throwing it up-slope to make an embankment. The embankment forms a runoff barrier and the trench (ditch) is used to retain or collect runoff. The embankments are usually stabilized with fodder grasses.
- **Stone lines -** are 25 - 35 cm contour lines made of locally available stones. They slow down runoff, increase water infiltration and form the basis for improved production in semi-arid areas.
- **Trash lines -** created across the slope along the contour using previous seasons' crop residues (millet, maize and sorghum stalks), grasses, litter and other dead vegetative organic materials. Trash lines control surface runoff, soil erosion and enhance water infiltration.

- **Retention ditches -** designed to harvest and retain incoming runoff and hold it until it infiltrates into the ground. They can be an alternative to waterways in high rainfall areas.
- **Grass strips -** are 1 m-wide strips of grass planted on terraces along contours to reduce the amount of water flowing down the slope and conserve soil. Grass strips are planted with fodder grass such as Napier or are left with natural grass; thereby providing fodder to livestock.
- **Check dams -** is a small temporary or permanent barrier constructed of rock, gravel bags, sandbags, fibre rolls, or reusable products, placed across a gully, channel or drainage to lower the speed of flows from storm events.
- **Zai pits -** are 10-15 cm deep, 15-50 cm wide and 80-100 cm apart. The pits promote an integrated soil, water and nutrient management by retaining water.
- **Tied ridges -** are small earthen ridges, 30 cm high, with an upslope furrow which accommodates runoff from a catchment strip between the ridges.

2.12.3 Rainwater harvesting for storage (ex-situ rainwater harvesting)

Rainwater harvesting for storage, also known as *ex-situ* water harvesting, is a practice in which rainwater is collected and stored for productive use, for example drinking, agriculture, sanitation and more. Structures for ex-situ water harvesting include: -

- **Rooftop water harvesting with above ground tank -** A roof becomes a catchment when it is used for harvesting rainwater. Roof catchment systems provide water that can be used for domestic purposes.
- **Water pans -** are shallow depressions (1 m to 3 m deep) constructed to collect and hold runoff water from various surfaces including from hillsides, roads, rocky areas and open rangelands.
- **Small earthen dams -** its constructed either on-stream or off-stream, where there is a source of large quantities of channel flow. The dam wall is 2 - 5 m high and has a clay core and stone aprons and spillways to discharge excess runoff.
- **Sand dams –** it is a wall constructed across the stream to restrict surface flow. The height of the dam wall is increased by 0.3 m after floods have deposited sand to the level of the spillway.
- **Wells and boreholes -** water obtained from underground sources.

2.12.4 Soil moisture conservation techniques

- The goal is to minimize the amount of water lost from the soils through evaporation (water loss directly from the soil) and transpiration (water loss occurring through the plants) – or combined, the evapotranspiration.
- Preserving soil moisture is important for agricultural production, and also helps minimize irrigation needs of the crops.

2.12.5 Methods for soil moisture conservation include: -

- **Spreading manure or compost over the soil –** this minimizes evapotranspiration and also provides valuable nutrients to the soil through decomposition
- **Mulching –** placing a layer of organic (or inorganic) material at the root zone of the plants.
- **Conservation tillage-** reducing or in extreme cases completely eliminating tillage to maintain soil structure and increase soil organic matter that improves soils capacity to absorb and retain water.
- **Crop rotation –** growing different types of crops every other season - improves soil structure; water holding capacity; soil fertility; and helps control pests and diseases.
- **Green manure –** growing of plant materials with the purpose of adding organic matter to the soil. The improved soil quality then also improves water retention capacity.
- **Mixed cropping intercropping and inter-planting –** involves cultivating a combination of crops with different planting times and different length of growth periods.
- **Contour ploughing –**ploughing along the contour instead of up- and downward slopes, reduces water velocity, creating even barriers, and more water is retained in the soils and distributed more equally across the cropland.
- **Strip cropping -** growing erosion permitting crops and erosion resisting crops in alternate strips.

2.13 Problematic Soils and their Management

Problematic or problem soils refer to soils that possess characteristics that make them uneconomical for cultivation of crops without adopting proper reclamation measures. We have three major types of problem soils:

- Physical problem soils
- Chemical problem soils
- Biological problem soils.

2.13.1 Soils with Physical Problems for Agricultural Production

These are soils whose physical properties have some limitations. They include: impermeable soils, soil surface crusting and sealing, subsoil hardpan, shallow soils, highly permeable soils, heavy clay soils and fluffy paddy soils.

2.13.2 Soils with unfavourable Chemical Properties for Agricultural Production

The major soils in this category are acidic and salt affected soils.

a) Acid soils

Soil with pH of less than 7 is generally referred to as acid soils. The acidity level however increases with pH decrease from 7 towards zero with pH levels lower than 5.5 being strongly acidic and pH of less than 4.75 being extremely acidic.

Acidity in soils can be caused by mineralogy of parent material, organic matter accumulation, leaching of base cations (calcium, magnesium, potassium and sodium), and management practices such as continuous use of acid forming fertilizers, application of elemental sulphur which undergoes reactions forming sulphuric acid, tillage practices and soil pollution.

Soil acidity can be managed by application of organic amendments such as manure. Application of pulverized Limestone or dolomitic limestone is one the fastest ways to increase soil's pH or reduction of soil acidity.

b) Saline soils

Saline soils are non-sodic soils containing sufficient soluble salt to adversely affect the growth of most crop plants with a lower limit of electrical conductivity of the saturated extract (ECe) being 4 deci Siemens / meter (dS/m), which is equivalent to a value of 4 mm hos/cm. Very salty soils are sometimes recognizable by a white layer or dry salt on the soil surface.

The saline soil problems are caused by the accumulated soluble salts in the root zone. In this soil due to high salt levels microbial activity is reduced. Specific ion effects on plants are also seen due to toxicity of ions like chloride and sulphates.

The reclamation of saline soils involves basically the removal of salts from the root zone soil through the processes of leaching with water and drainage. Provision of lateral and main drainage channels of 60 cm deep and 45 cm wide and leaching of salts could reclaim the soils.

i) Irrigation of Saline Soils

Proportional mixing of good quality (if available) water with saline water and then using for irrigation reduces the effect of salinity. Alternate furrow irrigation favours growth of plant than flooding. Drip, sprinkler and pitcher irrigation have been found to be more efficient than the conventional flood irrigation method since relatively lesser amount of water is used under these improved methods.

ii) Fertilizer Management for Saline soils

Addition of extra dose of nitrogen to the tune of 20-25% of recommended level will compensate the low availability of N in these soils. Addition of organic manures like, FYM, compost, etc. helps in reducing the ill effect of salinity due to release of organic acids produced during decomposition. Green manuring and or green leaf manuring also counteracts the effects of salinity.

c) Sodic soils

Sodic soils are soils containing sufficient exchangeable sodium to adversely affect the growth of most crop plants. These soils have high levels of exchangeable sodium (Na) and low levels of total salts caused by natural presence of minerals producing sodium carbonate (Na_2CO_3) or sodium bi-carbonate ($NaHCO_3$) upon weathering. They are usually defined as containing an exchangeable sodium percentage greater than 15% and a pH of 8.2 or more. Extreme cases may have a pH of above 10.5. These soils tend to occur within arid to semiarid regions and are innately unstable, exhibiting poor physical and chemical properties, which impede water infiltration, water availability, and ultimately plant growth.

Sodic soils may impact plant growth by: a) Sodium toxicity to sodium sensitive plants; b) Nutrient deficiencies or imbalances; c) High pH of > 8.0 and d) soil structure destruction or dispersion or flocculation of clay minerals.

Sodic soils can be reclaimed or managed using several approaches, they include:

i. Establishment of sodic tolerant crops

ii. Application of organic manures.

iii. Application of chemical amendments such as soluble calcium salts (gypsum, calcium chloride), acids or acid forming substances (sulphuric acid, iron sulphate, aluminium sulphate, lime-sulphur, and pyrite) or calcium salts of low solubility like ground limestone. The compounds in the salts or acids reacts with the sodium carbonate (Na_2CO_3 or $NaHCO_3$) forming a leachable compound.

iv. Agronomic management such as planting at the edge of hills, leaching, crop rotation among others.

d) Alkaline soils

Alkaline soils are clay soils with high pH, poor soil structure and low infiltration capacity. Often they have a hard calcareous layer at 0.5 to 1 meter depth. The causes of alkaline soils can be natural or man-made. Natural causes are the presence of minerals producing sodium carbonate (Na_2CO_3) or sodium bi-carbonate (NaHCO3) upon weathering. The soils can be reclaimed by incorporation of grass cultures, organic compost, waste hair and feathers, organic garbage, acidifying materials (inorganic or organic material) into the soil, and enhancing dissolved Ca in the field water by releasing CO_2 gas. Deep ploughing and incorporation of the calcareous subsoil into the topsoil also can be of help.

2.13.3 Soils with unfavourable biological Properties for Agricultural Production

These include soils with low organic matter content, soil living organisms or harmful soil living organisms such asbacterial wilt, Fusarium wilt and nematodes.

3 FARM-LEVEL AGRICULTURAL RESILIENCE AND ADAPTATION TO CLIMATE CHANGE

Climate change and variability affects agriculture particularly rural livelihoods, incomes and food security. This is through increased temperatures, changing rainfall patterns which have become unreliable, increased frequency and intensity of floods and droughts. Because of this, it is important for farmers to learn and practise appropriate farm level adaptation measures so as to build their capacity and resilience in food production systems.

These impacts of climate change on agriculture can be classified into:

- **Crop production i.e.** changes in quantity and quality of crop yields, forages and crop residues; changes in the timing and duration of crop growing seasons; interference with the coordination of farm activities and distribution of labour etc.
- **Soil fertility:** Reduced soil carbon, soil moisture, soil organisms, vegetation cover leading the soil prone to erosion, soil degradation.
- **Water availability: flooding,** waterlogging or water deficit at the crop root zone; affect the quality and quantity of water for human and animal consumption.
- **Livestock production:** Poor quality feeds, poor feed yields, increased diseases and pests, invasive pasture and lose of others from ecosystem.

3.1 What is Resilience?

This is the ability of farm production systems to deal with major climatic shocks such as rainfall variability, drought, floods, pest infestation and other stresses. This ability helps the farmer or agricultural system to absorb the stress impact and recover quickly.

3.2 Major Technologies and Management Practices for Enhancing Farm Level Resilience

3.2.1 Soil Health Management Practices

Soils as a natural resource and base for agricultural productivity is critical in enhancing farm level resilience. A healthy soil has the capacity to sustain agricultural production. A health soil should have good tilth, sufficient depth, good water storage, good drainage, sufficient supply of nutrients, minimal plant pathogens and insect pests, free from chemicals and toxins, resistant to degradation among others. This is however impacted by climate change as shown in Table 3.1.

Table 3.1: Impact of climate change on soil health

Climate change indicators	Impact on soil health	Impact on crop production
Increased temperature	a) Reduced soil organic matter b) Reduced capacity to retain and supply nutrients to crops c) Reduced soil water holding capacity	a) Reduced crop yields

Climate change indicators	Impact on soil health	Impact on crop production
Increased rainfall intensity	a) Increased ground water pollution and soil acidity b) Loss of soil nutrients c) Increased pests & diseases and weeds	a) Reduced crop yields b) Low quality yields
Reduced rainfall intensity	a) Poor soil water infiltration and retention b) Limited root penetration c) Poor water and nutrients uptake by crops	a) Poor or no crop growth b) Reduced crop yields or crop failure

Table 3.2 describes various interventions to enhance soil health for increased productivity and farm level resilience

Table 3.2: Interventions for enhancing soil health

Intervention	**Targeted constraint(s)**	**Contribution to resilience**
Reduced tillage (CA)	Low soil organic matter content; Limited soil water content; Poor soil aggregation; Low water retention; High soil erosion status	Restores soils physical, chemical and biological status; Reduces soil erosion; Improves environmental biodiversity
Crop rotations and intercrops (crop diversification)	High pests & disease infestation; Low soil organic matter content; Low soil nutrients levels	Reduces pests & diseases incidences; Increases soil nutrients; Provides diverse sources of food, feed and revenue
Growing cover crops	Low soil organic matter content; Poor soil aggregation; Low water retention; Low soil fertility; High erosion	Restores soils physical, chemical and biological status; Reduces soil erosion; Provides diverse sources of food, feed and revenue
Agro-forestry	Low soil organic matter content; Poor soil aggregation; Low water retention; Low soil fertility; High soil erosion status	Restores soils fertility; Reduces soil erosion; Provides diverse sources of food, feed and revenue
Inoculation of leguminous crops	Low soil nitrogen levels; Expensive inorganic nitrogen fertilizers	Increases soil fertility; Reduces use of inorganic fertilizers
Integrated Soil Fertility Management (ISFM)	Low soil nutrients levels; Low soil organic matter content; Poor soil aggregation; Low water retention	Increases soil nutrients and organic matter; Restores soil fertility; Reduces application of soil fertility inputs.
Organic fertilizer addition	Low soil organic matter content; Poor soil aggregation; Low soil water retention; Low soil nutrients levels	Restores soils fertility; Reduces use of inorganic fertilizers
Inorganic fertilizer addition	Low soil nutrients levels	Increases soil nutrients levels
Acidic soil liming	Low soil pH level; Toxic levels of micro nutrients; Low soil Phosphorus nutrient level	Increases soil pH, reduces toxic levels micro-nutrients and increases availability of Phosphorus to crops.

3.3 Rainwater Harvesting and Management Practices

Farm level resilience principles aims at reducing the vulnerability of farmers and their agricultural systems to water scarcity. This can be achieved by increasing the availability and access to water during the drier seasons by developing structures (such as contour schemes, terracing, pits and bunds to reduce `run-off and increase water availability for crops) or reduced water loss in the soil by adding organic matter in the form of compost, manures or plant residues.

3.4 Water Efficient Irrigation Systems

Drip irrigation technology supports farmers to adapt to climate change by providing efficient use of water supply (Figure 3.1). The technology saves water by managing and minimizing evaporation losses, and delivering water at the crop root zone where it is required. The system consist of elevated water source (tank), pumping unit, filters, drippers and drip lines which can either be on the surface or sub-surface (buried). Below is a simple illustration of a drip irrigation system

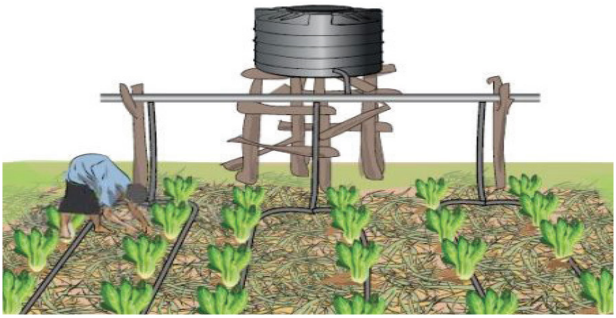


Figure 3.1: Illustration of simple drip irrigation system

3.5 Contributions Of Drip Irrigation System To Farm Level Resilience

- Producing more crops with less water.
- Uses less energy for pumping and conveying water.
- It has minimal nutrient leaching and local environmental pollution.
- Contributes to increased food security and incomes since crop production can be done on and off rain season.
- Leads to reduced workload for women allowing them to re-allocate their time and resources to other livelihood activities.

3.6 Seed Management Practices

Seed has direct links to food security and resilient livelihoods. It's important to develop seeds that are resilient to current and future climatic shocks. These include:

3.6.1 Use of early maturing crop varieties –

Crop that matches with the rainfall patterns. An example is the "Mwezi Moja" bean variety that matures within one month.

3.6.2 Adopting heat tolerant crop varieties–

Crops that can withstand increases in temperatures

3.6.3 Use of salt tolerant crop varieties-

Crops that survive soil and water conditions that are saline

3.6.4 Contribution of seed management practices to agricultural resilience

1. Adopting drought tolerant or faster maturing seed varieties increases resilience to dry spells and assures them a harvest.
2. Adopting drought tolerant or faster maturing seed varieties contributes to food production. Drought tolerant crops like cassava, millet or sorghum, despite their low market value, ensure that farm households have at least some food for consumption when crops like maize fail.
3. Adopting drought tolerant, heat tolerant and saline tolerant varieties contributes to household incomes.

3.7 Crop Management Practices

Crop management is one of the cost-effective methods of building resilience into agricultural systems. It takes into account seasonal climatic stresses such as changes in rainfall distribution, increased temperatures, increased incidence of pests and diseases, extreme floods and sea level rise which will hamper crop yields. The major crop practices are;

3.7.1 Use of salt tolerant crop varieties –

Crops that survive soil and water conditions that are saline

3.7.2 Matching crop/varieties with ecology -

You need to plant crops that suit specific environment or farms.

3.7.3 Seeding/seed rate –

When planting make sure that the number of seeds planted per unit area considers the plant requirements (feeding space), purpose of cultivation (grain, silage, etc.), soil fertility status, climatic conditions, and other factors to ensure maximum `yield. The farmers should practice timely planting to maximize on the rainfall

3.7.4 Crop diversification-

This suppresses pest and diseases, assures the farmers a harvest from one of the crops.

3.7.5 Crop fertilization (organic or inorganic fertilizers) –

Fertilizers increases soil fertility that enhances and sustains growth of plants. The type and quantity of fertilizer to apply should be well identified and farmers should first know their soil fertility status through soil testing.

3.7.6 Soil Liming –

Overuse of fertilizers, pesticides, mono-cropping and depletion of soil organic matter might increase soil acidity that negatively affects crops as discussed in section 2.12.2 above. Application of lime provides improves such soils leading to increased crop growth and yield.

3.7.7 Timely harvesting –

Timely harvesting reduces losses and impact on quality. Farmers need to follow crop harvesting recommendations to avoid losses.

3.7.8 Post-harvest handling –

Selecting appropriate crop handling, processing and storage technology minimize losses, increases food security, incomes and household resilience

3.7.9 Contributions of seed system management to resilience

- Crop diversification reduces the susceptibility of the farm to crop pests and diseases
- Stabilizes farm production as climate risks do not affect all crops to the same degree e.g. mixing drought tolerant crops with non-drought tolerant crops ensures some harvests under drought conditions.
- Crop diversification ensures that income can be derived from produce as different crops have different market values.
- Using nitrogen-fixing plants reduces the amount of money needed to purchase inorganic fertiliser, thereby reducing the cash expenditure of smallholder farms.
- Holds some potential for greater social resilience by building social capital – crop rotation and mixed cropping are good farm management practices that ensure that the farm does not become a source of risk for surrounding farms through the concentration of crop pest and disease as would happen without crop rotation or mixed cropping.
- Potential improvement in farm income and job creation.
- Improved soil quality and reduced erosion.
- Reduces the risk of crop failure hence enhance farm level incomes and food security

3.8 Agro-Forestry Management Practice

This is the deliberate practice of growing woody perennials (trees, shrubs) as agricultural crops alongside other crops and livestock in the same land. It has potential of enhancing productivity and sustainability. Farmers are recommended to choose the right type of tree species for their farms.

3.8.1 Contribution of agroforestry management practices to farm level resilience

- Trees fixes nitrogen which contributes to enhanced soil fertility, crop yields and general farm productivity.
- Increased soil fertility have the potential to reduce the impact of droughts in the farm
- Tree biomass increases the soil organic matter that leads to increased soil water infiltration and retention capacity.

- Farm trees stabilizes the soil structure and thereby reduces soil erosion.
- Sale of agroforestry products such as fodder, woodfuel, honey, medicines, mulch, vegetables and fruits are sources of income for farmers.
- Enhanced soil fertility as a result of nitrogen-fixing plants reduces the amount of money needed to purchase inorganic fertilisers, thereby reducing the cash expenditure of smallholder farms.
- Farm diversification through agroforestry reduces both environmental and economic risks by spreading harvests and income throughout the year.
- Agroforestry canopy are sinks of GHGs (Carbon) hence mitigating the impacts of climate change.

3.9 Pests and Diseases Management Practices

Climate change and variability causes highly variable environmental conditions leading to increased pest and diseases. This phenomena causes reduced crop yields, low quality of agricultural produce, loss of life, malnutrition, loss of income, loss of crop diversity and environmental pollution resulting from increased use of pesticides. Farm level resilience pest and disease management practices methods include:-.

3.9.1 Biological pest management

This involves the use of biological methods to control pests and diseases. It includes use of beneficial insects such as ladybirds (predator), digger wasps (parasite) and bacteria (pathogen) to kill larvae. Push and Pull Technology' (PPT) can also be used to control fall armyworms. Through this approach, the potential risks to farmers, plants and animals are reduced, thereby enhancing farm resilience and long-term environmental improvements.

3.9.2 Mechanical pest management

Here pests are controlled by non-chemical direct physical measures. It includes hand-picking to remove insects, tilling to remove weeds and trapping to catch insects or rodents.

3.9.3 Pesticides pest management:

Pesticides may be chemical, biological or physical agents used to prevent, destroy, repel, mitigate, harm or kill organisms which are considered to be pests.

3.9.4 Cultural methods for pest management

This methods used alter the plant environment and may include irrigation and fertilization schedules, early planting, sanitation practices, intercropping (crop rotation, relay) and use of improved crop varieties.

3.9.5 Integrated pest management (IPM)

This are techniques used to reduce or stop pests and diseases from multiplying. It includes the introduction of beneficial insects (biological control); using crop-resistant varieties; improving cleanliness (field and store hygiene); using alternative agricultural practices such as pruning and spraying; improving crop health by either using organic, inorganic or combination of organic and inorganic fertilizers.

3.9.6 Contribution of pest and disease management practices to farm level resilience

- Using biological control, the soil and water pollution is reduced thereby improving environmental conditions for the farmer.
- Biological controls are cheaper and easier to access. Therefore, the farmers have less expenditure implying that profits to the farmer are maximized.
- By using biological pesticides, farmers will use indigenous knowledge that is fast disappearing. This will allow farmers contribute to maintaining and transferring indigenous knowledge on handling crop pests and diseases.

3.10 Livestock, Pasture and Rangeland Management Practices

Climate change and variability is a real threat to the productivity of rangelands. There is increased degradation and livestock grazing fields is decreasing and unable to support livestock stock. This has negatively impacted on the communities and production systems resilience. Therefore, various farm level strategies are required to promote good rangeland management. These include:

3.10.1 Grazing management control:

This involves changing the control and regulation of grazing pressure through the reduction of grazing intensity and reforestation (vegetation improvement). The controls can be achieved through fencing, rotational grazing, 'cut-and-carry' of fodder, and vegetation improvement.

3.10.2 Fodder substitution and fodder banks:

This can be achieved through:

- Creation of fodder banks – areas delineated with fodder to be used in lean times; harvesting and keeping fodder to be used later
- Management of invasive species
- Investing in alternative fodder like Cactus for livestock feed
- Production of fodder under irrigation.

3.10.3 Livestock substitution:

This is the replacement of the large stock (e.g. cattle) with small stock to merge carrying capacity or switching to camels which are more drought-resilient.

3.10.4 Management of crop and industrial residues:

These are investments in the production of livestock feeds to reduce pressure on the natural feed sources. An example is the production of Multi Nutrient Blocks to fed livestock during drought seasons

3.10.5 Contribution of livestock, pasture & rangeland management practices to farm level resilience

- The practice increases soil carbon which positively affects soil fertility and overall rangeland production.
- Through the improved grazing land management measures which leads to increased fodder availability, farmers enhances livestock fodder sufficiency.
- Through the collective management of community pastures, the practice fosters social resilience thereby enhancing social cohesion.

3.11 Climate Information Services

As a result of unpredictable climatic pattern, farmers requires robust climate information services to enable them make informed decisions. This includes information about past, present and future climate scenarios, and their implications on farming enterprises, livelihoods and environment.

3.11.1 Importance of climate information services

1. Increased understanding of climate change and related risks on agricultural livelihoods.
2. Helps farmers make good choices of farm enterprises – seasonal and long-term
3. Short-term national development planning e.g. to plan for subsidies and farm inputs like irrigation water infrastructure.
4. Long-term national development planning e.g. decisions on agricultural infrastructure like where to locate dams and water reservoirs for irrigation.
5. Pest and disease surveillance and early warning.
6. Development of appropriate adaptation and mitigation technologies

3.11.2 Contribution of climate services to farm level resilience

1. Adequate and timely weather information helps farmers make informed decisions on the timing of agricultural activities for increased productivity
2. It enables farmers to manage the negative impacts of weather-induced risks in the season while also taking advantage of good climatic seasons.
3. It helps agricultural actors to adjust their plans as climate stressors and shocks unfold.
4. It provides information that supports mitigation (i.e. use of fertilizers) to reduce emissions of greenhouse gases responsible for global warming

3.12 Agricultural Insurance

Climate change and variability presents numerous social, economic and environmental risks. At farm level, farmers face a number of risks ranging from production, produce transportation and marketing that are linked to climate. Therefore, risk management techniques, tools and policies are important to minimize adverse losses and develop resilience to agricultural production systems.

Agricultural insurance practices are applicable to all sectors such as crops, livestock, forestry, and aquaculture. Insurance allows a farmer to transfer a risk of an agricultural loss in exchange for a premium to prevent a devastating loss.

3.12.1 Contribution of Agricultural Insurance to farm level resilience

a) It increases farmer willingness to adopt the climate-smart agricultural technologies leading to increased productivity; food security and economic gains.

b) Improves farmers access to credit for agricultural activities

c) Supports agricultural and rural development by helping farmers, financial service providers and input suppliers cope with climatic risks.

d) It reduces the need for *ad hoc* disaster programmes which tend to be expensive, ineffective, and inefficient.

e) By accessing credit, farmers take additional risks by investing in improved practices that increases farm productivity and food security.

4 CEREALS

This section covers production, crop protection and post-harvest handling of three main cereal crops namely; maize, sorghum and millets.

4.1 Maize

4.1.1 Agro-Ecological Requirements

Maize grows on a wide variety of soils, but performs best on well-drained, well-aerated, deep warm and silt loamy soils with sufficient nutrients. Maize does not tolerate water logging; it can wither if it stands in water for more than two days (Table 4.1)

Table 4.1: Soil, PH, Temperatures and rainfall requirements for Maize

Crop	Soil type	pH	Temperature (°C)	Rainfall (mm)
Maize	Loamy	5.0-7.0	30-34	250-900

4.1.2 Agronomic Practices

a) Selection of Suitable Varieties

The choice of appropriate maize varieties for a given location is very important because every variety has extensively been tested and recommended based on climatic conditions, yield potential, resistance to pests and diseases and maturity period (Figure 4.1) and Table 4.2.

Figure 4.1: Criteria for selecting maize varieties

Table 4.2: Recommended maize varieties in Kenya

Variety	Source	AEZ where grown	Maturity (Days)	Yield potential 90Kg bags/acre
KCB	KALRO	Dry lands	90-110	11
KDV 1	Dry land Seed company	Dry lands	100-120	12
KDV4	Dry land Seed company	Dry Lands	100-120	14
Sungura	Agri-Seedco	Dry land	100-120	15
SAWA	Dry land Seed company	Drylands	100-200	14
DH02	Kenya seed company	Dry lands	90-120	11
DUMA43	Agri-Seedco	Coffee region	90-110	22

Variety	Source	AEZ where grown	Maturity (Days)	Yield potential 90Kg bags/acre
PAN4M-19	PANNAR	Dry lands	90-110	25
PH4	Kenya seed company	Coastal Lowlands	100-120	24
PH1	Kenya seed company	Coastal Lowlands	95-110	22
SY594	Syngenta	Coastal Lowlands	110-120	24
DH04	Kenya Seed company	Moist Mid-Altitude	110-120	16
TOSHEKA	East Africa Seed	Moist Mid-altitude	100-110	24
DK8033	BAYER	Moist Mid-Altitude	120-130	38
DK777	BAYER	Moist Mid-Altitude	120-180	40
KH500-43A	East Africa seed	Moist Mid-Altitude	100-130	
TSAVO3106	Gicheha Farm Limited	Moist Mid-Altitude	100-150	32
TSAVO4141	Gicheha Farm Limited	Dry lands/Coffee regions	100-120	30
Bingwa	Ultraveties	Moist Mid-Altitude	120-180	35
DKC90-89	BAYER	Moist Mid-Altitude	150-180	44
PH3253	Pioneer	Moist Mid-Altitude	110-120	30
H 6218	Kenya seed company	Highlands	160-210	56
H 6213	Kenya seed company	Highlands	160-210	50
H6210	Kenya seed company	Highlands	160-210	45
H629	Kenya seed company	Highlands	160-210	43
H614D	Kenya seed company	Highlands	160-210	33
WH505	Western seed company	Moist Mid-altitude	120-180	35
H517	Kenya seed company	Moist Mid altitude	120-180	20
H520	Kenya seed company	Moist Mid-altitude	120-130	32
PHB30G19	Pioneer Seed Company	Moist Mid-altitude	90-120	30
KH500-31A	KALRO	Moist Mid-Altitude	120-140	33
MH-401	East African Seed	Moist Mid-Altitude	90-120	32
H624	Kenya seed company	Highlands	140-180	32
SIMBA 61	Seed Co	Highlands	150-200	25

b) Germination test

Procedure for testing seed germination: Count 100 seeds of a selected maize variety and put between moist old newspapers. After four days of incubation, the germinated seeds are counted and divided by the total seeds and expressed as a percentage. For example, if out of the 100 seeds 85 seeds germinated, germination is ((85/100)*100)) 85%.

A germination of between 85% and 100% is considered good for the maize seed. In case germination rate is lower, you may increase sowing density correspondingly to ensure appropriate plant density for example plant 2-3 seeds per hole.

c) Land Preparation

A maize farm can be prepared by hands, an ox plough, tractor and/or by spraying with recommended herbicides. It is important to prepare the land early enough to allow weeds to dry and decompose.

Table 4.3: Land preparation practices/technologies

LAND PREPARATION PRACTICES/TECHNOLOGIES		
Conventional Land preparation: Virgin land	**Conventional Land preparation-Stubble land**	**Conservation Agriculture: Virgin land**
Plough twice and harrow once or plough once but at least 3 months before the anticipated time of planting + 2 harrows with the last just before planting	One plough (disc or moldboard) + one harrow	Use Glyphosate based herbicide at 2 L/acre during fallow and 1.2 L/acre 24 hours before planting
Plough twice and harrow once or if using a tractor and/or virgin land, plough once at least 3 months before the anticipated time of planting + two harrows with the last harrow just before planting	One plough (disc or moldboard) + one harrow	Use Glyphosate based herbicide at 2 L/acre on fallow and 1.5 L/ha 24 hours before planting
Plough twice and harrow once or plough once but at least 3 months before the anticipated time of planting + two harrows with the last harrow just before planting	One plough (disc or moldboard) + one harrow	Use Glyphosate based herbicide at 2 L/acre during fallow
Plough twice and harrow once or plough once but at least 3 months before the anticipated time of planting + two harrows with the last harrow just before planting	One plod (disc or moldboard) + one harrow	Use Glyphosate based herbicide at 2 L/acre during fallow
Plough twice and harrow once or plod once but at least 3 months before the anticipated time of planting + two harrows with the last harrow just before planting	One plod (disc or moldboard) + one harrow	Use Glyphosate based herbicide at 2 L/acre during fallow and 1.2 L/acre 24 hours before planting

d) Soil fertility management

Fertilisers are recommended based on existing soil fertility status.

Table 4.4: Fertilizer recommendation rates for maize in Kenya

Choice	**Maize**		**Maize/bean intercrop**
	Planting	**Top dress**	**Planting**
Choice 1	NPK (23-23-0) **2 bags/acre**	Top-dress with CAN (26-0-0) **1.5 bag/acre**	NPK (23-23-0) **Extra 25 kg/acre**
Choice 2	MEA Mazao (10-26-10 + 25% Ca and micronutrients) **2 bags/acre**	Top dress CAN (26-0-0) **1 .5 bag/acre**	MEA Mazao **Extra 25 kg/acre**
Choice 3	Mavuno Basal (10-26-10 + Ca and micronutrients) **2 bags/acre**	Top-dress with Mavuno **1.5 bag/acre**	Mavuno basal **Extra 25 kg/acre**

e). Planting

- Planting time is a very critical step in maize production. Maize should be planted according to the following recommendations. Maize depth ranges from 2 to 3 cm.

Table 4.5: Recommended spacing and planting density of maize for different zones

Region	Spacing	Density (plants per acre)
Highland	75x25cm 1 plant/hill (pure stand) 75 x 50cm 2 plants/hill (intercrop)	21,333 21,333
Medium	75 x 30cm 1 plant/hill (pure stand) 75 x 60cm 2 plants/hill (intercrop)	17,778 11,778
Dry land	90 x 30cm 1 plant/hill (pure stand) 90x 60cm 2 plants/hill (intercrop)	15,140 15,140

f) Weed management in cereals

- Weeds reduce maize yields by competing for moisture, nutrients, space and light. The most critical stage of weed competition in the life of a maize plant is during the first four to six weeks after emergence of the crop. Some of the recommended practices include:
    - **Hand weeding:** Weed twice but the first weeding should be done 4 weeks after emergence followed by a second weeding at knee high
    - **Use of herbicides**: The recommended herbicides can be applied before the crop emerges.
- Other approaches include establishing a dense legume cover crop such as lablab *(Lablab purpureus)*, velvet bean *(Mucuna pruriens)* or sunhemp *(Crotalaria juncea)* to suppress weeds.
- *Striga being* a parasitic weed that grows by attaching itself to roots of a host plant like maize and sorghum can be managed by using clean seeds and equipment as well as s*triga* resistant or tolerant maize varieties, in case they are available. Legumes that are grown in rotation or as intercrops with maize stimulate the germination of *striga,* but inhibit post-germination growth of the weed because it cannot grow on the roots of legume crops. It is recommended to use push and pull technology where fodder crops such as *desmodium, sesbania, crotalaria* or fodder grasses like Napier grass for at least two seasons until all *striga* is eliminated. Farmers can also apply *'Kichawi Kill'* at 1-2 grams of the freshly prepared substrate in each maize planting hole to arrest the striga seeds. However, farmers should regularly scout their fields and uproot the *Striga* weeds early enough before they produce seeds.

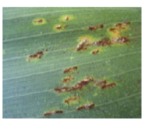
g) Crop rotation

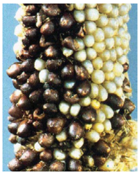
Practise crop rotation and avoid planting maize continuously. This is due to challenges of diseases like the maize lethal necrosis disease. Some options will include rotating with pulses like beans, cowpeas and peas. Avoid rotating with cereal crops like sorghum and millet. Vegetables could be used for rotation however, careful selection needs to be done to ensure that the hosts and vectors are not same as for the maize diseases e.g. Aphids and thrips.

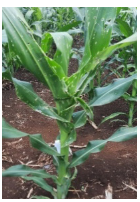
4.1.3 Crop Protection

Pests and diseases are a major constraint in maize production in Kenya that lead to heavy yield losses and income for farmers and other value chain players Losses of 30 -100% have been reported due to maize diseases such as maize lethal necrosis disease (MLND) and insect pests such as the fall army worm depending on the period the crop is affected, incidences and severity of the problem. Hence the information provided in this section aims at empowering farmers in pest & disease identification and management to minimize losses

Table 4.6: Pests and Diseases management of Maize

Problem	Symptom	Description	Management
Gray leaf spot (*Cerospora mayidis*)	 Photo source: James Karanja, KALRO	• Necrotic brown spots on younger leaves that are parallel to leaf veins • Later brown spots merge and become ashy grey starting from the lower leaves and increase in number after silking. • The wounds change from light to gray and join together killing the entire leaf	• Plant resistant varieties • Remove plant debris • Encourage deep ploughing to reduce fungal spores causing infection. • Crop rotate with potato, beans or pea • Use recommended doses of fertilizers • Destroy diseased plants before it lodges by burning or burying 2 feet deep • Spray with Azoxystrobin & Difenoconazole (Amistar top SC @200ml/Acre and Ortiva @ 125g/20L.
Common leaf rust	 Photo source; Abel Too, KALRO	• Elongated raised bumps (pustules) scattered or clustered on both leaf surfaces that are red to dark brown in colour • Pustules appear on the mid and upper canopy of the crop especially during tasseling • As the plant matures, the leaf epidermis breaks and resulting wounds turn black while releasing spores	• Using tolerant varieties • Deep ploughing to bury crop residue after harvest • Use clean certified maize seed from a reliable source. • Rotate maize crop with beans, , chickpea at least every 2-3 years • Remove lower leaves which are infested to improve air circulation and reduce the amount of the infectious spores

Problem	Symptom	Description	Management
Common smut (*Ustilago mayidis*)	 Photo source; University of Georgia  Photo source; University of Georgia	• Symptoms include presence of whitish grey tumour- like galls/ swelling on tassels, husks, ears/ kernels, stalks, leaves, roots. • A black mass of spores on sorghum head • Infected plants are dwarfed and tillers profusely produce smutted heads, stunted growth may be experienced and some seeds rot leading to development of mycotoxin. • Affects millets immediately after booting stage	• Practice crop rotation with cassava and sweet potatoes • Plant certified seeds Plant tolerant varieties • Timely planting • Destroy infected plants and galls before the smut ruptures by burning • Seed dress seeds using carboxin 15%+Thiram 13% (Vitaflo 280) 1.5g/ kg seed
Maize lethal necrosis disease	  Photo source; Abel Too, KALRO	• Colourless patches on leaves starting from the base of young leaves in the whorl and extending upwards to leaf tips. • Dwarfing and premature aging of the plant, necrosis of young leaves • Dead heart symptom in the whorl of the plant • Kernels are poorly filled in the cob and tassels have no pollen.	• Avoid moving plants from infected to non-infected regions to reduce spread • Practise crop rotation with beans, garlic, onions and vegetables for at least 2 seasons. • Avoid continuous planting of maize to stop persistence of virus and possible vectors • Plant early with fertilizer and manure • Use certified seeds dressed with insecticides and avoid planting recycled seeds. • Keep the field free from weeds, uproot and destroy diseased plants by burning or burying 2 feet deep • Spray vectors (thrips &aphids) using Lambda-cyhalothrin based products
Streak virus disease		• Narrow white to yellowish streaks on the leaves whorls, the streaks form broken lines that run parallel • The central leaves die, resulting in a dry, withered parallel to the mid rib 'dead-heart' symptom.	• Plant resistant varieties • Plant early in the season at the onset of rains • Rotate maize, sorghum and millet with potatoes, cabbages, beans, avoid overlap of two maize crop seasons

Problem	Symptom	Description	Management
	 Photo source: Miriam Otipa, KALRO		• Uproot infected plants and feed livestock or burn • Spray using Alpha-cypermethrin (Albaz; Alfacyper, Alfagold; Alfapor), uusually 20-30ml/20l of water. Spraying should start 1 month after planting
Fusarium ear rots	 Photo source; James Karanja-KALRO	• White streaks on the surface of grains and occasionally as whitish to pink cottony powder (web-like) over the grains. • *Fusarium* ear rot results in mycotoxins which are toxic to humans and animals	• Control stem borers since they carry the fungus and harvest the grain when mature to avoid disease spread • Rotate maize with beans and soy beans after 3 years • Spray with neem (*Azadirachta indica)* to kill young stem borer larvae. All planting seed must be dressed with thiram at 280 ml/100kg.
Aspergillus ear rot	 Photo source: James Karanja-KALRO	• Cobs silk appear with yellowish-green powder • The maize crop are stunted with small cobs, while their grain is discoloured • Take action as soon as 1-2 in 10 plants per acre have ear rot.	• Plant certified seeds on the onset of rains Apply nitrogen fertilizer (Basal: 20 – 40 kg/ha D-compound and top dress: 20 kg/ha Urea) to overcome stress. • Harvest the grain early when dry to avoid spread of fungus to uninfected cobs • Destroy crop residues by composting and rotate maize with soya beans, cowpea and beans.
Stem borers (*Bussiola fusca*, *Chilo partellas*, *S. calamistis*)	  Photo source; Gerphas Ogola, CIMMYT	• Moths lay eggs on maize leaves which hatch into caterpillars that feed on young plants and later burrow stems for water and nutrient flow • Symptoms appear as actively feeding caterpillars on the plant young leaves which later spread to the stem	• Plant resistant varieties • Intercrop with non-host crops such sweet potato, pigeon pea and common beans • Practise push pull management using desmodium (push) and Napier grass or Bracharia (Pull) around the plot • Destroy maize residues after harvest • Maintain a hedge around the farm to conserve biological controls such as predators and parasites

Problem	Symptom	Description	Management
Fall armyworm (*Spodoptera frugiperda)*	  Photo source; Z. M. Kinyua, James Karanja-KALRO	• Inverted Y pattern at the forehead of the caterpillar • Gray to back larvae with pale stripe down the back	• Spray with botanical based products such as neembicidine at rate100ml/ 20l water • Spray Flubendazole based products such as Belt to manage the pest • Spray Chlorantraniliprole based products such as Voliam targo at rate 5ml/20l water to manage fall armyworm • Spray with Thiamethoxam and lambda cyhalothrin such as Engeo at rate 20ml/20l water and repeat interval of 7 days
Termites *Reticulitermes* spp.	 Photo source: James Karanja	• They attack sowed seeds as well as whole plant and damage the stems at ground level • Can occur before and after maturity depending on the time of infestation	• Destroy the queen to prevent increase of termite population. • Flood the fields if you are using irrigation • Remove plant debris and burn after harvesting • Use baits laced with termicides that the workers will carry to the colony resulting in colony destruction • Seed dress seeds using thiram, imidacloprid, chlorpyrifos and fipronil based products • Destroy the queen to prevent increase of termite population. • Flood the fields if you are using irrigation
Termites *Reticulitermes* spp.			• Remove plant debris and burn after harvesting • Use baits laced with termicides that the workers will carry to the colony resulting in colony destruction • Seed dress seeds using thiram, imidacloprid, chlorpyrifos and fipronil based products

4.1.4 Post-Harvest Management And Handling

a) Harvesting green Maize

Maize that is to be eaten green is ready for harvest when the grain starts hardening or when the silky flowering at the top of the maize cob turns black (Figure 4.2).

Figure 4.2: Green Maize cobs ready for harvesting

b) Harvesting dried maize

Maize should be harvested at physiological maturity. However, maize can be left in the field beyond physiological maturity to allow further drying. This can be done through stooking for about 2 to 4 weeks.

c) Processing

i. Shelling

Shelling should be done immediately after drying the cobs to reduce weevil damage. Shelling of the grains should be done carefully, so that the grains do not get damaged/break. Shelling can be done using a hand-held sheller. After shelling, grains should be cleaned by removing any dirt, foreign matter, small and damaged grains.

ii. Drying

After harvesting, it is recommended that the maize should be dried to a moisture content below 13%. Drying should not be carried out on the bare ground, but on a cemented floor, on mats or tarpaulins (Figure 4.3) on a raised structure like cribs or specially constructed drying sheds. This is to avoid the grains picking up moisture, dirt and insects. In case of open air-drying, the grain should be protected from rain, night dew, domestic animals and birds.

Maize laid on the ground for drying

Maize drying on a tarpaulin

Figure 4.3: Methods for drying maize before and after shelling

Salt method can be used to test if the maize is dry enough and with the required moisture content. Use a clean, dry glass bottle of about 750 ml capped. Grains are put into the bottle (which should be about one third full) and 2–3 tablespoons (20–30g) of dry salt are added, shaken vigorously for 1 minute to mix the salt and grain, and then left for 15 minutes. If the salt sticks to the side of the bottle, the moisture content of the grain is above 15% and is not safe for storage. If the salt does not stick to the bottle, the moisture content is below 15% and the grain is safe for storage.

iii. Storage

The dried and cleaned shelled grains should be stored in metallic silos (Figure 4.4) or packed in Hematic bags (Agro-Z bags) and stored well on pallets in clean and well-ventilated stores. For farmers who do not have adequate storage capacity, it is advisable to sell off the grain immediately to avoid incurring losses.

Figure 4.4: Maize storage methods

iv. Marketing of grain

Efforts are geared towards produce aggregation and warehousing with an to provide an organized marketing channel for farmers, to attract better prices and leverage their stored grain to access credit. Formation of village collection centres that are certified for warehouse receipting is important. They serve as focal points for interaction of farmers and other stakeholders as well.

4.1.5 Value Addition and Utilization

Maize has three possible uses: as food, feed for livestock, raw material for the industry particularly manufacture of starch or may be dry milled into several intermediary products including maize grits of different particle sizes and maize flour. These materials in turn have applications in a large variety of foods including alcoholic beverages. The most popular maize dish is “Githeri” (maize + bean).

Clean and well-dried maize grain is milled into flour and used to prepare porridge and Ugali. Maize germ is used as a source of edible oil. Although the technology has been available for a long time, the increase in fuel oil prices has resulted in much research on the fermentation of maize to produce alcohol. Fermentation also provides some alcoholic beverages.

4.2 Sorghum

Sorghum is a drought tolerant crop and is an important food and nutritional security crop especially in semi-arid lands (SALs) of Kenya. It is a high-energy, nutritious food, which is suitable for consumption by all. It is particularly recommended for children, lactating mothers, convalescents and the elderly.

4.2.1 Agro-Ecological Requirements

Table 4.7: Agro-ecological requirements

Crop	Soil type	PH	Temperature (°C)	Rainfall (mm)	Altitude
Sorghum	Clay-Loamy	5.0-8.5	15-35	250-900	500-2500

4.2.2 Agronomic Practices

a) Sorghum Varieties Selection

The choice of appropriate sorghum varieties is very important because of specific attributes based on climatic conditions, yield potential, resistance to pests and diseases, maturity period, household utilization and market preference (Table 4.8).

Table 4.8: Sorghum varieties, special attribute, maturity and yield potential

Variety	Attributes	Maturity	Yield (90 kg bag)
Gadam	• It has high malting quality	85-95 days	8-20 bags/acre
Sila	• Has high malting quality	120-150 days	10-20 bags/acre grain and 17 bags (4 t/ha) fodder
KARI Mtama 1	• Has high malting (brewing) quality and a stay green stress tolerance	95-100 days	11-17 bags/acr
Macia	• Large head size and high grain yield • Low dehulling losses		10-20 bags/acre
Serena	• Bird tolerant	110-120 days	10-20 bags/acre
Seredo	• Bird tolerant	110-120 days	12 bags/acre
KM 32 -1 (Kamani)	• Has malting (brewing) quality	90-110 days	20 bags/acre
IS 76	• Medium yielding, brown	90-110 days	10-12 bags/acre
E 1291	• It is good for sorghum beverage.	150-210 days	10-15 bags/acre grain and 10-15 bags/acre forage
E 6518	• Dual Purpose for grain and high quality fodder	210-240 days	12-17 bags/acre grain and 7.2 t/ha forage
BJ 28	• Dual purpose variety suitable for grain and forage	150-210 days	12-15 bags/acre
Ikinyaruka DP	• Dual purpose variety suitable for grain and forage	210-240 days	26 bags/acre grain and 8tons forage/ha

For best yields always endeavour to use certified seeds. However, as a last option recycle seeds but for only three seasons. Grow only one variety in the same field for parity. The following steps are essential in seed selection;

1) Identify healthy plants with large panicles in the middle of the crop field.
2) Tag the identified plants.
3) Harvest them separately before harvesting the rest of the crop
4) Sun dry to the recommended moisture content (12%).
5) Discard the tip of the panicle to avoid small malformed grains.
6) Thresh and sort the seed to remove the broken, damaged or shriveled seed
7) Dress the seeds with chemical products like Thiram, Marshall, Poncho FS 600 and Cruiser 350 FC at the recommended rates. Mix the seeds thoroughly with the chemical

b) Germination test

Test seeds before planting to determine their viability. The seed testing steps are:

i. Select a site near the homestead where there is access to water.
ii. Prepare a 1m by 1 m seedbed and make 100 planting stations (10 by 10 cm).
iii. Plant 100 seeds and cover with soil. Water adequately for seven days.
iv. Take first germination count after 5 days and the final count at seven days.
v. 85% germination count is considered adequate for sorghum.

i) Land preparation

Prepare fields well in advance. It is recommended that land be ploughed immediately after harvesting the previous crop. Sorghum seeds are small in size and require a fine seedbed for better seedling establishment. If tractor or oxen plough is used to open up the field, it is advisable to harrow it once in order to break the large soil boulders (Figure. 4.5a). When hand-hoes are used for land preparation, the large soil boulders should be reduced by breaking them to provide a moderately smooth seed bed (Fig. 4.5b).

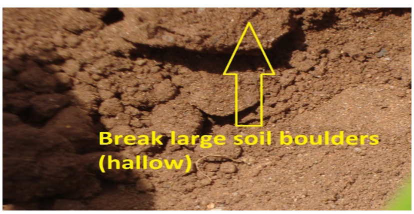


Figure 4.5a: Poor seed bed

Figure 4.5b: Good seed bed

ii) Soil fertility management

At planting apply one bag (50kg) per acre of compound fertilizer NPK (20:20:0, 23:23:0 or 17: 17:17). Top dress with one bag (50kg) of calcium ammonium nitrate (CAN) per acre preferably after first weeding.

Drill the fertilizer along the planting furrows and thoroughly mixed with the soil before planting and covering the seed. Manure improves soil organic matter which impacts positively on soil moisture retention and structure. Broadcast well-decomposed manure in the field close to the onset of the rains at a rate of 2 tons per acre and mix it with the soil during ploughing. Manure can also be spread in bands along the planting furrows and mixed with the soil before seeds are sown.

iii) Planting

Dry planting is highly recommended. Plant before or at the onset of rains by either drilling seeds in the furrows made by oxen plough, tractor, or hill plant in holes made by hoe (Jembe) or Panga.

Plant at a depth of 2.5 cm to 4.0 cm when soil is moist (after onset of rains) and 5 cm when dry planting. If planting is done when soil is moist press the soil to get in good contact with the seeds.

Use the recommended spacing and seed rates as indicated in Table 4.9 and Figs. 4.6a & b.

Table 4.9: Recommended sorghum spacing, and seed rates

Crop	Spacing (cm)	Seed rate (kgs/ acre)
Sorghum (sole crop)	Oxen (90 × 15); Manual (75 × 20)	4-5
Sorghum (intercrops) Single alternate rows	90 × 20 and legume between rows of sorghum	4
Sorghum (intercrops) Double rows of legumes	Sorghum 120× 20-two rows of legume between sorghum rows	2-3

Figure 4.6a Furrows made by ox-plough

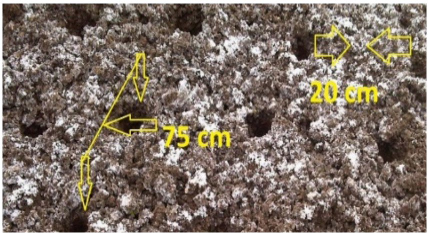


Figure 4.6b: Furrows made by hoe

iv) Weeding

Weeding should be done within 2-3 weeks after emergence. The second weeding depends on the rainfall and weed density.

v) Thinning and rogueing

Thinning is best done around 3 weeks after emergence after first weeding. Thin when the soil is moist to minimize disturbance of the roots of the remaining plants to leave one plant per hole. Leave 2 plants adjacent to a gap to compensate for a missing plant within the row. To achieve good yields, the vegetative regrowth (tillers) ensure 2-3 plants per stool.

Remove plants that are diseased or has characteristics which are different from the others. For example, plants that are taller than the general height of the other plant population or those whose head or grain colour is different.

vi) Crop rotation

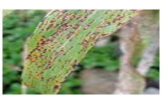
Crop rotation is highly recommended to reduce build-up of sorghum diseases and insect pests. Avoid rotating of sorghum with other cereal crops like maize and millet.

4.2.3 Crop Protection

Pests and diseases management

Integrated pest and disease management is recommended. Some examples of common sorghum diseases and pests and their control measures are shown in Tables 4.19 and 4.11, respectively.

Table 4.10: Important diseases and their control

Diseases	Symptoms	Control Measures
Anthracnose 	Anthracnose damages foliage and stems of grain sorghum. Dry lesions appear on the leaf surface. A brown sunken area with distinct margins develops appears on the stem holding the head (peduncle). When infected stems are cut lengthwise they have brick-red discolorations. The infection inhibits the flow of water and nutrients to the grain causing poor development.	• Plant resistant/tolerant varieties • Rotate with non-cereals preferably with pulses. • Good management of crop residues.
Leaf blight 	Small reddish-purple or yellowish-brown spots on the leaves. Severely affected plants look as if they have been burnt. Under warm, humid conditions the disease may cause serious damage by killing all leaves before plants have matured.	• Plant resistant varieties • Use certified disease-free seeds. • Good management of crop residues.
Leaf rust 	Small raised pustules or blisters on both the upper and lower leaf surfaces that rupture and release many reddish-brown spores. Appears when plants nearly flowering. Forage yields are affected most. Grain yield losses are usually not serious.	• Use resistant varieties such as KARI Mtama 1 • Rotate with non-cereals. • Control weeds

Diseases	Symptoms	Control Measures
Long smut 	The spores are seed borne and germinate soon after the seed is planted and invades the young sorghum plant. It continues to grow unobserved until heading stage, when the long pointed smut galls appear in the heads in place of normal grains. Unlike covered smut, this disease stunts the infected plants and often induces abundant side branches.	• Certified disease-free seeds. • Control weeds. • Rotation with non-cereals. • Field sanitation.
Covered smut 	Black masses of powdery spores instead of grains; the entire head becomes black. Plants become infected while in the seedling stage but infection is not apparent until heading stage. The smut gall produces thousands of spores, which become soil-borne and initiate systemic infection of seedlings in subsequent years.	• Plant resistant hybrids to avoid losses. • Use certified disease-free seed. • Rotate with non-cereals. • Plough deep.
Ergot 	Dark brown to black sclerotia develop in place of seeds on the panicle. The spores are carried by insects or splashed by rain to infect flowers, where they invade the young kernels and replace them with fungal growth. The spores are also seed borne and soil borne but the damage becomes apparent when they reach flowering stage.	• Plant resistant varieties, • Remove affected panicles. • Plant clean seeds. • Plough deep. • Rotate with non-cereals • Good field sanitation

Table 4.11: Sorghum pests

Pest	Symptoms	Control
Shootfly 	The yellowish or white maggots bores into the hearts of the shoot causing drying of the central growing shoot (dead heart)	• Early uniform planting • Spray with systemic insecticide like Actara, • Seed dress with systemic insecticide such as Bellamid 600 FS at 3g/1Kg seed
Stalk borers 	Caterpillar feed inside the stalks causing a stunted plant growth, windowing of leaves, withered shoots and often and poorly developed heads	• Plant early into the season • Field sanitation • Apply insecticide into the funnels such as Bulldock, Dipterex, Thiodan • Practice Push Pull technology by intercropping with desmodium and napier round the edge of the farm
Birds 	Birds are one of the most important pests of sorghum. They are capable of causing heavy losses. The most notorious species is Quelea	• Use bird scaring device • Destroy their roosting sites • Avoid isolated fields • Timely harvesting

Post-Harvest Management and Handling

Harvest sorghum when it has reached physiological maturity (when the grain is hard and does not produce milk when crushed) by cutting the heads with sickles or sharp knife.

i. Sorghum Ratooning

- Ratooning is a practice of getting more than one crop (tillers) from a single sowing through proper crop husbandry.
- Cut back the plants immediately after harvesting to about three inches above the ground to allow vegetative regrowth in the following rain season.
- The well-established root system of the ratoon crop has the ability to utilize the environmental resources better than a freshly sown crop. It reduces labour requirements by minimizing costs such as ploughing, planting and bird scaring associated with migratory birds at off seasons.

ii. Drying and storage

- Sun dry or use a dryer to dry the harvested panicles to moisture content of 12 to13% to avoid fungal growth which can lead to aflatoxin accumulation. Avoid drying sorghum grain in field to reduce the risk of yield losses due to pests, especially birds
- Sorghum may be stored as unthreshed panicles or threshed grain.
- Panicles can be threshed on mats to maintain qualityby beating on a threshing rack, tarpaulins or by using a mechanised thresher.
- Threshed grain is thinly spread on plastic tarpaulins, mats, plastic sheets or raised wire mesh trays to allow air to pass through it and turn it regularly to ensure proper drying before storage
- Winnow and sort the dry grains to remove chaff, dust, foreign matter such as stones, broken, shrivelled, mouldy, insect damaged, rotten, discoloured or faded grains, and any remaining plant parts (leaves and stalks)
- Dust the panicles or grain with storage chemicals like Actellic or Actellic at rate 50g/90kg grains
- Store in a clean store, hermetic bags or metal silos.
- If grain is kept for more than 90 days especially in hot areas, a second dusting is recommended after 3 months to protect it during storage pest
- Use a secured storage system to protect the seed from damage caused by insects, fungi and rodents.

4.2.5 Value Addition and Utilization

Sorghum grain can be utilized either as whole or dehulled and processed further to give various products (sorghum pilau, sorghum cookies and cakes, uji, ugali and many others).

4.3 Millet

Millets are a group of cereals grown in semi-arid regions. They include pearl millet, finger millet, foxtail millet and Proso millet. They have a short growing season, can withstand high-temperatures and escape drought. They are cultivated as human food or as fodder for animals. The Government of Kenya has put more emphasis on production of millet to mitigate food safety and nutritional security.

4.3.1 Agro-Ecological Requirements

Table 4.12: Millet agronomic requirements

Crop	Soil type	PH	Temperature (°C)	Rainfall (mm)	Altitude
Millet	Clay-loamy	5.0-8.5	15-30	200-500	500-2400

4.3.2 Agronomic Practices

i. Variety selection

Choice of appropriate millet varieties is very important because every variety has extensively been tested and recommended based on climatic conditions, yield potential, resistance to pests and diseases, maturity period and household utilization and market preferences.(Table 4.13).

Certified seeds of improved varieties are recommended. Farmers can also select and save seeds from the harvest and replant them for 3 seasons before buying certified seed once more.

These steps are essential when farmers are selecting their own seed.

- Identify disease and pest free plants in the field.
- Select plants with large panicles and preferably in the middle of crop field.
- Tag the identified plants.
- Harvest them separately before harvesting the rest of the crop.
- Sun dry to the recommended moisture content (12%).
- Discard the tip of the panicle to avoid small malformed grains.
- Thresh and clean the seed before treatment.
- Store seeds in a cool dry environment.
- Dress the seed with Apron star, Poncho FS 600, Cruiser FS 350

Table 4.13: Millet varieties, Maturity, grain colour and yield potential

Crop	Variety	Maturity (months)	Grain colour	Yield (90 kg bag) /acre
	KAT/PM-1	2.5-3	Grey	8 – 10
	KAT/PM3	2.5-3	Grey	10-12

Crop	Variety	Maturity (months)	Grain colour	Yield (90 kg bag) /acre
	P224	4	Brown	10 – 12
	Gulu E	4	Brown	8 bags
	KAT/FM-1	3	Brown	6 -8 bags
	LANET FM-1	4	Brown	7 – 10bags
	KAT/PRO-1	2.5	Cream	6- 8 bags
	KAT/FOX-1	4	Cream yellow	8 -10bags

For a recommended plant density to be achieved during planting, a simple germination test of owned saved seeds help in determining the viability of the seed before planting. The testing steps are:

- Select a site near the homestead where there is access to water.
- Prepare 1m by 1 m seedbed and make 100 planting holes spaced at10cm by 10 cm.
- Plant a 100 seed and cover with soil and water adequately for seven days.
- Take first germination count after 3 days and the final after seven days.
- 85% germination count is considered adequate for millet.
- Select seeds with good vigour (Figure 4.7).

Figure 4.7: Normal seedlings with vigour

ii. Land preparation

Millet is a small seeded crop and therefore requires a fine seedbed for good seed germination and seedling establishment. A tractor or oxen plough can be used to open the field, harrow to break the large soil boulders (Figure 4.8a). When hand-hoes are used for land preparation, the large soil boulders should be reduced by breaking them to provide a moderately smooth seed bed (Fig.4.8b). Select fields not far from homesteads and avoid birds breeding sites.

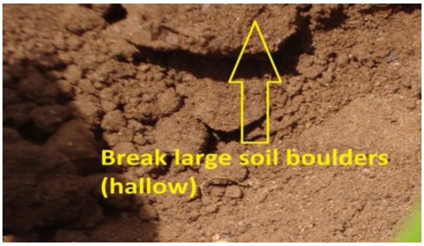


Figure 4.8a: Poor seedbed

Figure 4.8b: Ideal seedbed

iii. Soil Fertility Management

During planting, it is recommended to apply NPK (20:20:0 or 23:23:0) at a rate of one bag (50kgs) per acre. In soils with low fertility and in instances where rainfall continues beyond 30 days after planting, top dress with CAN at a rate of one bag (50 Kgs) per acre. Apply fertilizer along the furrows and thoroughly mix with soil before placing the seeds.

One can also apply manure to improve nutrients, structure and increases moisture retention capacity level in the soil. Only use well-decomposed manure by broadcasting in the field close to the onset of the rains and mix with the soil during ploughing. In case of low volumes of manure, it can be spread in bands along the planting furrows and mixed with the soil before seeds are placed (Figures 4.9a and 4.9b). Application of farmyard manure at 5 tons acre is recommended.

Figure 4.9a: Manure banded in rows

Figure 4.9b: Mixing manure with soil

iv. Planting

The spacing for planting furrows depends on; the variety being used and whether it is a sole or intercrop. However, for optimum plant density a spacing of 90 cm between row and 20 cm between plants is recommended (Figures 4.10a and 4.10b). The recommended planting depth is 5 cm on dry soils, and 2 and/or 4 cm on wet soils. Seed rates

Pearl millet - 2 kg/acre

Finger millet - 1.2 kg/acre

Proso millet - 1.6 kg/acre

Fox millet - 1.6 kg/acre

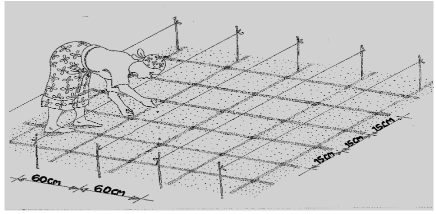


Figure 4.10a: Furrows made by ox-plough *Figure 4.10b: Manual planting*

Millet can be intercropped with pulses such as pigeon peas and green grams. The row arrangement for the cereal and legume could be a single alternate where a legume falls between two rows, or rows of millet spaced at 60 cm (Fig. 4.11). Two rows of pulses could also be alternated with two rows of millet.

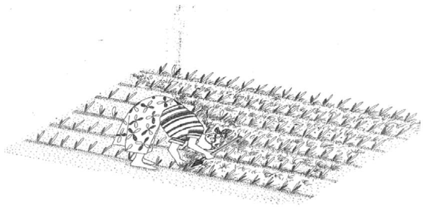


Figure 4.11: Pearl millet-legume intercrop *Figure 4.12: Weeding*

v. Weeding and Thinning Stages

- The first weeding should be done within 2-3 weeks after emergence (Figure 4.12) and second weeding is recommended depending on the weed density. Chemical weeding can also be done using pre-emergence herbicides.
- Thinning should be done when the soil is moist to ensure minimal disturbance of the roots of the remaining plants for a healthy growth. Thinning should be done 3 weeks after emergence (at 3-4th leaf stage and leave 1 plant per hole. This is best done after first weeding in order to accommodate appropriate plant density adjustments, and leaving two plants adjacent to it compensates for a gap within the row.
- Uproot plants that display abnormal characteristics like being taller than other plants, if the flower colour deviates from the majority of other plants, or grain colour that is different from that of majority of plants.

4.3.3 Crop Protection

Table 4.14: Millet diseases

`Disease	Symptoms	Control
Head smut 	The disease generally manifest few days after flowering. The affected heads show enlarged green sacs instead of grain The grains are scattered randomly in the head. The affected ovaries get converted into black gall like bodies, which are bigger than the normal grains.	• Plant resistant varieties • Rotate with non-cereals. • Plough deep into the soils • Practice good field sanitation

`Disease	Symptoms	Control
Ergot 	Cream to pink mucilaginous droplets of "honeydew" ooze out of infected florets. Within 10 to 15 days, the droplets dry and harden, and dark brown to black mass develop in place of seeds on the panicle.	• Plant resistant varieties • Remove affected panicles. • Use clean seeds • Rotate with pulses. • Good field sanitation
Downy mildew 	Leaves develop chlorotic lesions starting at the base and progressively to higher leaves. The plant assumes a bunchy and bushy appearance. Severely infected plants are generally stunted and do not produce panicles. Floral parts are transformed into leafy structures.	• Provide good drainage • Practice crop rotation • Rogue infected plants • Weeding

Table 4.15: Millet insect pests

Pest	Damage	Control
Birds 	Birds feed on the grains and can completely devastate the crop	• Use bird scaring devices • Early uniform planting • Early harvesting • Destroying roosting and breeding sites

4.3.4 Harvesting and Post-Harvest Handling

Heads are harvested manually by cutting with knives at physiological maturity and sun-dried before threshing and drying to 12-13% moisture content. Threshing and sorting of the dry grain can be dusted with Actellic or Actellic for protection against storage pests. If the grain is meant for seed, then it should be dressed with Bellamid 600 FS or Gaucho FS 350 for protection against soil pests.

The grain should be kept in either metal or plastic containers. When sisal bags are used, they should be kept in a cool, dry and well-ventilated place. If grain is kept for more than 90 days especially in hot areas, a second dusting is recommended after 3 months.

4.3.5 Value Addition and Utilization

Millet is a high-energy nutritious cereal. It is particularly recommended for children, lactating mothers, convalescents and the elderly. Some of the healthy benefits of millet includes; prevention of cancer, help management of diabetes, offer a dietary option for people with Celiac disease, improve digestive health, build strong bones, promote red blood cell development, and boost energy and fuel production. Pearl millet is traditionally used for making a variety of foods including thin porridge, "Ugali" and local brew.

5 PULSES

There are four pulses covered in this hand book and they include: common beans, green grams, pigeon peas and cowpeas.

5.1 Common Beans

5.1.1 Agro-Ecological Requirements

Table 5.1: Summary for the agro-ecological requirements of beans.

Table 5.1: Agro-ecological requirements for beans

Crop	Soil type	PH	Temperature (^oC)	Rainfall (mm)	Altitude
Beans	Silt loamy	5.8-7.0	18-30	500-1500	900-2100

5.1.2 Agronomic Practices

i. Variety Selection

For successful production, it is important that high-quality seed be used. Using disease-free seed reduces the incidence of seed-borne diseases.

Use of certified seed is preferable, however, a farmer may select from his bean harvest. This should be done carefully ensuring all wrinkled, damaged and diseased seeds are removed. Bean seed bought from shops or markets may have been damaged by insects, or may be rotten, broken or mouldy. Beans should be well sorted and only the best be used for planting. Good quality bean seed has the following properties:

- pure: all seeds are of the same variety and size;
- clean: not mixed with foreign matter such as stones or dirt, or other seeds;
- not damaged: broken, shriveled, mouldy, or insect damaged;
- not rotten, not discoloured or faded ; may be diseased.

Selected seeds must be dressed with insecticides such as Aldrin 2.5% at 5g/kg seed or thiram or Fenasan D at the rate of 3g per kg of seed against pests and fungal diseases. Once the seeds is treated, it should not be used for human consumption and should be planted immediately.

Always test your/cycled seed for germination before it is planted. Take samples of seeds (a handful) place them between moist newspapers for five days. If 90% (9 out of 10) germinate the seeds are good, if less than 80% (8/10) germinate plant two seeds per hole instead of one. If less than 40% (4/10) germinate discard the seeds.

Table 5.2: Recommended Bean varieties, potential yield, maturity and special attribute

Variety name/ code	Seed source	Optimal altitude range (masl)	Duration to maturity (months)	Grain yield (90kg bags per acre)	Special Attributes
Mwitemania (GLP 92)	KALRO/ KSC	900-1600	2-3	6-8	Drought tolerant
Rosecoco (GLP 2)	KALRO/ KSC	1500-2000	2-3	8-10	High yield; wide adaptation; attractive seed colour; Good taste
Red Haricot (Wairimu)	KALRO/ KSC	1500-1800	2-3	6-8	It is susceptible to bean root rot.
KK 8	KALRO	1500-1800	2-3	8-10	Tolerant to root rot
Chelalang'	Egerton University	500-1,500	2.5-3	10-12	It is disease and insect pest tolerant.
Tasha	Egerton University	1,000–1,800	2.5-3	8-10	It is disease and insect pest tolerant.
KATRAM	KALRO	900-1600	2.5-3	7-8	Drought tolerant to bean rust, mosaic virus and bean common mosaic and necrotic virus, tolerant to angular leaf spot, anthracnose, common blight and web blight
Nyota	KALRO/ Bubayi/Dry land/Seedco	900-1800	2.5-3	6-7	Drought tolerant, high iron content (>95ppm), high zinc content (>39ppm)
Angaza	KALRO/East Africa seed (Agriscope)	1200-1900	2.5-3	6-7	High grain iron content (>97ppm), zinc grain content (>57ppm), fast to cook
Faida	East Africa Seed (Agriscope)	1300-2000	2.5-3	6-7	High zinc content (>56ppm), high potassium (2,746ppm), high manganese (27.51ppm), tolerance to angular leaf spot, common bacteria blight and common mosaic virus

ii. Land Preparation

To realize high yields, select highly productive land. Always avoid steeply sloping land which is near a swamp, areas with shallow surface sandy soils with a lot of couch grass. Land preparation should be done early to remove weeds and ready for planting at the onset of rains. Seed bed should have fine soils and leveled to facilitate planting at uniform depth and uniform distribution of water.

iii. Soil Fertility Management

Use 15-20 tons/ha of farm yard manure especially in areas where soils are low in organic matter content. Well decomposed animal manure or compost should be applied under dry conditions and then mixed with the top soil. This should be done about one week prior to planting.

One can also use 80kg DAP or 23:23:0, or Mavuno per acre. The fertilizer should be thoroughly mixed with soil before covering the seed. It is recommended to artificially inoculate the seeds with an appropriate strain of *Rhizobium to* increase nitrogen fixation. Dissolve 60g of molasses thoroughly in half-litre of water and add a packet of the culture is mixed so as to form slurry. Mix 10kg seed (free from dust) thoroughly with the slurry of the culture taking care that all the seeds are equally coated with the product. Spread the coated seed on a polythene sheet or a clean cloth in the shade and allowed them to dry. Plant the dried seed immediately.

Always check the expiry date of the culture (inoculum). Store the inoculum in the refrigerator (do not freeze). Do not mix the inoculum with either pesticide or fertilizer.

iv. Planting

Beans should be planted at the onset of rains since heavy rain may lead to soil crusting and restrict seedling emergence. Delay in planting may result in reduced yields or crop failure.

Figure 5.1: Bean planted under monocrop

In mono cropping (beans alone) plant at spacing of 50 cm x 10 cm (one seed per hole within a depth of 2.5 to 5.0 cm below the soil surface (Figure 5.1). If weeding will be done by animal use 60 cm spacing.

In intercropping with maize, plant maize at the recommended spacing for the agro-ecological zone. Interplant two bean rows between the maize rows at 15 cm within the row, one seed per hole. The other alternative is to have one bean row between maize rows and two seeds per hole.

The amount of seed required for a given area vary from variety to variety depending on the size of the seed. The bigger the seed size the more the seed quantity required. It ranges between 16-25kg/acre.

v. Weeding

Keep your bean field free from weeds. Timely and thorough weeding is absolutely essential. This is achieved by a first weeding at 2-3 weeks after emergence followed by a second weeding 3 weeks later (just before flowering) in mono-cropping.

In case of intercrop, one weeding 3 weeks after planting may be sufficient except in high rainfall areas where a second weeding 3 weeks after the 1st weeding may be necessary. Care should be taken to avoid damaging the shallow roots especially during the first weeding. Avoid weeding during flowering time to avoid flower shedding and when the field is wet to avoid spread of diseases and soil compaction.

Where the use of herbicide is economically feasible, apply Lasso 4 E-C (Alachlor) – 3 liters product in 160 litres of water per hectare pre-emergence and when the soil is moist, or Galex (metabromuron + metolachlor) 6.0 litres product in 160 Iitres of water per acre. Other pre-emergent herbicides are Stomp (Pendimicthalira) at 1.0 litres per acre and Linuron. Basagran (Bentazons) can be applied post - emergent at 1.0–1.2 litres per hectare in both pure and mixed cropping to control broad leaved weeds.

vi. Crop Rotation

This practice is recommended to avoid pest and disease build up. Rotation is mainly done with cassava, maize, sorghum or any other non leguminaceae family member crop.

5.1.3 Crop Protection

Table 5.3: Crop Protection Aspects

Disease	Symptoms	Description	Management
Powdery mildew	 Powdery mildew (Source: Sila Nzioki, KALRO)	• Small white powdery spots on leaves, stem and pods • They later turn dirty white • Leaves turn yellow and fall when disease is severe	• Crop rotation with cereals • Use recommended spacing • Uproot and destroy severely infected plants • Avoid overhead irrigation to reduce splash of pathogen to healthy plants • Spray with Sulphur based products (e.g. Jet, Cosavet DF) or Azoxystrobin based (Ortiva SC; Target Top 325SC)
Rust	 Rust (Source: Ruth Amata, KALRO)	• Dark brown raised spots appear on leaves • In severe cases stems and pods get infected and leaves later fall off	• Crop rotation with non-legumes for 2-3 seasons • Use certified seed • Plant early • Remove diseased plants and weeds - some act as alternative hosts • Uproot & bury/burn infected residues • Avoid working in the field during wet weather • Spray copper based fungicides e.g Cuprocaffaro or isocap once initial symptoms are observed, or Azoxystrobin (Rustop 250)

Disease	Symptoms	Description	Management
Anthracnose	 **Anthracnose on pods)** (Source; Ruth Amata (KALRO)	• Sunken dark brown spots appear on the pods and leaves • Spots have orange, pink spores • Reddish brown spots on leaf veins/stem/ pods	• Crop rotation with non-legumes • Use certified seeds (seed borne disease) • Uproot and destroy severely affected plants & bury or burn • Spray with Kabendazim or Azoxystrobin based products e.g. Bendazim 500SC and Target Top 325 SC respectively
a) Angular leaf spot	 **Angular leaf spot** **Source: ipm. pbgworks.org**	• Grey spots appear on leaves • Later they turn brown • Spots are enclosed within leaf veins • Dark brown circular spots on stems and pods • Leaves fall in severe cases	• Crop rotation with non-legumes • Use certified seed / or treat seed with cabendazim based products e.g. Seed Plus WS • Plant early • Uproot diseased plants /weeds / volunteers- some act as alternative hosts • Uproot & bury/burn infected residues • Avoid working in the field during wet weather • Spray plants with copper based fungicides e.g. Cupro caffaro or isocap and alternate with Azoxystrobin based fungicides e.g. Affair Top 800WDG
Halo Blight	 **Halo blight** (Source: Ruth Amata KALRO)	• Small brown spots on leaves surrounded by a yellow ring • Entire leaf turns yellow • Oval greasy water-soaked spots on pods which become sunken reddish/ brown in colour • Seed borne	• Use tolerant varieties- • Use certified seeds • Practice crop rotation with non-leguminous crops • Uproot and destroy infected plants/ volunteers by burning • Disinfect farm tools in jik solution (50ml:litre) • Avoid working in wet fields • Apply copper based fungicides (e.g. Cupro caffaro or Isacop 50WP) at the mid vegetative stages
Bacterial Blight	 **Bacterial blight** (Source: infonet-biovision.org)	• Water soaked spots appear on leaves and pods • Spots on leaf margins appear in an angular orientation • Water soaked spots on pods like those for halo blight	• Crop rotation with non-legumes • Plant certified /clean seed • Plough deep and bury infected crop residues • Use drip and furrow irrigation to avoid spread of the disease • Avoid field operations when leaves are wet • Disinfect farm tools • Spray with copper based products (Cupro caffaro and Isacop).

Disease	Symptoms	Description	Management
Mosaic viruses	 **Mosaic virus** (Source; Howard Schwartz, University of Colorado)	• Distorted leaves • Stunted growth • Leaves appear dark green along the main veins and light green yellow in between • Leaves curl and roll downwards • Infected plants fail to form pods	• Plant certified • Establish fields in isolated areas not near bean fields • Uproot infected beans and destroy by burning to prevent spread
Bean fly/ Bean stem maggot	 Bean stem maggots on the stem (Source: Plantwise. org)	• Affect at seedling stage • Thickening of the stem at soil level • On splitting the stem, a brown feeding area and larvae or pupae are seen • Holes on leaves and stem • Stunted & wilting plants • Adult flies are small shiny black with clear wings	• Use mulch around the plant rows to promote root development and enhance tolerance to maggots • Crop rotation with non-legumes crops • Frequently irrigate to reduce water stress in the beans • Uproot wilted plants and destroy by burning crop debris to avoid emergence of bean fly adults • Spray with acetamiprid based products such as "Acetak 200 SL" to manage bean fly • Seed dress with Cruiser; Spray with imidacloprid and thiamethoxam based products
African Bollworm	 Bollworm larvae Source: Infonet Biovision)	• Large roundish holes in the green pods • The caterpillar also feeds on flowers, leaves and terminal buds • Presence of waste on the surface of affected plants	• Practice crop rotation with non-legumes crops • Avoid planting susceptible crops adjacent to each other • Deep plough the soils after harvesting to expose the pupae to predators • Spray with biopesticides e.g Neemraj Super, Ozoneem 1% • Spray with Deltamethrin and Bifenthrin based products such as "Decis" and "Atom" respectively
Aphids	 Aphids on bean (Source; James Karanja KALRO)	• Black /grey soft bodied insects found on the stem young shoots pods and underside of leaves • Suck plant sap and cause stunting, plants wilt, yellow and die. • Black sooty mold on surface of leaves	• Early planting • Destroy volunteer crops and weeds that act as alternate hosts • Crop rotate with non-legumes • Use of yellow sticky traps • Spray with soapy solution at the rate of 10-15 tablespoon liquid soap in 20 litres of water • Spray with neem based botanical products e.g. nimbecidine • Spray with insecticides Lambda-cyhalothrin, deltamethrin or Acetamiprid based products under heavy infestation

Disease	Symptoms	Description	Management
Thrips (*Thrips tabaci*)	 Thrips (Source; Infonet Biovision)	• Small slender yellow, brown to black insects found in flowers and underside of leaves • Cause water soaked spots and curling of pods • Leaves appear silvery • Cause flower abortion, and deformed pods	• Destroy volunteer crop and weeds which may serve as alternate hosts • Intercrop beans with repellant crops such as garlic and onions to keep aphids away • Use blue sticky traps to manage aphids in the bean plantation • Chemical sprays with active ingredients of deltamethrin and lambda Cyhalothrin (Asataf SP, Tata Umeme 2.5 EC) may be used
Root knot nematodes	 **Root knot nematodes** Source: Infonet biovision	• Stunting • Yellowing • Wilting • Galling on roots • Patchy field	• Crop rotation with grass crops • Prevent surface run off to control spread of nematode • Clean farm tools and footwear to remove adhering contaminated soil and crop debris • Uproot affected plants and bury or burn in deep pits • Use biopesticides (e.g. Achook, Nimbecidine, Neemraj Super)
Bean bruchids	 **Bean Bruchid** Source: africasoilhealth.cabi.org	• Small reddish brown beetles • Bore thin tunnels beneath the seed coat and circular holes on surface of grain	• Harvest timely • Ensure good storage hygiene • Clean stores before storing new grain • Do not mix old grain and newly harvested grain in same storage area • Before storage, treat or mix stored seed with a mixture of plant parts (e.g. neem, lantana and pyrethrum and others) • Dust grain with Actellic 50g/90kg

5.1.4 Post-Harvest Management and Handling

Harvest the beans when all the pods have turned yellow and before they become so dry that the pods begin to shatter or rot away. Dry beans should have a moisture content of about 50% at physiological maturity. However, beans are ready for harvesting when the moisture content drops to 16%.

If dry beans have not attained 16% moisture content, sun dry them before threshing. Test the moisture of the seed before threshing using your teeth or pinching with your Fingers. Avoid threshing immediately after harvesting this can damage the seed because it is too moist. Threshing on the ground or in a gunny bag can easily damage the seed. Threshing on a threshing rack protects the seed from damage and dirt and prevents it from scattering. Broken or cracked seed is likely to be attacked by insects and fungi.

After the seed has been threshed, dry again to about 10% moisture content. If the moisture is still high, dry the grains on mats, or wire mesh trays raised on a platform. Spread the seed thinly on the drying surface to allow air to pass through it. Turn the seed regularly to avoid overheating.

Winnow the dried grains to remove chaff. Sort to remove foreign matter such as stones and all grains that are broken, shriveled, mouldy, insect damaged, rotten, discoloured or faded.

Make sure the store is well ventilated. Clean and dust with Malathion 25% at 400gms in 5 litres of water for every 100 m^2 before storing your beans. Bruchids are major storage pests, dust beans with Actellic (50g per bag) before storage. Beans intended for consumption should be treated with Actellic or 2% Malathion dust at the rate of 50g per bag of 90kg or sunflower or maize oil at 200ml per bag. The beans can also be stored in air-tight bins or drum or well secured gunny bags.

Beans for planting should be treated with Fernason D (contains) Linclance Thiran) at 3g/kg seed or Aldrin 2.5% at 5g/kg seed.

5.1.5 Value Addition and Utilization

The seeds are utilized in various ways which include boiling pure beans mixed with other grains to make the following dishes;

- Boiling beans with maize mixture to soft (*Githeri*)
- Boiling beans with maize mashing with potato and greens (*mukimo*)
- Boiling beans alone and mashing with sweet potato (mushenye)
- Boiling beans alone with testa or without and marsh or not and used to eat with *Ugali*, and cooked rice
- Pre-cooking plus tomato sauce and canned (bean variety Mexican 142)

5.2 Green Grams

Green grams also known as Mung beans and in Kiswahili Ndengu are well suited to diverse environments and fit in various cropping systems, low input requirements, fast growth, nitrogen fixing and weed smothering ability. They are commonly grown in central, south Nyanza, eastern and coastal regions. Its edible grain is characterized by good digestibility, flavor, high and easily digestible protein content and absence of any flatulence effects. It's also a crucial source of vitamins A and B, micro-nutrients such as iron and zinc which are good for pregnant women and children.

5.2.1 Agro-Ecological Requirements

Table 5.4: Agro-ecological requirements for green grams

Crop	Soil type	pH	Temperature (^oC)	Rainfall (mm)	Altitude
Green Grams	Sandy loamy	6.3-7.2	25-30	350-700	50-1600

5.2.2 Agronomic Practices

a. Varietal Selection:

There are two major varieties that can be differentiated through the grain colour. These are the yellow and the green grain grams. The N26 green gram variety is small and ripens unevenly while the improved variety KS20 has bigger seeds and tends to ripen uniformly (Table 5.5).

Table 5.5: Green gram variety characteristics

Variety/ Description	Seed Source	Seed Colour	Maturity	Yields (90 kg bags)/ acre
N22 or KVR 22 	Dryland Seed	• Golden yellow seeds • Semi-determinate plant • Tolerant to aphids, yellow mosaic and to powdery mildew	• Flowers in 55 - 60 days and matures in 80-90 days	4 – 7
N26 or KVR-26 (Nylon) 	KALRO Seed Unit	• Shiny green seeds • Determinate growth habit	• Flowers in 40 to 45 days and matures in 60 to 65 days	6 – 8
KS20 (Uncle, Cotton) 	Kenya Seed Company	• Grains are dull green in colour • Grains are bigger in size compared to N26.	• Flowers in 60-65 days and matures in 80-90 days	7 -10

Table 5.6: Summary of Green gram varieties Eastern Sub-region e-voucher Package, 2019

SELECTED GREEN GRAMS VARIETIES			
COUNTIES			
Kitui	**Embu (Mbeere)**	**Tharaka Nithi**	
Varieties			**Remarks**
N 26 (Nylon)	N 26 (Nylon)	N 26 (Nylon)	Available with Agrodealers
KS 20 (Uncle, Cotton, Makueni)	KS 20	KS 20	Available with Agrodealers
	N 22	N 22	N22 is available with Agrodealers KAT 1, KAT 2, and KAT 3 received a score of zero (0) and hence not selected by farmers for the e-voucher system

b. Germination test

Farmers are advisable to conduct a simple germination test by taking a few seeds of the green grams (e.g. a table spoonful), soak them in water overnight and wrap them in a moist cotton cloth or old newspaper. Water them 3 times a day and exam the number of sprouted seeds on the 3rd day. Count the number of seeds that sprout and divide by the total number of seeds. If the germination is 60% (6/10), plant 3-4 seeds per hole while, if 90% (9/10) germination, plant 2 seeds per hole.

c. Site selection

In order to realize good yields, avoid steep sloppy land, swampy fields, heavy clays and fields with a lot of couch grass. It is important to look for high soil fertility indicators and also fields where green grams have been grown for not more than two seasons. Crop rotation should be practiced using non-leguminous crops like maize, sorghum, millet and cassava.

d. Land Preparation

To realize high yields, select highly productive land suitable. Always avoid steeply sloping land, land which is near a swamp, very sandy soil and areas with shallow surface soil and a lot of couch grass. Land preparation should be done early enough so that the field is free of weeds and ready for planting at the onset of rains. Seed bed should have fine soils. A level seedbed facilitates planting to a uniform depth and uniform distribution of water

e. Improving soil fertility

It is advisable to use fertilizers on the basis of soil test and recommendations, a basal dose of NPK (23:23:0) 1 bag (50Kgs)/ acre may be broadcasted. Nitrogen fertilizer is usually not applied as green grams fix their own nitrogen, but 10-20 tons (100 wheel barrows) per acre farm yard manure can be applied. The manure should be broadcasted just before rains start and ploughed in. Fertilizer should be well mixed with the soil before placing the seed. Lime should be applied one year prior to growing green grams and thoroughly incorporated

f. Planting, spacing and seed rate

Seeds for planting should obtained from a known source and should be clean and of good quality. For local varieties a source with good quality seed should be sought.

Plant seeds 3-5cm deep in a well-prepared seedbed with good moisture content. If the surface layers are dry, increase the depth to 7.5 cm but only if the soils do not crust easily. When using oxen plough for planting, place the seed at the side of the furrow.

Green grams can be planted as a single crop or intercropped with other crops like sorghum. When planted alone, the spacing should be at 45cm (1.5ft) between rows and 15cm (0.5ft) between plants (Figure 6.2). In intercropping, the green gram rows are planted in the middle of the accompanying crop and the intra row spacing is maintained at 15cm. Plant 4-5kg/acre or 2‘gorogoro’ per acre.

Figure 5.2: Spacing of green grams

g. Weeding:

Weed control in green grams is essential, to reduce competition for nutrients which result to low yields. Weed-free crop of green grams decreases insect pest infestation. The most common weeding method is hand weeding but oxen can be used too. The first weeding should be done 2 weeks after emergence and the second before flowering.

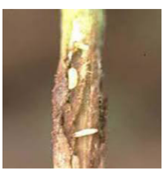
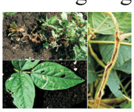
h. Crop Rotation

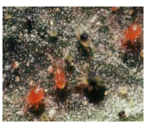
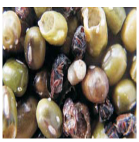
Green grams in a mono cropping system should be rotated with non-leguminous crops such as maize, millet, sorghum, sweet potatoes and cassava. This practice is recommended to avoid pest and disease build up. It is not advisable to grow mug beans for two consecutive seasons on the same field. Mug beans leave a nitrogen-rich soil allowing subsequent crops to benefit and grow successfully.

5.2.3 Crop Protection

Losses of up to 10-45% in green grams have been associated with common blight while 80% due to angular leaf spot disease. Therefore, pests and disease management is very important for high grain yield and quality. The major pests and diseases for green grams are indicated in Table 5.7.

Table 5.7: Common green gram pests, diseases and their management

Pest	Symptom	Description	Control
Bean fly (*Ophiomyia spp)*  Affected stem	Seedling stage 	• Leaves droop, yellow and dry up • Stem swells and cracks	• Early planting • Plant certified seed or seed dress with Apron Star 42WS • Practice crop rotation with non- legumes • Remove severely affected plants & volunteer plants & burn • Spray using Acetak 200SL

Pest	Symptom	Description	Control
Thrips *(Megalarothrips Sjostedti)* 		• Feeds on flower stigma, leads to flower abortion • Severe infestation causes shriveled grains	• Destroy volunteer crops /weeds • Intercrop with repellant crops e.g onions & garlic • Spray neem seed kernel extract (50 g/l) and neem oil 3000 at 20 ml/l or use biopesticides e.g nimbecidine or Achook 0.15%EC or chemicals e.g Atom 2.5 EC & Tata Umeme 2.5EcUse blue sticky traps
Bean Aphids *(Aphis fabae)* 		• Feeds on foliage and pods • Cause distortion of leaves • Stunting	• Early planting • Destroy volunteers and weeds • Use yellow sticky traps • Spray with neem products e.g biopesticides e.g nimbecidine or achook 0.15% EC or chemicals e.g Alfa cyper EC or Atom 2.5EC
Whitefly (*Bemisia tabaci*) 		• Transmits yellow mosaic virus (MYMV) disease	• Maintain natural enemies e.g parasitic wasps, lady bird beetle, lacewings • Use neem biopesticides e.g nimbecidine or achook 0.15% EC • Use chemicals e.g Aceta 20 SP or Halothrin 2.5EC
Red spider mites (*Tetranychus* spp.) 		• Causes speckling of leaves and form webs on underside of leaves cause drying of plants	• Plant early • Control weeds-;alternative hosts • Use dish washing soap-2 tablespoons /4L water • Use abamectin products eg Abalone 18EC; Agrimec 18EC
Bruchid (*Callobruchus maculates*)		Infested grain show holes in the seeds and a whitish larva or pupa can be found inside.	• Grains should be dried up to 10% mc and stores cleaned • Mix neem leaves with the grain in store. Smear mustard oil, neem oil @ 10ml/kg of seed and activated charcoal powder @ 10g/kg seed. • Use Actellic dust before storage • 50g/90kg
Powdery Mildew (*Erysiphae polygonii*) 	• White powdery spots on leaves stem and pods • They later turn dirty white	A major fungal disease that causes severe yield loss. The disease spreads fast once it sets in	• Crop rotation with non-legumes for 2-3 seasons • Uproot and destroy severely affected plants and burn/bury • Avoid overhead irrigation to reduce splash

Pest	Symptom	Description	Control
	• Leaves fall if the disease is severe	It is favored by cooler conditions and is severe in the late planted crop	• Use baking soda 1tsp/litre of water • Spray with Sulphur based products (e.g. Jet, Cosavet DF) or Azoxystrobin based (Ortiva SC; Target Top 325SC)
Cercospora Leaf Spot 	• Leaf spots with brown to greyish centre and reddish brown border Leaves, stems and pods get affected. Spots increase in size and at the time of flowering and pod formation lead to defoliation	• Cercospora leaf spot (CLS) may cause severe losses of yield under humid weather conditions. Fungus survives on the infected seeds and crop debri	• Crop rotation with non- legumes for 2-3 seasons • Destroy infected crop debris by burning or burying • Remove alternative crop hosts from the vicinity of the cropSpray with Sulphur based products (e.g. Jet, Cosavet DF) or Azoxystrobin based (Ortiva SC; Target Top 325SC)
Anthracnose  Source: Link. Springer .com	• Circular brown sunken spots with dark centers and bright red orange margins on leaves and pods.	• The disease occurs on green grams and other legumes. The disease affects aerial plant parts, however, the leaves and pods are more vulnerable	• Crop rotation with non-legumes for 2-3 seasons • Use certified seeds • Uproot and destroy severely affected plants & bury or burn • Spray with cabendazim (Bendazim 500SC) or Azoxystrobin (Target Top 325) SC respectively

5.2.4 Post Harvest Management and Handling

Harvesting should take place when most of the pods have turned black. Pods should be picked individually or whole plants by uprooting before they start shattering in the field. Dry the pods for about 2 to 5 days before threshing to avoid grain damage due to high seed moisture content. Mechanical harvesting can also be done in order to save on labour costs.

i) Threshing

Before you start threshing test the moisture by crushing a few grains with the teeth or pinching with fingers. If the seed is easily crushed, the moisture is still too high and the harvests should be dried further. Threshing can be done using either mechanical or by biting. Use a stick to hit the pods either placed on a tarpaulin or inside a bag to avoid dirt and foreign materials. For the mechanical method, a thresher can be used which makes work easier and faster. Spread the threshed grains on a raised cement platform or tarpaulin to dry.

ii) Winnowing and sorting

Sorting and winnowing is the process of removing foreign material from the threshed grain. This can be done by either picking the broken/rotten/deformed grains or by scooping the grain and subjecting it to wind action (winnowing) (Figure 5.3). The grain drops to the ground while the chaff or foreign material is blown away.

Figure 5.3: Winnowing process

iii) Drying

Dry the winnowed grain to 12% moisture content before storage.

iv) Storage

Clean he grain bins/silos and fumigate to control bruchids. Make sure the store is well aerated, leak proof and damp proof. Dust the grains using different recommended chemicals such as Actellic at a rate of 50gm per 90 kg bag. Make sure the storage bins, silos or hermetic bags are airtight.

5.2.5 Value Addition and UTILIZATION

The grains are utilized in variable ways such as;

- Boiling as stew which can be served hot with rice, chapatti, *Ugali*, cassava or sweet potatoes
- Green grams sprouts that can be consumed directly with lemon and salt as a healthy snack or added to salad
- Green grams flour for preparing soups, porridge, snacks, bread and noodles.z

5.3 Pigeon Peas

5.3.1 Agro-Ecological Requirements

Table 5.8: Agro-ecological requirements for pigeon peas

Crop	Soil type	PH	Temperature (^oC)	Rainfall (mm)	Altitude
Pigeon peas	Medium heavy loams	5.0-7.0 but can tolerate 4.5-8.4	18-30	400-750	0-1800

5.3.2 Agronomic Practices

a. Varietal Selection

Pigeon pea varieties differ in form of seeds, colour taste, growth habit, time of flowering, maturity period and susceptibility towards pests and diseases.

Table 5.9: Pigeon peas varieties and their characteristics

Variety	Maturity (Days)	Potential yield (Kg/Acre)	Description
Mbaazi 1 (ICPL 87091)	105 - 120	• 400 in one season. • 800 for two seasons	• Flowers in 55-70 days • Pods are green with purple streaks • It is determinate variety that grow to 80-120 cm high depending on the season and altitude. • It is compact and is grown as sole crop. • High susceptible to insect pests mainly pod sucking bugs and pod borers
KAT 60/8	135 - 150	• 400-600 for one season. • 1200 for two seasons	• Yellow flowers (standard and wing) • Flowers in 95-120 days • Has indeterminate growth habit and grow to 85-130cm depending on the altitude and season • Grains are white in colour with brown spots and smaller than long duration local landraces • Susceptible to insect pests mainly pod sucking bugs and pod borers • Tolerant to wilt and leaf spot diseases
Mbaazi 2 (ICEAP 00040)	150 - 180	• 520	• Has yellow flowers while the pod are green with dark stripes • Flowers in 60-90 days • Has indeterminate growth habit and plant height ranges from 120 to 240cm depending on season and altitude
			• Normally planted in the short rain season (October-November) – mainly two season variety. • The plant is taller and stronger at lower altitudes (less than 1000 m) than at higher altitudes • Grain colour is greyish

Table 5.10: Varieties selected for the semi-arid lands in 2016-2020

County		
Kitui	**Embu (Mbeere)**	**Tharaka Nithi**
Variety		
Mbaazi 1	Mbaazi 1	Mbaazi 1 Lower zone
Kat 60/8	KAT 60/8	KAT 60/8 Upper zone
Peacock	Mbaazi 2	

b. Seed treatment

Seed treatment plays an important role in protecting the seeds and seedlings from seed, soil borne diseases and insect pests affecting crop emergence and its growth. Seed-borne diseases result in poor germination, poor plant vigour, low yield and poor quality seed. The seed is dressed with either a dry formulation or wet treated with a slurry or liquid formulation.

c. Germination test

The results of the test inform the farmers how much seed they need to plant per given acreage to get good yields. To calculate the germination percentage, a random sample of 100 seeds is taken from the seed lot. They are placed on moist newspaper and covered with another piece of moist newspaper. The seeds should be kept moist, but not wet. Seedlings should begin to emerge 7-11 days after planting. The germination percentage is calculated by counting the number of seeds that have germinated and dividing this by the number of seeds that were planted. Then multiply this number by 100.

d. Site selection

To ensure high pigeon pea yields, one needs to select highly productive land suitable for pigeon pea production and avoid steeply sloping land, which is near a swamp, or very sandy soil or areas with shallow surface soil with a lot of couch grass. Areas that indicate high soil fertility are the best.

e. Land Preparation

Land preparation should be done as early as possible to ensure early planting. Pigeon peas require a medium tilth and soils with huge soil clods should be avoided.

f. Improving soil fertility

Although pigeon pea is a nitrogen fixing species, fertilizer is recommended at levels of 9-11kg/acres(20–25 kg/ha) N. Phosphorus is the most limiting factor for pigeon pea and a basal application of one 50kg bag / acre of NPK fertilizer (either 20:20:0 or 23:23:0) should be applied at planting. To enhance nitrogen fixation the seeds can be inoculated with *Rhizobium.* Pigeon pea can be used as a green manure crop.

g. Planting

In most cases pigeon pea is grown as an intercrop with cereals (maize, sorghum and millets) or other legumes, which are harvested to avoid competition before flowering and seed set. Pigeon pea does best when broadcast and covered or drilled into a well-prepared seedbed at a depth of 2.5–10 cm. Early planting is recommended. Seedlings are difficult to transplant.

Seed rate: 10 kg/ha (4 Kg/acre)

Spacing: Sole cropping

Mbaazi 1 (ICPL 87091) - Sow at 50 cm between rows and 10 cm between plants if using plough, skip one furrow.

Kat 60/8 - Plant 75 cm between rows and 50cm between plants. When using oxen for ploughing and planting sow after every other two furrows.

Mbaazi 2 (ICEAP 00040) - Plant 100 cm between the rows and 50 cm between plants at lower altitudes where temperature are warmer. At higher altitudes these spacing's should be reduced by 20-30 cm.

Local varieties – Plant at 120 cm between rows and 60 cm between plants.

h. Intercropping

Kat 60/8 and Mbaazi 2 can be intercropped with maize, sorghum or millet during the first season which is normally the short rains (October-December). If intercropped with maize, sow either one row of pigeon pea after one row of maize or one row of pigeon pea followed by two rows of maize at a distance of 90cm between maize and sorghum and pigeon pea rows. Mbaazi 1 should always be planted as a pure stand.

i. Weeding

Seedlings emerge 2–3 weeks after sowing. The initial growth is slow until the taproot develops. The plant is very sensitive to weed competition in the early growth stage and it is important to keep the crop weed free in the first 45 to 60 days of growth. Effective weed control at the early growth stages of the crop is one of the most important factors contributing to high yields. The first weeding of all varieties must be done within the first 2-3 weeks after germination whereas subsequent weedings will depend on the growth of weeds and amount of rainfall.

5.3.3 Crop Protection

a) Pests and diseases control

Insect pests and diseases have negative impact on pigeon pea productivity; also leading to poor quality seed. Pests and diseases reduce the plant stand; however, these can be controlled by the use of pest and disease resistant cultivars, crop rotations, weed removal, inoculation with the cowpea group strain of *Rhizobium* and intercropping with cereals.

Common Insect Pests

Aphids, thrips, pod fly, pod sucking bugs, pod borers and bruchids are major pigeon pea pests. Mbaazi-1 and KAT 60/8 flowering normally coinciding with peak periods of the insect pests infestations. Different insect pests are best controlled in the following stages:

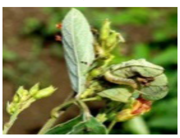
Before flowering - Thrips and aphids

After flowering - Pod fly, pod borers, pod sucking bugs

Storage - Bruchids

General recommendation - spray once before flowering and twice after flowering. Table 5.11 summarises the most common insect pests and their management.

Table 5.11: Common insect pests and their management

Pest	Symptoms	Control
 Flower thrips (*Megalarothrips* sp.)	Shiny yellow/ black insects which cause flower abortion or failure to flower	• Intercrop with repellant crops e.g garlic and onions to keep aphids away • Use blue sticky traps to manage thrips • Chemical sprays with deltamethrinand lambda Cyhalothrin based products
Aphids 	Feed on foliage, pods and causes distortion of leaves, and stunting of plants.	• Early planting • Destroy volunteers and weeds • Use yellow sticky traps • Spray with neem biopesticides e.g nimbecidine or Achook 0.15% EC or chemicals e.g Alfa cyper EC or Atom 2.5EC
Pod borers *(Maraca testulallis)* 	Yellowish-white or greenish-white or reddish-white caterpillars feed on flower buds and seed	• Destroy plant residues • Crop rotation with non-legumes for 2-3 seasons • Spray with Lambda cyhalothrin products e.g Pentagon 5%EC
Bruchids 	Thin tunnel beneath the seed coat and circular holes on the surface of the grain.	• Clean stores before storing new grain • Store in hermetic bags. • Dust grain with Actellic at 50gm per 90kg bag

b) Common diseases

The crop is susceptible to *Fusarium* wilt especially on wet soils. Table 5.12 presents the common diseases and their control.

Table 5.12: Common diseases in pigeon peas

Disease	Symptoms	Control
Fusarium wilt *(Fusarium udum)* 	• The fungus survives on infected debris and in soil for upto 3years • Symptoms appear 4-6 weeks after planting. • Plants wilt , yellow	• Crop rotation for 3-4 years with non-legumes • Plant resistant varieties (KAT 60/80, Egerton Mbaazi 1 • Disinfect tools with jik (50ml/l water) • Rogue infected plants and burn
	• Leaves fall • Stem develops black purple streak	• Use *Trichoderma* products (e.g *Trianum*-P; *Trichotech,*)at planrting • Drench soils with Carbendazim products (Rodazim, Pearl, Saaf)
Leaf and pod spot *(Ascochyta pisi)* 	-Circular, often sunken brown spots on leaves, stem and pods	• Crop rotation with non-legumes • Avoid working in the field during wet weather. Use copper fungicides e.g. Cuprocaffaro alternate with Azoxystrobin fungicides e.g. Affair Top 800WDG
Powdery Mildew *(Erysiphe polygoni)* 	• White to greyish spots on leaves, stems and pods • They later turn dirty white • Leaves fall if the disease is severe	• Crop rotation with non-legumes • Use recommended spacing • Destroy severely infected plants • Spray with Sulphur based products (e.g. Jet, Cosavet DF) or Azoxystrobin based (Ortiva SC)

5.3.4 Post Harvesting Management and Handling

a) Harvesting:

Harvest dry grains when most of the pods are dry and have turned brown. Harvesting is done by hand picking individual pods or cutting the bearing branches. Farmers use human labour or domestic animals to transport and thresh the harvest. Harvesting ground is not usually covered with canvas in most cases and the grain collects a lot of dust and dirt, and at times gets mixed up with animal dung and urine. Therefore, winnowing and sorting is necessary to remove foreign materials. Sorting is also done to remove stones.

b) Threshing

Carried out using either mechanical or manual methods. For mechanical method, a thresher can be used to makes work easier and faster but for manual threshing sticks are used to hit the pods either placed on a tarpaulin or inside a bag. To avoid dirt and foreign materials, the threshed seeds should be spread on polythene paper

c) Winnowing and sorting

Winnowing is the process of removing foreign material from the threshed grain and this is achieved by use of winnowing trays ('*uteo*') or by scooping the grain and subjecting it to wind action. The grain drops to the ground while the chaff or foreign material is blown away. Sorting is the process of removing foreign material from the threshed grain. This can be done by either picking the broken/rotten/deformed grains.

d) Grain dressing and storage:

Grains should be stored when thoroughly dried (13% Moisture content or less), dressed with neem leaves or treated with wood ash (4-6 kg per 90 kg bag) or Actellic (50g per 90 kg bag) if stored for longer period. The grains can also be kept in airtight drums or in hermetic bags. However, if seeds are to be used for planting, they should not be stored in airtight containers so as to maintain viability however gunny bags are recommended.

5.3.5 Value Addition and Utilization

Pigeon peas provide both human food as well as livestock feed. It is an excellent source of dietary protein. It can be consumed in form of whole grain or split (dehulled). It is also eaten as a vegetable (immature pods or green pea) or a dried grain (cooked and eaten as dhal (dry split cotyledons).

The dry peas may be sprouted briefly, and then cooked, for a flavour different from the green or dry peas. Sprouting enhances digestibility of dried pigeon peas by reduction of indigestible sugars that would otherwise remain in cooked dried peas. Pigeon peas leaves and husks provide livestock feed.

Pigeon peas are also useful as tall hedges on dry soils and on the bunds of paddy fields. The branches and stems can be used for baskets and firewood. It is often grown as shade crop, cover crop or windbreak.

5.4 Cowpea

Cowpea is an important grain legume in the farming systems of Kenya since it is a major source of dietary protein and income for the people. It also known to improve soil fertility, suppressing weeds, supply of vegetables and dry grain after maturity. It is usually grown as an intercrop with maize, sorghum, millet and/or cassava. It is mainly grown in Western, lower eastern, Coast and Nyanza regions for vegetables, grain and animal feed. However, 85% of total area under cowpea production in the eastern region of Kenya as an intercrop with maize and or cassava.

5.4.1 Agroecological Requirements

These are summarised in Table 5.13.

Table 5.13: Agro-ecological requirements for cowpeas

Crop	Soil type	PH	Temperature (°C)	Rainfall (mm)	Altitude
Cowpeas	Sandy to well drained clays	5.0-6.5	20-35	200-500	0-1500

5.4.2 Agronomic Practices

a) Varietal Selection

One of the main reasons for the low cowpea productivity is lack of access to improved seed varieties. Improved, farmers' preferred cowpea varieties and are also tolerant to major diseases and insect pests but high yielding are presented in Table 5.14.

Table 5.14: Cowpea varieties

Variety name/code	Optimal altitude range (m a.s.l)	Duration to maturity (days)	Grain yield (90kg bags per acre)	Special attributes
Machakos 66 (M66)	1200-1500	80-95	4 - 7.	• Tolerant to aphids and thrips. • Tolerant to cowpea yellow mosaic virus and scab
Katumani 80 (K80)	750-1500	75-85	4 – 8	• Resistant to aphids and moderately tolerant to thrips, pod borers.
KVU 27-1	600-1200	70-90	4 – 8	• Dual purpose • Moderately tolerant to aphids, thrips and pod borers • Moderately resistant to foliar fungal disease and mosaic virus
KVU-419	600-1200	65-72	1.0 -1.5	• Mainly grown for grain than leaves • Grains are smaller than both M66 and K80 • Tolerant to cold and recovers from drought very fast
Kunde-Faulu	750-1200	70 - 80	7 – 10	• Large sized grain • Early maturing • Tolerant to *Alectra vogelii*
Kunde-Tamu	500– 1500	70 - 80	7 – 9	• Tender and sweet leaves when cooked • Dual purpose
KAT- Kunde	600- 1800	80 - 90	6 - 9	• Early maturing • Tolerant to *Alectra vogelii* • Dual purpose
Kunde-Soko	600- 1800	80 90	6 - 8	• Grain colour:- Large sized grain • Early maturing • Tolerant to *Alectra vogelii*
Kunde-Tumaini	500 – 1500	70 - 80	6 – 9	• White grained • Early maturing • Tolerant to *Alectra vogelii*

b) Germination test

It is advisable to conduct a simple germination test for cowpeas seeds before planting;

- Take a few seeds of cowpeas (e.g. a table spoonful) and soak them in water overnight.
- Wrap the soaked seeds in moist cotton clothing or new paper.
- Keep the cloth/paper moist by watering 3 times a day.
- Examine sprouted seeds on the third day. If at least 90%(9/10) seeds have emerged, then it is good for planting. If less than 60% (6/10) emerge get new seeds as it will result to poor establishment.

c) Site selection

To ensure high cowpeas production, avoid steeply sloping area, land that is near a swamp, or very sandy soil, areas with shallow surface soil and a lot of couch grass. Planting on fields that had a leguminous crop previously should also be avoided to reduce pests and diseases. Crop rotation is encouraged with maize, sorghum and millet.

d) Land Preparation

Land preparation should be done early enough so that the field is free from weeds and ready for planting at the onset of rains. The seedbed should have fine tilth, to suppress weed growth and enhance moisture retention, easy germination and root penetration. The land must be ploughed and harrowed after clearing and all the debris removed. The ground must be deep, level and firm because this ensures better surface contact between the seed and the soil, increasing the absorption of moisture.

e) Soil Fertility

Organic fertilizers

As a legume, cowpea fixes its own nitrogen. Too much fertilizer will push leafy growth and reduce grain production. The use of at least 2.5 tons/acre of farmyard manure is especially in areas where soils are low in organic matter content. Well-decomposed animal manure or compost should be applied under dry conditions, and then mixed with the soil at ploughing or planting.

Inorganic fertilizers

Cowpea requires more phosphorus (P) than nitrogen in the form of single super phosphate (SSP). About 16 kg of P/acre is recommended for cowpea production to help the crop to nodulate well and fix its own nitrogen from the air. The fertilizer should be thoroughly mixed with soil before placing the seed.

f) Planting

Cowpeas should be planted at the onset of rains. For a good plant stand and high yields, seeds must of high quality. Generally, for early maturing types, planting at the beginning of the rains is advised. Ideally, planting should be timed in relation to the maturity period of the variety such that the crop is harvested during the dry weather. Delay in planting may result in reduced yields or crop failure.

Figure 5.4: Planted cowpeas plant

- ***Spacing:*** In sole cropping system of cowpeas planting erect/semi-erect type the recommended spacing is 60cm × 20cm with two seeds per hole representing 66,400 plants/acre. For the spreading types wider spacing of 50 cm x 75 cm can be used representing 21,600 plants/acres and later thinned to two seedlings per hole, one week after germination. When intercropping with maize, sorghum or millet the recommended spacing is two equidistant cowpea rows between the rows at 20cm within the row, one seed per hole. The other alternative is to have one cowpea row between the cereal rows, two seeds per hole. Generally the seeds are placed 2.0 to 2.5 cm deep in the soil.
- ***Seed rates:*** Use about 12–25kg/acre of cowpea seeds, depending on the variety, seed size, cropping system, and viability of the seeds. More seeds are required when erect varieties are used than when prostrate varieties are adopted. Similarly, fewer seeds are required when the cowpea is to be intercropped with other crops. The larger the seeds, the more seeds per acre are required.

g) Crop rotation

This practice is recommended to avoid pest and disease build up. Rotation is mainly done with cassava, maize, sorghum, millet or any other non-leguminous crop.

h) Weeding

- ***Manual weeding:*** Cowpea should be kept free from weeds. Timely weeding should be done as soon as weeds emerge and/or before the weeds flower. Weeding reduces the spread of pest and disease infestation at the early stages. First weeding should be done two weeks after emergence followed by a second weeding three weeks later (just before flowering). Avoid weeding at flowering time to prevent shedding of flowers and when the field is wet to avoid spread of diseases and soil compaction.
- ***Chemical weed control:*** The choice of herbicide depends on the predominant weed species and the availability of the herbicide. Herbicides are available for control of weeds before they emerge (pre-emergence) or after they

emerge (post-emergence). If pre-emergence herbicide is applied at or just before planting, one manual weeding may be required at 4-5 weeks after planting.

5.4.3 Crop Protection

Diseases and pests are main contributor to unstable production. Incidence and severity vary between seasons because of environmental and management practices. Integrated disease and pest management, using all suitable control measures, is recommended (Table 5.15).

Table 5.15: Cowpea pests and diseases and their control measures are as given

Problem	Description	Symptoms	Control
Aphids		• Infested leaves curl and become chlorotic. • Aphids excrete black sooty mould that covers the leaf surface • Transmit the Cowpea mosaic virus	• Use yellow sticky traps • Spray nimbecidine/Achook • Spray with Alpha-cypermethrin 10 EC. 20-30ml/ 20 litres of water
Pod borers		• Causes defoliation in early stages. Larvae's head is thrust inside pods with the rest of the body hanging out.	• Destroy infected plant residues • Spray neem products or nimbecidine or Achook • Spray with Pentagon 5%EC
Flower thrips	**Insert photo**	• Affected flowers are brown, dried, or completely distorted. • Flowers drop prematurely leading to • decreased pod production. Pods are deformed.	• Use blue sticky traps • Use neem based products e.g. Nimbecidine or Achook 0.15%EC • Spray with Alpha-cypermethrin 10 EC. 20-30ml/ 20 litres of water
Pod sucking bugs		• Suck sap from pods and seeds • Cause necrosis, pod malformation, premature drying, shriveling of seeds, loss of germination ability, and formation of empty pods.	• Spray neem seed kernel extract (50 g/l) and neem oil 3000 ppm at 20 ml/l. • Spray with Pentagon 5%EC
Cow pea Bruchids		• Larvae feed on seeds destroying them • .Adult emerges from the seeds leaving small round holes on the cowpea seeds	• Grains should be dried up to 10% mc and stores cleaned • Dress seeds with neem seed oil at 5ml/kg • Apply Actellic 50g/90kg

Problem	Description	Symptoms	Control
Powdery Mildew			
Rust		• Circular reddish brown pustules on the underside of the leaves • Shrivelling and defoliation	• Early planting • Uproot and destroy affected plants • Spray copper oxychloride at a rate of 50gm/20litres water
Anthracnose		• Circular, black, sunken spots with dark centre and bright red orange margins on leaves and pods	• Crop rotation with non-legumes for 2-3 seasons • Use certified seeds • Uproot and destroy diseased plants & bury or burn • Spray with Cabendazim (Rodazim SC) or Azoxystrobin (Target Top 325 SC) respectively

5.4.4 Postharvest Management and Handling

a) *Leaves harvesting*

Leaves for vegetables use must be young and tender and this is done three weeks after planting at weekly intervals up to the time flower buds appear (just before flowering). If the crop was grown for leafy vegetables then uprooting the entire plant at the 3-5 true leaf stage before the leaves become too mature and fibrous/ tough. Harvesting cowpea at 7-days intervals give higher leaf vegetable yields.

b) *Dry seed harvesting*

Harvest cowpea when the pods are fully mature and dry. In early-maturing and erect varieties, one picking may be sufficient. For indeterminate and prostrate varieties, the dried pods can be picked two or three times. The pods do not mature at the same time because of the staggered flowering period. Matured, dried pods should be harvested promptly, delay in harvesting will encourage shattering and weevil infestation in the field.

c) *Threshing and winnowing*

Cowpea can be threshed manually by thrashing the plants or pods on a clean cement floor, tarpaulin, or beating bagged pods with sticks once they are dry enough. Various types of threshing machines are available in different sizes, powered by petrol, diesel, or electricity, for small-, medium-, and large-scale. Whatever the method used cowpea seed can be easily damaged if threshed too roughly or when too dry. Test the grain to see if it is dry enough for storage or market by biting or pinching grain with your finger nails or teeth. When dry enough, grain should break or crack rather than bend or stick between teeth or fingernails. Afterwards, winnow against the airflow so that materials such as chaff and broken seeds are blown away.

d) Moisture content before storage

After the seed has been threshed, dry them on mats, plastic sheets or wire mesh trays raised on a platform to about 10% moisture content. The seed should be spread thinly on the drying surface to allow air to pass through it and turned regularly to avoid overheating. The seed should be protected from rain, insects, animals and dirt.

e) To check moisture

Pick a clean, dry bottle/jar with a lid, scope a sample (handful) of cowpea seed and add one tea spoon of salt. Shake the bottle/jar well and then allow the seed to settle for about 10 minutes. If after 10 minutes one can see damp salt stuck to the sides of the jar, the seed is too moist. This means that the moisture is above the required 13%. If the jar is dry and there is no salt stuck to the sides of the bottle/jar, the seed is well dried.

f) Sorting and grading

Sort to remove broken, discoloured, rotten, pest-damaged, immature, shrivelled seeds and foreign matter as they are characteristics for grading the grains

g) Storage

- Clean the store thoroughly before a new harvest is brought in.
- Only well-dried and properly cleaned grain should be stored.
- Well-dried cowpea seed should have less than 13% moisture content with 8-10% moisture content recommended for long term storage.
- Use hermetic bags such as PICS (Purdue Improved Cowpea Storage) bags to keep away insects from the grain.
- Ensure the hermetic bags are protected from rats and mice for effectiveness.
- The grain can also be dusted with Actellic before storage in metal or plastic silos

5.4.5 Value Addition and Utilization

Cowpeas are cultivated for the grain (shelled green or dried), the pods or leaves that are consumed as green vegetables or for green manure. Livestock thrive on the stems and leaves left once the seeds have been harvested. In Kenya, cowpea grains are consumed in three basic forms: Cooked together with vegetables or maize, spices and oil, to produce a thick soup, which accompanies the staple food (rice, ugali or chapati). They are also cooked as vegetables and they are a good source of Vitamins A, B and C and are rich in calcium, phosphorus, carbohydrates proteins and fibre. Green cowpea grains are boiled, canned or frozen.

6 FARMING AS A BUSINESS

Farming for the market is a business. It is a business in that farmers use land, labour, and capital to produce goods for sale. To say that farming is a business is in no sense to downgrade its importance or to adversely criticize it. Farmers as businessmen need to understand the risks that they take and the benefit they provide for all of their customers. Farming is certainly a risky business because it depends on changes in prices in domestic and foreign markets, and environmental aspects.

6.1 Advantages/ Importance of Farming as a Business

Farming as a business (FAB) helps farmers to get the best out of their farms and their resources. Applying business methods such as record keeping, benefit–cost analysis, marketing skills, group management skills, gender considerations and good communication skills can greatly improve the efficiency of farming. It involves weighing, sorting, grading and packaging farm produce collectively at aggregation centres. In order to understand the farming business, farm goals are clearly defined. This calls for an individual farmer to know what to produce (specific farm enterprise); how to produce it (technological issues); for whom to produce (target market); when to produce (appropriate market price and profitability); and, how much to produce (where is the farming business heading to). When everyone involved with the farm (family members, extension workers, development agencies) understands the goals, they will work better together towards them.

6.2 Farm Records and Record Keeping

A record is written proof of what happened. Record keeping is an important activity that is necessary for operating farm enterprises effectively. It involves gathering valuable data or information on the happenings of a particular undertaking, with a view to processing it in the future (for example, analysing sales and costs and calculating profits). Lack of well documented farm records, makes it problematic for farmers to establish whether their businesses are making profit or losses. Farm records gives an account of the various activities carried out on the farm on a regular basis. Farm records include crops cultivated, livestock kept, varieties planted, breeds reared, management activities carried out, quantity harvested among others.

6.3 Importance of Record Keeping

Records provide essential information which assists the farmer to do proper farm planning; credit sourcing; monitoring farm performance and provides basis for proper decision making. Records give an insight into the money spent if different farm enterprises and or operations; money received; money obtained from produce sales; and, determine if a profit or a loss was made.

The common types of farm records include production records (vital in determining performance of difference enterprises); labour records (Show the amount and type of labour hired or employed to work on the farm); Cash flow records (they record all the cash flow in and out of the farm business each year); home consumption records (indicate household intake, date, item and amount consumed, unit and total price if item was sold); fixed assets records (indicate all the items present on the farm at a particular time); and, profit and loss records (are major farm records that show the economic performance of the farm). Most farmers tend to keep only this record. However, other records are important in order to come up with this type of records.

6.4 Markets and Marketing for Cereals and Legumes

A market **is** a means by which the exchange of goods and services takes place as a result of buyers and sellers being in contact with one another, either directly or through mediating agents or institutions. It is a place where buyers and sellers meet to exchange goods, services

and other relevant information. Marketing refers to the process through which the gap between the producers and consumers is bridged. In this definition, producers are separated by time and distance. It involves finding out what the consumers want and then supplying them with the same at a profit. Organized farming business helps reduce the costs of storage and transportation. This is because it is easier to centrally manage farm produce at aggregation centres for ease of quality checks and grading; while reducing transport costs. It also gives the farmers a bargaining advantage when selling their aggregated farm produce.