Cereal-Legume Intercropping and Rotations in Eastern and Southern Africa

Farmer's Manual

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This work was supported by the European Union H2020 Research and Innovation programme under the grant agreement number 727201

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The International Maize and Wheat Improvement Center (CIMMYT) – is the global leader in publicly-funded maize and wheat research and related farming systems. Headquartered near Mexico City, CIMMYT works with hundreds of partners throughout the developing world to sustainably increase the productivity of maize and wheat cropping systems, thus improving global food security and reducing poverty. CIMMYT is a member of the CGIAR System and leads the CGIAR Research Programs on Maize and Wheat and the Excellence in Breeding Platform. The Center receives support from national governments, foundations, development banks and other public and private agencies.

Contents

Preface

This manual on cereal-legume systems is written as a guide for use by farmers intending to grow crops such as maize, sorghum and millets as rotations or intercrops with legumes such as common beans, soybeans, groundnuts and others. The manual seeks to enable farmers to increase productivity and achieve improved food and nutrition security. It provides step by step general guidelines to farmers based on the experiences of InnovAfrica in in Sub-Saharan Africa as well as many others. However more detailed specific information on these can be obtained from local extension services in each country.

1 Introduction

Maize, sorghum and millets are important cereals for food and nutrition security in the Eastern and Southern Africa (ESA) region as a staple food and constitute major sources of dietary carbohydrate. Legumes such as groundnuts, common beans, pigeon pea and soybean are important and affordable sources of proteins and vitamins.

To meet the growing demand for foods attributed to a rapidly growing population in ESA, there is a need to increase the production of these crops. A practical approach for increasing farm productivity, to maintain healthy crops and fertile soils, and maximizing resource use efficiency would be intensification of land use through growing multiple crops simultaneously (intercropping) or in succession (rotations).

Growing cereals and legumes in the same land not only supplies dietary carbohydrates, proteins and vitamins to households but also improves soil fertility through symbiotic nitrogen fixation from the legumes which also provide quality crop residue for livestock. Besides this, these methods can improve income and livelihood of smallholder farmers in ESA. This manual describes the advantages of intercropping and rotations and provides technical details of how to implement these sustainable agricultural intensification (SAI) systems. In addition, the manual shares knowledge and experiences of farmers who adopted cereal-legume intercropping or rotations system as a part of the InnovAfrica project in Ethiopia, Malawi and South Africa.

InnovAfrica has been testing intercropping/rotations of cereals (maize, sorghum and finger millets) and legumes (common bean, groundnut, cowpea, soybean, Bambara nut and pigeonpea) in farmer fields in Ethiopia, Malawi and South Africa from year 2017 to 2020 (3 growing seasons). The use of intercrops and rotations particularly in Conservation Agriculture (CA) enhances the resilience of farmers to climate change-induced risks such as dry spells and thus, crops withstand better during severe moisture stresses. Furthermore, intercropping increases crop diversification and thus reduces the risk of crop failure due to drought, excessive rainfall, pests and disease attacks. This means that the use of these SAIs in rainfed cropping systems could enable farmers to be more productive, leading to better food and nutrition security and incomes.

2 Cereal-Legume cropping systems

Intercropping is the practice of growing two or more crops in the same area, at the same time. Crop rotation is the practice of growing different crops in the same area, in a special sequence over seasons. The cereal-legume systems comprising maize followed by legumes (common beans, soybeans, groundnuts or cowpea) are common crop rotation practices in many parts of the world.

In general, mixed cropping is better suited to farmers with small landholdings whereas crop rotation is more suitable to farmers with larger landholding. However, there are other factors such as household needs and farm economics that determine choice of these two SAI practices. The land equivalent ratio (LER) is often used to measure benefits of intercropping compared to planting a single crop (sole cropping). The LER is defined as the land required for production of the same yield in the sole crops compared with the intercrop. A LER greater than 1 indicates intercropping is advantageous to sole crops (Table 2.1).

Advantages of cereal-legume intercropping systems

Intercropping was practiced traditionally by African farmers as mixed cropping but later abandoned when high input-demanding cash

Figure 2.1. Maize intercropped with common beans.

Table 2.1. Advantages and disadvantages of intercropping practice.

Advantages	Disadvantages
• Increases total crop productivity. • Diversifies sources of food, reduce risk of crop failure and increase food and feed security. • Improves soil cover and minimizes soil water loss and soil erosion. • Suppress insect pests and diseases. For example, farmers using intercrops often experience reduced attack of maize by Fall Army Worm. • Suppression of weeds including witch weed (*Striga asiatica*) • Diversification of soil flora and fauna andincrease water infiltration.	• Initially yield decreases of the individual component crops to sole crops, and increased crop density enhances competition for water, light and nutrients • Demands more time and expertise. • Difficulties in mechanization so most cultural operations and harvesting should be done manually. • More nutrients and water needed. • Poor supply of legume seeds for intercropping

crop production systems were introduced in the 1930s but now being promoted again due to their sustainability merits. The advantages and disadvantages of intercropping have been summarized in Table 2.1.

Advantages of cereal-legume rotation systems

Crop rotation using cereal and legumes is another commonly used practice by smallholder farmers. The main advantages and disadvantages of crop rotation are presented in Table 2.2.

Table 2.2. Advantages and disadvantages of cereal-legume rotation.

Advantages	Disadvantages
• Increased crop yields especially in conservation agriculture systems. • Improves soil structure and reduce erosion • Improves soil fertility from nitrogen fixation by legumes. Some legumes can fix up to 30kg N/ha per year. • Suppression of pests and diseases by breaking the life cycle of attacking pests. • Mitigate climate change through carbon sequestration in soils. • Improve soil health through macro and micro fauna diversity	• Rotations can effectively be implemented only by farmers with adequate land sizes. • Low adoption due to limited availability and high cost of legume seeds • Risk of losing an entire crop in a rotation. • The need to stick to a defined crop sequence even when the other crop is not financially rewarding

3 Implementing intercropping or rotation cropping systems

Decisions to make:

1. Crop rotation or intercropping?
2. Suitable crops / crop combinations?
3. Do the crops selected fit within the cropping season or crop calendar?

Crop rotation or intercropping

The decision to adopt cereals-legumes **intercropping, or rotation** depends on:

1. What type of crop: Cash crop, staple food crop, a crop that provides more grains or residues for livestock feed?
2. How much land is available to accommodate rotations? Many smallholders who own less than 1 ha land prefer intercropping of cereal and legumes to meet dietary household needs.
3. If a farmer is aiming for the high yields of legume, usually as a cash crop, then rotations provide a better assurance of higher productivity.

Examples:

- In South Africa (SA), common beans are produced as a cash crop and rotations are preferred to intercropping. Soybeans and cowpeas may be grown as sole crops in rotation with maize as farmers often have large farm sizes in SA.
- Maize yield increases from rotations under conservation agriculture ranged in between 30 and 50% in Malawi.
- However, intercrops tend to perform well under high rainfall and high soil fertility conditions. Very low rainfall may cause moisture stress to both intercropped crops thereby compromising yields.
- In Malawi and Ethiopia farmers prefer intercrops as they have smaller farm sizes of less than 1 ha.

4. The planting configuration and density in intercrops vary depending on agro-ecology or the seasonal rainfall (see also choosing appropriate cereals and legumes).

   - In high rainfall areas, the planting density of cereals may be the same as for sole crop planting while the legume planting density is reduced to about half the density used for a sole legume crop.
   - An intercropped legume does not get as much light due to the shedding effects of the cereal and so certain planting configurations such as double row, back to back and strip cropping which can help the legume gain access to more light.

5. The time of planting of cereals and legumes in an intercrop system is an important factor to consider when planning intercropping. Usually cereals and legumes are planted at the same time but for fast growing legumes such as Mucuna and Sunnhemp, it is best to delay or relay them for up to two weeks to reduce competition. For slow growing legumes such as pigeon pea, cowpea and common beans, it is best to plant them at the same time with maize or other similar cereal (see also crop calendar).

Choosing appropriate cereals and legumes

The choice of cereals and legumes for intercropping and rotation also depends on farmer needs (food security or cash crops), climatic conditions and soil types (Table 3.1).

- Maize does well on well-drained soils with high fertility and sub-humid to humid climates and rainfall of about 800 to 1400 mm. Maize is also widely grown in semi-arid to arid regions with rainfall below 600mm. The high rainfall (>1200 mm per season) and hot environments result in faster growth of crops thus farmers can use high plant densities along with high fertilizer application rates whereas low plant density is recommended for areas with low rainfall (<600mm).
- The use of legumes as intercrop often causes moisture stress, therefore, higher rainfall conditions are ideal for intercrops.

Table 3.1. Typical climatic and soil requirements for various cereals and legumes.

Crop type	Crop	Seasonal rainfall	Optimum Soil characteristics	Temperature	Growing period (days)	Remarks
Cereals	Maize	800-1200	Well drained fertile soil pH 5.5-6.5	18-32 °C	80-150	An important crop in ESA New drought tolerant varieties available
	Sorghum	300-800	Well drained, deep loamy textured soils pH 5.5-8.5	25-30°C	110-130	Drought tolerant and suitable for semi-arid conditions
	Finger millet	500-1000	Fertile and well drained soils pH 5.0-8.2	11-27°C		Drought tolerant and suitable for semi-arid conditions
	Pearl millet	250-700	Light well drained loamy soils, and low pH (4-5) tolerant	23-30°C	70-100	Susceptible to waterlogging but can tolerant infertile soils
Legumes	Common beans	400-650	Well drained loamy soils pH 5.8-6.5	18 to 24 °C	80-120	
	Cowpea	400-900	Well-drained, sandy loam to clay loam soils pH 5.8-6.5	20-30 °C	80-120	Susceptible to aphid attack and needs frequent use of insecticides
	Groundnut	500-1200	Well-drained, light sandy loams, pH 6.0-7.0	18-33°C	100-180	Heavy soils make harvesting difficult. Calcium requirement is high.
	Soybeans	500-900	Deep well drained medium to heavy textured soils with high fertility, pH 6.0-6.5	15-25°C	110-140	Does well with rhizobia inoculation
	Pigeon pea	600-1400	Well drained light or heavy textured soils, pH 6.0-7.0	18-30°C	120-180	Deep rooted and drought tolerant

Crop calendar

The Crop Calendar provides information on planting, sowing and harvesting periods of locally adapted crops in specific ago-ecological zones. This helps to identify the most suitable cropping combinations. A crop calendar for a maize - soybean intercrop system applied in Malawi and South Africa is presented in Figure 3.1.

The key issue is to ensure both crops are established and mature within the rainy season.

It is also clear that the cropping season dependent on the onset and end of the rainy season which determines the length of the crop growing period.

However, crops that grow on residual moisture such as pigeon pea can be relayed in such a way that the peak water demand period for maize will not coincide with that of pigeon pea. Pigeon pea matures after maize and can be harvested as late as July in Southern Africa if livestock (such as goats and cattle) can be kept away from the crop.

Figure 3.1. A typical crop calendar for Free State of South Africa.

Crop	Activity	Jul	Aug	Sep		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
	Rainfall													
Maize	Land preparation													
	Planting													
	Weeding													
	Harvesting													
Soybeans	Land preparation													
	Planting													
	Weeding													
	Harvesting													

Figure 3.1. A typical crop calendar for Ethiopia.

Crop	Activity	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
	Rainfall	x	x	x								x	x
Maize	Land preparation								x	x	x		
	planting											x	
	Weeding	x	x	x									x
	Harvesting					x							
Common Bean	Land preparation									x	x		
	planting											x	x
	Weeding	x	x										
	Harvesting			x	x								

4 Choice of cereal and legume varieties

The next step would be to identify the varieties of crops to grow and access to seeds. Availability of seeds of non-commercial legumes can be challenging as most farmers rely on informal seed sources. Therefore, it is important that decisions on varieties are made well before the onset of the crop season.

Choosing maize variety

For maize, the seed system is in place in most African countries and farmers may simply need to decide on what variety to grow.

Time to maturity, ability to tolerate moisture and heat stress, resistance to pests and diseases, grain milling quality and yield potential are some important considerations when selecting a right variety.

Long duration or late maturing maize varieties tend to have higher yields. Early maturing varieties, on the other hand, grow faster and mature early thereby perform better in the short seasons. Ability to tolerate moisture or heat stress is important specifically in arid or semi-arid conditions where temperature is high and result in severe moisture stress to the crop. Drought tolerant maize varieties are bred to cope with these adversities and often yield much higher than normal varieties. Similarly, pests and diseases resistant varieties carry more value in environments where pests and disease problems are prevalent. Newer maize varieties are often bred to resist diseases such as grey leaf spot, maize streak virus and other such diseases. Milling quality, taste, and yield are often also considered important variety characteristics when farmers choose varieties for household uses or for the market.

Open Pollinated Varieties (OPVs)

The OPVs self-pollinate, or pollinate by another plant of the same variety, resulting in seeds genetically identical to their parents. Traditional maize varieties belong to this category and yields tend to be low or modest. When several OPV genotypes are grown together and cross each other the result is an improved OPV. The main advantage of OPVs is that farmers can grow the same seed year after year, there is more genetic diversity in each seed, tastes better, stores well and can tolerate seasons with erratic rainfall. Unfortunately, the yield is lower eg 3-6 t/ha and gets poorer over time. More diversity means less uniformity and crop matures at different times and farmers need to find fresh seed after 4-5 years of growing an OPV.

Hybrids

A hybrid variety is an offspring from a deliberate mixture of two different varieties with desirable characteristics. In maize significant improvements have been made over the years in developing Hybrid seeds generally have very higher yields than OPVs. Some advantages of hybrids are greater uniformity, usually more vigorous growth, high yields (>8t/ha) and breeding takes less time. However, hybrid seeds cannot be recycled so farmer must buy seeds every year, they are expensive and demand high fertilizers and do well with irrigation.

Drought tolerant maize

In recent years CIMMYT and its partners invested heavily in developing drought tolerant maize varieties. Some of these are white while some of them are orange in colour. The drought tolerant varieties grown in Malawi are MH30, MH31, MH34 and MH36. In SA new varieties such as PAN 3A-157 while in Ethiopia popular varieties were BH 661 and BHQPY 545.

Key characteristics of these drought tolerant varieties are as follows:

- Relatively better in dry years and yield between 20-30% more under moderate drought conditions than other non-drought tolerant commercial varieties.
- Greater yield stability – means good yields in both good and bad rainfall seasons and so.
- High yield potential (no yield loss in optimal years).
- Resistance to major diseases (e.g., maize streak virus (MSV), Turcicum leaf blight (TLB), and grey leaf spot (GLS) and superior milling or cooking quality.
- Very uniform.
- Seed must be purchased every season.

ProVitamin A Maize

These are orange coloured maize varieties that have been bred or biofortified with Provitamin A. These varieties are quite different but often confused with yellow maize that is usually grown as stockfeed. ProVitamin A Maize marketed in Malawi are MH43A and MH39A. Orange maize are available in the form of hybrids or OPVs and have the following characteristics:

- Orange maize varieties have enriched levels of about 6-8 g/g provitamin A (carotenoids). Lack of Vitamin A can result in morbidity and blindness in humans.
- Provitamin A hybrids are high yielding, drought tolerant and often disease resistant.
- They have a high micronutrient density and hence sometimes referred to as nutrient dense maize varieties.

Quality Protein Maize varieties

These can be white in colour but are open pollinated. They are high in protein content. The nutritive value in milk protein is 90%, while the average maize variety has only about 40% protein value. In Ethiopia, for example, the variety BH QPY 545 proved to be popular with farmers

Choosing sorghum and millet varieties

Improved sorghum and millet varieties have come on the market in most countries in the last 20 to 30 years. In Malawi, for example, sorghum varieties such as Pilira 1 and Pilira 2 have been released on the market and the other popular variety in Southern Africa is Macia. Traditional varieties tend to be tall and low yielding. However, traditional varieties are usually less vulnerable to bird attack but the grain is less susceptible to weevils. It is not advisable to continuously plant a sorghum crop due to pest build-up. Recommended spacing: 75 x 5 cm, 5-7 kg seed/ha for small seed and up to 10 kg for large seed. Planting time is from end of November through to end of December in Southern Africa. Fields should normally be kept weed free through manual hoe weeding or the use of herbicides where appropriate. Harvesting should be done early to avoid bird damage and farmers should engage bird scares when growing susceptible varieties. Certain varieties such as Shirikure has spiky heads which keep birds away. Seed rates also vary from 5 kg/ha for low rainfall environments to 15 kg/ha in irrigated cropping systems (Table 4.1).

Table 4.1. Recommended seed rates for sorghum.

Rainfall	<500 mm	<500-650 mm	650-800mm	Irrigated
Population (plants/ha)	60 000	90 000	110 000	250 000
Seed required (kg/ha)	5 kg/ha	8 kg/ha	12 kg/ha	15 kg/ha
Row width 90 cm	15.5 cm	8.5 cm	6 cm	3 cm
Row width 75 cm	14.0 cm	10.0 cm	7.5 cm	4 cm

Source: Seed Co Sorghum Grower's Guide

Choosing legume varieties

Legume seeds are a major challenge for many smallholder farmers in ESA as many seed houses find them unattractive to market since farmers can reuse them year after year. Most legumes discussed here can be grown as intercrops or sole crops. Table 4.2. highlights recommended planting densities and seed requirements per ha when grown as intercrops or in rotation with cereals.

Cowpea

Improved cowpea varieties have been in market in the last 2 or 3 decades. These varieties are erect, determinate, early maturing and have high yielding characteristics and the grain cook easily and are tastier compared to some traditional runner type cowpeas. However, they are highly susceptible to pests such as aphids and will thus need periodic insecticide spraying particularly during prolonged dry spells. Common newly availed cowpea varieties include IT18, CBC1 and CBC2.

Common beans

Common beans have been grown extensively as intercrops by smallholder farmers in Africa. The choice of varieties depends on the agro-ecology or expected rainfall regime of the area. Most beans drop their flowers if excessive rains are experienced during the flowering period. Therefore, farmers prefer to delay planting of beans in intercrops until the season starts tailing off so that the beans grow on residual soil moisture. In recent years bean breeding efforts have focussed on improving yield under stress conditions and farmer taste preferences. Popular varieties in the region include SUG123, Napilira, NUA45, NUA 56, Pan 148 and others. Varieties such as Dursitu and Tinike were popular in Ethiopia for example. More recently efforts have been on biofortified high Iron and Zinc varieties such as NUA45.

NUA45 bean variety high in Fe and Zn.

Soybeans

Soyabean has been grown traditionally as a commercial crop mostly for the food and feed industries in most countries. Soybean oil for example is very popular among consumers. Soybean traits to consider in selecting a variety include maturity, yield potential, disease and pest resistance, iron deficiency tolerance (chlorosis), lodging score, height, and specific soybean quality traits such as protein and oil content. Due to its commercial orientation soybean seeds are widely marketed by many seed companies in the ESA region. In most countries local seed companies distribute locally recommended varieties. In the smallholder sector promiscuous soybean varieties which have the ability to nodulate with indigenous Bradyrhizobium strains that do not need inoculation, are also widely promoted. Commonly grown soybean varieties include Nasoko and Sable.

Pigeon pea

Early or medium maturing varieties are often preferred by farmers due to their fast maturing characteristics.

Table 4.2. Recommended planting densities and timing of planting for various legumes.

Crop	Sole crop in rotation in maize				Intercrops with maize				Recommended time of planting	Recommended popular improved varieties in ESA
	Plant density/ha	Seed requirements kg/ha	Attainable yield (kg/ha)	Days to maturity	Plant density/ha	Seed requirements kg/ha	Attainable yield (kg/ha)	Days to maturity		
Cowpea	2-300 000	20-40	2500	70-90	1-150 000	10-20	800-1000	70-90	Same time as cereal	IT18 CBC1 and CBC2 (determinate or upright varieties) IT82E16
Common beans	+/-200 000	90-100	6000 (in Ethiopia the national average is about 1.6 to 1.7 tons/ha	95-110	+/-100 000	45-50	1000 (???)	95-110	Same time as cereal	SUG123, Napilira, NUA45, NUA 56, Pan 148, Dursitu, Tinike
Groundnuts	74 000		4-6 000	100-180	37 000		1500	100-180	Same time as cereal	CG7, MG5
Soyabeans	444 000	90	5000	100-140	222 000	45	1500	100-140	Same time as cereal	Nasoko
Pigeonpea	22000	50		151-200	11 000	25	2000	151-200	Same time as maize	Medium maturing varieties eg. Mwaiwathu alimi
Mucuna	44000	40	4000		22 000	20	1500		2-3 weeks after maize	
Dolichos lab-lab	44000	20	3500		22 000				1-2 weeks after maize	

5 Land preparation

Land preparation often costs the highest amount of labour and time particularly if carried out by hand. Weeds that germinate and grow before planting are often the major reason why farmers need to plough or till their fields before planting. Traditionally land preparation is the operation of tilling the land by turning over the soil that leads to a fine weed free seedbed that is suitable for planting crops. Conventional tillage using hoes, ox-drawn or tractor drawn ploughs often results in excessive soil erosion and loss of water. However the turning over of the soil through tillage incorporates organic materials usually left on the surface and accelerates their decomposition which results in the release of soil nutrients such as nitrogen, potash and phosphorus, making them available to crops. Yet soils loosened using conventional tillage often quickly get compacted resulting in higher run-offs leading to soil erosion.

Where farmers must till their land, it is recommended to plough down to a depth of 20-25 cm to create a fine seedbed into which seeds may be planted. Preparing a conventional maize seed bed by hand using hoes requires about 8-10 days of manual labour per hectare compared to 8-10 hrs per ha using oxen and 4-4.5 hrs per ha using a tractor. Farmers who try to prepare their land at the onset of the season thus always find themselves not being able to plant on time. Land preparation should therefore be started well before the onset of the crop season so that all fields are ready for planting by the start of the wet planting season. For this reason, practices such as conservation agriculture help to reduce the energy demands associated with land preparation.

Conventional tillage

Land that is tilled annually often suffers a lot from erosion particularly if it lies on sloppy areas. To ensure erosion and water losses through run-off are minimized, it is important to ensure tillage operations are carried out across the main slope. Although commonly practiced by many farmers in Eastern and Southern Africa, important measures that can help reduce soil degradation include the following:

1. Ploughing or tillage should run across the main slope to reduce the loss of both soil and water.
2. On sloppy ground, farmers should install mechanical barriers commonly known as channel terraces, contour ridges or use grass or hedge strips at intervals of 20 to 40 m depending on slope. The main objectives behind the use of mechanical channel terraces are to reduce the slope length and minimize soil erosion, and to intercept the runoff and divert it to a safe point. The common structures used in the region include level channel terraces or contour ridges Fanya Juus and Vetiver or other grass strips.

However, to be sustainable, conventional tillage should be used in conjunction with biological erosion control methods and intercropping with effective cover crops such as cow peas and pumpkins, which can help protect the soil from erosion. Crop rotations and fallowing could also be used to enhance soil fertility. The major advantages and disadvantages of the conventional ploughing techniques are as follows:

Advantages

- Provides for less troublesome performance of cultural operations.
- Results in greater soil nutrient mineralization.
- Distributes soil nutrients throughout the soil.
- Enables effective weed control at planting.
- xposes pests to predators and unfavorable conditions.
- Aerates the soil.

Disadvantages

- Leaves a surface susceptible to splash and sheet erosion.
- Results in high nutrient leaching.
- Smooth surface susceptible to crusting.
- Results in a decline in soil organic matter content and increases erosion.
- Results in a limited rooting volume due to high resistance layer (plough pan) formed at shallow depths.
- Requires high draft power.
- High moisture loss.
- Disrupts the lifecycle of beneficial soil organisms.
- Needs more labour cost for the soil preparation.

Conventional tillage is best used on relatively flat land where erosion risks are minimal, and on fields where weeds are a serious problem. It may also be used to incorporate manure and crop residues as well as where fertility management is possible through application of organic and inorganic fertilizers.

Conservation Agriculture

The Conservation Agriculture (CA) started in 1930s in the United States following a severe soil erosion crisis in the Mid-West which became known as the 'Great Dust Bowl' and later spread to South America, Australia and into Africa. In Africa, use of CA started in the 1970s in Zimbabwe and then to Zambia, Malawi and elsewhere. CA is premised on three key principles: minimum soil disturbance, provision of permanent soil cover and the use of rotations or associations (Figure 5.1). These CA principles are applicable to a wide range of crop production systems from low-yielding, rainfed conditions to high-yielding, irrigated conditions. However, the techniques used may vary from place to place depending on farm power, system management conditions and farmer circumstances. CA is based on the principles of rebuilding the soil, optimizing crop production inputs especially labour, and optimizing profits. The combined social and economic benefits gained from combining production and protecting the environment under CA, including reduced input and labour costs, are greater than those from production alone. With CA, farming communities become providers of more healthy living environments for the wider community through reduced use of fossil fuels, pesticides, and other pollutants, and through conservation of environmental integrity and services.

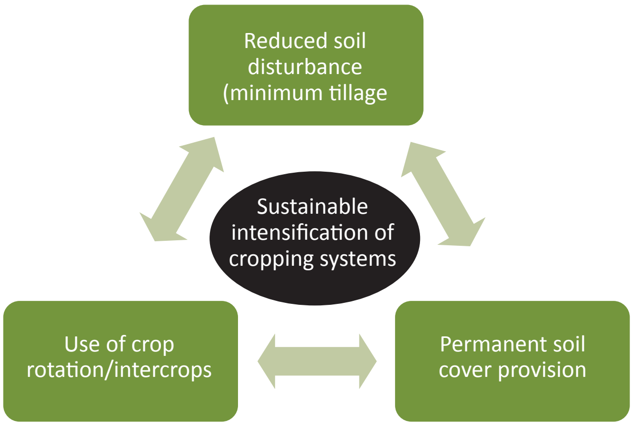

Figure 5.1. The three principles of conservation agriculture.

Other complementary principles also often known as good agronomic practices (GAPs) governing the implementation of CA comprises of (i) timely implementation: carrying out all operations at the best time of the year (preparation, planting, manuring and fertilization, controlling weeds and pests), (ii) precise operations: paying attention to detail and doing all tasks carefully and completely, and (iii) efficient use of inputs: not wasting any resources including labour, time, seeds, stover, manure, fertilizer and water. Other techniques such as the tied ridging system are often used by farmers who cannot apply residues as surface cover in CA.

Tied ridging

Tied ridging is a system of constructing ridges and furrows with cross ties at 2 to 3 m intervals along the furrows that help to reduce run-off along the furrows for maximizing water infiltration as well as for harvesting water in rainfed cropping systems. Ridges 15 to 20cm high are normally constructed across the slope at crop row spacings of 75 to 90 cm. Crops are planted on the ridges to maintain the same plant populations as for the flat planting systems. This system is known as banking in Malawi and other Southern African countries.

6 Timely planting and planting configurations/ arrangements for successful intercrops

In rainfed systems, farmers often fail to plant crops on time. Due to the changing climatic and seasonal weather patterns, farmers need to ensure that they make full use of any available moisture in the soil by timely planting at the onset of the cropping season. Late planting often results in lower yields for both cereals and legumes. Key steps to ensure farmers optimize yields in any rainfall season include the following:

a) Climate Services information: In many countries, meteorological services organizations often give seasonal forecasts of what the rainy season is going to be. It is important for the farmers to make use of this information usually shared on radios, newspapers and even social media platforms such as WhatsApp. To access this information, farmers are advised to ask their local extension advisers on where to find this information.

b) Timely planning: It is important for farmers to know well before the season starts what crops they intend to grow and on which fields. Once a decision is made on this, the next step is to calculate the required inputs (seeds, fertilizer and agro-chemicals) for the different blocks of land. Please ask your local extension officer for help on this if not sure.

c) Timely land preparation: Irrespective of whether you use conventional ploughing or no-till methods, it is always important to timely prepare the land before the season starts. Attempting to prepare land when the season has started often leads to disastrous results because land preparation demands high energy, time and resources.

d) Ensure all fields to be planted are free of weeds.

What planting configurations to use

Performance of different intercropping systems depends on several factors that include (i) time of planting of both crops, (ii) prevailing moisture, (iii) planting density, and (iv) planting configuration i.e. planting pattern.

(1) Conventional intercrops

Traditionally the planting of intercrops was disorganized with no special pattern of planting the mixed crops. The intercrop seeds are usually broadcasted in the field and would thus germinate randomly. With the advent of machinery and the need to maintain prescribed plant populations, farmers in many countries now grow the main cereal crop and the legume on the same row. This is also done to minimize labour required to prepare planting stations for both crops (Figure 6.1). For example, in a maize and beans intercrop system, the maize seeds are dropped in the same hole as the beans so both crops grow from the same rows.

Advantages

- The Cereal and legume crops occupy the same space and same planting furrows / holes.
- Easier to cultivate using mechanical weeders resulting in better weed control.

Disadvantages

- Increased competition for water and nutrients in the same space.
- Shading effects on the legume may be higher.

(2) Alternate row systems

The alternate row systems involve alternating rows between the intercrops. However, it is important to ensure the main crop maintains the same planting density as in sole crop systems. For example, while maize may be spaced at 90 cm interrow, the legume crop such as cowpea needs to be planted in between the maize rows i.e. at 45 cm. between the maize rows.

(3) Double row cropping systems

The double row intercrop system involves two rows of cereal alternated with 2 rows of the legume crop. In other places this is known as the back to back configuration. In Kenya this arrangement is also popularly known as the Mbili system. Advantages are that the system allows more light to reach the lower legume crop and thus reduces shading on the legume intercrop. This system has been used successfully in Malawi and South Africa for maize/groundnut and sorghum/ legume intercrops and proved to be worthwhile.

(4) Strip cropping arrangements

Strip crops also work very much in the same way as double-row systems but in this case one may have 4 or 6 rows of legume alternating with 4 or 6 rows of cereal (Figure 6.2). The advantage

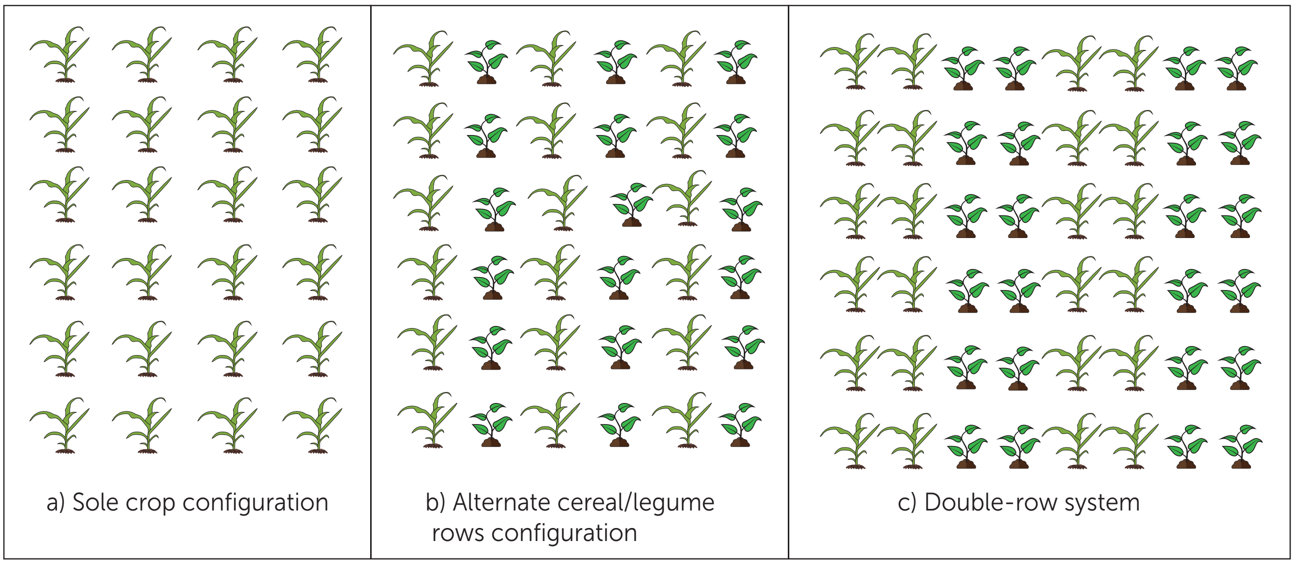

Figure 6.1. Different types of plant configurations in intercrops.

Figure 6.2. A typical strip cropping arrangement with 4 rows of maize and 4 rows of beans.

is again increased light penetration to the short legume particularly if the crop rows are oriented in an east west direction.

All in all, the important issue about planting configurations is that planting density employed for each of the component crops should match the average rainfall received in the area as well as the fertility status of the soil. In general, farmers are advised not to compromise the plant density of the cereal main crop which is the staple food.

(5) Relay intercropping

Relay intercropping is the practice of planting the legume intercrop a couple of weeks after the maize or cereal crop. For example, climbing legumes such as mucuna or velvet bean, are well known for strangling the maize crop to the extent that the maize yield gets compromised. To avoid this, such legumes are only planted much later in the season to enable the cereal crop to make a head start before the legume kicks in. As soon as the maize starts dying after maturity, the legume crop then reaches its peak and can continue to grow either on residual moisture or on terminal showers that fall towards the end of the main cropping season. Legume crops often relayed with maize include mucuna, climbing beans, *Tephrosia vogelli*, and *Crotalaria gramiana*. The suggested in-row and between row spacings for different legumes planted under the different plant configurations are presented in table 6.1 below.

Planting depths and when to plant in rainfed systems

If planting by hand it is important to ensure the following:

a) Ensure the seed (legume or cereal) is planted at a depth of between 5 and 10 cm.

b) Cover the seed with soil and press it firmly with your feet or hand to ensure the soil has good contact with the seed.

c) In rainfed systems, planting should only be carried out when the soil is wet at least in the top 20 cm depth. To achieve this, one needs at least 30 mm of rainfall being received in 2-3 consecutive days. After receiving this amount of rain planting should be carried out within 3 days of receiving the rain or else the soil becomes too dry for germination to take place successfully. Heavier or clay soils generally require more rain to get fully wet compared to sandy or light textured soils.

d) Soaking the seed by immersing in water overnight to ensure the seed germinates quickly after planting but ensure you only soak enough seed to be planted in the following morning. The seed may rot or get damaged if soaked for longer than a day.

Table 6.1. Recommended plant configuration arrangements for different legumes intercropped with maize.

Legume intercropped with maize	Alternate rows	Double rows	Strip cropping 4 rows maize/ 4 rows legume	Relay Cropping
Cowpea	80-90vcm x 10vcm	40-45 cm x 10 cm	45 cm x 10 cm	80-90 cm x 10 cm
Common beans	80-90 cm x 15 cm/75 x 10 cm	40-45 cm x 15 cm	45 cm x 15 cm	80-90 cm x 10 cm
Groundnut	80-90 cm x 30 cm	40-45 cm x 30 cm	45 cm x 30 cm	N/A
Soyabeans	80-90 cm x 5 cm	30-40 cm x 5 cm	40-45 cm x 5 cm	N/A
Pigeonpea	80-90 cm x 100 cm	N./A	N/A	80-90 cm x 100 cm
Mucuna	80-90 cm x 30 cm	40-45 cm x 30 cm	45 cm x 30 cm	80-90 cm x 30 cm

7 Weed control in intercrops

A weed is any plant that grows where it is not wanted and competes with cultivated crops for nutrients, moisture and light. Weeds are thus undesirable in any cropping system as they cause yield reduction through competition for the same resources needed by the cultivated crop and often interfere with crop harvesting. Weeds also provide a shelter for pests and diseases that can attack the cultivated crop leading to a reduction in crop yields and crop quality. The yield reduction from weeds can be a very serious problem in smallholder farming systems (Figure 7.1).

Studies conducted in Malawi in 2018 showed that returns to one weeding run were equivalent to 1000 kg/ha of maize in systems in which farmers weeded up to 3 times per season, meaning that each weeding enabled a farmer to harvest 1 extra tonne of maize. Elsewhere studies have suggested that the benefit of one weeding can be equivalent to 1 bag of top-dressing fertilizer. In maize, the most serious yield reduction due to weeds happens in the first 6 weeks of crop establishment.

Figure 7.1. maize crop heavily infested with weeds.

When should weeds be controlled?

Effective weed control starts all the way from the time of land preparation until harvest. Farmers should strive to prevent weeds from growing to the point of seeding as this helps to reduce the seed bank in subsequent seasons. Some weed seeds are thought to remain dormant for up to 20 years. Therefore to control weeds effectively the farmer needs to keep reducing the seed numbers that are dormant in the seed bank. Weeds are also the biggest challenge especially in the initial years of practicing CA. It takes about 3-5 years for the number of weeds in the soil to be reduced so that very few weeds grow. CA improves soil fertility; hence weeds are encouraged to grow as well. Couch grass and yellow nutsedge are the most difficult weeds to control because they are difficult to uproot.

Weeds are best controlled during the following times:

a) Soon after harvesting to prevent seed multiplication during the dry or off crop season.

b) After the rains but before harvest is important to manage winter weeds, minimize moisture loss and make harvesting easier.

c) During the cropping season weeds should also be controlled before or at planting e.g. through land preparation.

d) Weeds should be controlled before flowering.

How to control weeds

The intercrops increase the plant density and have a shading effect on emerging weeds. So generally less or fewer weeds emerge in intercrops compared to sole cropping. Weed pressure is also generally higher under the following conditions.

a. High soil moisture conditions: This may arise from excessive rains or residual moisture as the season tails off. The use of crop residues under CA also helps to increase moisture, and may also result in more weeds although residues are generally known to suppress weeds.

b. High fertility conditions. Fertile soils also create conducive conditions for weed growth. So it is important to ensure the improved fertility is not taken up by the weeds through effective weed control methods.

Apart from mechanical methods of weed control, chemical weed control methods using herbicides (Table 7.1.) are available in most countries but farmers should be careful when using these as they can kill the crop or may poison the user if recommendations are not properly followed. It is thus important for farmers to read the label on the chemical. Some herbicides such as glyphosate can kill everything that is green (non-selective), while others (selective) may kill broad leaved plants or grasses only (Tables 7.1 and 7.2).

The most widely used herbicide applied before planting is glyphosate. Glyphosate needs at least 4 hours free of rain after application and may be applied at the rate of 2-3 litres per ha. Further details on herbicides should be sought from local extension staff for farmers planning to use herbicides to help reduce labour pressure for weed control.

Table 7.1. Some recommended application rates for herbicide use in cereal crops.

Herbicide	Recommended rate (l/ha)	Weed species controlled	Notes
Round Up (Glyphosate)	• Sandy soil: 1.5-2.5 • Clay soil: 2.5-5.0	Couch grass , Wandering jew, *Ricardia scabra*, Striga, Sedges, Rapoko grass (*Eleusine corocana*)	Application rate will depend on weed species and height
Atrazine (Aat rex)	• Sandy soil: 3.6 • Clay soil: 4.5-5.5	Wandering jew, Mexican clover, Sedges, Witch weed, Black jack, some grasses	Use higher rates when weeds have emerged. Minimize runoff in fields treated with Atrazine
Paraquat (Gramoxone)	• Sandy soil: 1.0-2.0 • Clay soil: 1.0-3.0	Rapoko grass, Shamva grass, Couch grass, some broadleaves	Application rate will depend on weed height. Avoid contact with crop
Dual (Metolachlor)	• Sandy soil: 1.0 • Clay soil: 1.0-1.2	Couch grass, Rapoko grass, Shamva grass, Sedges, some broadleaves	Use higher rates for control of sedges
Basagran (Bentazon)	• Sandy soil:3.0 • Clay soil:3.0-5.0	Wandering jew, Mexican clover, Sedges, Witch weed	Application rate will depend on weed plant height
Accent (Nicosulfuron)	• Sand and clay soils: 46 grams/ha + a wetter, apply in 200-300 L water/ha	Shamva grass, Rapoko grass, Couch grass	Ensure good agitation of the mixture during application
Harness (Acetochlor)	• Sandy soil: 0.5-1.0 • Clay soil: 1.0	Rapoko grass, Shamva grass, Couch grass, some broadleaves	Normally used with broadleaf herbicide. Apply higher rates when used alone
Bullet (Alachlor)	• Sandy soil: 2.5-3.5 • Clay soil: 3.0-4.0	Rapoko grass, Shamva grass, Couch grass, some broadleaves	Apply immediately after planting

Table 7.2. Some recommended application rates for herbicides used in legumes and other crops.

Herbicide	Recommended rate (l/ha)	Weed species controlled	Notes
Round Up (Glyphosate)	• Sandy soil: 1.5-2.5 • Clay soil: 2.5-5.0	Couch grass, Wandering jew, *Ricardia scabra*, Striga, Sedges, Rapoko grass	Application rate will depend on weed species and height
Paraquat (Gramoxone)	• Sandy soil: 1.0-2.0 • Clay soil: 1.0-3.0	Rapoko grass, Shamva grass, Couch grass, some broadleaves	Application rate will depend on weed height. Avoid contact with crop
Dual (Metolachlor)	• Sandy soil: 1.0 • Clay soil: 1.0-1.2	Couch grass, Rapoko grass, Shamva grass, Sedges, some broadleaves	Use higher rates for control of sedges
Basagran (Bentazon)	• Sandy soil:3.0 • Clay soil:3.0-5.0	Wandering jew, Mexican clover, Sedges, Witch weed	Application rate will depend on weed plant height
Agil (Propaquizafop)	• Sandy soil: 0.5-1.5 • Clay soil: 2.0-3.0	Rapoko grass, Shamva grass, Couch grass	Ensure thorough agitation during mixing and spraying

8 Soil Fertility Management

Continuous production of a crop as sole crops, a practice called monoculture, usually results in a decline of soil fertility over time. The use of cereal-legume intercrops or rotations is one of the effective ways for improving soil fertility in cropping systems.

In general, legumes have the capacity to manufacture nitrogen through nitrogen fixation process. Cowpea, groundnut and pigeonpea, can fix high amounts of nitrogen into the soil (> 30 kg N/ha). In general, the higher the amount of biomass produced by the legume the higher the amount of nitrogen fixed. However, legumes such as soybean can fix nitrogen if the seed is inoculated or coated with a rhizobia inoculant that helps the crop to capture naturally occurring atmospheric nitrogen into the soil. The nitrogen is captured by the plant in root nodules. When the crop dies some of the nitrogen left in the soil can be taken up by the next crop thereby benefitting crops that come after the legumes. The use of legumes either as sole crops in rotation with maize or as intercrops increases yields as other nutrients apart from nitrogen is also activated to become available to the next crop because of the legume crop.

The most important nutrients required by crops in large quantities annually are Nitrogen (N), Phosphorus (P) and Potassium (K). Continuous cropping results in a decline of these primary nutrients and thus they need to be replenished through organic and inorganic fertilizers. Nutrients that are required in smaller quantities such as Sulphur, Calcium, Zinc, Iron, Molybdenum and others are often found in specialized fertilizers but can be found in sufficient quantities in organic manures.

Use of Manure

Apart from the nitrogen fixation from legumes, nutrients required by the crops can also be added to the soil through the use of organic manures from livestock such as cattle, goats, chicken and pigs. Organic manures may also be prepared through use of farm prepared composts. Local extension officers can advise farmers on how to prepare this type of manure from commonly decomposing organic manures. The use of such manures can save farmers from purchasing expensive mineral fertilizers and they also improve the soil's ability to hold water. Rates of application vary depending on the quality of compost or manure but in general 5 to 10 tonnes/ ha are needed. Application rates may be lowered if farmers apply the manure in rows or on planting stations instead of broadcasting. Composting and fermentation techniques are also commonly used to prepare farmyard manure using techniques such as Bokash manure.

Basal Fertilizer

Basal fertilizer is applied to a crop at planting and supplies nutrients needed by the crop in its early stages of growth and most of these nutrients are released slowly to the crop during the life of the crop (see Table 8.1). The main nutrient needed by maize at early stages of growth is phosphorus (P) and because of its limited mobility it needs to be applied at planting. Most basal fertilizers, also known in some countries as NPK, contain sufficient quantities of nitrogen to meet the needs of maize and other crops at early stages. About one third of the recommended fertilizer nitrogen (N) rate can also be applied at planting. The rest of the nitrogen needs may be supplemented through top dressing using Urea or other such fertilizers.

Farmers should seek the guidance of local extension staff on recommended fertilization strategies for their area and soils (Table 8.2). Most soils become acidic over time and periodic application of lime every 3 to 5 years is often recommended. Lime helps to reduce acidity in the soil. Farmers seeking to produce cash crops should also have their soil tested before cropping if suitable laboratories are available in their locality.

Topdressing Fertilizer

Top dressing fertilizers e.g. Urea, Ammonium Nitrate, are applied to maize and other cereals at 4 to 6 weeks after emergence to supplement crop with extra nitrogen. Common deficiency symptoms of nitrogen is yellowing of the crop and a dark green coloured maize crop is a sign of good or adequate nitrogen fertilization. Top dressing fertilizer is applied as side dressings in small quantities and in places of high rainfall may need to be applied twice as the nitrogen can get washed out of the soil by rainfall. Farmers should avoid applying top dressing fertilizer when the soil is dry as this causes fertilizer burn to the crop. Always ensure top dressing is done after receiving at least 20mm of rainfall.

Table 8.1. Fertility management techniques.

Fertility amendment	Recommended practice	Why is it important
Use of manures /composts	Organic matter management practices i.e. composting, green manure, farmyard manure • Ensure high quality of manures is kept	Build soil organic matter and improve soil structure and fertility
Mineral fertilizers	Use phosphorus and nitrogen fertilisers e.g. TSP, DAP, NPK, SSP • Use fertilizers with micro-nutrients and lime to improve soil responsiveness • Use the right methods and quantities • Check level of fertility or health of your soil to guide your actions	Improve soil fertility rapidly and improve crop production • Address the high nitrogen and phosphorus deficiency • Increase biomass production for soil cover • Build soil organic matter, improve soil structure and fertility
Lime	Use agricultural lime or dolomitic lime for soils deficient in magnesium Rates may vary from about 200-1500 kg/ha Use fertilizers with lime such as calcium ammonium nitrate	Reduce acidity or improve pH to between 5.5 and 6.5. Nutrient uptake improves when the soil is neutral or slight acidic Most mineral fertilizers make soil acidic so the use of lime helps to mitigate that effect.

Table 8.2. General recommended fertilizer rates for maize if no specific soil analysis or local recommendations are available.

Target yield (t/ha)	Nutrient requirements (kg/ha)		Basal fertilizer (kg/ha)	Top dressing
	Nitrogen	Phosphorus	DAP (kg/ha)	UREA (kg/ha)
2	30	10	60	40
3	60	20	120	80
4	90	30	180	120
5	100	40	240	160

9 Pest Control

Pest control is an important component of good crop management. Therefore, crops need intensive management, including close and frequent observations (walking in the field) to detect any discrepancies such as pests and diseases infestations and correct them before they can cause any permanent damage to crops. For maize the most common pest is the maize stalk borer and recently Fall Army Worm. For legumes such as cowpea, aphids are common problems. Stalk borer control is often quite easily achieved with granular pesticides applied on the funnel of the growing maize plants at 4 to 6 week leaf stages and insecticides are commonly available. However, the use of sand and laundry powders has been reported to work in some countries such as Malawi. Fall Army Worm is a more recent pest causing serious damage to maize and consequent yield losses of up to 30%.

The recommended cultural methods for FAW control are - use of intercrops and rotations with legumes has been reported to be effective in reducing Fall Army Worm Infestations, and early planting.

Figure 9.1. FAW damage to maize.

10 Harvesting and Post-harvest Management

In most smallholder farming situations harvesting crops requires considerable amounts of labour. Harvesting usually consumes 20-30% of the labour needed to produce a crop. Yield losses from late harvesting of crops may occur so farmers should ensure crops are harvested on time. Common challenges arising from late harvesting include the following:

- Weevils and other pests attack the crop.
- Crop may rot in the field before being harvested.
- Roaming livestock may feed on crop.

Crops that are being harvested may also get spoilt if rains come when the crop is heaped as this results in the crop rotting due to excessive moisture. Harvested crops should be allowed to dry sufficiently before threshing or shelling and stored in dry to avoid rotting.

Various drying option are available range from sun drying, solar drying and more advanced techniques employing electric drying systems. For maize drying may achieved through cutting and putting the standing stalks on stacks which allow it to slowly dry out further but without direct exposure to the sun. Alternatively, the cobs may be removed from the stalks when mature and dried in a raised crib with a roof for shedding to prevent direct sun heating and then thrashed on clean surface. Clean the grain by winnowing to remove any chaff or foreign objects. For maize grain to store well, the moisture content must be below 12.5%. Similarly for legumes the mature dry pods can be harvested and dried in the sun before threshing on a clean surface. Harvested grains are dried further, cleaned by winnowing and stored in appropriate conditions. For storage the grain must be below 11% moisture content.

Checking grain moisture content: To check if the grain is dry enough to be stored a simple technique is suggested here. A few grains are put in a dry glass bottle together with 2-3 spoons of salt. The contents can be mixed thoroughly for a few minutes and left for 15-20 min. If the salt particles are left sticking on the glass walls, it shows that they have absorbed some moisture from the grains. This is an indication that the grains are not yet dry indicating further drying is required. If the salt particles do not stick to the glass walls, it means the grain is dry enough for storage.

As soon as threshing/shelling has been completed the next step is usually to store the grain in a place where losses due to weevil attack may be minimized. Different types of storage methods are used from country to country and in different cultures. Post harvest losses of grain through weevil damage and other pests or diseases is thought to amount to between 20-30% in maize, thus impacting negatively on food security and income generation. This means farmers lose at least 20% of their little harvested grain to weevils such as the grain borers thereby further worsening the situation. Different grain storage methods are used in ESA and some of the most common are presented here.

Grain storage structure: Raised or suspended grain storage structures with compartments are used for storing different types of grain. Inside walls are plastered with a mixture of cow dung and clay. This allows aeration and exchange of gases with the outside and helps to keep the grain cool.

Metal Grain Silos: A metal silo is a cylindrical structure, constructed from a galvanized iron sheet and hermetically sealed (airtight). The metal silo technology has proven to be effective in protecting the harvested grains from attack not only from the storage insects but also from rodent pests. Any pests inside the silo die of suffocation as no oxygen can enter the the structure. Different sizes can be made, typically ranging from 100-3000 kg of grain and can cost between USD 30 to100 USD per unit silo.

Hermetic storage bags

The hermetic storage bags system originates from Purdue University in the United States. The bags are also commonly known as Purdue Improved Cowpea Storage (PICS) having been originally designed for storing cowpea in Chad. With the PICS system, farmers place their grain maize or cowpeas in a polyethylene bag and seal it by tying it with a string. This inner bag is inserted into another identical polythene bag and sealed with a string, and the double-bagged grain then inserted in a third woven nylon bag. The principle is like that of metal grain silos because in both systems air is kept out and this suffocates the insects or pests. All materials used for this are cheap and affordable to farmers, and PICS are increasingly available in cowpea-growing regions.

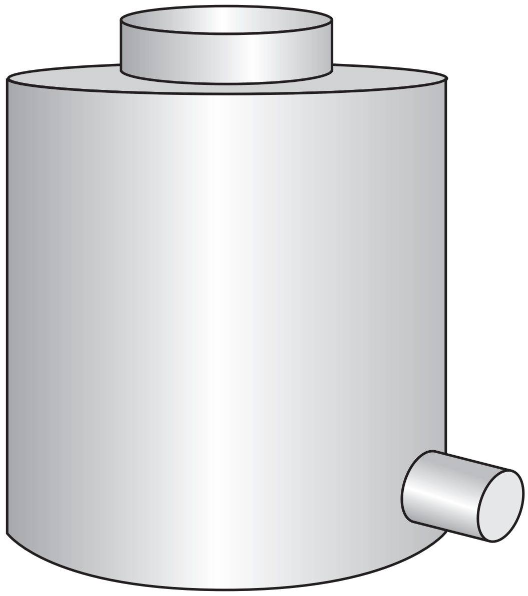

Figure 10.1. A typical grain metal silo.

Use of grain protectants

Farmers can treat grains with recommended storage chemicals to control damage by storage pests, especially if storing in containers that are not air tight. Grain protectants are commonly available in Africa and fairly affordable but as with all chemicals, farmers need to read the label carefully and follow the instruction while using.

11 Input and output marketing

Seed quality and access

- Good harvests start with good seed selection.
- Quality seeds are essential for the growth of strong and healthy crops which can resist diseases or even drought.
- Good quality seeds can be purchased from trusted sources like certified seeds stockists or agro-dealer shops.
- Farmers can produce their own seeds but seed selection and management are very important. Best seeds offer higher yields.
- Farmers should ensure the seeds are handled and stored properly. Poor storage of seed results in poor germination and vigour.

Factors to consider in Quality Maize and Legume Seed purchase

- **Adaptability**
  Selected maize and legume seed should be adaptable to the existing soil and climate conditions. It is important that the seed of choice is suitable for your area before purchasing.
- **Yield Potential**
  All things being equal, choose seeds with high yield, this will determine very much the profitability of your farms.
- **Cost of Seed**
  Farmers should purchase quality seeds within the limits of their budget. Remember a good quality seed cost more. Other indirect costs to consider when purchasing seed include seed handling and transportation.
- **Pests and diseases resistance**
  Seeds that are resistant to diseases and pests will help reduce risks and losses. Farmers should purchase quality seed of crop variety that are resistant to major diseases and pests common in their area. Though, it is always difficult to find seeds with all the desired traits on the market, choose seeds based on the most important yield limiting factors.

Understanding smallholder participation in maize and legume markets

- Market participation is the ability of smallholder farmers to participate in a market efficiently and effectively.
- Smallholder farmers market participation in Eastern and Southern Africa is limited due to biophysical, socio-economic and institutional factors. These smallholders face high transport and production costs due to geographic barriers such as remoteness or biophysical limits to productivity (e.g. water availability). Road infrastructure is poor, and this causes high transport and production costs; remoteness increases costs and reduces competition.
- Smallholder farmers in ESA have limited productive assets such as land, livestock, labour, and farm equipment which limit their capacity to produce and market any surplus.
- They face difficult and variable institutional arrangements including difficulties in contract enforcement conditions, product grades and standards, access to credit, insurance, and technical information through extension services and ICTs.
- They also lack commercial information, bargaining, screening, monitoring and coordination skills. Uncertainty about these raises the risks to farmers, which must be managed.

- Smallholder farmer due to these constraints tend to avoid risks.
- Risks come from adverse weather, pests and diseases, unstable prices and policy environments.
- The adoption of technology packages creates risks associated with production.
- They are also targeted by unscrupulous traders generating risk both in formal and informal markets.

Potential solutions for integrating smallholders into the markets

- Support socially inclusive market development through cooperatives, farmer commodity groups, auction markets and enforced forward contracts.
- Facilitate development and implementation of policies supportive of smallholder market integration.
- Technological solutions:
  - facilitate development and implementation warehouse receipt systems.
  - Improved access to market information, weather, pests and diseases information through use of ICTs, weather index-based insurance services for seeds and other inputs.
  - Reduce transport costs through use of e-commerce.
  - Facilitate access to subsidised credits and reduction of credit risks through collaborations of value chain actors.

Further readings

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Website: http://innovafrica.eu/

Knowledge Platform: http://kp-innovafrica.africabiosciences.org/

Disclaimer

Some of the information presented in this manual is general. Farmers should consult with extension agent for specific information regarding growing cereal -legumes in their farm. All persons using the information in this manual assume full responsibility for application of the recommendation made. The authors views expressed in this publication do not necessarily reflect the views of EU Horizon 2020.

Notes:

European Commission

Horizon 2020
European Union funding
for Research & Innovation

This work was supported by the European Union H2020 Research and Innovation programme under the grant agreement number 727201

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Food security through smallholder adaptability