










ASARECA

Transforming Agriculture for Improved Livelihoods

Quality protein maize production and post-harvest handling handbook for East and Central Africa



Quality protein maize production and post-harvest handling handbook for East and Central Africa

Godfrey Asea, Julius Serumaga, Zubeda Mduruma, Lydia Kimenye and Moses Odeke

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Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA)
Plot 5, Mpigi Road
PO Box 765
Entebbe, Uganda
tel: +256 414 320212/320556/321885
fax: +256 414 321126/322593
email: asareca@asareca.org
website: www.asareca.org

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The authors

Godfrey Asea
National Crops Resources Research Institute
PO Box 7084, Kampala, Uganda

Julius Serumaga
National Crops Resources Research Institute
PO Box 7084, Kampala, Uganda

Zubeda Mduruma
Aminata Seed Company
PO Box 6115, Tanga, Tanzania

Lydia Kimenye
Association for Strengthening Agricultural Research in East and Central Africa
PO Box 765, Entebbe, Uganda

Moses Odeke
Association for Strengthening Agricultural Research in East and Central Africa
PO Box 765, Entebbe, Uganda



Table of Contents

Foreword..... vi

Preface..... vii

Introduction..... 1

Soil type and land selection..... 3

Field preparation methods..... 4

Planting..... 6

Weed control..... 10

Some aspects of QPM seed and grain contamination..... 15

Soil nutrient management..... 17

Constraints to QPM production and control measures..... 24

Important features of quality in QPM..... 32

Harvest and post-harvest management of QPM..... 33

Value addition..... 43

The role of standards in maize..... 51

Definitions of maize defects..... 52

Essential composition of quality factors..... 54

References..... 56

Foreword

Maize will continue to play a very important role in the livelihoods of most of the population in East and Central Africa (ECA) to meet households' needs for food, feed and income. The development and release of quality protein maize (QPM) varieties, which contain high levels of protein has meant that it can be a substitute for the more costly sources of protein for human food such as meat and for fishmeal or artificial lysine used in the production of feeds for poultry and pig enterprises. The handbook was developed by NARS institutions in Kenya, Tanzania, DR. Congo, Uganda in partnership with the Knowledge Management and Upscaling Programme of ASARECA while promoting scaling out of the QPM technologies in these countries under a project known as *"Dissemination of New Agricultural Technologies in Africa (DONATA)".*

This handbook is a comprehensive one-stop source of information on how QPM is grown using recommended practices to achieve genetic potential of the varieties. It also contains management options for economically important diseases and insect pests, post-harvest handling and utilization. The practices documented in this manual are based on practical experience of researchers in the region who worked with farmers to identify common problems in production of QPM and to validate the improved practices presented in it. These can be applied to other types of maize and areas within the region that broadly fall within the same mega-maize environment.

It is my hope that this handbook will be useful to farmers and extension agents in their efforts to increase maize production and productivity and achieve targeted food and nutrition security and household incomes. I would like to thank authors and all other stakeholders who contributed to the production of this handbook.

About ASARECA

The Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) is a not-for-profit sub-regional organisation comprising 11 countries: Burundi, the Democratic Republic of Congo, Eritrea, Ethiopia, Kenya, Madagascar, Rwanda, South Sudan, Sudan, Tanzania and Uganda. Its mission is: *To enhance regional collective action in agricultural research for development, extension and agricultural training and education to promote economic growth, fight poverty, eradicate hunger and enhance sustainable use of resources in ECA.*

ASARECA brings together scientists and other partners to generate, share and promote knowledge and innovations to solve common problems in agriculture in member countries and contribute to productivity and growth of the sector. Its partners include farmers, national, regional and international research, extension, and training organisations, public and private sector actors, non-governmental organisations (NGOs) and development agencies.



Dr Fina A Opio
Executive Director, ASARECA

Preface

This book was developed under the 'Dissemination of New Agricultural Technologies in Africa' (DONATA) project whose purpose was to increase uptake and adoption of quality protein maize (QPM) technologies in the Eastern and Central Africa region (ECA). In ECA, maize is a dominant food and feed as well as a source of income for majority of rural households. In addition to overcoming food security concerns in the region, there is potential to address malnutrition in children and vulnerable groups who are at risk from consuming maize as the main staple food. Quality protein maize (QPM) contains twice the amount of essential amino acids required for growth by humans and monogastric animals. It therefore has an advantage over normal maize to ameliorate the effect of malnutrition cost effectively. Research efforts in the ECA region have developed and released a number of adapted and high yielding QPM varieties. However, average farm yields remain extremely low compared to the potential genetic performance of the varieties. One major reason for the big yield disparity is poor crop management and low use of inputs, especially fertilizers.

This handbook was developed based on experience with farmers over the years in a simplified manner for the users to identify common and major biotic and abiotic constraints that limit QPM production and management options to address them. The handbook is therefore intended for farmers, extension agents and agricultural practitioners. The book also provides an opportunity to disseminate and emphasize recommended agronomic practices for optimal QPM production. The agronomic practices used in this book are common and can be applied by farmers anywhere within the region who are within the same maize agro-ecological environment.

We wish to thank collaborating partners and institutions who have contributed to this handbook in various ways. In particular, Ms Rose Ubwe from Selian Agricultural Research Institute, Tanzania, Mr Charles Bett from Kenya Agricultural and Livestock Research organization and Dr Mbuya Kankolongo from INERA, Democratic Republic of Congo and Mr Isaak Mashauri of Tanseed International for their valuable inputs. We acknowledge reviewers who generously reviewed drafts of this handbook and provided useful comments. We also thank Ms Jacqueline Nyagahima, Head of Communication and Public Relations, ASARECA, for valuable editorial inputs.

Lydia Kimenye, PhD
Programme Manager, Knowledge Management and Upscaling ASARECA



Introduction

Maize (*Zea mays L.*) is one of the main crops grown in Eastern and Central Africa (ECA) as staple food by over 70% of the population. It has also become an important non-traditional export crop as well as being used for animal feed. However, the regional maize production is dominated by smallholder farmers whose production is generally characterized by small farm acreage (0.2–2 ha), low yields (1.0 –1.8 MT/ha) and high production costs and consequently low returns. Supplying maize grain with quality characteristics conforming to target markets is vital to increasing consumption and export value. However, normal maize contains limited contents of two essential amino acids namely Lysine and Tryptophan, hence having low quality of protein. Thus, use of normal maize without supplementing with other protein sources will lead to acute malnutrition. Quality protein maize (QPM), developed from a mutant maize, contains nearly twice the amount of Lysine and Tryptophan amino acids essential for protein synthesis in humans and monogastric animals as well as protein bioavailability that rivals milk casein (Nuss and Tanumihardjo, 2011). Therefore QPM can help to reduce malnutrition, improve body immunity and overall health in communities that are constrained by economic and environmental factors to access expensive sources of protein such as meat, fish, eggs, milk and legumes.

Agricultural research efforts in ECA in collaboration with International Center for Improvement of Maize and Wheat (CIMMYT) have resulted in development and identification of QPM varieties with higher yields and resistance to major biotic and abiotic constraints prevalent in all agro-ecologies. However, it's critical that QPM post-harvest handling processes are known by farmers in order to minimize losses and ensure food security and maximum benefits are achieved. Recent work in ECA has shown that QPM can be used wholly (100%) or as an ingredient (30–50% QPM) in preparation of composite flours to supplement wheat flour for bread, cakes, buns and biscuit preparation. Since farmers are able to grow their own maize, more savings would be made on more expensive wheat flour that is mostly imported. Thus, QPM can be a source of income for family and young entrepreneurs including women. Promotion of

such alternative uses of QPM can stimulate more production of this type of maize thus improving communities overall livelihood. This manual provides an insight of QPM quality aspects from post-harvest, storage and processing. This information will be useful to researchers involved in improvement and dissemination of QPM varieties, extension and development agents responsible for promotion of QPM technologies and farmers who need to improve the quality of QPM products so as to fetch good prices in the markets within and outside the ECA member countries.

Nutrition and QPM utilization

The purpose of Dissemination of New Agricultural Technologies in Africa (DONATA) QPM project is to increase uptake and adoption of QPM technologies in the ECA region. The ECA region has very high malnutrition rates where 32% of children under five are underweight for their age, and 45% under height (QPMD, 2006). In certain countries such as Malawi, Lesotho and Zambia that derive more than 20% of their daily energy from maize, young children are weaned on maize porridge that lacks sufficient protein and these results in nutritional disorders such as kwashiorkor (Rolfes, 2009). The ECA region has also been severely affected by the HIV/AIDS scourge that has had a negative impact on agriculture. Good nutrition is also known to ameliorate the conditions of the HIV/AIDS victims. Quality protein maize is advantageous over normal maize because it contains twice the amount of essential amino acids that are required for growth but usually insufficient in humans and mono-gastric animals such as poultry and pigs. Under smallholder farmer conditions, increasing dietary protein in maize is similar to raising income, because families benefit from enhanced nutrition without additional field work or spending scarce money on animal sources of protein such as meat and milk.

Nutrition is the process in which food is consumed, digested and absorbed. It has influence in promoting health, functions of all body processes, preventing disease and improving quality of life. Good nutrition should be combined with moderate levels of physical activity. Detection of growth faltering in children is based on underweight, stunting, wasting and growth velocity. Usually children under 10 years are expected to have weight and height gain corresponding to their age.



Soil type and land selection

Maize can be grown on a wide variety of soils, but performs best on well-drained, well-aerated, deep warm and silt loams containing adequate organic matter and well supplied with available nutrients. Although it grows on a wide range of soils, it does not yield well on poor sandy soils, except with application of required nutrients inform of fertilizers and good moisture regimes. On heavy clay soils, deep cultivation and ridging is necessary to improve drainage and aeration. Maize is suited for off-season cropping in swamps provided drainage is adequate (though planting in swamps is not always recommended due to its sensitivity to water logging). Maize does not tolerate water logging and can be killed if it stands in water for at least two days.

Maize can be grown successfully on soils with a pH of 5.0–7.0 but a moderately acidic environment with of pH 6.0–7.0 is optimum. Soils with pH outside this range results in nutrient deficiency and mineral toxicity. Liming and other soil amendment practices are required for good yields on more acid soils. Maize has a high nitrogen requirement and high yields (of maize) make a heavy drain on soil nutrients. High yields are obtained from optimum plant population with appropriate soil fertility, and adequate soil moisture. Where possible, it's advisable to have soils routinely analyzed in order to know the characteristics of the soils, levels of available soil nutrients and get advice from researchers on how to improve soil fertility and/or correct soil pH for optimum maize production.

Temperature

The optimum temperature for plant growth and development ranges from 30°C to 34°C. The cool conditions at high altitude lengthen the cycle or growing period (up to six months). Temperatures below 5°C and above 45°C result in poor growth and death of the maize plants. In general, temperatures in ECA are favorable for maize production as long as appropriate varieties are grown in areas for which they were bred. For example, highland maize is suitable for highland areas. In ECA, there are varied agro-ecologies with potential for maize production provided that appropriate varieties that are adaptable are grown.



Field preparation methods

Conventional methods

There are many methods of land preparation for growing maize, including the following:

- Hand hoeing;
- Animal traction (oxen plough);
- Conventional tractor;
- Walking tractor; and
- Conservation tillage

Hand hoeing—In ECA countries, the majority of maize farmers are small scale and use hand hoes for land preparation. The method is slow and labour intensive.

Animal traction—This involves the use of oxen to plough the land. With this method the farmer is able to open more land and plant more maize as compared to hand hoe. It is however not appropriate where soils are heavy and terrain is steep. It also requires the acquisition and management of the oxen (figure 1).

Conventional tractors—These are mainly used by progressive farmers (large and medium scale) on hire basis or owning them. Due to high purchase cost, lack of spare parts in the rural areas and high fuel cost, even hiring them is not affordable to most farmers.

Walking tractor—This is an appropriate and proven technology for small and medium scale farmers. It is fuel efficient and cost effective, though it might not be efficient on heavy soil because of the their low power. The tractor is multi-purpose and easy to use. However, most farmers are not aware of the benefits of this type of tractor, probably because it is still new technology on the market.

Conservation tillage—This method is used by large and medium scale farmers. In this system, maize is grown with minimal cultivation of the soil. The stubble is not completely incorporated and thus contributes to run off control. It allows timely planting at a reduced cost of land preparations. Weeds are controlled using cover crops or herbicides rather than by cultivation. Fertilizers and lime are either incorporated earlier in the production cycle or placed on top of the soil at planting.



Figure 1: Using oxen to plough land

Field management practices

A fairly rough seedbed is preferable since it enhances water infiltration and prevents water run off to a greater extent than a fine seedbed, while allowing germination and seedling emergence to take place. When planting is to be done by hand, each seed can be placed at the correct depth of about 5 cm by hand even on a rough seedbed. With machine planting, a fine seedbed is necessary to avoid interference from large soil clods. Well prepared seed bed will allow uniform and rapid germination and crop establishment, hence creating a relatively weed-free environment. However, a fine seedbed has the risk of soil erosion (especially when the field is on a slope), silting and soil compaction which often leads to poor aeration. For proper germination, maize requires moist soil. This should be taken care of no matter what type of land preparation to be used.



Planting

When planning to grow maize crop, there are three major considerations to be taken into account. These include:

i. When to plant;

ii. Depth of planting; and

iii. Plant population.

I. When to plant

Usually the first season rains normally start in mid-February or March and end in June, while the second rains start around mid-August to December. Planting is generally recommended to be done at the onset of rain but since maize is a robust crop, dry planting can be done when rain is expected. In dry planting, seeds are placed in dry soil when rainfall season is one or two weeks to start. Dry planting is advantageous because it spreads out the planting duration hence enabling the farmers to open up more land. Delayed planting in relation to the onset of rains will lead to reduced yield. When maize is planted late, the critical growth period at flowering will coincide with drought that will make the crop become stressed and lead to poor grain filling. The suitability of the varieties has been taken into account by the breeders when they categorized them as early maturing (85–90 days), medium maturing (105–115 days) and late maturing (120–150 days). The information regarding maturity groups of maize varieties should be taken into consideration by farmers when choosing a variety for cultivation. However, time to plant is not such a critical factor when one has irrigation facility in place.

Calendar of activities

It is important that a calendar of activities is drawn with farmers so that all activities from planting to harvesting are clearly indicated and carried out according to schedule.

As shown in Table 3, maize production takes place at different times of the year in the different districts of Uganda. This therefore ensures a stable supply of maize throughout the year. The peak harvest seasons are given as January –March and July–August. This crop calendar is just indicative but may also be used in other ECA countries with similar agro-ecologies to that of Uganda. However, breeders and extension

Table 1: Example of maize production calendar in Uganda

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
			1st Rains					2nd Rains				
Iganga	2nd Harvest		1st Planting				1st Harvest 2nd Planting					
Mbale			Planting				Harvesting					
Kapchorwa			Planting							Harvesting		
Kasese	2nd Harvest		1st Planting				1st Harvest 2nd Planting					
Masindi	2nd Harvest		1st Planting				1st Harvest 2nd Planting					
Uganda	Peak Harvest						Peak Harvest					

workers in other ECA States with different agro-ecologies from that of Uganda are encouraged to draw-up appropriate crop calendar(s) related to rainfall pattern in their respective countries.

II. Depth of planting

The first step in planting is to determine seed viability (if this was not indicated on seed bag) by conducting a simple germination test using any one of the following materials: saw dust; sand, or news papers. This operation will help the farmer to know the status of seed at least few days before the actual planting of the maize crop.

Planting depth depends on the moisture level of the soil where depth of 2–3 cm is adequate for moist soil and 5–10 cm is recommended for dry planting. Deep seed placement under dry planting is recommended so that seed germinate only after adequate rains. However, the depth of planting should be uniform to allow uniform seedling emergence, crop establishment and plant growth.

III. Plant population

The recommended spacing for planting maize is 75 cm (2½ feett) between rows and 30 cm (1 feet) between hills when planting one seed per hill. When plant population of 2 seeds per hill is desired, a spacing of 75 cm (2½ feet) between rows and 60 cm (2 feet) between hills is recommended. With this spacing the amount of seed required will be 25 kg per hectare or about 10 kg per acre. However, spacing between hill within a row is dependent upon variety maturity groups. For example, when planting an early maturing maize with a population of 2 seeds per hill, an intra-row spacing of 40 cm (between hills) is appropriate; while intra-row spacing for intermediate and late maturing varieties is in the range of 50–60 cm (between hills).

Plant populations that are higher than the optimum will lead to competition among the maize plants resulting into thin plants that will give low yield. Lower plant populations will result into low yields (though with bigger cobs) due to reduced number of ears per unit area. It might be appropriate under intercropping but may lead to increased weed intensity when maize is under monocropping system. The maize crop should be planted in rows to allow for easy field operations like weeding, field inspection as well as facilitate harvesting. Without planting in rows, a farmer will never achieve an optimum plant population.

Methods of planting

Planting of maize can be done either by hand or mechanically.



Figure 2: Well-planted maize field

a) Hand planting

Hand planting is the most commonly used method in most ECA countries. If properly used, the method can produce excellent results because it gives a proper and uniform plant stand. The general planting procedures usually include the following:

The field is marked out using a string at an inter row distance of 75 cm (1½ feet) apart; another string for intra-row spacing between hills marked at 30 cm. This is only true for plant population of 1 seedling per hill. The marking of strings for planting early maturing maize varieties at population of 2 seedling/ hill will be 75 cm and 40 cm between rows and hills, respectively. Similarly, spacing between rows and between hills within rows for an intermediate/a late maturing variety is 75 cm and 60 cm, respectively. With experience, farmers can estimate the distance without the string.

After marking of the field has been concluded, then;

- Divide the field team into three for the following activities:
- Holing out (digging of holes along the 30 cm mark on the string);
- Placement of fertilizer and its covering; and
- Planting and final covering.
- Make holes with 2 or 3 strokes of the hoe to a depth of at least 10 cm to allow for fertilizer, soil, seed and the final covering.
- Place the fertilizer at the bottom of the hole and make sure it does not get spread over the soil surface where it will be wasted.
- If you are using corrosive fertilizer like diammonium phosphate (DAP) and urea, place the fertilizer and cover lightly with soil to prevent damage to the seed. Most other fertilizers can be placed in the hole with the seed without separating them with a layer of soil.
- Place the seed and make the final covering with the soil. Make sure that the seed is well placed in a hole to ensure good contact with moisture. All seeds must be well covered.

b) Mechanical planting

This type of planting has the advantage of being quick, and if well supervised will give excellent results. However, if it is poorly supervised, it will give poor to disastrous results. This method allows planting of a large acreage within pre-determined planting period. A compatible spacing with other mechanical operations like fertilizer application and weeding can be implemented. Check the machine well before the anticipated planting date to make proper adjustment.



Figure 3: Marking of the field using strings

Always read the operator's manual and seek advice from the suppliers for effective usage. Every season, make sure that the planter is calibrated to avoid making costly mistakes. Below are some guidelines for calibration:

- Each planter must be tested separately.
- Select plates that will allow the largest seed of your seed sample to go through. Make sure the plate does not allow two seeds at a time.
- After determining an optimum plant population, choose a cog set that drops 10 –15% more than the desired seed rate.
- Make sure that the driving wheel drops seeds in the furrow opener.
- Count the number of seeds dropped by the planter over a measured length in the field at a set driving speed. The number can be multiplied to get total number dropped per hectare. The correct operating speed (e.g. 5 km/h) is normally indicated in the operator's manual.

Supply of seeds

To ensure near-perfect to perfect plant stands in a maize field, missing stands can be replanted from the remaining seeds. This process is termed as gap filling. This operation should be carried out 5–7 days after planting (since maize seedling takes up to 5 days to emerge).



Weed control

A weed may be defined as any plant that is growing where it is not wanted (Altieri and Letourneau, 1982). Thus, in a crop field, all plants other than the crop(s) planted in the field are weeds. Weeds if not controlled can cause significant yield losses. Therefore, weeds in the maize fields should be controlled for the following reasons:

- Weeds compete with maize crop for nutrients, water, light and space.
- Some weeds can be poisonous to both humans and livestock.
- Weeds can harbor pests and diseases that may attack crops, and interfere with harvesting.
- If weeds are not controlled properly crop yields will be reduced by up to 50%.

Weed competition

The most critical period of weed competition is during the first 4 to 6 weeks after seedling emergence. Weeds thrive better than the maize crop under marginal environmental conditions, including moisture stress (drought stress). A maize field may be infested with broad-leaf or narrow-leaf weeds, or with a mixture of both. If crops are kept weed-free during the early stages of plant growth, yields will not be affected significantly. At later stages the maize plants will be well established and out-compete the weeds. Although early weeding is critical to producing a good yield, weed control at later stages is also important in preventing the weeds from flowering and producing seeds, which would increase weed load in subsequent seasons. Harvesting maize fields is also easy if the crop is weed free. Weeding of a maize field at least twice (at 4 and 8 weeks after planting) are required to keep the field weed-free until harvest. It is important to note that the first weeding can be done manually (by hand hoe) but the second one (8 weeks after planting) could be carried out by use of herbicides to avoid root damage.

Farmers and weeds

Farmers should become familiar with the types of weeds present in their fields. For instance, broadleaf weeds should be distinguished from grasses. The farmer needs to learn which weeds are annuals (i.e. with life span for only one

season) or perennials (i.e. live for more than one year). This will help in designing appropriate control measures for the weeds, especially in the application of chemicals.

Types of weeds

Weeds can be categorized as annual and perennial.

• Annual weeds

These types complete their life cycle within one season; e.g. black jack. The seeds they produce will germinate even faster than the maize crop and are able to survive by producing a lot of seeds that will germinate in the next season. After planting the maize, usually annual weeds will germinate faster than the rate at which maize seeds will germinate. They interfere with the growth of the crop during the critical period within first three weeks. One of the most notorious weeds in maize production is *Striga* (figure 4). *Striga* spp. are parasitic weeds that attack mainly cereals like maize and other crops such as sorghum, millet and upland rice. In Uganda, there are two species of economic importance; *Striga* hermonthica and *Striga* asiatica. Yield losses attributed to *Striga* in maize can go up to 100% at farm level (Kanampiu and Friesen, 2004).

• Perennial weeds

These are weeds that are always in a maize garden all the time every year. They multiply through roots and stems e.g. couch grass. Mechanical weeding only cuts off the top parts while the bottom parts of the weeds continue consuming nutrients and water meant for the maize plants. These weeds should be controlled early before the beginning of the season as later attempt to control them will damage the crop, especially the roots.

Methods of weed control

(i) Prevention—Practices that prevent the introduction, propagation, and spread of weeds. For example: destroying the weeds before they set seeds, planting weed-free seed, using clean equipment on the farm, and keeping the field margins clean to prevent weed invasion.

(ii) Cultural—Cultural practices such as crop rotation, intercropping and mulching help to control weeds.

(iii) Manual—Practices whereby human energy is directly utilized to remove the weeds. This involves hand weeding using hoes or pangas, hand pulling, hand slashing and push-type weeders. However, hand weeding is so slow and labor intensive that may make weeds catch up with maize crop.

(iv) Mechanical—This involves the use of farm tools and implements such as hoes, cultivators, pangas, and a clean seedbed



Figure 4: Severely infested *Striga* fields

preparation to control weeds. In addition to clean seedbed preparation, it is usually necessary to take other measures of weed control such as inter-row cultivation. Weeding should be done twice or three times and it must start as early as possible because a young maize plant is very sensitive to weed competition. It should start when the crop is about 7.5 cm high but once the crop is about 45 cm tall, weeding should not be necessary except in a few cases where there are favourable conditions for weed growth. At 45 cm, the leaves of vigorous maize plants will start covering the ground to suppress weeds. In addition, weeding after this stage will destroy the root system. For successful inter-row cultivation, farmers should note the following:

- Start inter-row cultivation when the weeds are still in their seedling stage.
- Do the cultivation when there is moisture in the field.
- Where possible, carry out inter-row cultivation when the sun is hot so that weeds die immediately after cultivation.

Weed control using mechanical methods has several disadvantages such as cost and distance to cover given fragmented land tenure systems.

(v) Chemical—Involves the use of herbicides selected for the soil, crop, weeds and stage of crop development. For instance, after the maize seed has been planted, atrazine (pre-emergence herbicide) can be applied to kill the weeds before they emerge. Atrazine, usually applied immediately after planting, controls most annual broadleaf weeds and some annual grasses. It is recommended for use on soil with more than 35% clay.

For successful weed control it is best to carry out the procedure when the weeds are still small, before competition sets in. It is recommended to use a combination of the methods to reduce weeds (Integrated Weed Management) as no one weed control method can meet the needs of any crop all the time.

Advantages of using herbicides

- Saves time in controlling weeds.
- Reduces the chance of damaging roots.
- Helps in controlling perennial weeds that are difficult to control by cultural and mechanical methods.
- Decreases the amount of tillage and allows a farmer to benefit from the advantages of reducing tillage operations.

Disadvantages of using herbicides

- All herbicides are poisonous. If they are not handled and used carefully, can be harmful to man, non-target plants and pollute the environment.
- Some herbicides have long term residual effects and thus may damage crops grown on the same field the following season.
- The use of herbicides requires technical skills acquired through training and guidance.

The advantages of using herbicides outweigh disadvantages. Thus, farmers are encouraged to use herbicides where applicable and safeguard against disadvantages through:

- Sticking to recommended herbicides for maize and recommendations for their safe use.
- Good understanding of the type, functions and purpose of the different herbicides on the market. This information can be obtained from the manufacturer as per label and stockists of herbicides, National Agricultural Research Institutes, Department of Crop Science at Universities, Agricultural Extension Officers and other relevant Agricultural Institution in ECA dealing with herbicides. In order for farmers to have good understanding on herbicide use, they should:



Figure 5: A stockist shop that handles herbicides

- Make efforts to visit stakeholders highlighted above
- Attend field days, workshops and seminars
- Visit demonstrations that stockists use to educate farmers on proper use of herbicides
- Read the label on each package of herbicide before use and follow the instructions as indicated.

The most commonly used herbicide for maize is Lasso plus Atrazine applied at the rate of 5 litres per ha (2 litres per acre) at the time of planting, will control grasses and broad leafed weeds effectively. Gramoxone, and Glyphosphate (2,4-D) at 1 litre/ha can also be used for control of broad leaf weeds before maize is 45 days old. Perennial weeds are controlled by application of 3 litres of Glyphosate per hectare.

Cultural practices for weed control

Cultural methods of weed control use practices common to good land and water management. These include planting clean seed free from weeds, planting crops at the right spacing, planting cover crops, using mulch, crops rotation, and intercropping.

Plant spacing—Plants spaced closely will develop a dense cover quickly and shade the weeds that try to grow and compete with the maize crop in the field. However, plant spacing should not be too close since this causes negative competition between the maize plants. The ideal spacing will depend upon conditions in which the crop is grown. Closer spacing is possible in favorable growing conditions including fertile soils and adequate moisture, whereas in drought-prone environments and soils with low levels of nitrogen (Low N), wider spacing is advisable.

Cover crops—Growing cover crops that develop quickly will help to suppress weeds before they grow. Some cover crops (such as black oats) control weeds by producing chemicals that prevent weeds from growing.

Mulching—Covering the soil with mulch makes it difficult for weeds to grow because they do not have enough space or light required for growth. Mulch should, however, be selected carefully. Mulch should not include flowers and seeds of

weeds, otherwise they may introduce more weed seeds into the field.

Crop rotation—Rotating crops helps to break the life cycle of certain weeds and pests common to a particular crop. Use of Mucuna beans (velvet bean) in rotation with maize, particularly in a field infested by spear grass (*Imperata cylindrica*) helps to reduce the population of the spear grass.

Chemical methods

This method of weed control makes use of herbicides. A herbicide is any chemical that has phytotoxic properties, which make it suitable for use as an agricultural chemical for weed control of weeds. However, there are resistant weed types for each herbicide. Therefore farmers should not expect 100% kill of all the weeds by application/use of herbicides.



Some aspects of QPM seed and grain contamination

Production of QPM seed is not different from the production of normal maize seed. The same stick standards (isolation distances, maintenance of parental lines, etc) of maize seed production must be followed (Beck, 1999). The only additional requirement to meet the standards for QPM seed is that the seed produced must be sent to the laboratory for tryptophan and protein analysis to ensure that the values are above the required minimum.

Brief description of QPM seed classes

1. Breeder's Seed—is the seed produced by the breeder in a small quantity (from a small plot), either by use of isolation (distance, time) or hand pollinations. In order to ensure the protein quality and endosperm modification of seed productions, it is recommended that QPM breeder's seed be produced in half-sib isolation blocks (Vivek et al., 2007). The responsibility of the breeder's seed production rests with the breeder.
2. Foundation Seed—is the increase of the breeder's seed in a reasonable quantity that can be use for demonstrations and adoption studies. The responsibility of the seed production rests with the seed companies and breeders. The QPM foundation seed producers should ensure that they produce their seed from fresh stock of breeder's seed (in case of open pollinated varieties) and from fresh stock of parental lines (hybrids). Quality check is maintained by sending representative bulk sample of the foundation seed for regular protein quality analysis.
3. Certified/commercial seed—is the increase of foundation seed. The responsibility of production of this class of seed rests with seed companies with supervision of seed inspectors. Use of isolation plots is the most preferred method employed in the production of certified seed. Some seed companies work with contract growers or progressive farmers to produce certified seed.

In order to produce good quality QPM grains, farmers are advised to buy seeds from reputable seed companies or agricultural institutions dealing in seed production. Care must be taken when choosing a source for QPM seed for production of quality grains.

QPM contamination in farmer's fields

Studies (Ahenkora et al., 1999; Twumasi-Afriyie et al., 1996b) have shown that planting a QPM field near/next to a normal maize field does not completely change the entire harvest QPM to normal maize but rather induces levels of contamination ranging from 0 to 11%. Also, farmers do not lose the entire benefit of QPM under normal farming conditions where normal maize farms may be in the vicinity (Vivek et al., 2007).



Soil nutrient management

Soil fertility

Properties of a fertile soil

Soil fertility is defined as the ability of the soil to produce and sustain high yields indefinitely. The properties of a fertile soil that can support the growth and yield of a good maize crop include the following:

- Good depth that affords plant roots greater volume to exploit.
- Good drainage to avoid water logging.
- Good aeration to promote healthy root development and functioning.
- High water holding capacity. Maize needs moisture that is evenly distributed throughout the growing season with the highest requirement at tasseling.
- High level of nutrients. Maize has high nutrient requirements, and the nutrients should be in a form that is available to the growing plants.
- Optimum soil pH—maize grows well in the soils with pH ranging from 5 to 8.

Loss of soil fertility

In farming, soil fertility may be lost through many ways. Some of the ways are as a result of the farmer's activities while others may be out of his control. Some of the common ways in which soil fertility may be lost include the following:

- Soil erosion where the top soil is blown or washed away by wind or water.
- Soil capping which involves formation of an impervious layer of soil on the surface of the soil which obstructs rain infiltration, leading to runoff.
- Development of hard pans a short distance below the surface of the soil. Hard pans may be caused by repeated ploughing at the same depth.
- Loss of organic matter through rapid oxidation by soil micro-organisms due to unduly too frequent cultivations.
- Leaching in which rainwater removes mineral salts from the top to the lower layers of soil where they become unavailable to crops.

- Crop removal which breaks the natural cycle and prevents nutrients contained in the crop from returning to the soil that provided them. Supply of available nutrients is thereby depleted. The soil is therefore like a bank from which deposits have been withdrawn and need replenishment.
- Weeds which compete with crops for nutrients.
- Change in soil pH associated with incorrect use of certain fertilizers which sometimes changes in the soil pH.
- Burning: burning of bush, grass or crop residues before cultivation exposes the land and leads to soil erosion. During burning, the heat destroys several plant nutrients in the soil whereas some essential elements are lost in the form of gases. Burning also destroys useful soil organism.
- Toxicity due to accumulation of salts, micro-nutrients such as manganese, iron, aluminum, boron, molybdenum, fluorine, etc, can poison the plants if present in excess.

Methods of improving soil fertility

There are many ways of improving soil fertility. The most important and common methods of maintaining and/or improving soil fertility include the following:

- Improvement of nutrient-retaining ability of a soil by adding organic manures (green manure, farm yard manure, etc.) to the soil.
- Improve drainage by breaking down surface capping and hard pans of the soil using implements.
- Practice crop rotation. Crop rotation means growing different crops in an ordered sequence on the same field. The objectives of crop rotation are to conserve soil, maintain nutrient balance in the soil, control weeds, diseases and pests by growing a variety of crops, which have significantly different growth habits, nutrient requirements, pests and diseases in sequence. A good rotation of maize must include a good leguminous crop (soybean, groundnut, cowpea) for improving the nitrogen level of the soil. Nitrogen is obtained from the air by legumes, which fix it with help of bacteria in their root nodules. Groundnuts, soya bean and to some extent common beans fix nitrogen. Maize grown after a leguminous crop will benefit from this nitrogen.
- Minimum disturbance of soil e.g. zero tillage to conserve its organic matter content and moisture.
- Soil conditioning e.g. by liming or using acidic fertilizer as may be appropriate to maintain soil pH
- Weed control to reduce depletion of nutrients by weeds
- Use of both organic and inorganic manures
- Moisture conservation by use of mulches
- Erosion control

Organic manures and chemical fertilizers

Materials added by farmers to replace those lost from the soil are called soil fertility amendments. These can be classified into two main groups:

- Organic manure; and
- Inorganic fertilizers.

Organic manures

Organic manures are the fully decomposed organic matter and are derived from plant and animal residues. The organic manures are further classified into the following groups:

(1) Farmyard manure (FYM)

(2) Compost manure

(3) Green manure

(4) Organic mulches

Where possible, farmers are encouraged to use organic manures because they maintain soil structure, improve water holding capacity and improve aeration in addition to providing the

majority of nutrients required for plant growth. In comparison to inorganic fertilizers, farmers can make their own organic manures or obtain from local sources at affordable prices as compared to inorganic fertilizers.

Methods of application of organic fertilizers

Surface application before planting- where quantities of organic manures are put in different parts of the field ear marked for maize planting and spread uniformly. The manure is then ploughed down so that it well incorporated into the soil before planting.

Spot application- where properly decomposed manure is either applied around the maize plants or between the rows of maize plants. The manure is then incorporated into the soil during weeding.

Inorganic fertilizers

These are mineral fertilizers containing high quantities of plant nutrients. The inorganic fertilizers provide specific chemicals, which may be lacking in the soil. In order to obtain maximum yield of the maize crop, it is advisable to use the correct rate, type and method of application of the fertilizers.

Nitrogen is commonly supplied not only by the application of Urea but also Calcium Ammonium Nitrate (CAN) as well as (N-P-K) which is sold as 25-5-5 and 17-17-17 that also supply other nutrients. The source of phosphorus commonly used in Uganda is Diammonium Phosphate (DAP) which is 48% phosphorus and 18% nitrogen. Other sources of phosphorus are Single Super Phosphate (SSP) and also Triple Super Phosphate (TSP) which can supply phosphorus Calcium and some Sulphur. No deliberate efforts are being made to apply potassium except for the amount supplied in the application of N-P-K which has varying amounts of nutrients depending on the formulation. For example, 17-17-17 NPK means that a bag of the fertilizer has 17% nitrogen, 17% Phosphorus and 17% Potassium. Nutrient combinations of NPK are usually indicated on the bag.

Method of application of inorganic fertilizers

Three methods are used to apply fertilizer. These are: broadcast, drill application and point application.

Broadcast application is when the fertilizer is applied all over the area. This is good for nutrients such as phosphorus that stay in one place for a long period of time, especially when it is incorporated into the soil. The fertilizer applied this way will benefit all the crops planted in the area and would be suitable in situations where

Table 2: Types of inorganic fertilizers commonly used in maize production

Source	N (%)	P (%)	K (%)
Nitrogen			
Urea	46		
DAP	18	48	
CAN	27		
Phosphorus			
DAP	18	48	
SSP		18	
TSP		46	
Muriate of potash			60
Sulfate of potash			52

maize is planted in a mixture with other crops. The main disadvantage is that it is spread too thinly and would not be sufficient if the farmer can only applies small amounts. However, broadcasting of fertilizers will encourage weed growth especially where weeds are controlled by weeding using hand hoeing. It is advisable to determine the rate of fertilizer(s) to be applied before the actual application is carried out.

The drill method is when the fertilizer is applied as a drill in the seed fallow. It has the advantage in that little fertilizer is applied but has the disadvantage of the fertilizer not benefiting the crops that are not planted directly along the seed fallow/ line.

Point application is where fertilizer is applied in the vicinity of the plant, this could be around the plant or under the seed or with the seed in the same hole. It has the advantage of applying the fertilizer where the plants can use it, and little fertilizer will cover a large area. This method of fertilizer application mostly benefits the crop. It is efficient and commonly used by small scale farmer in Uganda. DAP is applied in the seed hole, lightly covered with soil after which the seed is dropped in the same hole before covering. DAP is covered with soil because of its corrosive nature that would otherwise kill the seed. Single and Triple super Phosphate can be applied in the same seed hole and covered in one operation. Nitrogen fertilizers are applied at the base of the plant and incorporated into the soil. Incorporation is necessary to avoid loss as runoff and loss to the atmosphere in case of most nitrogen sources.

Rate of application of Inorganic Fertilizers

The amount of fertilizer to be applied will depend on the initial soil fertility, the expected yield and other factors that affect crop production. If the soil is fairly fertile, the additional fertilizer will be less than in the case where the soil fertility has been used up.

Yield of one ton (1000 kg) of maize grain takes from the soil 24.3 kg Nitrogen, 10 kg of phosphorus and 21.14 kg of Potassium. Thus, if a yield of 4 tons of maize is expected, the fertilizer application should aim at 97.2 kg of nitrogen, 40 kg of phosphorus and 85.6kg of potassium. Fortunately, a fair percentage of these minerals are being supplied by the soil.

At smallholder farmer level, the general recommendation is to apply one bottle-top cover of DAP per hill at planting and apply 2 bottle tops of Urea at about 6 weeks after germination. This rate of application is recommended for spacing of 75 cm (2.5 feet) between rows and 60 cm (2 feet) and two plants per hill.

The rates above are just indicative. The amount will vary depending on the plant population and soil fertility at the beginning of the season. In areas with reasonable levels of soil fertility, one might find that there is no need to apply DAP. In some cases one cap of urea per hill might be sufficient. Since fields differ in fertility, it is recommended that farmers together with researchers carry out some trials on a smaller area to determine the rate at which they can apply fertilizers to their crops. The extension staff will be helpful in

Table 3: Fertilizer recommendation for a smallholder farmer

Fertilizer type	Application rate using bottle top cap	
	Rate (kg per ha)	Rate (kg per acre)
DAP—one cap per hill	94.22	38.13
Urea—2 caps per hill	144	58.28

conducting such field trials. Farmers will require services of extension staff to help them estimate the appropriate area for a given quantity of fertilizer(s) to be applied.

Although its merits outweight demerits, inorganic fertilizer(s) is expensive and might not appear affordable by most small scale farmers. It is important to make decision as to whether it is necessary for all the farmers to apply inorganic fertilizers. Although the stockists normally sell fertilizers in 50 kg bags, some distributors package it in smaller weights such as 1 or 2 kg which is more affordable and farmers can at least get part of the field fertilized, especially if they are able to identify the poor spots within the field/ plots in good time during growing season.

The above rate is for the small scale farmers who normally apply fertilizer per hill. In the case of larger farmers, it is vital that the rate of fertilizer to be applied as determined after the soil has been tested by qualified soil scientists. Then rates can be recommended for a particular farm based on the soil analysis results.

Time of application of inorganic fertilizers

Nitrogen moves in the soil with water and will be easily lost by sinking deeper into the soil where roots will not get it. It should therefore be applied near the time when the plant needs it most. This explains why only a little quantity of nitrogen is applied at the time of planting and the bulk of it supplied 6 weeks later when the plants are beginning to need it most. Phosphorus does not move in the soil, which means, it can be applied at planting during the season (supplied by DAP). This is convenient especially as it is required for the development of the root system. It should be incorporated, as much as possible, in the soil for even distribution in the root zone. However, Potassium moves in the soil (similar to nitrogen) and, should therefore, be applied when the plants need it most before flowering.

Soil testing

In order to precisely target correcting nutrient deficiencies, soils should be tested. This is done at the appropriate soil testing laboratories. Quick indicative results can be obtained using a simple-to-use 'soil testing kit' developed by the Soil Science department of Makerere University. These services are available to the farmers on request.

The importance of micronutrients to maize growth

Crop growth depends on, among other things, available soil nutrients. Both macro- and micronutrients are essential for plant growth and if a plant does not get enough of a particular nutrient it needs, the deficiency symptoms will show in the general appearance of the plant. Macronutrients are those elements needed in large amounts by the crop, and large quantities have to be applied if the soil is deficient in one or more of them. Nitrogen (N), phosphorus (P) and potassium (K) are the 'primary macronutrients' and these form the basis of NPK fertilizer compounds. The 'secondary macronutrients' are calcium (Ca), magnesium (Mg) and sulfur (S). Fertilizers containing these elements are available on the market but not many in east and central Africa use these fertilizers. Meanwhile, micronutrients are those elements required in very small quantities. Despite being needed in small quantities, micronutrients are essential for the overall performance and health of the maize crop. They include iron (Fe), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo), and boron (B).

Sources of macro and micronutrients

Plant nutrients are normally abundant in the soil. However, due to cropping practices and poor soil management, soil reserves have been depleted

in many arable soils and nutrient deficiencies have been linked to low maize yields. Overall, fertilizer application rates by farmers are very rare in most areas in ECA. Many farmers assume that most soils are fertile for the time being, hence do not need any additional nutrients. Micronutrient fertilizers are rarely used by farmers except in few cases (commercial farmers). Deficiencies of magnesium, sulfur, zinc, boron, copper, and manganese are on the increase in the recent past, probably due to effects of climate change. The problem is more acute on sandy soils, which make up a large portion of agricultural soils in the region. Specific fertilizer formulations can be used to replenish declining soil stocks. However, use of micronutrient fertilizers requires consultations with specialist to advice on effective application and proper management of the fertilizers, since improper use (e.g. excess doses) can result in poisoning/ killing of the crop.

Besides declining natural reserves in soil, and inadequate fertilizer use, nutrient deficiencies are compounded by the prevailing conditions in the soil environment. For example, if soil is too acidic (pH < 4.0) or too alkaline (pH ≥ 7.0), some nutrients in the soil solution will become unavailable for uptake by the maize crop. All micronutrients, except molybdenum, are more soluble in acid conditions. Thus, care should be taken when using liming materials as over-liming (increasing pH) can make them unavailable to the crop.

Micronutrient deficiencies are usually apparent on the new leaves of maize since it is during the development of new tissue that they are most required. Some symptoms of soil micro nutrient deficiencies in maize crop are given below:

Zinc (Zn) deficiency symptoms may appear within the first two weeks after crop emergence as a broad band of yellowing tissue on one or both sides of the leaf midrib (leaf centre). These symptoms may be reversed by using zinc sulfate fertilizer.

Symptoms of soil nutrient deficiencies in maize

Symptoms of nutrient deficiencies in maize show in the general appearance as well as the colour of the plant. Typical symptoms are small (stunted) plants, pale green leaves, and spotting or striping on leaves. If the symptoms are not reversed, grain yields can be severely affected. Field assessment is usually the first step to take in order to identify symptoms of soil nutrient deficiencies in a growing maize crop. Deficiency symptoms of most elements are unique; however, in some cases, where there is no clear distinction, a specialist should be involved to help identify the problem. Some disease symptoms are quite similar to nutrient deficiencies (e.g. striping or spotting), so it is important to clearly differentiate between the two symptoms.

Boron (B) is one of the micronutrient deficient in acute quantities in arable soils on smallholder. The deficiency may easily be mistaken for iron deficiency where there is a general stunted growth and leaves fail to uncurl properly. However, without boron, leaves may fail to emerge altogether. Boron availability is reduced under low rainfall/drought conditions or in soils low in organic matter. Farmers maintaining high levels of organic matter in their fields normally do not face boron deficiencies.

Iron (Fe) deficiency symptoms are characterized by a stunted growth and yellow stripes between green veins along the entire length of the leaf blade. However, in most maize systems of southern Africa, iron deficiency is rare because of its general abundance in most soils.

Molybdenum (Mo)—a typical deficiency symptom is noticed in dwarfing growth. Maize crop grown in soils with low levels of molybdenum develops yellowing of older leaves and younger leaves usually fail to unroll

Manganese (Mn) has a deficiency symptom of dwarf growth which is similar to Mo. Some of its unique deficiency symptoms include the failure of maize seed to germinate entirely.

Copper (Cu) is an important micronutrient for maize production. Its deficiency symptoms may be induced by excessive application of nitrogen and phosphorus fertilizers. Typical symptoms include a general yellowing (chlorosis) of younger leaves. In older leaves, leaf tips curl like pig tails and die and yellowing may also be apparent at the lower end of leaves.

Sulfur (S)—hunger symptoms in maize are similar to those of nitrogen and it is easy to mistake symptoms of the two macronutrients. Plants show a pale green colour that generally appears first on the younger leaves.

Magnesium (Mg)—Inadequate supply of Mg appears as definite and sharply defined series of yellow/green streaks on all leaves due to a general loss of green colour which starts with the bottom leaves and later moves up the stalks to the upper leaves. Leaf veins remain green, resulting in a distinct striped appearance.

It is important to note that the extent and severity of nutrient hunger symptoms can be addressed by a variety of fertilizers, which may be applied basally (for macronutrients) or as foliar applications (in the case of micronutrients).

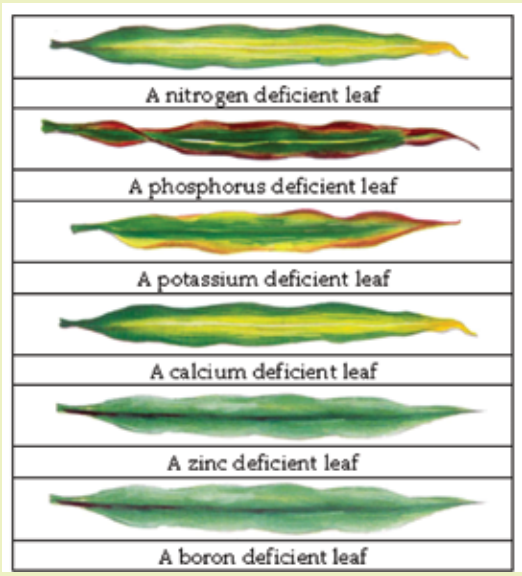

Figure 6: Symptoms of nutrient elements in the maize leaf



Constraints to QPM production and control measures

The main reasons for the stagnation or decline in QPM production include pests and diseases, competitive weeds, extensive use of unimproved maize seeds, depletion of soil fertility, erratic rainfall, prevalence of, little improvement in agronomic and post-harvest technologies, and limited use of yield-enhancing purchased inputs such as fertilizers and other agrochemicals. In addition the farmers experience a lot of loss in seed and grain due to poor post -harvesting handling.

Important diseases and pests of maize

The leading foliar pathogens of maize include: *Cercospora zeae-maydis,* causal agent of *gray* leaf spot (GLS); *Exserohilum turcicum*, causal agent of *Northern Leaf Blight* (NLB); maize streak virus (MSV); insect pests (store pests, stem borers) as well as parasitic weeds (*Striga*).

Characteristics of some important diseases of maize

1. Grey leaf spot

The disease is caused by *Cercospora zeae-maydis, C. sorghi var maydis.* This disease, also known as *Cercospora* leaf spot, and is characterized by lesions beginning as small, regular, elongated brown-gray necrotic spots growing parallel to the veins. Minimum tillage practices have been associated with an increased incidence of GLS. Development of the disease is favoured by extended periods of leaf wetness and cloudy conditions, and can result in severe leaf senescence following flowering and poor grain filling.

2. Northern leaf blight

The disease is caused by *Exserohilum turcicum.* Early symptom is the lesion (burn like) that normally appear on lower leaves and increase in number as the plant develops, and can lead to

complete burning of the foliage, characterized by slightly oval, water-soaked, small spots produced on the leaves. These grow into elongated, spindle-shaped necrotic lesions. Development of the disease later in the season (after grain filling stage) might not cause heavy yield losses to QPM.



Figure 7: Foliar symptoms manifested by infected grey leaf spot

3. Maize streak virus

This disease is caused by a virus and transmitted by Cicadulina spp. Leafhopper. The leafhopper transmits the virus for most of its life after feeding on an infected plant. Symptoms begin within a week after infection and consist of very small, round, scattered spots in the youngest leaves. The number of spots increases with plant growth; subsequently enlarge parallel to the leaf veins. Fully elongated leaves develop chlorosis with broken yellow streak along the veins, contrasting with the dark green colour of normal foliage. Severe infection causes stunting, and the maize plants can die prematurely without developing ears.



Figure 8: Foliar symptoms of Turcicum leaf blight

Maize lethal necrosis (MLN)

A new disease of maize that appeared in the farmers' fields in Kenya in 2011 has since spread to Uganda, Tanzania and South Sudan. This disease can cause up to 100% loss hence threatening food security and income. The disease is difficult to control for two reasons:

1. It is caused by a combination of two viruses.
2. The vectors that transmit the disease-causing viruses may be carried by wind over long distances.

The disease was first identified in the USA in 1976 (Niblett and Claflin, 1978). MLN is caused by the double infection of maize plants with maize chlorotic mottle virus (MCMV) and any of the cereal viruses in the Potyviridae group, such as sugarcane mosaic virus (SCMV), maize dwarf mosaic virus (MDMV), or Wheat streak mosaic virus (WSMV). MCMV or SCMV produce milder symptoms when they infect maize alone; in combination, these two viruses rapidly produce a synergistic reaction that seriously damages or kills infected plants.



Figure 9: Foliar symptoms of maize streak virus disease

Typical symptoms of MLN

- Mild to severe mottling on the leaves, usually starting from the base of young leaves in the whorl and extending upwards toward the leaf tips.
- Stunting and premature aging of the plants.
- Dying (known as "necrosis") of the leaf margins that progresses to the mid-rib and eventually the entire leaf.
- Necrosis of young leaves in the whorl before expansion, leading to a symptom known as "dead heart" and eventually plant death.
- Premature drying of cobs and tip die-back result in no pollen production and subsequently poorly filled cobs.

Prevention and control MLN

- Plant certified seed produced from MLN free areas

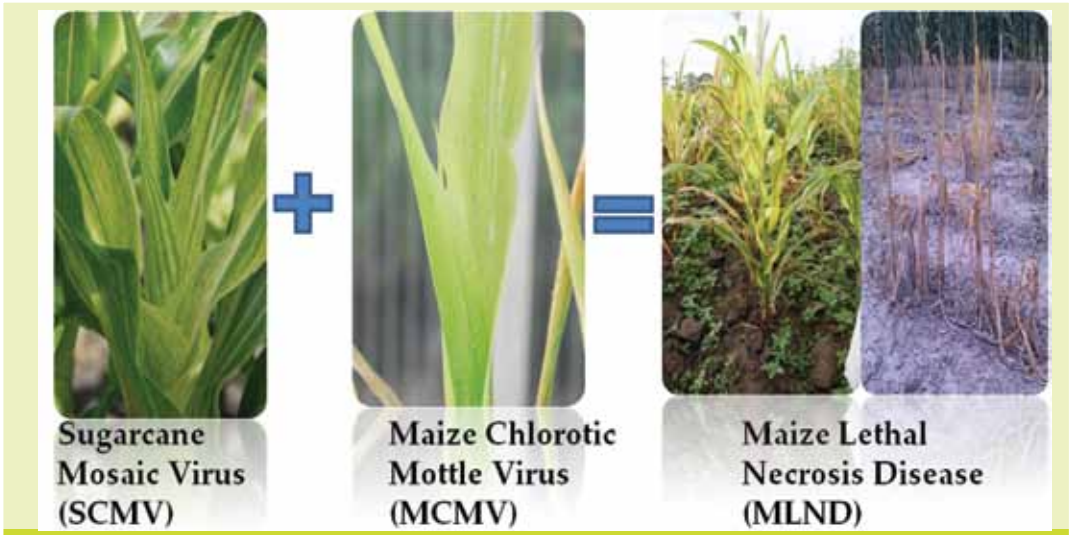

Figure 10: Foliar symptoms MLND and other virus diseases of Maize



Figure 11: Premature drying of cobs



Figure 12: Leaf necrosis and dead heart



Figure 13: Diffuse mosaic symptoms



Figure 14: Whole field infected with MLND

- Rotate maize with non-cereal crops like beans, sweet potato, sunflower, Irish potato.
- Do not plant a new maize crop near an infected field. Wind-blown insect vectors can transmit the disease from the infected field to the new crop
- Plant maize at the onset of the main rainy season, rather than during the short rain season; this creates a break between maize crops and interrupts the disease cycle.
- Scout fields at least once a week to identify diseased plants
- Uproot and burn all plants showing symptoms immediately
- Do not move diseased plant materials far from the field



Figure 15: Maize ears infected by ear rot

- Weed fields regularly to eliminate alternate hosts for insect vectors, especially grasses.
- Boost plant growth and vigor by: planting at onset of rains, applying manure, basal and topdressing fertilizers
- Control insect vectors using appropriate insecticide. Treat seed with Imidacloprid 350 g/L (Gaucho), followed by insecticide spray with Imidacloprid 100 g/L + β-cyfluthrin 45 g/L (Thunder) at the rate of 0.3 l/ha starting at 1 or 3 weeks after emergence (WAE)
- Use maize varieties that are tolerant or resistant to MLN

Ear rot

Ear rots are commonly found in hot, humid maize-growing areas. Maize ears show characteristic development of irregular bleached areas on husks. These areas enlarge until the husks become completely dried, although the plant is still green. If husks are removed, ears appear chaffy and bleached, with a white, cottony growth between the kernels. Stem borer injury in the ear often increases incidence of this disease. Stenocarpella maydis produces the mycotoxin diplodiatoxin and S. macrospora produces diplodiol, both harmful to birds.

General field management practices for disease control in maize

- Rotate diseased fields to non-cereal crops (like sunflower, soybean) for at least one year. Never plant QPM after a diseased maize crop.
- Bury infected debris soon after harvest to enhance breakdown of the residue so that the fungus dies in a short period of time.
- Because moisture on leaf surfaces is important throughout the disease cycle, efforts should be made to avoid practices that extend dew periods. Therefore, irrigation should not be scheduled during late afternoon or early evening, especially after outbreaks have already occurred.
- With GLS, other cultural practices appear to have little effect on gray leaf spot development. However, fungicides are important for the spot control of GLS.
- Avoiding mechanical damage to plants will reduce plant injury, which is the primary means of infection by the fungi.
- Control of insect damage (e.g. maize stem borers damages) will also limit plant injury.



Figure 16: Termite damage in QPM field

- A well-balanced fertilizer regime will reduce disease severity. High levels of nitrogen fertilization encourage plant growth (making the plant succulent) and hence increase disease attacks. However, application of phosphorous reduces disease incidence.
- Management of overwintering infected crop residue will reduce the amount of available inoculum at the onset of the subsequent growing season.

Stem borers

Stem borers are the most important insect pests of economic importance in the QPM production fields, followed by the termites. (Please write one paragraph on the most important types of stem borers and some control measures; a picture of damaged maize crop will be helpful)

Termites

Various species of termites attach maize and damage is particularly noticeable during drought seasons or in areas with erratic rainfall. They destroy the roots and the base of the stem leading to lodging. Destruction continues even on fallen plants. In extreme cases, damage can lead to almost 100% yield loss especially if it occurs at an early stage of crop growth. Damage after physiological maturity will lead to grains of poor quality because after lodging, the ears are exposed to soil contamination.

Control

- Several plants have been identified which could be used as trap or repellent plants in a 'push-pull' strategy. Those plants that appear particularly promising are Napier grass (*Pennisetum purpureum Schumach*), Sudan grass (*Sorghum vulgare sudanense Stapf.*), molasses grass (*Melinis minutiflora Beauv.*), silver leaf desmodium (*Desmodium uncinatum Jacq.*) and greenleaf desmodium (*Desmodium intortum Urb.*).
- Dusban (Chloryrifos): Dusban kills by contact. About 20–40 ml of dusban dissolved in 10-20 litres of water is sufficient to kill a termite mound/antihill. Other chemicals for the control of termites include terminator, dusban , pyrinex, troban, endosulphan, malataf.
- Regent 3-G (Fipronil): This is used where there are no mounds in the garden. Mix 50 gm with two litres of water and apply to locations of feeding termites. Apply to several locations

within the field infested by termites. The Fipronil kills the worker due to excitement, leading to over working and exhaustion, then eventually death. The queen stops feeding and dies of starvation.

- Imidacloprid systemic insecticide is also an important agrichemical for the control of termites.

Striga

The main species of *Striga* that reduce maize production significantly in ECA is *Striga hermonthica*. Generally, *Striga* spp. produce numerous tiny seeds (50,000–500,000 seeds per plant). The seeds are normally dispersed by wind, water, livestock, man, farm machinery and contaminated crop seeds. Once shed, the seeds can stay viable in the soil for up to 20 years. The seeds normally germinate only in response to chemical stimulants exuded by the host roots of maize plant. Once germinated, the weed establishes parasitic attachments with the root of the host and starts deriving all its nutrients from the host.

The control of *Striga* is a special case and expensive for farmers to manage; *Striga* tolerant QPM varieties can be useful. Generally, *Striga* infested fields should be avoided. However, *Striga* infestation may be minimized by planting legume crops in rotation with maize.

Post-harvest losses

Inadequate maize production facilities and inappropriate methods for seed and grain storage are the major causes of seed and grain insecurity among rural farmers. This impairs the maintenance of sufficient and safe seed production compounded with poverty, and insufficient technical and financial support.



Figure 17: Two different drying methods used by small-scale farmers

Maize weevil (*Sitophilus zeamais*)

Maize weevils the unwanted insect pests in most of the storage areas. Maize weevils are small and easy to kill, but they can complete their life cycle quickly. Adult females start laying eggs almost immediately. Once they start production activities in a storage structure, their population is sure to blossom into a problem which will need attention. Maize weevil is a primary pest and the damage to maize is caused by adult feeding and larvae tunneling within the grains.



Figure 18: Maize weevils on infested maize ear

Sources of maize grains infestation

- Cross infestation from neighbouring lots of stores.
- Migration from waste or rubbish.
- Hiding places in stores e.g. cracks.
- Use of infested bags.
- Introduction of infested lots.

A high rate of reproduction and short development period enable the maize weevils to cause important damage by rapidly developing from a small number of individual insects to a large mass. There are genetic differences among maize varieties with regard to resistance to storage pests. Where possible, farmers should select resistant varieties to weevil attacks and other storage pests.

Control

- Harvesting maize at the right field moisture. Weevils can only breed in grain with moisture content of more than 9.5% t and at temperatures within the range 13–35°C.
- Apply storage insecticides.
- A routine fumigation of storage facilities.
- Proper construction and maintenance of the stores.



Figure 19: Harvesting at proper moisture content and insecticides used for the control of store pests



Important features of quality in QPM

Quality of QPM products is usually an agreement of farmers, traders and processors on the criteria to use from post-harvest, marketing and processing of the QPM grain. It is important that QPM must be safe and suitable for human consumption and livestock feeding. It should be free from abnormal flavours, odours, and living insects. Buyers also prefer grain with the moisture content not exceeding 14% by mass in accordance with US 98 standard. The effects on grain quality thus start from harvesting of the QPM through transporting and to storage. Yields should be optimized once the plant reaches physiological maturity. This is when the kernel has the maximum content of dry matter. Therefore, post-harvest handling processes harvesting, drying, shelling, treatment and storage are very important in terms of minimizing losses not only in quality but also in quantity.

The first impression of the consumers about the quality of a QPM product begins with its appearance (grain size and colour) which determine visual attractiveness of finished QPM products. Consumers in ECA prefer white QPM for food while feed manufacturers prefer yellow QPM with high levels of carotene which is important for chicken production. Organoleptic aspects like mouth feel (texture) and flavour of the finished products like QPM cakes and bread are important to the consumers. Based on the texture required by different consumers, 100% QPM can be used in preparation of products or as an ingredient (30–50%) in preparation of composite flours to supplement wheat flour for bread, cakes, and biscuit. Hence, quality aspects of QPM preferred by consumers may be determined by sensory evaluations of different food products containing different proportions of QPM flour.



Harvest and post-harvest management of QPM

Harvesting

Maize is a non-perishable commodity that can be stored for a long period of time in unprocessed form without undergoing rapid deterioration. Therefore, QPM shelf life can greatly be increased by manipulating the prevailing ambient temperatures, relative humidity, moisture content, storage pests and diseases to obtain high quality grains.

The optimum time of harvesting QPM is after physiological maturity when the moisture content is about 20–35%. Different QPM varieties take different times at different agro-ecological zones (AEZs) to attain physiological maturity (usually between 90-180 days). There are several indicators that show the crop has attained physiological maturity and these include:

- Yellowing of most of the leaves and some start drying up
- Maize stalk and husk turn yellow and eventually brown
- Ears begin to droop (hanging downward) on the stalk
- The grain acquires a glossy surface and hard with floury texture when bitten through.
- The kernel shows a black layer at the bottom when peeled

The chemical components and nutritive values of QPM are susceptible to change immediately the grain is harvested. In addition, subsequent operations such as storage and processing may also cause changes and need to be carefully considered.

Generally, harvesting must be done when the conditions are dry to avoid rotting, germination of the grain and mold growth. Harvest of QPM does not have a strict specific time like other crops because maize does not shatter. Most farmers prefer to harvest maize when the moisture content of the grain is between 18–20%. Prior to harvesting, farmers must prepare the



Figure 20: Dry maize ready for harvesting

following before commencing the actual harvest QPM crop in the field:

- Clean the store by removing old grain and dirt from place where the ears will be put after harvesting.
- Harvesting tools, carts, wheel barrows, bags and baskets must be cleaned to avoid infestation of new maize grains by insects.
- The drying place, e.g. crib or equipment must be cleaned and disinfected.
- Harvest is mostly done by hand; enough labour force should be involved to harvest and carry the ears from the field to the drying place soon after harvest.

Harvest of QPM can be done manually or mechanically; there are two types of harvest systems namely:

a) Timely harvesting system where QPM is harvested timely after attaining physiological maturity to minimize post maturity losses in the field.

b) Field drying and late harvesting system where QPM is left to dry in the field for 4 – 7 weeks beyond maturity, either on stalks, stacks or heaps.

Recommendations during harvesting

- Harvest QPM after physiological maturity; avoid leaving the QPM to stay too long in the field as this will increase post -harvest losses due to lodging, damages by termites and birds.
- Complete all harvest processes within a short time to reduce the risk of post-harvest losses.
- Do not throw ears in dirty places which can be sources of contamination. While harvesting, put the ears in a clean container like basket, bag, etc.
- During harvesting, sort out ears infested by insects, or those with discoloured grains. Put together only the good looking ears with well filled grains.



Figure 21: Bending down the upper part to speed up drying process

- Transport the ears to the drying place as soon as possible and put them in improved cribs to start drying process.
- Do not heap the ears in any open spaces outside as this will expose them to all the dangers of post-harvest losses.

Post-harvesting activities

After harvesting, all the materials such as baskets, bags, etc, used during harvest must be cleaned and stored properly, away from sources of contamination and insect breeding places.

Drying

Drying is the systematic reduction of crop moisture to safe levels of 12–13% suitable for storage. Drying is one of the key post-harvest operations since all other operations depend on it. Wet grains go bad and attract insects and mould. High moisture content causes damage through fungal growth/ infestation and aflatoxin poisoning, thus making the grains unfit for both human and livestock consumption. Thus, drying is an important operation before storage so as to keep down grain moisture content, relative humidity (RH), hence ensure quality grains for marketing and final use. The QPM grain must be dried soon after harvesting to prevent germination, growth of bacteria and fungi. In addition, drying retards the development of mites and insects considerably. However, if drying is carried out too rapidly and at high temperatures, it will induce the formation of stress cracks, and discoloration, which will affect the efficiency of dry milling and other processes.

Drying methods

Drying can be done manually or by use of fully mechanized operations. In most tropical countries, drying is sped up by bending down the upper part of the plant holding the ear, a practice that also prevents the kernels from becoming soaked when it rains. Similarly, in northern Tanzania, after physiological maturity, the upper part is cut to feed the animals and the ears are left on the plant to dry.



Figure 22: The local cribs

1. **Traditional drying methods**—there are several traditional methods of drying maize and these include:
   - De-husked ears are spread on bare ground to sun dry.
   - De-husked or ears with husks are placed in poles or tree branch to dry; ears in the husks (sheaths) may be stringed up into bunches and then suspended.
   - Ears with or without husks are tied and hung above fire places in the kitchen.
   - De-husked ears stored in round farm structures or rectangular slatted wall farm structures.



Figure 23: An improved crib within the homestead



Figure 24: Drying and cleaning maize seed on plastic sheet

Drying maize on plastic sheets or local mats is a common practice with farmers who are trying to keep maize off the ground during drying period. Therefore, this method is time consuming and labour intensive as it involves lots of grain handling. Farmers must avoid drying the QPM on the ground because the grain that is in contact with the ground will absorb moisture and pick up dirt, insects etc.

Disadvantages of drying maize on mats or plastic sheets or tarpaulins include:

- The grain must be watched while it dries.
- At night or when it rains, the grain must be brought under shelter.
- Risk of contamination from soil dusts, stones, animal droppings, fungal and insect infestation.
- Losses from birds, poultry and domestic animals, resulting into contamination and losses in quantity.

2. Improved drying methods

Layer drying

- Harvested QPM grains are placed in a bin one layer at a time.
- To improve efficiency, the partially dried grain is stirred and mixed with the new layer.

Portable batch dryers

- These types of dryers are mobile and can be moved from place to place.
- The dryers operate with heated air between 60°C to 82°C.

Continuous flow dryers

- Dryers with a continuous flow of QPM grain through heated and unheated sections so that it is discharges both dry and cool conditions. The equipment is the central point in grain storage depots or seed companies.

Threshing/shelling

This is the removal of maize grains from the cob and winnowing. The ears must be dried well before shelling as it is difficult to shell at a moisture level content above 25%. The most efficient shelling is achieved when the grain has been dried to 13–14% moisture content. Traditionally, shelling is done by hand but it is a tedious labour intensive

operation with low productivity (output of 10 – 25 kg/hour).

Advantages of shelling

- Reduce required storage capacity.
- Facilitate effective application of insecticide.
- Reduce grain susceptibility to large grain borer (LGB), maize weevils and other store pests.

Low-cost shelling equipment is available and can reduce much of the current high and tedious labour requirements. These include the following:

- Hand-held devices of various designs and outputs
- Small rotary hand sheller
- Free standing manually operating sheller
- Pedal operated air screen grain cleaner

Storage

During storage, the QPM grain like normal maize grain must remain dry, cool and clean. Storage period can be extended for up to 2 years without significant reduction in quantity and quality. However, the majority of farmers sells off their QPM grains cheaply soon after harvesting due to financial needs

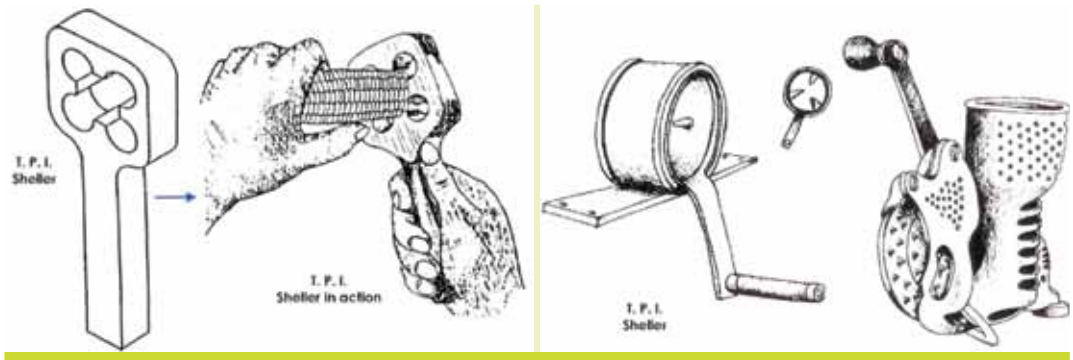

Figure 25: Various types of hand-held maize shellers

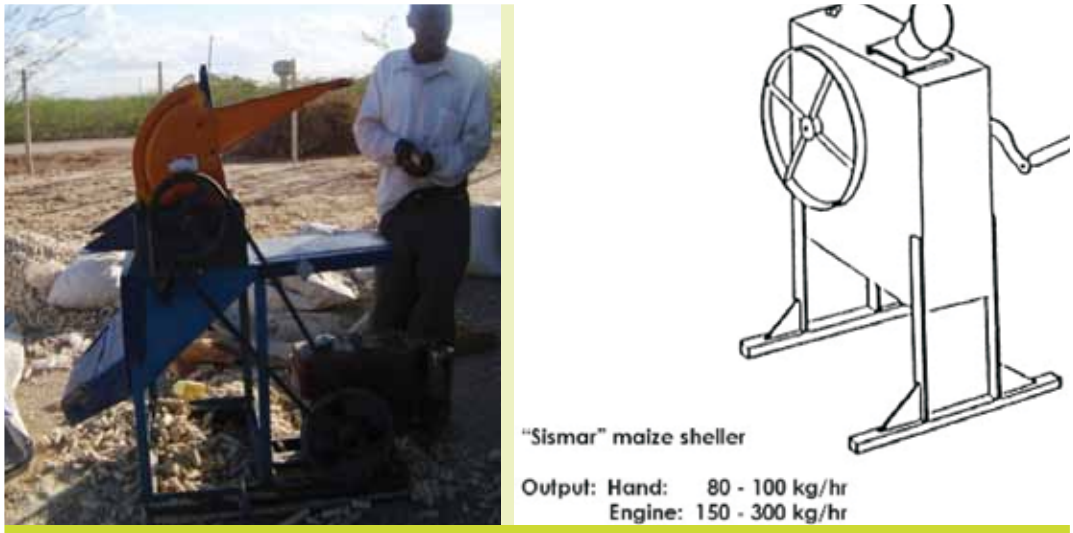

Figure 26: Free standing manually operating sheller

as well as anticipated losses in stores and later buy food at exorbitant prices.

The important emphasis in any maize grain storage system is to maintain the stored grains in good condition so as to avoid deterioration both in quantity and quality. QPM grains can be stored either on cobs or shelled in various storage structures or containers for different lengths of time. The storage period can be for short-term (4–5 months), season-long (6–9 months) and long term (>9 months).

Objectives of storage facilities

- To service a marketing and trading system from rural to national level.
- To supply food to the farm household from one harvest season to the next.
- To save food for household until next harvest.
- To provide carry-over in case of crop failure and natural disasters.
- To preserve seed for planting the next season.
- To preserve the quality of grains from deteriorating for a long period of time.
- To keep food grains away from rains and unfavourable temperature fluctuations.

There are two main types of storage structures for maize: traditional and improved storage structures.

Traditional storage systems

- Outdoor storage structures where maize ears are stored in traditional granaries.
- Indoor storage facilities where maize ears are stored in a specific store-room, either hanged above a fire place or grain stored in small containers such as guards, tins, etc.
- Underground storage facility- is a ground dug structure lined with straw and thick plastic sheets.

Improved storage structures

There are many improved storage structures that can extend the storage duration of QPM grains until when market prices are favorable. Examples of improved storage facilities include metal silos, store rooms/ warehouse.

A good long-lasting storage structure should have the following features:

- Maintain an even, cool and dry storage environment.
- Should not allow re-wetting of grain by either moisture migration or rain.
- Offer protection from storage loss agents such as insect pests, rodents, moulds, birds and thieves.
- Be simple and inexpensive to construct using locally available materials and skills.
- Be easy to operate, clean and repair.

Good hygiene is the basic requirement for successful storage at farmer level. Farmers must strive to undertake hygiene measures because they are simple, effective and cheap.

Hermetic bags

These bags are commercially available at affordable prices and help to keep grains in storage for a long period. These bags work by excluding oxygen that will make it difficult for insect pests to survive and those that manage to get in will die.

Metal silos

The metal silo is airtight cylindrical equipment used for storing and preserving grains. Metal silos can protect grains from rodents, fungi, insects and thieves. The silos can keep QPM for up to 3 years without being attacked by large grain borer or weevils. The metal silos are made in different sizes that can store 400, 800, 1200 or 2000 kg. Another advantage of the metal silos is that they can be kept inside the house such that thieves cannot steal



Figure: 27: GrainPro 'superbags' MaskAgrik 'smartbags' IRRI bag

easily and neither can there be destruction from vermin. Losses in QPM grains can be reduced to minimum levels through adoption of the metal silo technology. The DONATA QPM project is currently disseminating the QPM technologies with the use of metal silos for efficient grain storage at household level. The technology will provide farmers with a reliable storage option to enable them store enough QPM grains for the family's consumption and sell the surplus later in the season at relatively better prices.

Store room and warehouse - bag storage of shelled grains in well designed store rooms is the most suitable method of storing maize grains in the tropical countries of ECA. Although a bulk system of storage also exists, bag storage is more appropriate for small scale farmers because of the following reasons:

- Currently, all buyers require bagging before dispatch of the maize grains.
- The transport system available is more suited to transporting bagged than bulk grains.
- Bagged grain is easily quantified when receiving, dispatching or checking the stock.
- Bag storage requires less capital investment than bulk storage.
- Bag storage is easy to manage, cheap and efficient.
- The bag system involves little risk in long term storage system.



Figure 28: Metal silos for improved household storage



Fig 29: Bag storage in store room

Store positioning

- The store should be located on a raised site with good drainage to ensure that there is no stagnant water in or around the store.
- Set up the store with the longitudinal side on an East-West axis (less radiation on the building) or exposed to the main wind direction. This creates balanced temperature conditions thereby reducing the danger of condensation.
- Locate the store on firm soil with good road connections to enable easy transportation.
- Crop residue may be used as fodder, fuel

Conditions favouring storage pest and methods of control

Insect pest populations in stored maize are influenced by availability of food, relative humidity, temperature and moisture content of the grains. Temperatures of 27°C to 31ºC are optimal for development of pests in stored maize grains. At temperatures below 14°C and above 42°C development of insect pests generally does not take place. Most storage pests die at temperatures below 5°C and above 45°C. The optimum relative humidity for most storage maize pests lies at around 70%, the minimum being 25–40% and the maximum 80–100%. Very few species of storage insect pests are able to survive in extremely dry conditions. The climatic conditions in ECA region obviously favor rapid development of insects that cause increase damage to maize in storage.

Storage insect pests for QPM grains are not able to develop quickly or multiply successfully in very dry conditions. Their rates of development below 11.5% moisture content are distinctly slower, and at moisture contents below 8% many fail to breed at all. Moisture contents of 12–18% favour rapid increase in insect pest population, especially under conditions of suitable temperature and favourable relative humidity conditions. Therefore, the moisture contents of maize in store should be below 13.5% to avoid insect attacks.

There are various techniques of controlling storage insect pests of maize including:

- Indigenous methods mostly used by farmers, but not always effective, are the use of ash, and smoke.
- Use of appropriate chemical products
- "Actelic" 1% use 100 g for 90–100 kg QPM grain is most effective for weevils and moths.
- A mixture of Actellic and Permethrin super dust is effective for most storage pests including large grain borer.



Value addition

Value addition refers to any handling or operational activity that increases the value of product. It aims at increasing returns or profit through provision of a solution to a product through the marketing chain. Value addition may not necessarily involve physical transformation of a product/ change of form. Although it has a cost and ultimately increases the cost of the product, value addition is important in increasing shelf life and usefulness of QPM products, improves taste, increases uniformity, reduces bulkiness hence easier to transport and store. It also guarantees confidence and satisfaction/visual in consumers. Hence, value addition requires creating awareness for the market to accept/demand the product at the value and should be profitable.

Development and support for commercial level QPM processing and value addition is a strategy to alleviate marketing constraints at farm level. Processing has potential for enabling QPM to attain an industrial status that would help to create more employment, improve nutrition and increase incomes for QPM farmers. Currently, there is high demand for technologies that can reduce the cost of production of processed goods in order to make businesses competitive among farming communities and QPM users. Therefore, women and youths can employ themselves by establishing small enterprises to prepare and sell the QPM foods and snacks. Introduction of the QPM snacks during Farmer Field days, Agricultural shows, in Mother Child Health Centres and school feeding programs has attracted a lot of interest and demand for QPM. In addition to its significance in human health, QPM is known to play an increasingly important role in reducing the protein supplement in pig and poultry feed when used as an ingredient.

The aggregate value or level of processing QPM can be of different levels and complexities, ranging from levels I to III.

- *Level I* involves simple operations such as washing, cleaning, ginning, roasting, classification, bulk packing and storage
- *Level II* includes more complicated processes such as refrigerating, milling,

cutting, mixing, dehydration, cooking and packaging.

- *Level III* involves operations such as extraction, distillation, and freezing.

Value addition of QPM includes some aspects of post-harvest handling namely cleaning, sorting, grading, drying, packaging, packing and labeling. QPM processing can be achieved through milling, boiling, roasting, deep frying, baking, cooking, steaming, fermentation, extrusion and enzymatic processes.

Processing of QPM products values include:

- Milling as straight flour;
- Composite flour/enriched flour;
- Packing and labeling;
- Flour fermentation and manufacture of alcoholic products;
- Starch and glucose manufacture; and
- Manufacture of animal feed.

Transportation and storage values include:

- Transport cost;
- Storage cost; and
- Labour cost.

QPM food processing facilitates eating, easy digestibility, easy absorption and utilization by the body systems. The following QPM products can be produced, marketed and utilized:

- QPM flour packed in 1, 2 and 5 kg packs;
- QPM germ;
- QPM oil;
- QPM snacks such as cakes, biscuits, bread, chapatis, cookies and cornflakes;
- QPM products like porridge mix flour recommended for feeding children who are malnourished under the age of five. Also the composite flour is recommended for weaning children and lactating mothers.



Figure 30: Fresh delicious QPM salad



Figure 31: Roasted fresh QPM being sold in the market

Fresh QPM grain processing

- Preparation of fresh QPM grain mixed with beans (kande).
- Porridge 'uji' of crashed fresh QPM.
- Preparation of fresh delicious QPM salad.
- Roasted fresh QPM are sweeter and nutritious. It offers high potential niche business for women and youths.
- Boiled fresh QPM is liked by many people in the cities in ECA.

QPM is suitable for use as ingredient in various food products to improve taste and nutritive value. A typical example of QPM ingredient in food products is "Kande". It is prepared from QPM grain for the whole family. This has been used for school children, orphaned children in centers as



Figure 32: Orphan children feeding on Kande at Mgolole, Morogoro, Tanzania



Figure 33: QPM food



Figure 34: Many QPM enterprises have been set up in the region



Figure 35: The CEO of TANSEED introducing the Tanzanian Minister to various QPM product exhibition

shown in Figure 27, taken at Mgolole Orphan Centre in Morogoro, Tanzania.

Plain or spiced QPM porridge suits people of all ages and in all environments

Preparation of cakes from a uniquely blended QPM + wheat flour for business and ceremonies include:

- Queen cakes;
- Cup cakes;
- Birth day cakes; and
- Send off/ wedding cakes.

As shown in Figure 30 below, the Tanzania Minister of Natural Resources and Environment, Dr Mwandosya, being introduced to the various QPM cakes by the chief executive officer (CEO) of TanSeed International during the 2008 "NANE NANE AGRICULTURAL SHOW" in Morogoro, Tanzania.

Preparation of Stiff porridge 'Ugali' with QPM for improved nutrition and digestibility. QPM processing provides wide selection of traditional ugali style to meet needs and preferences of wide consumers in ECA.

- 100% QPM ugali;
- QPM + Cassava ugali;
- QPM + sorghum ugali; and
- QPM + finger millet ugali.

QPM in livestock feeds

Protein of high quality is required in the preparation of feeds; hence large amounts of fish meal are always used. Worldwide, about 70% of the maize produced is utilized in livestock feed. Fifty percent of the commercial poultry feeds consist of maize. In addition synthetic amino acids mainly lysine and methionine which are imported, must be added to poultry feed.

Quality protein maize is superior to normal maize in its amino acids (lysine and tryptophan) balance and nutrient composition, and improves the performance of livestock and poultry. Since QPM contains 50 % more lysine and tryptophan than normal maize, it is useful in the commercial livestock feeds production. It is more economical to use diets incorporating QPM as it can lead to progressive reductions in the use synthetic feed additives. QPM will reduce the use of fish meal and imported synthetic amino acids. This will reduce the cost of the feed, making the feed more profitable. It will also improve the commercial poultry industry which will provide a sustainable market for QPM grain in the region.

Implication of using QPM in animal feed

- It improves the quality of the feed because of its superiority to normal maize in its amino acid balance and nutrient composition.
- It will reduce the additional requirements of lysine and tryptophan.
- It has been demonstrated that chickens fed QPM grow faster and lay more eggs.
- More QPM will find a ready market in the Livestock Feed Industry especially for yellow QPM
- It has been proved to more profitable to use QPM as this will reduce the use of fish meal and synthetic lysine.



Figure 36: QPM feeding to pigs in Busia, Uganda



Figure 37: Poultry fed on QPM Bran at Kamuli Uganda



Figure 38: Chickens fed with QPM and Non QPM in Mweneditu IPTA in DRCongo



Figure 39: Chickens fed with QPM and NON QPM in Ogum group IPTA in Lira Uganda



Figure 40: Various QPM food products



The role of standards in maize

Promotion of standardization and grading of agricultural commodities is an important aspect of agricultural marketing. The agricultural commodities are heterogeneous and hence it is very essential to grade these commodities as per standards to command better prices both at domestic and international market. Sale of maize is offered on the basis of variety, wholesomeness, appearance, colour, presence of foreign matter, damaged grains, broken grains, admixture of inferior variety, moisture, harmful contaminants, etc. A quality grain is that which meets the end user's specifications with respect to range of pre-determined quality and safety standards.



Definitions of maize defects

Damaged or blemished grains: Grains which are insect or vermin damaged, stained, diseased, discoloured, germinated, frost damaged, or otherwise materially damaged.

Insect or vermin damaged grains: kernels with obvious weevil-bored holes or which have evidence of boring or tunneling, indicating the presence of insects, insect webbing or insect refuse, or degermed grains, chewed in one or more than one part of the kernel which exhibit evident traces of an attack by vermin.

Stained kernels: Kernels whose natural colour has been altered by external factors. This includes ground, soil or weather damaged kernels, which may have dark stains or discolourations with a rough external appearance.

Diseased grains: Grains made unsafe for human consumption due to decay, moulding, or bacterial decomposition, or other causes that may be noticed without having to cut the grains to examine them.

Discoloured kernels: Kernels materially discoloured by excessive heat, including that caused by excessive respiration (heat damage) and dry damaged kernels. Kernels may appear darkened, wrinkled, blistered, puffed or swollen, often with discoloured, damaged germs. The seed coat may be peeling or may have peeled off completely, giving kernels a checked appearance.

Germinated kernels: Kernels showing visible signs of sprouting, such as cracked seed coats through which a sprout has emerged or is just beginning to merge.

Frost damaged kernels: Kernels which appear bleached or blistered and the seed coat may be peeling, germs may appear dead or discoloured.

Mouldy kernels
Maize grains with visible mycelia growth on its tip or surface.

Immature/shriveled grains: Maize grains which are underdeveloped, thin and papery in appearance.

Broken kernels: Maize and pieces of maize which when tested according to ISO 5223-Test sieves for cereals, shall pass through a 4.5 mm metal sieve.

Other grains: Other grains are edible grains, whole or identifiable broken, other than maize (that is cereals, pulses and other edible legumes).

Foreign matter: All organic and inorganic material (such as sand, soil, glass) other than maize, broken kernels and other grains.

Filth: Impurities of animal origin.



Essential composition of quality factors

General quality factors

Maize shall be free from foreign odours, moulds, live pests, rat droppings, toxic or noxious weed seeds and other injurious contaminants as determined from samples representative of the seed lot. Maize shall be of a reasonably uniform colour according to type, be whole and clean.

Specific quality factors

Moisture content

Moisture content of lots of clean and dry maize grains shall not exceed 13.5 % by mass as determined from samples representative of the seed lot in accordance with EAS 285.

Grades

Maize grains shall be classified as Grade 1 or 2 according to the limits indicated in the Table below.

Table 4: Factors used to measure quality of maize grain

Defects	Maximum limits	
	Grade1 (% m/m)	Grade 2 (% m/m)
Foreign matter	0.5	1.0
Inorganic matter	0.25	0.5
Broken grains	2.0	3.0
Pest damaged grains	1.0	3.0
Rotten & diseased grains	2.0	4.0
Discoloured grains	0.5	1.0
Moisture	13.5	13.5
Immature/Shriveled grains	1.0	2.0
Filth	0.1	0.1
Total Defectives Grains	4.0	5.0
Aflatoxins in accordance with ISO 16050	10 ppb incl max 5 ppb B1	10 ppb incl max 5 ppb B1

Toxic or noxious seeds

Maize shall be free from toxic or noxious seeds such as Datura, *Striga*, etc.

Undergrade maize

Maize, which does not come within the requirements of grades 1 and 2 of this hand book and is not a reject shall be termed as undergrade. Undergrade maize can be sorted out to either grade 1 or 2.

Reject Maize

Maize, which is mouldy, musty, chemically or otherwise hygienically objectionable rendering it unfit for human consumption.

Contaminants

Maize shall be free from heavy metals in amounts within the limits of Codex Alimentarius Commission.

Hygiene

Maize shall be prepared, packed, stored, transported and distributed under hygienic conditions.

When tested by appropriate methods of sampling and examination, maize grains shall be free from pathogenic microorganisms, substances originating from microorganisms, or other poisonous or deleterious or substances in amount(s), which may constitute a health hazard.

Packing

Maize, when not handled in bulk, shall be packed in new bags or similar acceptable protective containers, which shall safeguard the hygienic and other qualities of the maize. The containers including packaging material shall be made of only substances, which are safe and suitable for their intended use.

Labeling

The following information shall be provided:

- The name of the product to be declared on the label shall be “maize”.
- Crop year—the year in which the crop was produced.
- Type and grade.
- Include a statement of genetically modified organism (GMO) status.
- Net contents in kilograms (kg).
- Name and address of the producer, packer, distributor, importer or vendor of the food.
- Country of origin of the maize.
- Lot identification.



References

Ahenkora K, Twumasi-Afriyie S, Sallah PYK and Obeng-Antwi K. 1999. Protein nutritional quality and consumer acceptability of tropical Ghanian quality protein maize. *United Nations University Food and Nutrition Bulletin* 20: 354–360.

Altieri MA and Letourneau DK. 1982. Vegetation management and biological control in agroecosystems. *Crop Protection* 1: 405–432.

Beck D. 1999. Management of maize seed production fields. In: CIMMYT, ed. *Maize seed production manual.* CIMMYT, Nairobi, Kenya.

Kanampiu F and Friesen D. 2011. *Striga weed control with herbicide coated maize seed.* CIMMYT, Nairobi, Kenya.

Nuss TE and Tanumihardjo SA. 2011. Quality protein maize for Africa: Closing the protein inadequacy gap in vulnerable populations. *Advances in Nutrition* 2: 217–224.

Rolfes SR, Pinna K and Whitney E. 2009. Protein: amino acids. In: Rolfes SR, Pinna K and Whitney E, eds. *Understanding normal and clinical nutrition.* Belmont, California, USA. p198.

Vanlauwe B, Kanampiu F, Odhiambo GD, De Groote H, Wadhams LJ and Khan ZR. 2008. Integrated management of *Striga hermonthica*, stemborers, and declining soil fertility in western Kenya. *Field Crops Research* 107:102–115.

Twumasi-Afriyie S, Ahenkora K, Sallah PYK, Frempong M and Agyemang A. 1996b. Effect of extraneous pollen from normal maize in adjoining fields on the nutritional quality of quality protein maize.12th South African Maize Breeding Symposium, Pietermaritzburg, South Africa.

Vivek B, Krivanek A, Palacios-Rojas N, Twumasi-Afriyie S, Diallo A. 2007. *Breeding quality protein maize (QPM): Protocols for developing QPM cultivars.* CIMMYT, Mexico DF, Mexico.





ASARECA
Transforming Agriculture for Improved Livelihoods

Association for Strengthening Agricultural
Research in Eastern and Central Africa (ASARECA)
Plot 5, Mpigi Road,
PO Box 765, Entebbe (Uganda)
Tel: +256 414 320 212/320 556/321 885
Fax: +256 414 321 126/322 593
Email: asareca@asareca.org
Website:www.asareca.org

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