A Quality Protein Maize (QPM)

MANUAL FOR AGRICULTURAL EXTENSION WORKERS IN ETHIOPIA

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CIMMYT
CGIAR RESEARCH PROGRAM ON Maize

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CIMMYT – the International Maize and Wheat Improvement Center – is the global leader in publicly-funded maize and wheat research-for-development. Headquartered near Mexico City. CIMMYT works with hundreds of partners worldwide to sustainably increase the productivity of maize and wheat cropping systems, thus improving global food security and reducing poverty. CIMMYT is a member of the CGIAR Consortium and leads the CGIAR Research Programs on MAIZE and WHEAT. The Center receives support from national governments, foundations, development banks and other public and private agencies.

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Abstract: This manual introduces the key features of QPM, its nutritional benefits and importance, and techniques of production. It gives an updated information about the QPM varieties that are available for commercial production and their agro-ecological adaptation areas in the country, together with the agronomic practices required for grain and seed production. It also include a brief accounts of management of the most important pests attacking maize. The manual has been prepared to assist agricultural extension staff at grassroots level to train and advice farmers by explaining in simple terms about QPM technology and its nutritional benefits, and to concisely describe production techniques. It also enables to communicate a uniform and consistent messages to farmers and consumers in training and field days across the country.

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Preface

Quality protein maize (QPM) refers to maize genotypes that contain approximately twice the amount of tryptophan and lysine compared to conventional maize (CM) varieties. The increased level of these two essential amino acids offers QPM a nutritional advantage over CM for consumers whose diet is dominated by maize and who lack adequate access to other sources of protein. With technical and material support from the International Maize and Wheat Improvement Center (CIMMYT) and other partner organizations, significant efforts have been made to develop, release, and disseminate QPM varieties in developing countries where maize is the dominant dietary source of energy and protein, to address the problem of protein undernutrition. More than 167 QPM varieties have so far been released globally across 39 countries. Almost half (53%) of these releases have been in Africa of which (as of 2016) eight were released by the Ethiopian Institute of Agricultural Research (EIAR).

In Ethiopia, QPM research was started in 1994 with evaluation of varieties obtained from CIMMYT. However, a concerted effort in QPM research and promotion was only started in 2003 with the launching of the Quality Protein Maize Development (QPMD) project funded by the Government of Canada. Subsequently, commencing in 2012, a more comprehensive research for development project called Nutritious Maize for Ethiopia (NuME), funded by the same donor, was initiated by CIMMYT and its partners in 36 focal Woredas of Amhara, Oromia, SNNP and Tigray Regions where impact is expected to be greatest. The project includes dissemination, research and seed system components with gender equality, capacity building, communications and M&E forming cross-cutting activities across the components. To implement the Project, CIMMYT formed a multi-institutional partnership with up to 17 institutions (GOs, NGOs, universities, private seed companies and farmers' cooperative union), each bringing its own strategic advantage and competence to the project implementation process. The major implementing partners are: EIAR, the Ministry of Agriculture and Natural Resources (MoANR), Regional Bureaus of Agriculture (RBoA), Sasakawa Global 2000 (SG2000), Farm Radio International (FRI), the Harvard School of Public Health, the Ethiopian Public Health Institute (EPHI), the Ethiopian Seed Enterprise, Hawassa University, and World Vision Ethiopia.

This manual is prepared to assist subject matter specialists (SMSs) and development agents (DAs) involved in the dissemination of QPM to train and advice farmers by explaining in simple terms about QPM technology and its nutritional benefits, and to concisely describe production techniques to ensure a uniform and consistent messages to be communicated to farmers and consumers; thus hastening QPM adoption and reducing food and nutritional insecurity among maize producing and consuming farm families.

Target Audience

This manual is intended to be used by development agents (DAs) and subject matter specialists (SMSs) that are engaged in the dissemination of QPM technologies in Ethiopia.

Purpose of the Manual

This manual is meant to serve as a guide for DAs and SMSs involved in training and advising farmers on the nutritional benefits and production techniques of QPM in Ethiopia. It introduces the key features of QPM, its nutritional benefits and importance, and various techniques of production. It gives information about the QPM varieties that are available for commercial production in the different agro-ecologies of the country, together with the agronomic practices required for grain and seed production. The manual is meant to complement and augment the QPM guide book produced and distributed recently; and tries to present the concept of QPM and its production techniques in a simple form. Ideally the use of the manual will contribute to improve household food and nutritional security through creating knowledge and skills necessary for the adoption of QPM varietes with their appropriate crop management practices that can increase farm productivity.

This manual has been prepared through Global Affairs Canada (GAC) financed NuME Project, as part of the ongoing efforts to introduce and popularize QPM production and utilization in Ethiopia.

Key Principles of Successful Extension Workers as Effective Communicator

Effectively Moderate Group Discussion

- clarify with the group the task or objective of the discussion;
- pick up the contributions from the group and help structuring different ideas;
- ensure active participation of women in the discussion; and
- mediate conflicting positions.

Ask Questions and Listen Actively

- ask questions to get information, clarify situations and opinions, and encourage active participation;
- ask preferably open questions;
- use questions to induce analytical thinking; and
- give feedback and invite participants to give feedback.

Attitude: Convey Empathy

- show your full respect to participants;
- listen actively to participants' experiences and needs;
- give positive and helpful feedback;
- be respectful and interested in their local experiences; and
- build up mutual understanding and trust, and encourage participants to respect mutual comments.

Malnutrition and Protein Deficiencies

The reality in rural Ethiopia:

- malnutrition in general and diseases associated with protein deficiency are the major food and nutrition problems;
- children are most affected and highly vulnerable to protein deficiency diseases and two out of five children are stunted;
- 28% of child mortality is associated with under-nutrition;
- 16% of all repetitions in primary schools are associated with stunting;
- lack of access to protein rich food is one attributable factor as most of the staple crops are deficient in protein content.
- 67% of the adult population in Ethiopia suffered from stunting as children;
- annual costs associated with child under-nutrition are estimated at 55.5 billion Birr (16.5% of the GDP).

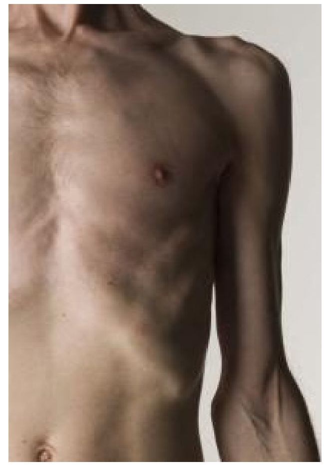

Figure 1. Person affected by protein deficiency disease symptom

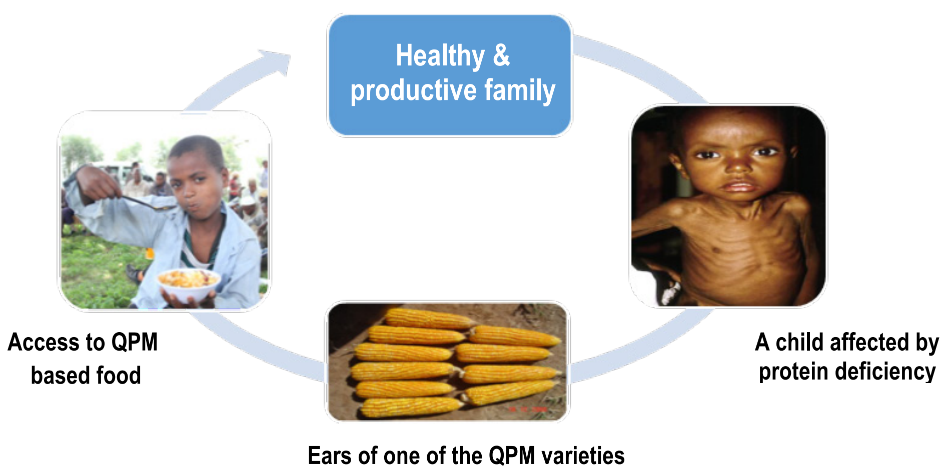

Figure 2. Role of QPM for healthy and productive life

Therefore, as indicated in the UNICEF report, eliminating stunting in Ethiopia is a necessary step for growth and transformation.

Then what solution can we provide?

- encourage production and consumption of protein rich foods: pulses, dairy products, egg, meat, fish and QPM;
- QPM can be an alternative source when availability of protein rich foods are limited.

Definitions and Concepts about QPM

What is QPM?

- QPM refers to maize genotypes having double of lysine and tryptophan content than CM genotypes;
- proteins are made up of building blocks called amino acids;
- amino acids are grouped into essential and non-essential;
- essential amino acids are those amino acids that cannot be synthesized by the organism and, therefore, must be supplied in its diet;
- lysine and tryptophan are essential amino acids which must be supplied in the diet from different sources such as meat, milk, pulses or QPM, etc;
- lysine levels in CM and QPM average 2.0% and 4.0% of total protein in whole grain flour, respectively; and
- tryptophan levels in CM and QPM average 0.4% and 0.8% of total protein in whole grain flour, respectively.

TABLE 1. Lysine and tryptophan levels as percentages of total protein in whole grain flour of conventional maize (CM) and *o2o2* maize

	CM	QPM
Protein	> 8	> 8
Lysine in protein	1.6-2.6 (mean 2.0)	2.7-4.5 (mean 4.0)
Tryptophan in protein	0.2-0.6 (mean 0.4)	0.5-1.1 (mean 0.8)

Note:

- One cannot differentiate between QPM and CM just by looking at the plant, ears or grain unless biochemical analysis is done to determine lysine and tryptophan contents;
- Total quantity of protein in both QPM and CM is the same; and
- Only the quantity (%) of the two essential amino acids in protein is greater for QPM than CM.

Nutritional Benefits of QPM

The nutritional benefit of QPM for people who depend on maize for their energy and protein intake is significant. Consumption of QPM increases the growth of infants and young children with mild to moderate under-nutrition among populations where maize is the staple food.

The production and consumption of QPM has the following advantages:

- Protein from QPM has higher levels of lysine and tryptophan than CM, and are more easily digestible, making the nutritional value of QPM protein comparable to milk.
- Protein quality of QPM is the highest among all cereal staple crop consumed by humans.

TABLE 2. Nutritional value of QPM and CM compared to milk

Food	Nitrogen Balance	Protein Quality (% of milk)
CM	0.31	39
QPM	0.72	90
Milk	0.80	100

TABLE 3. Protein quality of QPM as compared to other cereals

Cereal crops	QPM (% Casein)
QPM	82.1
Rice	79.3
Oats	59.0
Barley	58.0
Pearl millet	46.4
Wheat	38.7
Finger millet	35.7
Sorghum	32.5
CM	32.1

- In east Wollega zone of Ethiopia, especially in Sibu Sire Woreda, where maize is a dominant crop, children (7 to 56 months) consuming QPM showed on average a 20% increase in weight-for-age over time than those who consumed CM.
- QPM may also help other vulnerable groups such as pregnant and nursing women, the elderly or the sick who have higher protein requirements.
- Compared with CM, QPM based foods (in addition to their nutritional advantage), have better taste and functional properties including:
    - injera prepared from QPM is soft and has longer shelf life;
    - QPM porridge is smoother;
    - QPM injera develop less of a sour taste when fermented, making it more palatable to children; and
    - the taste of green QPM ears is superior to that of CM because of its perceived sweetness.
- QPM in foods prepared from fresh green ears (e.g. roasted or boiled ears) or matured grain maintains its protein quality and nutritional advantage relative to CM.
- Due to its enhanced content of tryptophan and lysine, QPM reduce target maize estimates to be consmed by nearly 40% compared to the CM to meet lysine requirements and 20% tryptophan.
- Besides doubling the amount of biologically useable protein in the diet, QPM also provides higher niacin availability, higher carotene bio-utilization in yellow QPM, higher carbohydrate utilization, and stimulates appetite.

[1] Casein are proteins commonly found in mammalian milk, making up 80% of the proteins in cow's milk and between 20% and 45% of the proteins in human milk.

Characteristics and agro-ecological Adaptation of QPM Varieties in Ethiopia

With technical assistance from CIMMYT and support from donors, largely the Government of Canada, EIAR breeders developed and released eight [six hybrids and two open pollinated varieties (OPVs)] of QPM for commercial production in different maize agro-ecologies of the country between 2001 and 2016.

A) Open Pollinated Varieties

An OPV is a genetically heterogeneous population maintained by open-pollination, which retains some distinguishing features, when reproduced or reconstituted. Important features of the two OPVs are given below.

Key characteristics of OPVs

- OPV is a population and/or a composite of plants that is relatively uniform and stable (e.g. Melkassa-1Q and Melkassa-6Q);
- OPV seed is produced by random cross pollination i.e., there is no control pollination.

Advantages of OPVs

- OPVs are relatively easy to develop;
- Seed of an OPV is simple and inexpensive to produce;
- Farmers can save their own seed for replanting in the following (about three generations) season; and
- Seed can easily be passed from farmer to farmer.

Disadvantages of OPVs

- The grain yield is relatively lower than and not as uniform as hybrids; and
- Not suitable for mechanized harvesting as compared to hybrids.

1. Melkassa-6Q	
Year of Release and Description	▪ 2008 ▪ OPV, early maturing and tolerant to low moisture stress
Agro-ecological Adaptation	▪ low moisture stress areas in central rift valley area of Oromia, Southern Nations, Nationalities and Peoples (SNNP) and Somali Regions and in some parts of Tigray due to its tolerance to low moisture
Days to Maturity	▪ on average 120 days
Yield Potential	▪ 4.0 - 5.0 t/ha under research management ▪ 3.0 – 4.0 t/ha under farmers` management

2. Melkassa 1Q	
Year of Release and Description	▪ 2013 ▪ QPM version of Melkassa-1 ▪ OPV and an extra early maturing type
Agro-ecological Adaptation	▪ best suited to the adaptation areas of Melkassa-1, areas with short rainfall duration and marginal for growing other varieties of maize
Days to Maturity	▪ on average 90 days
Yield Potential	▪ 3.5 - 4.5 t/ha under researcher management ▪ 2.5 - 3.5 t/ha under farmers management

Note:

- Both Melkassa-1Q and its conventional counterpart (Melkassa-1) are not recommended for relatively high potential areas within moisture stress areas as they mature earlier and yield lower than other maize varieties.
- They are preferred by birds and wild animals because of their early maturity and shorter plant stature.

B) Hybrid QPM Varieties

A hybrid (F_1) is the product of a cross between two unrelated (genetically dissimilar) genotypes, one of which is designated as female and the other as male parent.

Hybrids can be:

- single cross, a hybrid resulting from a cross between two inbred parents (e.g. BHQPY545), and
- three-way cross, a hybrid obtained by crossing three inbred parents (e.g. MHQ138).

The hybrid QPM varieties and their area of adaptation are presented below.

Advantages of hybrid varieties

- Higher grain yields; and
- More uniform and suitable for mechanization.

Disadvantages of hybrid varieties:

- Expensive to develop (many generations of selfing is required to develop parental lines);
- Higher seed price; and
- Farmer should get fresh F_1 seed every year as use of recycled seed reduce yield.

1. BHQP542 (Gabissa)	
Year of Release and Description	▪ the first QPM variety released in Ethiopia in 2001 ▪ an intermediate maturing three way cross hybrid
Agro-ecological Adaptation	▪ adapted to the moist mid-altitude maize growing-ecology (1000-1800 masl) ▪ shares the same adaptation zones with BH540
Days to Maturity **Yield Potential**	▪ on average 145 days ▪ 7.0 - 9.0 t/ha under researcher management ▪ 5.0 - 6.0 t/ha under farmers management

Note:
Because of its susceptibility to leaf rust disease this variety is now out of production.

TABLE 4. Released QPM varieties with their agro-ecological adaptations, disease reaction and some agronomic characterstics

Variety	Year of Release	Adaptation	Plant Height (cm)	Ear Height (cm)	DM	Tassel Color	Seed Color	Grain Texture	Prolificacy	Yield (qt/h)		Disease Reaction		
										RS*	FF+	GLS	TLB	CLR
BHQPY542	2001	Moist mid-altitude	220-250	100-120	145	Dark pink	White	Semi flint	Prolific	70-90	50-60	T	MT	MS
BHQPY545	2008	Moist mid-altitude	250-260	120-140	144	Pinkish	Yellow	Semi flint	Prolific	80-95	55-65	T	MT	MT
Melkasa- 6Q	2008	Low moisture stress	165-175	70-75	120	White	White	Semi flint	Non-prolific	40-50	30-40	-	T	T
AMH760Q	2011	Highland	245	143	183	50% white, 50% purple	White	Semi flint	Prolific	85-95	75-80	T	S	MT
MHQ138	2012	Low moisture stress and moist mid-altitude	200-235	100-120	140	White	White	Semi flint	Prolific	75-80	55-65	T	T	MS
Melkasa-1Q	2013	Low moisture stress	140-160	65-70	90	White	Yellow	Flint	Non-prolific	35-45	25-35	-	T	T
BHQPY548	2015	Moist mid-altitude	229	109	145	Purple	White	Semi flint	Prolific	75-85	55-70	T	MT	T
AMH852Q	2016	Highland	250	145	183	Purple	White	Semi flint	Prolific	90-100	75-85	T	T	-

*RS=research station; +FF=farmers' field: DM=days to maturity; T=tolerant; MT=moderately tolerant; MS=moderately susceptible; S=Susceptible

2. BHQPY545 (Kello)	
Year of Release and Description	▪ 2008 ▪ yellow grain, single cross hybrid with high yield potential and lodging resistant ▪ a little earlier in maturity than other intermediate maturing varieties ▪ prolific and under good management it can produce up to four full-sized cobs
Agro-ecological Adaptation	▪ adapted to the moist mid-altitude maize agro-ecology
Days to Maturity	▪ on average 144 days
Yield Potential	▪ 8.0 - 9.5 t/ha under researcher management ▪ 5.5 - 6.5 t/ha under farmers' conditions; up to 9.8 t/ha reported from demonstration plots managed by farmers in Gobu Seyo woreda, East Wollega zone

Figure 3: Ear (left) and plant (right) morphology of BHQPY545

Demand for yellow maize is low as consumers prefer white grain, but its demand may increase for the following reasons:

- increased in awareness about the nutritional benefit of the variety particularly for children and pregnant and breast feeding mothers;
- suitability for making corn flakes;
- suitability for poultry feed in the flourishing poultry industry; and
- other peculiar characteristics of the variety such as prolificacy, tolerance to lodging and leaf diseases, and sweetness for green ears consumption.

Note:
BHQPY545 is susceptible to ear rot disease that ranges from low to medium rates. To reduce the problem, the following strategies can be used:

- avoid growing in areas where the ear rot problem is prevalent;
- adjust planting dates to escape rainfall during filling and ear drying stages;
- use this variety for green ear production and marketing as it is prolific under optimum plant density and management conditions;
- grow during off-seasons using irrigation in areas where the variety is adapted; and
- turn the ears down as the crop matures to prevent rain entering the husk.

3. AMH760Q (Webi)	
Year of Release and Description	▪ 2010 ▪ a three way cross hybrid variety with mixed tassel and leaf sheath color (purple and white)
Agro-ecological Adaptation	▪ adapted to sub-humid highlands (1800 to 2600 masl) with extend rainfall
Days to Maturity	▪ on average 160 days
Yield Potential	▪ 8.5 - 9.5 t/ha under researcher management ▪ 7.5 - 8.0 t/ha under farmers' management

Webi is the outcome of the conversion of the parental lines of BH660 into QPM version through backcross breeding method. The conversion was aimed at developing QPM variety that is competitive with BH660 in grain yield in the transitional and true highland areas.


Figure 4: Ear (left) and plant (right) morphology of AMH760Q

Note:
AMH760Q is susceptible to turcicum leaf blight. In highland areas where turcicum leaf blight is a serious problem, farmers are advised to grow alternative QPM varieties (like AMH852Q) which are tolerant to the disease. It has mixed tassel colour of purple and white (50:50) as a varietal characteristics.

4. MHQ138	
Year of Release and Description	▪ 2012 ▪ three way cross hybrid tolerant to drought
Agro-ecological Adaptation	▪ adapted to dry land areas such as the Central Rift Valley, northern, eastern and southern parts of Ethiopia
Days To Maturity	▪ on average 135 days
Yield Potential	▪ 7.5 - 8.0 t/ha under researcher management ▪ 5.5 - 6.5 t/ha under farmers' management

Note:
This variety shares the same female single cross parent with BHQP542 (CML144/CML159), but its male parent has been derived from POOL15Q. It has manifested high yield on demonstration plots conducted on farmers' fields in the vicinity of Bako. Therefore, it can be used as an alternative QPM variety in some high potential transitional midland areas (lower side of the midland); but one should seek advice from research centers before planting it for large scale production.

Figure 5: Ear (left) and plant (right) morphology of MHQ138

5. BHQPY548	
Year of Release and Description	▪ 2015 ▪ three way cross hybrid
Agro-ecological Adaptation	▪ adapted to the moist mid-altitude maize agro-ecology
Days To Maturity	▪ on average 145 days
Yield Potential	▪ 7.5 - 8.5 t/ha under researcher management ▪ 5.5 - 7.0 t/ha under farmers' management

Figure 6: Ear (left) and plant (right) morphology of BHQ548

Note:
The release of this variety will potentially accelerate the adoption of QPM due to: (i) higher seed yield enough to meet seed productivity threshold of seed companies; and (ii) providing a white-seeded alternative of similar maturity and superior yield to the yellow-seeded QPM variety (BHQPY545).

6. AMH852Q

Year of Release and Description	▪ 2016 ▪ three way cross hybrid
Agro-ecological Adaptation	▪ adapted to sub-humid highland agro-ecology (1800 to 2600 masl)
Days To Maturity	▪ on average 183 days
Yield Potential	▪ 9.0 - 10.0 t/ha under researcher management ▪ 7.5 - 8.5 t/ha under farmers' management

Figure 7: Ear (left) and plant (right) morphology of AMH852Q

Note:
This is a high yielding QPM variety that shares the same agro-ecology with AMH760Q; hence, it can be a potential substitute to AMH760Q which already has shown poor performance and susceptibility to turcicum leaf blight.

Maintenance of QPM Varieties

The production and maintenance of QPM seed do not differ from those of CM seed. The only additional requirement for QPM seed maintenance is to perform tryptophan and protein analyses to ensure that values are above the required minimum standard.

Key Issues in QPM grain contamination on farmers' fields:

- pollination of a QPM cultivar with CM pollen results in non-QPM grain; and
- grain production of both hybrids and OPVs in farmers' fields is exposed to the danger of contamination, depending upon the farm size and other environmental conditions such as wind direction, distance and number of surrounding farms planted with CM varieties.

Contamination of QPM grain from adjacent maize fields can be reduced by:

- planting relatively larger plots to reduce the border areas relative to the area of the whole field;
- planting square plots to reduce the length of the borders;
- planting QPM plots up wind from normal maize plots or planting other crops; and
- harvesting border areas (< 5 m) separately from the whole QPM plot and treating the grain as CM maize grain.

Note:
When QPM and CM plots are planted side by side, the maximum contamination level will be on average 11% (percentage of CM grain produced in the QPM field). Loss of QPM benefits occur only when the contamination level is more than 20%. Therefore, planting a QPM in a field next to a CM field does not significantly affect the quality and nutritional benefits of the harvested QPM grain.

Recycling of seed

- The advantage of OPV seed is that farmers can save part of the harvested grain for plantings in the next seasons but only for about three generations; and
- As is in the CM, OPVs of QPM also can be reused for about three generations.

How should farmers select and save seed from his/her OPV QPM grain?

- select OPV seed from a sub-plot located in the middle of the fields as shown in Figure 8 below;
- select 200 to 300 ears for saving as seed for the next planting;
- shell the selected ears and mix the seed thoroughly; or
- purchase fresh OPV seeds from seed producers after using own seeds for not more than three times/ years.

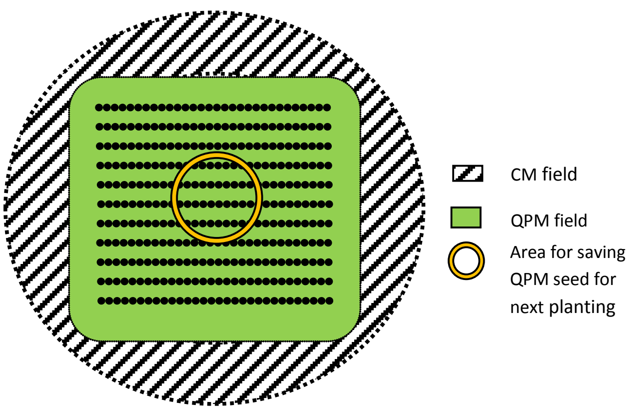

Figure 8: Schematic representation of QPM OPV field surrounded by CM field under small scale on-farm condition

Note:
For recycling QPM seed, plants located in the central parts of the field, at least 20 m away from the QPM field bordering with other maize fields, (including fields planted with different QPM varieties) has to be selected. The QPM seed should be harvested from plants in the middle of a relatively large field (a minimum size of 50 m x 50 m, or 0.25 ha, is recommended).

QPM Field Management (Agronomy)

The agronomic management of QPM is similar to that of CM. Hence, only brief guidelines on the subject are given as follows.

Spacing and plant density

Choice of plant density and spacing depends on several factors such as length of maturity period, plant geometry (erect or non-erect leaves), agro-ecology in which it is to be grown, and moisture availability.

- use seed rate of 25-30 kg per hectare;
- plots should be planted with either one extra seed per hole or per alternate hole to compensate for possible losses in germination due to poor seed quality, damage by wild animals, birds and insect pests, etc;
- for medium maturing varieties of mid-altitude sub-humid agro ecology and all highland varieties, the recommended spacing between rows and between plants are 75 x 30 cm, one seed per hill which will produce 44,444 plants/ha;
- for early maturing varieties of low moisture stress areas and the recommended spacing are 75 cm x 25 cm which gives 53,333 plants/ha; and
- for the extra early maturing varieties like Melkassa-1Q the recommended spacing are 75 cm x 20 cm.

To achieve the optimum plant population on farmers' fields, the following conditions are necessary:

- the seed must be of high quality with high germination percentage (at least 85%);
- optimum sowing depth must be used to ensure that the germinating seedlings penetrate the soil surface before they exhaust their nutrient/energy reserves (this is important to BHQPY545 which has smaller seed size); and
- there has to be adequate soil moisture (especially when planting depth is shallow) and good soil-seed contact to ensure uniform emergence of seedlings.

TABLE 5. Recommended plant density and spacing for different QPM varieties in different agro-ecologies

Variety	Spacing	Plant density	Agro-ecology
AMH760Q	75 x 30	44444	Mid-altitude sub-humid agro-ecology
AMH852Q	75 x 30	44444	Mid-altitude sub-humid agro-ecology
BHQPY542	75 x 30	44444	Mid-altitude sub-humid agro-ecology
BHQPY545	75 x 30	44444	Mid-altitude sub-humid agro-ecology
BHQPY548	75 x 30	44444	Mid-altitude sub-humid agro-ecology
MHQ138	75 x 25	53333	Low moisture stress areas
Melkassa1Q	75 x 20	66666	Low moisture stress areas
Melkassa 6Q	75 x 25	53333	Low moisture stress areas

Depth of planting

- for optimum plant population, plant QPM seeds at uniform soil depth to attain uniform seedling emergence;
- the optimum depth of planting may vary with seed size and generally depth of 5 - 7 cm is recommended; and
- for varieties with small seeds, like BHQPY545, 3-5 cm depth is optimum. The seed should be covered with soil in such a way that a good contact between the seed and soil is obtained.

Thinning

- plots must be thinned to the recommended density no later than three weeks after planting; and
- while thinning, always consider two adjacent holes together and thin out the number of extra plants per two holes.

Fertilizer application

- fertilizer rates for QPM production do not differ from those used to produce CM; and
- the fertilizer recommendation currently in use is only for nitrogen (N) and phosphorus (P), sourced from urea (46% N) and DAP (18% N and 46% P_2O_5).

Note:
A multi-nutrient fertilizer blend will soon be publicized for wide-scale dissemination, after it is verified by EIAR and officially adopted by the MoANR and BoAs.

Timing and method of fertilizer application

- all dose of DAP is applied at planting; fertilizers should be placed below or to the side of the seed; and
- direct contact between fertilizers and seed must be avoided; open the planting hole (10 cm deep), place the fertilizer in it and cover with 5 cm of soil; then place the seed on top or on the side of the planting hole and cover with soil to the desired depth.

Urea fertilizer can be applied all at once or in two or three splits, depending on the agro-ecology:

- in highland areas, apply urea in three splits: one-third at planting (with DAP), one-third at knee height (8-10 leaf stage), and one-third at flowering stage;
- in mid-altitude, sub-humid agro-ecologies, apply urea in two splits: one-half at planting and the other half at knee height stage;
- in moisture stressed areas, the full dose of urea should be applied once at knee height stage; and
- in all cases, spot apply the fertilizers 3-5 cm away from the seed/plants to avoid seed burn and improve fertilizer use efficiency.

Harvesting and drying

Different maize varieties have different harvesting time based on their maturity group and the agro-ecology where they are grown. Harvesting time is best judged by the grain physiological maturity.

Consider the following to decide when and how to harvest:

- harvesting dry ears should take place when the husks have yellowed and 75% of the grain at the central part of the ears develop black layer;
- harvest each QPM ear by picking from every plant;
- harvest when the moisture content of the grain is 13-14% to reduce cost of drying;
- if harvested with higher moisture content, dry the ears/grain until the moisture level reduces to about 12.5-13% as follows:
  - o hang the ears vertically in the direction of the wind in order to ensure maximal drying out;
  - o remove the husks to allow better drying; and
  - o dry the ears in open spaces, on plastered threshing ground, or plastic sheeting/ canvas.

- protect the dried crop from insects such as weevils by treating it with appropriate insecticide chemicals such as Pirimiphos-methyl (Actellic) 2% D at 30 to 50 g/100 kg or Malathion 5% D at 50 g/q of grain, and
- store the grain in a clean container and keep it in cold place.

Note:

- Don't leave matured QPM for long in the field; it increases the incidence of insect and disease (rotting) attack that reduce the nutritional quality of the grain.
- Remove any QPM ears from the harvest before shelling, if they are affected by insects and disease and/or show discoloration or molding.

Management of Weeds, Diseases and Insect Pests

A) Weeds and weed control

Key points regarding weeds and their control:

- successful production of maize depends largely on the efficacy of weed control;
- weed control during the first six to eight weeks after planting is crucial;
- special attention needs to be given to weeds that grow from underground tubers or rhizomes, and parasitic weeds such as striga; and
- in addition to direct competition with crop plants, weeds are alternative hosts of diseases and insect pests of maize.

When to weed QPM fields:

- First weeding - 14 to 21 days after sowing or at three leaf stage;
- Second weeding - 4 to 6 weeks after sowing or at five leaf stage before urea is applied; and
- A third weeding/slashing may be required, depending on the degree of weed infestation and crop growth stage.

Herbicide recommendations:

- apply pre-emergence herbicides such as Primagram Gold® at the rate of 4 liter/ha; and
- apply post-emergence herbicides such as 2-4-D at the rate of 2 liter/ha to control broad-leaf weeds.

Note:
Farmers should use an integrated approach for the management of weeds that combines all available options (deep and repeated ploughing, crop rotation, use of recommended spacing, timely planting, hoeing and hand pulling, improving soil fertility, use of weed free seeds, use of herbicides, etc.).

B) Major maize diseases and their management

1. Turcicum leaf blight (TLB)

- is a fungal disease;
- diseased leaves show lesions which are first formed as a small and diamond shaped and then elongate as they mature;
- each lesion is light brown with a reddish-brown border and a light yellow ring around it;
- lesions may merge, producing a complete burning of large areas of the leaf; and
- may lead to stalk and ear rot.

Figure 9: Symptom of Turcicum leaf blight

The following control options can be used:

- plant resistant/tolerant QPM varieties;
- avoid planting maize after maize in infected fields; rotate maize with legumes or other non-cereal crops; and
- bury plant residues that carry disease inoculums by deep ploughing.

2. Grey leaf spot (GLS)

- is a fungal disease;
- occurs in warm to hot areas of Ethiopia especially in humid seasons; and
- lesions are pale brown or gray to tan, long, narrow and rectangular, restricted by the veins.

Figure 10: Symptom of Grey leaf spot

The following control options can be used:

- plant resistant/tolerant varieties;
- avoid planting maize after maize in the same field; rotate maize with legumes or other non-cereal crops; and
- remove infected crop residues from previous season.

3. Common leaf rust (CLR)

- is a fungal disease;
- small round to oval, brown or orange pustules distributed uniformly over the upper leaf surface; later spreads to the upper parts of the plant;
- severely affected leaves turn yellow and die early; and
- ears of severely affected plants are much lighter than normal and the seeds are pinched and loose on the ear.

Figure 11: Symptom of Common leaf rust

The following control options can be used:

- avoid all alternate hosts of the fungus;
- remove and burn diseased maize plants; and
- plant resistant/tolerant QPM varieties.

4. Maize streak virus (MSV)

- is a viral disease;
- MSV is transmitted by leafhoppers of Cicaduina species;
- initially it appears as a small whitish spots, which then becomes colorless streaks running parallel to the veins along the entire length of the leaf;
- when plants infected at the seedling stage, the streaking appears on all except the lowest leaves; and
- infected plants become stunted and may not produce ears; if produced, ears are smaller than normal.

Figure 12: Symptom of Maize streak virus

The following control options can be used:

- plant a variety resistant/tolerant to MSV;
- remove alternate hosts (grasses); and
- remove and bury or burn infected maize plants at an early stage of crop development.

5. Stalk and ear rot (*Fusarium and Gibberella spp.*)

- is a fungal disease;
- causes stalk and ear rots and seedling blights;
- later whitish-pink cottony fungal growth develops on and between the seeds and sometimes on the silks;
- infected plants are weakened and can break easily during strong winds and rains; and
- mycotoxins, which are harmful to humans and livestock, are also produced on ears.

Figure 13: Symptom of Stalk rot

The following control options can be used:

- plant resistant/tolerant varieties;
- use of recommended plant populations density; and
- application of recommended rate of nitrogen fertilizer.

6. Maize lethal necrosis (MLN)

- a new disease recorded in Ethiopia in 2014;
- viral disease caused by the maize chlorotic mottle virus (MCMV) and any of the cereal viruses in the Potyviridae group, especially sugarcane mosaic virus (SCMV);
- MLN infected plants show chlorotic mottling on the leaves, usually starting from the base of the young leaves in the whorl and extending upward towards the leaf tips;
- advanced stages of the disease are reflected by necrosis of the leaf margins and progressing to the midrib, stunting of the plant, and eventual necrosis (drying up) of the leaves and the whole plant;

- plants that are affected at later growth stages show chlorotic mottling on the leaves and dry leaves starting from the top, and either show barrenness (with no ear formation) or poor seed set;
- severely affected plants often produce diseased ears and low quality grains that are unfit for consumption;
- MLN causing viruses are transmitted by insect vectors;
- MCMV also survives on maize crop residues; and
- MCMV and SCMV can also be either seed-borne (i. e. seed produced by an infected plant can carry the disease) or seed-transmitted (i. e. the virus can pass from infected seeds to a newly germinated plants).

Figure 14: Symptom of Various symptoms of MLND

The following control options can be used:

- plant resistant/tolerant varieties (being developed by CIMMYT);
- the best approach for MLN management is integrated pest management practices encompassing cultural control (such as crop rotation, crop diversification, and good field sanitation) and vector control using seed treatment followed by foliar sprays with appropriate insecticide chemicals; and
- seed dressing with insecticide such as Gaucho® (diluted in 1.5 liters of water) at the rate of 120 ml/q.

C) Major insect pests and their management

1. Maize stem/stalk borer

Figure 15: Symptom of Maize stem/ stalk borers

- the common species are maize stem borer (*Busseola fusca*) and spotted stem borer (*Chilo partellus*);
- cause more serious damage when occur at the seedling stage;
- young larvae cause the damage by feeding on leaves, stalk and ears;
- the initial symptom of infestation on young plants is rows of oval perforations in leaves of the unfolding whorl;
- as they develop, the larvae tunnel into the leaf midribs, damage the growing point causing a condition referred to as "dead heart";
- older larvae tunnel extensively in stems, eating out long frass-filled galleries which may weaken stems and cause breakages; and
- larvae of later generations also tunnel into maize ears and may seriously damage the grain on the ears.

The following control options can be used:

- destruction of crop residues;
- deep and repeated ploughing of the soil before planting;
- early sowing, following early rains;
- intercropping maize with crops that are non-hosts for stem borers (e.g. cassava and grain legumes) and less susceptible, and repellent plant such as desmodium;
- use of push-pull strategy;
- cultural practices such as horizontal laying of maize stalks thinly on the ground for some weeks before stacking them for future use; and
- when infestation is severe apply Cypermethrin 1% or Diazinon 10% granules at the rate of 3-5 kg/ ha.

2. Termite

- there are different species of termites that attack maize (mound building and subterranean termites);
- termites chew roots and dry the plant out, usually resulting in patches of crop death; and
- subterranean termite spp. do not build mounds and are more difficult to control because they nest and attack the crop beneath the soil surface.

Figure 16: Termite soldier

The following control options can be used:

- dismantle termite mounds/nests by deep ploughing/digging and application of insecticide chemicals such as malathion® at the recommended rate;
- spray Diazinon 60% EC® at 2.5 liter/ha and GUFOS® (Chlorpyrifos 48%, also called Dursban®) at 200 ml/ha;
- seed dressing with Fipronil (Regent 500 FS®) at the rate of 8-13 ml/kg, or SeedPlus 30 WS® at the rate of 5 gm/kg seed;
- rotate QPM with less susceptible crops e. g. sorghum is known to be less susceptible;
- plant lodging resistant/tolerant varieties; and
- harvest promptly.

3. African army worm

- very damaging pest capable of destroying entire field in short period; and
- small dark green worms hatched out from eggs laid usually on the underside of leaves by a dark gray moth.

Figure 17: African armyworms

The following control options can be used:

- monitor fields for infestations during outbreak periods;
- apply one of the following insecticides:
  - o Malathion 50% EC and fenitrothion 50% EC each at 2 liter/ha;
  - o Fenitrothion 95% ULV at 1.5 liter/ha;
  - o Diazinon 60% EC at 1 liter/ha; and
  - o Carbamate (carbaryl 85 WP) at 1.5 kg/ha.

Note:
Spray insecticides when caterpillars are still small. Once caterpillars are grown, reaching 3 - 3.5 cm long, they might have caused serious damage and insecticide applications may no longer be feasible.

4. American armyworm *(Spodoptera frugiperda)*

- A new and devastating pest 1st reported in Ethiopia in the 2016/17 crop season.
- It attacks maize and many other plant species in patches and causes a serious damage unless timely controlled.
- It attacks maize at different growth stages and eats all plant parts (leaf, stem, tassel, silk, and cob).
- Larva hides in the whorl of the leaf and forms a plug from frass which protects it from insecticide applications.
- It spreads very fast as the adult moth can fly long distances within a day.
- The pest completes its life cycle within a short period and can have several generations in a year.
- It usually feeds during early morning and late afternoon and is difficult to see in the field throughout the day.

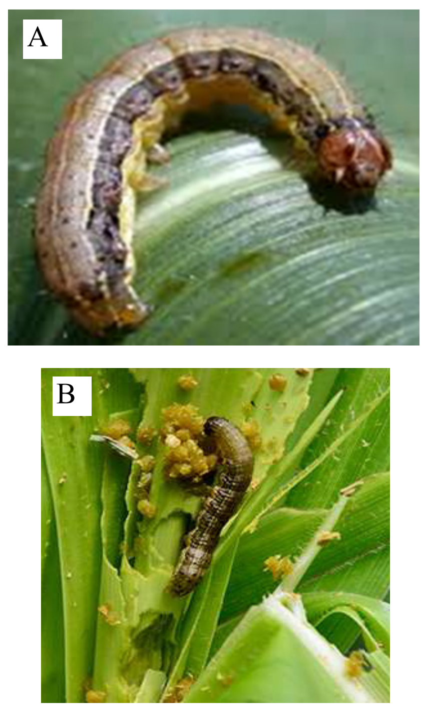

Fig 18. Fully developed American armyworm larva (A) and its damage symptom on maize (B)

Management options

- Monitor maize leaves, specifically the whorls, for the presence of larvae in farm plots and the surroundings areas at least twice a week.
- Pheromone traps can be used to determine incidence of adult moths and disrupt mating during the whorl stages.
- Squash caterpillars in the whorl with hand or collect and drop in hot water.
- Insecticide application should commence before larvae burrow into the whorls or ears and when the sprayed insecticide easily penetrate the crop canopy.
- Common insecticides that can be used for the control of armyworm in Ethiopia include: Malathion at 2 liter/ha; Chlorpyrifos at 0.5 liter/ha; Diazinon at 1 liter/ha; Dimethoate at 1.5 liter/ha. Other insecticides recommended for the African army worm can also be used.
- Spray early in the morning or late in the evening when caterpillars are actively feeding and target spraying over the whorl of the plant.
- Insecticide resistance has been widely reported; hence, avoid spraying the same class of insecticides repeatedly.
- Chemical insecticides should be used as part of integrated pest management strategy that involves deep plowing, early planting, clean weeding, use of optimum rates of fertilizers to boost plant growth, use of early maturing varieties, rotating maize with other less preferred crop, etc.
- Mobilizing the whole community and coordinated implementation of management options is crucial.

5. Cut worm

- larvae are grayish, brownish, or black in color;
- larvae cut seedlings at or a little below ground level at night; and
- during day time, larvae hide nearby the cut or injured seedlings below the ground.

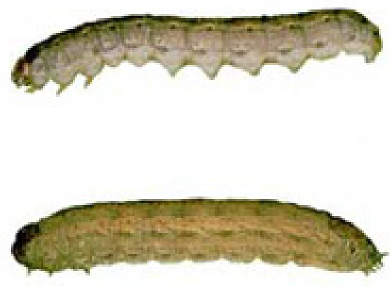

Figure 19: Cut worms

The following control options can be used:

- eliminate weeds as early as possible, at least two weeks before planting;
- deep and repeated ploughing and harrowing the field to expose cutworms to the sun and natural enemies;
- destroying plant residues that could harbor cutworms; and
- dress seeds with insecticide chemicals or through the application of soil insecticides such as Imidacloprid® at the rate of 56-140 gm/ha.

Note:
Farmers should be trained and advised to follow an integrated pest management (IPM) strategy for effective and sustainable management of diseases and insect pests of maize. IPM combines all available options (deep and repeated ploughing, crop rotation, use of resistant/tolerant varieties, timely planting and weeding, improving soil fertility, use of healthy seeds, careful use of appropriate pesticide chemicals, etc.).

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