The Development and Promotion of Quality Protein Maize in Sub-Saharan Africa

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Progress Report 2003

by the

International Maize and Wheat Improvement Center (CIMMYT)

to the

Nippon Foundation

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CIMMYT®

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FOREWORD

Quality Protein Maize (QPM) development and promotion activities have grown tremendously in Africa during 2003. The strong support from the Nippon Foundation is being complemented through synergies with various other regional projects, resulting in impressive achievements only partially reported herein. Finally, QPM country working groups in several countries are functioning, albeit with varying success, to coordinate stakeholder activities toward achieving greater impact in their respective countries.

Five complementary projects are especially crucial to the success of this Nippon Foundation QPM project:

1. The WECAMAN (West and Central Africa Maize Network) network, whose Research Committee has ensured transparency and regional ownership of QPM research activities and grant allocation in the West and Central Africa sub-region.
2. The ECAMAW (East and Central Africa Maize Network) network, which has performed a similar role in the eastern and central Africa sub-region.
3. The SADLF (Southern Africa Drought and Low Soil Fertility) network, which has performed a similar role in the southern Africa sub-region.
4. The QPM-D project for eastern Africa, funded CIDA (Canadian International Development Agency), has provided strong support to socio-economic, nutrition and QPM dissemination activities.
5. The QPM project funded by the Rockefeller Foundation enables eastern African National Program scientists to convert to QPM their preferred OPVs.

In addition to the above five projects, the Harvest Plus project will begin in 2004 to develop maize (and other crops) with enhanced pro-vitamin A, iron and zinc content. Considerable opportunities for synergies will need to be developed between QPM and Harvest Plus activities, particularly related to nutritional advocacy and dissemination of nutritionally enhanced varieties.

This report describes a selection of QPM-related activities conducted during 2003. Although QPM research and development efforts are still growing, it is already impossible to discuss all of the work that is ongoing. Two sections of this report may be particularly helpful to assist the reader in gaining an overview of the QPM activities: 1) Highlights of 2003 activities are presented in the "Highlights" section, and 2) progress toward achieving the milestones stated in the QPM workplan for 2003 is summarized in the section entitled "Achievement of 2003 milestones."

This report was prepared by more than one dozen scientists from CIMMYT, IITA, and National Programs of several countries, whereas the work reported herein involved hundreds of partners and stakeholders (e.g. farmers, extension workers, nutritionists, food technologists, economists, agronomists, plant breeders, field technicians, NGO personnel, policy makers, and more).

The QPM stakeholders and beneficiaries of this project take this opportunity to thank the Nippon Foundation for its support of this work.

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HIGHLIGHTS

Eastern Africa

- In-country QPM Working Groups (WG) became operational in Ethiopia, Tanzania and Uganda, fostering much closer consultations and joint planning by all QPM stakeholders.
- Three promising QPM hybrids were identified for the mid-altitude zones of Ethiopia: CML144/CML159//CML182, CML144/CML159//CML181 and CML140/CML146//CML143.
- Two QPM hybrids were pre-released, and two QPM hybrids and one QPM OPV were nominated for testing in the National Performance Trials (NPT) in Kenya.
- One pre-released QPM hybrid performed as well as the popular commercial (normal) hybrid check in “mother/baby” farmer-participatory, on-farm trials in Kenya.
- Conversion to QPM of the three parental lines of BH660, the most popular hybrid in Ethiopia, reached near completion.
- Conversion to herbicide resistance was initiated for 5 QPM OPVs and 7 QPM inbred lines. This will enable use of low-dose herbicide seed dressing technology that offers effective control of *Striga* (“witchweed”).
- Breeding for weevil resistance within QPM germplasm was initiated with the formation of an early maturing experimental synthetic among families selected using artificial infestation of grain with weevils.
- Seed production of released QPM varieties: In Uganda, 570 t of certified seed of Nalongo was produced; in Ethiopia, 35 t of certified seed of BHQP-542 was sold to farmers and 40 ha of certified seed was planted; and in Tanzania, about 20 t of QPM foundation seed and 50 t of certified seed were produced by small seed companies and community-based organizations.
- Training in four countries in the region focused on “hands-on” training in the use of light tables and on further understanding QPM and its development.
- A regional QPM laboratory became operational in Ethiopia with the necessary equipment provided by the QPM Project.
- Mapping of malnutrition and maize consumption patterns determined that impact potential of QPM in Kenya is greatest around the lower slopes of Mount Kenya and various dryland areas of eastern Kenya.
- Studies were initiated to collect base line data on production, utilization and local perceptions on QPM in four leading QPM countries in the region.
- A comprehensive community nutritional impact study was completed in Ethiopia and the final report is expected in the latter part of the year.
- Animal feeding studies to focus on QPM commercial feed formulation were initiated in four countries in the region.

Western and Central Africa

- The Research Committee of WECAMAN reviewed 32 proposals submitted by the national agricultural research systems (NARS) in West and Central Africa and selected 22 proposals from nine countries. A total of US$55500 was allocated to support research, seed production and promotion of QPM activities in 2003.
- In collaboration with SG2000, MSV resistance of Obatanpa, Sussuma and DMRE-SR-WQPM was upgraded. These varieties will be multiplied for use in QPM project activities in 2004.
- Conversion to QPM was initiated for selected extra-early, early, intermediate and late maturing normal elite varieties, populations and inbred lines with stress tolerance and good adaptation to West and Central Africa.
- A total of 55 lowland and 81 mid-altitude lines from diverse QPM populations and crosses were grown to select promising lines for further screening under the light box/laboratory analysis. The selected best QPM lines will be used to form hybrids and/or synthetic varieties.
- 31 breeders, agronomists, extension workers and seed producers from the private and public sectors in 11 countries attended a training workshop on QPM development and seed delivery systems in Kumasi, Ghana.

Southern Africa

- Farmer-participatory, on-farm evaluations of QPM varieties were conducted in Malawi and Mozambique during 2003; this will expand to include South Africa, Zambia and Zimbabwe during 2004.
- Four very promising new QPM hybrids were identified in regional trials across 33 sites during 2002. Preliminary results from 14 locations during 2003 confirm their superior performance, with one three-way hybrid looking particularly good.
- Maize streak virus (MSV) resistant versions of the widely used hybrid CML144/CML159//CML176 have out-yielded the original hybrid in preliminary multi-location trials. MSV resistant versions of the parent lines, and superior MSV resistant versions of the hybrid will be available within one or two years.
- More than 3.5 tons of QPM seed was produced by CIMMYT in 2003 and distributed for further multiplication or on-farm demonstrations during 2004. Quantitative data are not available, but private seed companies are producing QPM varieties (especially Obatanpa) in Mozambique and Zimbabwe.
- A Zimbabwean laboratory was selected, among 10 applicant laboratories, to serve as regional QPM laboratory for southern Africa.

Global: Lowland Tropics

- **In Nicaragua,** NUTRINTA Amarillo, a new open-pollinated, yellow grain variety was released in a ceremony attended by Dr. Norman Borlaug and Mr. Yoey Sasakawa. QPM was sown on 8,000 hectares in Nicaragua.

- **In Vietnam**, HQ2000 (CML161 x CML165) was grown on more than 15,000 hectares. A new QPM hybrid, HQ-2004 (CML161 x CML493), will replace HQ2000. All seed production in Vietnam is done by transplanting.
- **In Bangladesh,** farmers have reported productive experiences with QPM hybrids. In 2003 they imported 20 tons of seed of HQ2000 from Vietnam—enough to sow 1,000 hectares. To meet future demand, the Agriculture Research Institute has begun increasing seed of the parents of HQ2000.
- **In India**, 15,000 hectares were planted to the white endosperm hybrid, Shaktiman-1. Two new QPM yellow hybrids were released in the State of Bihar and one QPM yellow hybrid released in the State of Karnal. Seed production will begin in winter 2003-2004.
- **In Bolivia**, the yellow QPM hybrid CML161 x CML165 was approved for release. Bolivia will be the 23rd country in which QPM maize is grown in the developing world, and the 18th new country, since the Nippon Foundation began providing support for work to develop, test, and disseminate QPM.
- **Four new tropical QPM lines** (two white and two yellow endosperm) were released. Of these, the white endosperm CML491 is outstanding, with excellent GCA for yield, protein quality, and ear rot and foliar disease resistance. The lines can enhance the performance and stability of new hybrid combinations.
- New generations of tropical QPM hybrids and synthetics were superior to normal and QPM seed industry checks, in tests at more than 40 locations during 2002-2003.

Global: Sub-Tropical

- A project was initiated to identify and/or develop QPM germplasm that also has high levels of Vitamin-A (beta-carotene) precursors in the grain.
- A newly established QPM laboratory, funded by Monsanto Foundation, was inaugurated at CIMMYT (Mexico) in October 2003 and will be fully operational before the end of the year.
- Aggressive use of molecular markers continues to accelerate the line conversion program involving normal x QPM lines.
- We continued seeking opportunities to exploit the heterosis between tropical and subtropical germplasm by crossing QPM lines adapted to these two mega-environments.

Global: Highland Tropics

- Conversion to QPM of elite highland lines was expanded to include late maturing lines with yellow grain type.
- Two highland white-grained QPM synthetics (experimental open-pollinated varieties) demonstrated encouraging results in preliminary first year evaluations.
- A highland-adapted, yellow-grained QPM synthetic (experimental open-pollinated variety) was formed.
- A project initiated in 2002, evaluating elite subtropical QPM germplasm in highland environments, has been expanded following encouraging preliminary results.

ACHIEVEMENT OF 2003 MILESTONES

This section provides a concise report of successes and failures in achieving the milestones that were proposed for 2003 in the QPM Workplan for 2003.

1. QPM Networking

Milestone 1: Partners from at least 6 countries will have participated in each of 3 sub-regional QPM planning meetings

- ✓ **Eastern Africa:** 35 NARS representatives, albeit only from 4 countries, attended the QPM working group meeting in Nairobi, 5-6 February 2003.
- ✓ **Southern Africa**: A planning meeting was held 11-12 March in Harare and was attended by QPM colleagues from Ethiopia, Kenya, Malawi, Mexico, Mozambique, Nigeria, South Africa, Swaziland, Zambia and Zimbabwe.
- ✓ **Western Africa:** The Research Committee of WECAMAN met from 10-12 April and approved 22 research projects in nine countries.

Milestone 2: QPM working groups will have been established and will have met in at least 2 countries of each sub-region

- ✓ **Eastern Africa:** QPM working groups were functional in Ethiopia, Tanzania and Uganda.
- ✓ **Southern Africa:** QPM working groups are active in Malawi, Mozambique and Zimbabwe.
- **Western Africa:** No information to report.

2. Germplasm Development

Milestone 3: For each of the 3 main ecologies, at least 2 new experimental OPVs and 4 new experimental hybrids will be identified for inclusion in regional or global QPM trials for 2004

- ✓ **Lowland Topical:** Trials of experimental QPM hybrids and OPVs have been sent from Mexico to multiple countries in Africa.
- ✓ **Mid-Altitude Tropical:** Trials of experimental QPM hybrids and OPVs have been sent from Mexico to multiple countries in Africa. In addition, one trial of QPM hybrids (including new streak virus moderately resistant hybrids) has been distributed to more than 50 locations, and another trial containing QPM OPVs has been distributed from Zimbabwe to about 60 locations in Africa.
- ✓ **Highland Tropical:** Preliminary trials including two white-grained synthetics were grown. Evaluation of highland QPM germplasm is increasing, but currently lags behind other germplasm categories.

3. Germplasm Testing

Milestone 4: Trial results will be summarized and widely reported

- ✓ Five-hundred copies of “Characterization of maize germplasm grown in eastern and southern Africa: Results of the 2002 regional trials coordinated by CIMMYT” were distributed to colleagues, partners and interested stakeholders during 2003. This report contains summary and detailed results of QPM trials grown at 33 sites in Africa.

Milestone 5: Best OPVs and hybrids will be identified for seed multiplication and further testing during 2004

- **Eastern Africa:** QPM hybrids have been released or are in pre-release stages in Kenya, Ethiopia and Tanzania. Similarly, QPM OPVs were released and seed produced in Ethiopia, Uganda and Tanzania. ✓
- **Southern Africa:** Malawi, Zambia and Zimbabwe have identified promising QPM hybrids and will include them in mother/baby trials during 2003/04. Commercial and/or community based seed production of a QPM OPV is ongoing in Mozambique, Malawi, South Africa and Zimbabwe. ✓
- **Western Africa:** A total of $20,000 was allocated to community-based seed production of QPM seed in nine countries. Additionally, $21,500 was granted for projects promoting adoption of QPM varieties in the same nine countries. ✓

4. Seed Production/Dissemination

Milestone 6: Seed production data will document an increased quantity of QPM seed available in each sub-region

- **Eastern Africa:** Well achieved, see Section 3.4 ✓
- **Southern Africa:** Data not readily available, see Section 5.4
- **Western Africa:** Data not available, but see Milestone 5

Milestone 7: At least one seed company will be a member of each country-level QPM working group

- **Eastern Africa:** Ethiopian Seed Enterprise, Ethiopia; membership for other country working groups could not be confirmed at press time for this report. ✓
- **Southern Africa:** Seed Co, Malawi; SEMOC, Mozambique; Seed Co, Zimbabwe ✓
- **Western Africa:** No information to report.

5. Training

Milestone 8: Training plans will be developed for each sub-region

- **Eastern Africa:** The focus was on hands-on, one-on-one training in QPM development methods (e.g. breeding methods, use of the light table, etc.) provided during visits to each national program. ✓
- **Southern Africa:** It was decided at the meeting in March that there were no urgent training needs for 2003 because several regional scientists attended QPM training in Mexico, and technicians attended QPM training in Ethiopia during 2002. ✓
- **Western Africa:** QPM scientists and stakeholders from 11 countries attended a training workshop on QPM development and seed delivery systems in Ghana. ✓

Milestone 9: At least one QPM training event will have been conducted in each sub-region

- **Eastern Africa:** Many one-on-one training events were conducted (see Sections 1.5 and 3.5) ✓

- ✗ **Southern Africa:** Although the decision was not to organize any training in southern Africa, two QPM breeders from southern Africa were funded to attend the Hallauer Plant Breeding Symposium in Mexico during 2003.
- ✓ **Western Africa:** The QPM development and seed delivery systems training event in Ghana was a huge success.

6. Laboratory Facilities

<u>Milestone 10</u>: Required number and location of QPM laboratories will be agreed for each sub-region

- ✓ **One laboratory** was selected in each of the three sub-regions, on competitive bid basis, to serve as regional QPM laboratory.

<u>Milestone 11</u>: At least one laboratory will be functional for tryptophan and/or lysine analyses in each sub-region

- ✓ **Eastern Africa:** The Food Science Laboratory at the Melkassa Research Center (EARO) near Nazareth, Ethiopia, will be fully functional by end of 2003.
- ✓ **Southern Africa:** ZIMLAB, a private laboratory in Harare, was selected and is now being equipped to begin performing analyses by end of January 2004.
- ✓ **Western Africa:** The laboratory at Crops Research Institute, Kumasi, Ghana, was selected as the primary regional laboratory and existing facilities have been upgraded.

7. Nutritional and Economic Studies

<u>Milestone 12</u>: Strategies to obtain required/desired nutritional and economic information will be documented for each sub-region and for at least one country in each sub-region

- ✓ **Eastern Africa:** This has been extremely well done (e.g. see Chapter 2 and Section 3.7) and constitutes a major component of the sister project, funded by CIDA.
- ✗ **Southern Africa:** A regional strategy was not developed in 2003, although pertinent activities were conducted in Malawi and Zimbabwe.
- ✓ **Western Africa:** The Research Committee of WECAMAN agreed on a strategy to be implemented as stated in Milestone 13.

<u>Milestone 13</u>: At least one nutritional or economic study with QPM will be initiated (or continued) in at least two countries of each sub-region

- ✓ **Eastern Africa:** Mapping of malnutrition and identification of likely QPM impact areas in Kenya, and the community health study near completion in Ethiopia are outstanding examples of achievement of this milestone!
- ✓ **Southern Africa:** Work with two “QPM villages” is ongoing in Malawi; chicken (broiler) feeding trials were conducted by Seed Co in Zimbabwe (not reported herein); and pig feeding trials are planned at Midlands State University during 2004.
- ✓ **Western Africa:** Research in Mali is studying utilization of QPM for animal feed, while work in Benin is assessing the use of QPM in the preparation of various traditional foods.

1. QPM ACTIVITIES IN KENYA

1.1 QPM Networking

The project management committee (PMC) of the QPM project met in Nairobi from 3-4 February. The meeting was attended by seven representatives of NARS, seven from CIMMYT, and one from CIDA.

The PMC meeting was followed by a broader Maize Working Group Meeting on 5-6 February, attended by 35 NARS representatives, 9 CIMMYT representatives and one CIDA representative

1.2 Germplasm Development

1.2.1 Release and promotion

Two hybrids were pre-released, and 2 hybrids and one OPV were nominated for testing in the National Performance Trials (NPT) in Kenya:

- CML144XCML159//CML181 - Pre-released
- CML144XCML159//CML182 - Pre-released
- CML181/CML175//OBATANPA - Nominated for the NPT
- GQL5/CML176//WWO1408//CML181 - Nominated for the NPT
- Pool15-QPM-SR - Nominated for the NPT

1.2.2 Stress tolerant QPM

Extra-early population formation

In 2002, 29 extra-early stress tolerant normal maize populations were crossed and backcrossed to POOL15QPM-SR. The resulting crosses were subjected to light table selection to form 29 BC1F1 bulks. These bulks were planted, and good plants were self-pollinated to obtain S1 ears. Following selection using light tables, 29 BC1S1 bulks were formed and distributed to our collaborators for the next cycle of self-pollination in 2004.

Early population/synthetic development

In 2002, 800 early full-sib (FS) families were generated from POOL15QPM-SR. In 2003, these families were tested under low nitrogen, drought and optimum conditions in Kenya. The selected 20% were analyzed for quality protein (total protein, nitrogen and tryptophan). The best families were chosen and planted to form six new stress-tolerant QPM synthetics and to form S1 progenies to initiate the development of early streak resistant QPM inbred lines. The six synthetics will be tested regionally in 2004, both as potential new open-pollinated varieties and as parents of double topcross QPM hybrids (using CML492/CML173 as the other parent for these hybrids).

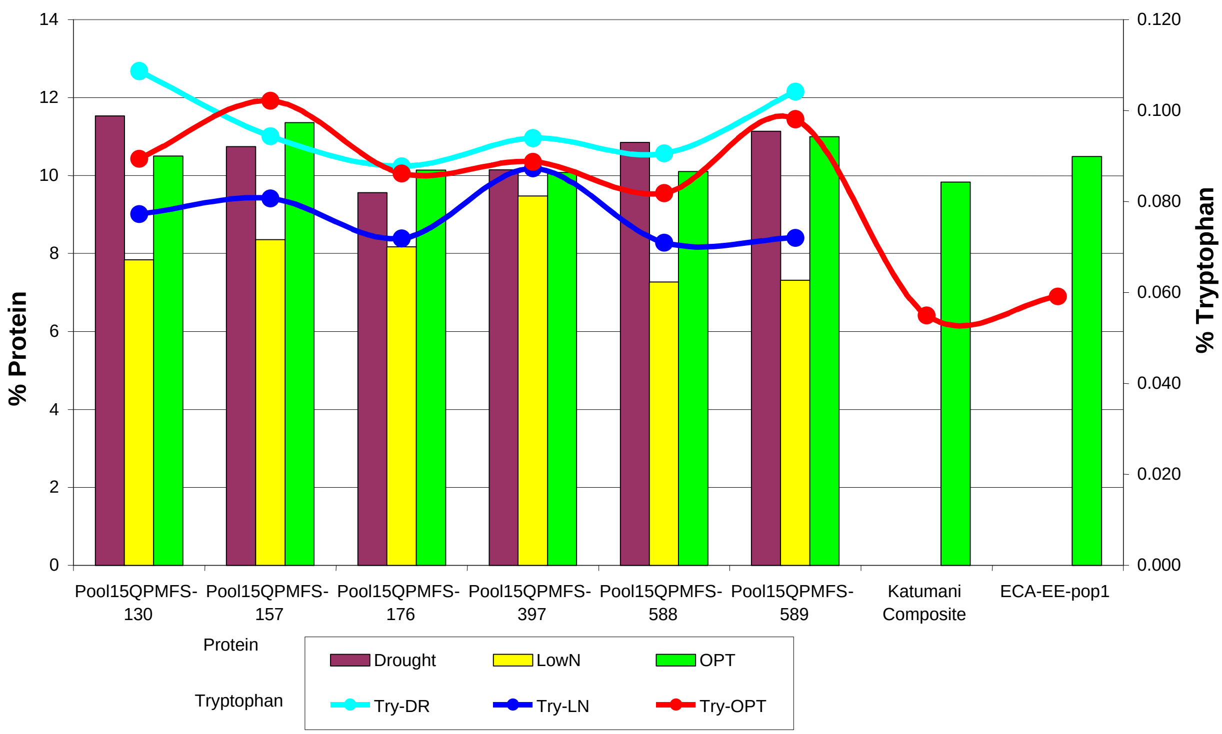
Intermediate maturity stress tolerant QPM populations

In 2002, 21 locally adapted stress tolerant normal CIMMYT maize lines (CMLs) were crossed with the famous QPM single cross (CML144/CML159) and the resulting F1 were crossed to POOL15QPMSR. The crosses were subjected to light table selection and 21 bulks were reconstituted, planted and self-pollinated. The resulting S1 were selected using the light table to reconstitute 21 S1 bulks for distribution to our collaborators for the next cycle of selfing.

1.2.3 Study of the effect of abiotic stresses (drought and low nitrogen) on protein quality

In 2002, our data showed that drought and low nitrogen stress can have a negative effect on the endosperm modification of QPM germplasm. Therefore, we decided to investigate the effect of these abiotic stresses on the protein quality of QPM. For this purpose, F2 seed of 6 FS families that performed well across environments were harvested from the optimum, drought and low nitrogen experiments and were analyzed for protein and tryptophan content. We found that (1) the % protein was lower under low N, and was similar under drought compared to optimum conditions, and (2) the % protein was similar for QPM and normal checks under optimum conditions (Figure 1). Regarding protein quality, we found that (1) % tryptophan was lower under low nitrogen compared to optimum and was not affected under drought, however, (2) the tryptophan level of QPM families under both low nitrogen and optimum conditions was higher than the tryptophan level of normal checks under optimum conditions. These results agree with Pixley and Bjarnason (2002)[1], who reported that protein quality was very stable, whereas protein content and endosperm modification of QPM varieties are less stable across environments.

Figure 1: Percent protein (bars) and percent tryptophan (lines) of six QPM families and two normal maize varieties grown under optimum, drought, and low nitrogen conditions



[1] Pixley, Kevin V. and Magni S. Bjarnason. 2002. Stability of Grain Yield, Endosperm Modification and Protein Quality of Hybrid and Open-Pollinated Quality Protein Maize (QPM) Cultivars. Crop Sci. 42:1882-1890.

1.2.4 Development of a weevil resistant synthetic

Introduction

Breeding for insect resistance in maize and other crops has received much attention in recent years due to development of strains of insect pests resistant to insecticides. Maize stored by smallholder farmers is often attacked by storage pests causing grain weight losses in excess of 30%. The major storage pests in Kenya are the maize weevil (Sitophilus zeamais Motsch.) and the larger grain borer (Prostephanus truncatus Horn). Because use of insecticides has had little impact in controlling these pests, breeders and entomologists must use either conventional or genetic engineering methods to improve host plant insect resistance. In this study screening was done only for maize weevil.

Materials and methods

Maize grain samples from open pollinated ears of 166 FS families were fumigated using Phostoxin in plastic drums for seven days to kill storage pests from natural attack in the field. Four replicates of 50g grain samples of each full sib family were allowed to equilibrate for 10 days (grain moisture content- 12%) in 0.25 L glass jars with ventilated lids lined with 40-mesh wire gauze. Samples were infested with 30 unsexed 30-day old adult maize weevils for ten days. The jars were placed on wooden shelves in randomised complete block (RCB) design for 90 days at conditions of 28±2°C and 60±5 % relative humidity. This incubation period was chosen as farmers store their crop untreated against storage pests for this duration after harvest. The contents of each jar were sieved across a 4.75 mm and 1 mm mesh to separate grains form insects and flour. Flour weight, number of progeny, grain weight and percent grain damage were recorded. A selection index was used by, dividing the family mean by population mean, and summing over the damage parameters. A value 1 is the population mean.

Results and discussion

Table 1. Mean number of weevil progeny emerged and percent grain weight loss caused by *S. zeamais* to selected 8 QPM FS families grown at Embu

Entry	Pedigree	Progeny		Wt-loss	
		No.	Log No.	Loss	Arcsine loss
179	Pool 15 QPMFS-179	14.0	1.86	1.2	0.67
573	Pool 15 QPMFS-573	7.0	1.92	1.2	0.70
338	Pool 15 QPMFS-338	11.0	1.98	1.1	0.63
541	Pool 15 QPMFS-541	7.3	1.98	0.9	0.52
655	Pool 15 QPMFS-655	101.8	4.50	10.5	6.05
422	Pool 15 QPMFS-422	89.8	4.50	10.6	6.10
612	Pool 15 QPMFS-612	102.8	4.58	10.0	5.72
137	Pool 15 QPMFS-137	131.3	4.86	14.3	8.25
	LSD	33.2	0.98	5.1	2.93
	SE	12.0	0.35	1.8	1.05
	P-value	0.0001	0.0001	0.0001	0.0001

There were significant differences in resistance levels of the maize germplasm to weevil (Table 1). About 20% of these maize materials showed good to modest resistance. Twenty percent of the families (30 families) were selected from the most resistant and susceptible fractions of the population, taking into consideration protein and tryptophan content. The family was not included in the selected fraction if protein content was below 7.5% or tryptophan content was below 0.07%. These selected fractions will be advanced to S1 and the bulks derived will be re-evaluated as part of a divergent selection study for storage pest resistance in QPM. There was no significant correlation between grain quality (biochemical basis) and parameters for storage pest resistance among the 166 families evaluated in the current study.

1.2.5 QPM population improvement

Two QPM open-pollinated varieties (PR8763 and Across8762) were self-pollinated to develop 230 S1 from each variety. The S1 bulks were self-pollinated and 154 S2 were selected in collaboration with the Ugandan National program at Namulonge (hot spot for turcicum leaf blight, grey leaf spot, and ear rot). These S2 lines were planted under streak virus artificial infestation at Embu and are being advanced to S3. The resulting S3 will be analyzed for protein quality and the best progenies will be crossed with appropriate testers to identify the lines to be used to (1) develop hybrids and synthetics, and (2) reconstitute new improved versions of CIMMYT Populations 62 and 63 SR.

1.2.6 QPM streak virus resistant line development

In 2002, 95 QPM F2 populations (QPM x Normal) developed at Harare were planted at 3 sites in East Africa for evaluation and selfing. 88 S2 bulks were generated and subsequently distributed to NARS in Uganda (Namulonge), Tanzania (Selian), Ethiopia (Nazareth, and Bako), and Kenya (Embu) for further breeding work.

The conversion to QPM of 7 early maturing streak resistant CMLs (CML212, 218, 219, 220, 221, 222 and 236) and 10 new early maturing lines was initiated.

1.2.7 Conversion of locally-adapted maize OPV's to QPM

<u>Conversion of intermediate maturity germplasm to QPM at Kiboko, Kenya</u>

Four intermediate maturity elite varieties ECAVL-2, SADVLA, P501-SRC0-F2 and P502-SRC0-F2 were each crossed to three QPM donors during the short rain season in 2002. In early 2003, the F1 crosses were harvested and a balanced bulk advanced to F2 during the main season. At harvest, 500-600 best ears were selected and shelled individually. Kernels were screened on the light table, and only kernels with modification between 2 and 4 (on a 1 to 5 scale) were selected. Selected kernels from the best 400-500 ears screened on the light table were planted ear-to-row during the short rain season in 2003 for the formation of the first backcross generation (BC1F1). The best 4 plants will be selected in each agronomically acceptable row, and leaf samples will be sent to the laboratory for DNA marker analysis to identify homozygous opaque-2 (recessive) plants. Bulk pollen of the recurrent parent OPV will be used to pollinate marker-selected plants.

<u>Conversion of intermediate maturity germplasm to QPM at Kibos, Kenya</u>

Three intermediate maturity elite varieties, Kakamega Pool A, Kakamega Pool B and Tuxpeno Sequia, were each crossed to three QPM donors during the short rain season in 2002. In early 2003, the F1 crosses were harvested and a balanced bulk advanced to F2 during the main season. At harvest, 500-600 best ears were selected and shelled individually.

The grain was screened on the light table at Kiboko and returned to western Kenya for planting during the 2003 short rain season.

Conversion of late maturity adapted germplasm to QPM at Kitale, Kenya

Activities at NARC, Kitale, are converting to QPM ‘Kitale synthetic II’ (R11C10), ‘Ecuador 573’ (R12C10), and inbred lines A, F, 82 and 93. In 2003, F1 crosses were advanced to F2. Materials are in the field at the time of this report.

Conversion of intermediate maturity germplasm to QPM at Selian, Tanzania

A huge effort to convert many elite cultivars at Selian was initiated in 2002 short rains. The Rockefeller-Foundation-funded project proposed to convert three OPVs to QPM (Staha-ST, Kilima-ST and TMV-1), but conversion of other OPVs (POP105, Kito and UCA) was also initiated. Advancement of F1 to F2 is in progress. The senior breeder left Selian in the middle of 2003 and this might slow down the progress in the conversion activities.

1.2.8 QPM hybrid formation and seed increase

- 13 QPM synthetics are being crossed to POOL15QPM-SR to (1) develop QPM varietal hybrids for the 2004 regional testing, and (2) initiate the MSV conversion for the best new QPM synthetics.
- 28 early QPM hybrids are being formed for the 2004 regional testing.

1.2.9 Imidazolinone QPM resistant (IQPMR)

The witch weed ‘Striga’ decimates maize, millet, sorghum, upland rice and Napier throughout sub-Saharan Africa. From the high plateau of East Africa, where peasant farmers struggle to survive on tiny fields of maize, to the arid savannas of northern Nigeria, where they rely on sorghum, African farmers today are fighting a losing battle against the Striga scourge. During the past seven years CIMMYT, in collaboration with the Weizmann Institute of Science (Israel), Kenya Agricultural Research Institute and BASF, with funding from the Rockefeller Foundation, have developed a unique product for Striga control in maize. It combines low-dose imazapyr (a systemic ALS-inhibiting herbicide) seed coating, applied to imazapyr-resistant (IR) maize seed, to leave a field virtually clear of emerging Striga blooms season-long.

Low-dose herbicide seed dressing on IR-maize controls Striga without impacting sensitive intercrops when they are planted 10 cm or more from maize hills. This allows small-scale farmers to continue intercropping, at most with slight modification, while using maize seed treated to control Striga. Converting the most popular QPM materials to IR will lead CIMMYT and partners to a win-win situation benefiting millions of farmers in sub-Saharan Africa.

Five QPM OPVs and 7 elite QPM inbred lines are being converted to IR:

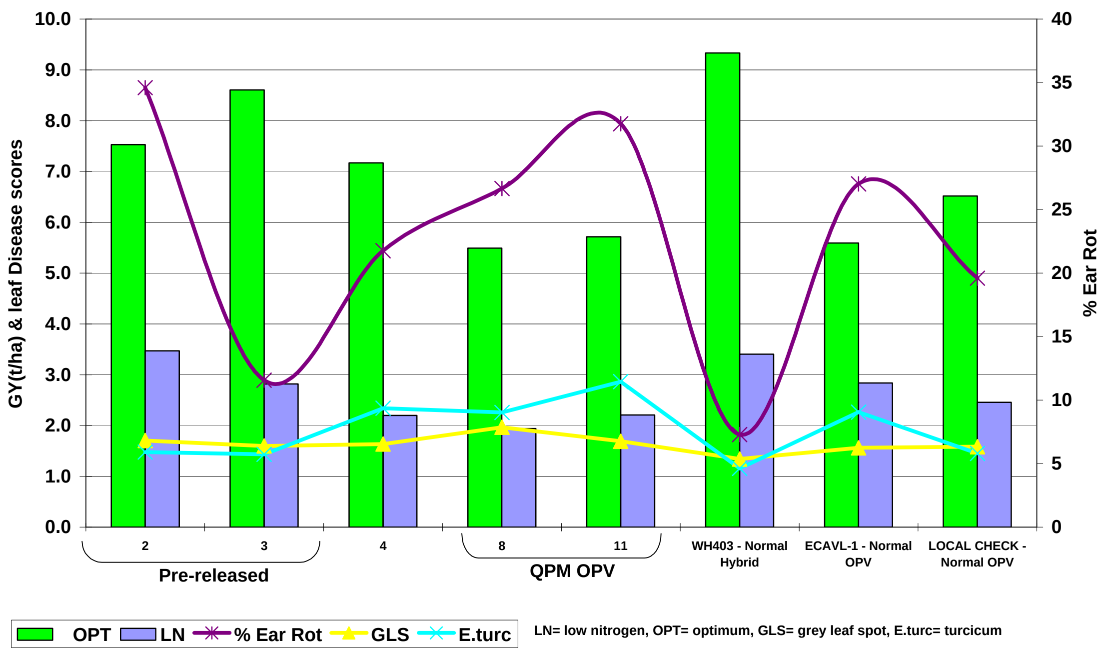
- Obatanpa and S99TLWQ, which will be available as IR QPM-SR by 2005
- POOL15QPM-SR, POP63-SR, and ACROSS8762 (currently at IR-BC0 level)
- CML144, CML159, CML154, CML176, CML173, CML181, and CML182 are at IR BC0 level of conversion

1.3 Germplasm Testing

In 2003, the following types of QPM germplasm were evaluated under both stressed and unstressed conditions in East Africa:

- QPM double top cross hybrids: 9 sets tested in 2 countries (Appendix 1, Table A1).
- QPM OPVs: 12 sets tested in 4 countries (Figure 2 and Appendix 1, Table A2)
- QPM Three way hybrids from Harare: tested across 6 sites in Kenya (Appendix 1, Table A3)
- QPM inbred lines: 5 sets tested in 2 countries (Appendix 1, Table A4).
- Obatanpa-OPV: including 3 different versions of Obatanpa, was tested at 2 sites in Kenya (Appendix 1, Table A5)
- 46 sets of various QPM materials including 346 genotypes from CIMMYT Mexico were planted at 2 sites in Kenya. By the time this report was prepared, the trials from Mexico had not been harvested.

Figure 2: Grain yield (t/ha), and disease (GLS, turcicum & ear rot) reaction of 2 QPM OPVs, 2 pre-released QPM hybrids, 2 normal OPVS and 1 normal hybrid, tested across 4 sites including low N and optimum in Kenya, 2003A.



1.4 Seed Production and Dissemination

1.4.1 Seed production

- Seed of 13 synthetics is being multiplied
- Foundation seed (20 kg) of parents of 2 QPM three-way hybrids released in Kenya was produced

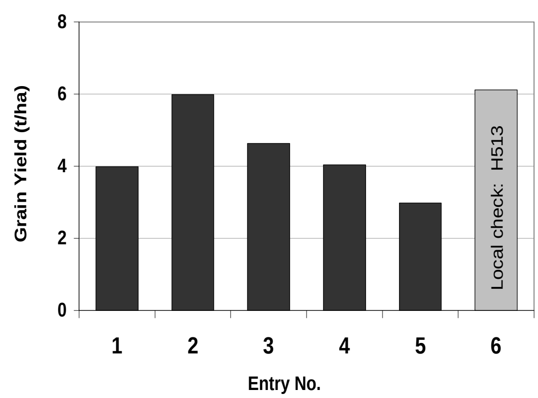
- Seed of those same above-mentioned hybrids (100 kg) was produced for mother/ baby trials and demonstration.
- 4 tons of QPM grains for animal feed experiment were produced.

1.4.2 Dissemination

On-farm evaluation of QPM germplasm is carried out in collaboration with NARS scientists in the ECAMAW Research Network. During 2002-03, these involved both multi-location testing of advanced QPM varieties using a farmer participatory approach with “Mother-Baby trials”, organized primarily in Kenya, and a study of N-response of the Ethiopian-released QPM hybrid, BHQP542, at increasing plant densities. Two sets of trials were prepared: 1) Four QPM hybrids and one OPV were evaluated at five sites in the transitional zone of the Central Kenyan Highlands. Baby trials comprising two entries plus the farmer’s check were distributed to 12 farmers at each of two sites. Farmers evaluated the entries in the Mother trials on two occasions, as well as providing the experiences with the materials in their “baby” trials. Generally, only one QPM entry (CML144/CML159//CML182, which has been pre-released for the area) performed as well as the local commercial check, H513 (Figure 3).

Figure 3. QPM performance across four sites in Mother Trials in the Central Kenyan hightlands

Entry	Name	- Grain Yields Across t/ha
1	CML144XCML159//CML181	4.0
2	CML144XCML159//CML182	6.0
3	CML181/CML175//OBATANPA	4.6
4	GQL5/CML176//WWO1408//CML181	4.0
5	POOL15QPM-SR	3.0
6	Local Check: H513	6.1
Mean		4.6
LSD (0.05)		0.6
MSe		0.3
CV		11.4
p		
p		
Min		3.0
Max		6.1



Ear rot was a particular problem during the 2003 season and incidence was high amongst all varieties except Entry 2 and H513. Farmers generally ranked H513 highest among the 6 entries although Entry 2 compared well with it. In addition to yield, attributes of interest to farmers were tolerance to pests and diseases, storage quality, husk cover, cob size and filling, and grain size. Based on these criteria, farmer preferences generally agreed with breeder evaluations.

Seven QPM OPVs and one double cross hybrid were evaluated in Mother trials at two sites in the humid lowland ecology of Coastal Kenya: 24 baby trials were distributed to farmers. Results from these trials are not yet available.

At Jimma, Ethiopia, a trial was conducted to determine the optimal N rate and planting density for the recently released QPM variety, BHQP542. This variety must compete with the popular taller, later maturing hybrid BH660. An objective of this trial was to determine whether higher plant densities are able to compensate for the lower yield potential of this earlier-maturing variety. BHQP542 yield increased significantly with N fertilizer up to 69-92 kg ha^{-1}, but increasing plant population densities from 44,000 to 66,000 ha^{-1} had no significant effect on yield (Table 2). Since the 2002 season was short in duration and total rainfall received, the trial is being repeated in 2003 at three sites on-station and 20 (unreplicated) sites on-farm and includes a direct comparision with BH660 at its recommended density of 44,000 ha^{-1}.

Table 2. Grain yield, t ha^{-1} of QPM as affected by plant density and N-levels on station of Jima Center in season, 2002.

Nitrogen levels (kg ha^{-1})	Plant density (D) (×1000 ha^{-1})				N - mean
	44	**50**	**57**	**66**	
46	6.02	5.89	5.39	6.89	6.05
69	7.59	8.01	7.64	7.01	7.56
92	7.63	8.14	8.12	8.22	8.03
115	8.02	8.56	8.38	6.61	8.39
Density mean	7.32	7.68	7.38	7.69	7.51
P<0.05		N = 0.56	D = ns	NxD = ns	

1.5 Training

6 sets of 88 QPM S2 bulks were sent to 6 NARS scientists in Ethiopia (Bako, and Nazareth), Uganda (Namulonge), Tanzania (Selian) and Kenya (Kiboko and Embu) for selfing.
At harvest, CIMMYT scientists (Alpha, Twumasi, and Duncan) will spend 3-5 days to help with selections using the light table. This hands-on training will benefit scientists and their technicians.

Nine scientists from East Africa attended the CIMMYT Special Training Course on Applied Statistics and Arnel R. Hallauer International Symposium on Plant Breeding, Mexico, August 4-22, 2003.

1.5.1 Training in QPM – economic analysis and impact assessment

Two students worked with CIMMYT scientists in the impact assessment component of QPM research. The first student, Timothy Nyanamba, did his M.Sc. in Agricultural Economics at the Egerton University, Njoro (Kenya). He did his thesis on the topic "Quality Protein Maize for the Feed Industry in Kenya." He also presented a poster of his work at the International Agricultural Economics Association, Durban, August 2003 (Nyanamba et al., 2003)[2].

A second student, Oiye Shadrack, of the Department of Nutrition, University of Nairobi, is assisting the Kenya team to identify the target areas, and to prepare and conduct Participatory Rural Appraisals.

[2] Nyanamba T., H. De Groote; R. Wahome. 2003. Quality Protein Maize for the Feed Industry in Kenya. Poster presented at the International Agricultural Economics Association Durban, August 2003.

1.6 Laboratory Facilities

A work place facility comprising one cold room, one working place with benches and light table incorporated for 20 persons, 2 offices were built in Kiboko, Kenya. These facilities can be used as training facilities for the whole region.

2. ECONOMIC ANALYSIS AND IMPACT ASSESSMENT OF QPM

2.1 Economic Analysis of QPM for the Feed Industry in Kenya

To estimate the potential value of QPM for the feed industry in Kenya, a collaborative study was conducted by CIMMYT, the Department of Agricultural Economics from the Egerton University (Kenya) and the Department of Animal Nutrition from the University of Nairobi, with financial support from FOODNET and the Nippon Foundation. Visits to several feed producers revealed that maize is a key ingredient in animal diets, constituting about 50% of the commercial formulations. Yearly, 379,000 tons of animal feed are produced in the Kenya, about half of which goes to poultry. In contrast to swine and cattle, commercial broiler producers use almost uniquely specially formulated feed. Along the Kenya coast, small scale producers keep a few batches of 100 birds each, in pens made from local materials. They purchase the one-day-old chicks from specialized companies. The feed, which represents about half of the total production costs, is also purchased from specialized companies.

Since QPM has twice the levels of lysine and tryptophan compared to regular maize, substituting it for regular maize in the production of broiler feed can reduce the amount of expensive protein sources used. In 2002, a linear optimization model was used to formulate the cheapest ratio, while fulfilling the different requirements for broiler feed, resulting in a 5% cost reduction. Trials (reported last year) showed that broilers raised on the optimized QPM mixture had the same feed intake, weight gain and taste as broilers raised on the normal, non-QPM feed mixture.

In 2003, the trial results were used for economic analysis of the use of QPM for the feed industry in Kenya, and its results were presented at the Conference of the International Association of Agricultural Economics (Nyanamba et al., 2003)[3]. If the feed industry for broilers in Kenya were to substitute QPM for regular maize, they could decrease the use of other, more expensive, sources of protein. This would reduce the cost of feed by 5% ($ 1.93/kg vs. $2.03/kg) or, for the whole industry, by US$300,000. If the new QPM-based feed were to be sold at the same price, these benefits would go to the feed companies. If, however, the cost reduction were to be passed on as cheaper feed, the benefits would go to the broiler producer, increasing their profits by US$10 for each batch of 200 birds. These producers are typically small-scale farmers, raising 4 batches annually for the local tourist industry. QPM-based feed would lead to an annual increase of profits of US$40.

During discussions with the feed producers, two concerns were raised. First, since these companies do not produce their own maize, but buy it in the market, quality control is essential. Companies need to be able to check the quality of the QPM, in particular its lysine and tryptophan content, at reasonable cost. Second, the QPM used in the trials was more susceptible to storage pests than the regular maize. For the feed producers it is important that the new QPM varieties have the same storage characteristics as regular maize.

[3] Nyanamba T., H. De Groote; R. Wahome. 2003. Quality Protein Maize for the Feed Industry in Kenya. Poster presented at the International Agricultural Economics Association Durban, August 2003.

2.2 Impact Assessment

2.2.1 Identification of areas where QPM can make an impact

QPM is likely to have an impact in areas where maize is constitutes a large proportion of the diet, especially as a source of protein, and where children and lactating mothers suffer protein deficiency. To identify and target the proper agroecological zones for QPM, preliminary studies were undertaken in Uganda, Kenya, Tanzania and Ethiopia. These studies will map the areas where QPM and other nutritionally improved maize is likely to make an impact, based on literature and secondary data. For each of the four countries, a digital map with administrative boundaries is being constructed, and complemented with geo-referenced statistical data. These studies typically make use of following data:

- Population data from the latest census (how many people live where?)
- Production data for the major cereals and pulses (indicators of importance in diet)
- Areas where farmers grow improved maize varieties (likely adopters)
- Areas where farmers have access to improved seed from private seed companies (adopters that can be reached through the private sector)
- Consumption data for major cereals and pulses (where is maize an important component of the diet?)
- Livestock production data (where do people eat dairy and other animal products)
- Health statistics (where do people have protein deficiency, in particular children from weaning age to 5 years old)
- Poverty indicators (where do the poor live, and how many are there?)

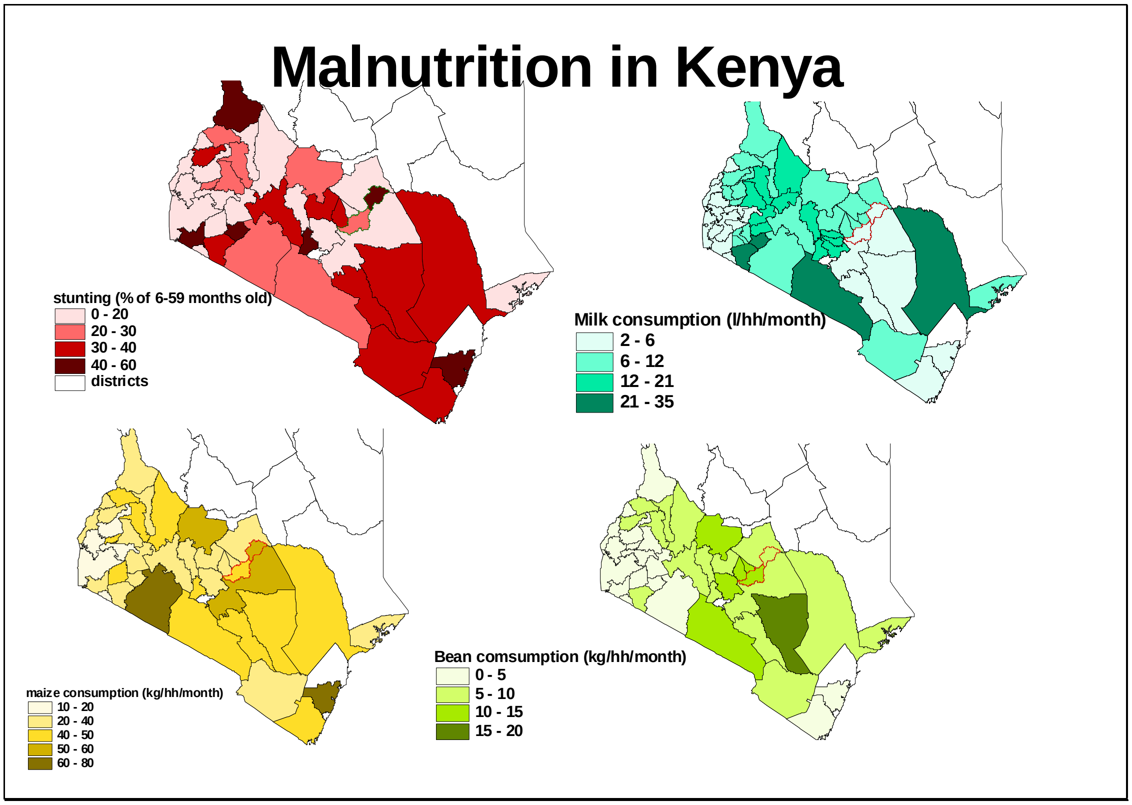
All data need to be combined in a GIS (geographical information systems) database, referenced to administrative units such as divisions or districts (for Kenya). The units should correspond to the latest census' basic units. This basic map will provide good indicators as to where maize is important, where there is a protein shortage (based on available protein from production in the region), and where people have limited resources to purchase high protein food. This map then needs to be complemented with studies on actual food consumption and household expenditure patterns. Anthropometric studies are also useful.

The collection of secondary data in Kenya is now finished, and consists of census data, data on food expenditure and production, malnutrition statistics and micronutrient deficiencies. Preliminary analysis, in collaboration with the Department of Nutrition at the University of Nairobi, found that stunting (measured as the % of children too small for their age) is particularly high at the coast (especially Kilifi district) and in the dry areas (Tharaka district and West Pokot), but also at some areas around Lake Victoria (Migori) (see map in Figure 4). Food consumption data show, however, that maize is not the primary weaning food in the lake basin, and agricultural statistics show that people at the coast only produce 20 kg of maize per person, as compared to a national average consumption of 100 kg/person. Therefore, QPM is most likely to have an impact in the dry areas of Eastern Kenya. For the QPM program that is based in Embu, the two districts most likely to benefit are Tharaka and Mbeere (which fall under the mandate of the KARI station in Embu), situated at the lower slopes of Mount Kenya. The program should give high priority to the development and dissemination of short maturing QPM varieties, and collaboration with the KARI station for the dryland areas at Katumani.

Studies on micro-nutrients found that deficiencies of iron, zinc and vitamin A are strongly linked to altitude. These deficiencies are common around Lake Victoria in the West, the drylands in the North and East, and at the coast. However, they decrease rapidly with increasing altitude in Central Kenya. Therefore, our research indicated that breeding for micro-nutrient enhanced maize should also focus on the lower slopes of Mount Kenya and the dry land areas.

So far, the secondary data collection is finished in Kenya, and is well under way in Uganda and Ethiopia. In Tanzania, the Rapid Rural Appraisals have been conducted, and in Kenya they are expected to be conducted in November-December 2003.

Figure 4. GIS analysis of areas with likely high impact of QPM



2.3 Participatory Rural Appraisals

After identification of appropriate targeted areas, where impact is expected to be high, the areas need to be visited. These visits, in the form of Participatory Rural Appraisals, involve further collection of secondary data in the field, as well as individual discussions with resource people (health, nutrition and agricultural extension workers), and group discussion with farmers and consumers.

3. QPM ACTIVITIES IN ETHIOPIA

3.1 QPM Networking

- A QPM Coordination Meeting for East Africa and the First Project Management Committee Meeting of the CIDA funded QPM Development Project (QPMD) were held in February, 2003 in Nairobi. The meetings were conducted for QPM stakeholders to develop their first annual workplan for the Project. Both meetings were attended by the Director of CIMMYT Maize Program.
- The Ethiopian QPM country working group was established during 2002, and met twice that year—the last date of meeting being December 6, 2002. In 2003, WG members communicated frequently concerning critical issues by telephone or email. One meeting of the WG is scheduled before the end of 2003—to update all stakeholders on activities completed during 2003 and to plan for 2004.
- The Ugandan QPM WG was established during 2003, and met four times during the year (25 April, 16 May, 23 June, 3 July).
- A QPM WG was formed in Tanzania, and met on 18 March 2003.

3.2 Germplasm Development

3.2.1 Highland source germplasm development

Efforts were continued to develop QPM source germplasm for the African highlands, which as described in the 2002 report, currently lags behind other environments with regard to availability of elite QPM germplasm. The first and second backcrosses were completed for 51 highland maize lines with turcicum, MSV and GLS tolerance, and already characterized into three heterotic groups. The conversion will be completed in the off-season of 2003/2004 when the BC2F2 will be formed.

<u>Conversion of elite cultivars</u>

The conversion of a number of cultivars for Ethiopia continued.

- QPM conversion of the parental lines of BH660, the most popular hybrid in Ethiopia, reached the second backcross stage for F-7215 and 142-1-e, and the first backcross for A-7033. The lines will be advanced to the next stage of conversion in the off-season of 2003. It is expected that conversion will be completed during 2004.
- The first backcrossing of four highland maize synthetics was completed in the main season of 2003, and the second backcross will be done in the off-season of 2003/2004.
- The Ethiopian National Maize Program initiated the conversion of two parental lines of BH540, the second most popular released single cross for the mid-altitude zone.
- Conversion of two popular OPVs (Melkassa 1 and Awassa 511) for the mid-altitude dry zone was initiated by National Maize Program at Melkassa. The National Maize Program at Bako also initiated the conversion of Kuleni, a popular OPV for the transitional highland.

Improvement of Obatanpa

Work continued on the improvement of Sussuma (the Mozambican version of the Ghanaian QPM variety Obatanpa) for tolerance to rust and leaf blight at Ambo, which is a hot spot for the two diseases. S1 lines planted in the main season showed a wide range of variability for tolerance to the diseases, especially for rust, and selected plants were advanced to S2 level.

3.3 Germplasm Testing

- The National Maize Program identified three promising CIMMYT QPM hybrids and entered two of them into their National Variety Trial to generate data to support future release. The hybrids were (CML144 x CML159) x CML182 and (CML144 x CML159) x CML181. However, the per se performance of both CML182 and CML181 was poor and further testing of these lines will be done to ascertain the viability of the hybrids for commercial production. A third promising hybrid identified in the national program was (CML140 x CML146) x CML143.
- At Bako, in the mid-altitude zone, nine CIMMYT QPM trials (from Mexico, Kenya and Zimbabwe) were conducted, including two under both optimum and low N conditions. Three CIMMYT trials were conducted at Melkassa (mid-altitude dry zone), while two highland QPM trials from CIMMYT-Mexico were evaluated at Ambo.

3.4 Seed Production/Dissemination

Significant quantities of certified seed of the QPM OPV cultivar Nalongo were produced and marketed in Uganda during 2003. During the first half of 2003, a total of 270 t of certified seed of Nalongo was sold by four small local seed companies with details as follows:

- NASECO Seeds (1996) Ltd.: 150 t
- East African Seed (U) Ltd.: 40 t
- Farm Inputs Care Centre (FICA) Ltd.: 60 t
- Harvest Farm Seeds Ltd.: 20 t

Furthermore, the QPM WG for Uganda reported that 500 t of certified seed of Nalongo was available for sale during the second half of 2003 (i.e., season 2003B).

In Ethiopia, the Ethiopian Seed Enterprise (ESE) marketed their entire stock of approximately 35 t of certified seed of the QPM hybrid BHQP-542 for planting during the 2003 cropping season. This stock of certified seed was produced during 2002 on 10 ha of ESE land. During 2003, the ESE allocated 40 ha of their seed farm for certified seed production of the same hybrid.

A report on seed production of QPM varieties in Tanzania during 2003—provided by the Tanzanian WG members—follows:

Partner	Variety	Quantity produced (kg)	Seed type
Usagara Women Group	Lishe-K1	6,300	Foundation
Monsanto	Lishe-H1	500	Certified
Arusha Foundation Seed Farm (AFSF)	Lishe-K1	50,000	Certified
AFSF	Lishe-K1	2,000	Foundation
Selian ARI	Lishe-K1	10,000	Foundation
Ukiriguru ARI	Lishe-K1	100	Foundation
Mtwara	Lishe-K1	50	Foundation
Zanobia Seed	Lishe-K1	500	Foundation
Tumbi ARI	Lishe-K1	100	Foundation
Ilonga ARI	Lishe-K1	200	Foundation
Selian ARI	Lishe-K1	500	Breeder
Selian ARI	Parental inbred lines	30	Breeder

3.5 Training

CIMMYT's maize breeders determined that it was critical to conduct a series of site visits and "hands-on" training to strengthen the capacity of QPM scientists and seed personnel at various locations throughout the countries of East Africa. Essentially, during 2003, the visits and training were focused on technical staff involved in QPM breeder and foundation seed production. The "hands-on" training consisted of:

- Provision of basic information on the breeding of QPM
- Training technical staff in the use of light tables for QPM seed selection using actual breeding materials they are working with
- Ensuring effective use of the "Fieldbook" software developed and distributed free of charge by CIMMYT

CIMMYT breeders conducted the "hands-on" training according to the following schedule:

Ambo RC, EARO, Ethiopia	Feb. 2003
Kiboko RC, KARI, Kenya	Feb. 2003
Bako RC, EARO, Ethiopia	May 2003
Melkassa RC, EARO, Ethiopia	June 2003

During March 2003, CIMMYT conducted a QPM and seed training course in Uganda for technical staff of small seed companies and for group leaders (often women leaders) of farmer/seed grower community-based organizations (CBOs). The course catered to 12 participants, including 4 women. The course participants comprised representatives from 10 small seed companies and CBOs.

A QPM seed production proposal entitled "QPM Seed Multiplication of Newly-Released OPV Variety Lishe-K1" was developed in collaboration with the Usagara Women Group (UWG) in Kimamba, Kilosa District, Tanzania. Funds were approved, and implementation began in the second half of 2003. A two-day "hands-on" training course will be given to UWG members during mid November 2003. An oversight committee for UWG activities was established, comprising of six women and two men.

3.6 Laboratory Facilities

A call for competitive bids for hosting a sub-regional QPM quality control lab was issued during the First QPMD Project Management Committee Meeting (Feb. 3-4, 2003, Nairobi). Subsequently, a review team evaluated the proposals received, and the initiative was awarded to the Food Science Laboratory at the Melkassa Research Center (EARO) near Nazareth, Ethiopia. CIMMYT developed a formal Memorandum of Agreement with EARO, which was signed by the Directors General of both institutions by mid 2003. The Memorandum of Agreement outlines general terms of collaboration for the regional laboratory facility, research arrangements, period of the agreement, financial provisions and reporting, intellectual property rights and ownership, termination of the agreement, and a dispute resolution mechanism.

Essential equipment and chemicals were ordered (totaling approximately US$29,000 in value) to facilitate the development and startup of the regional screening facility. The facility is anticipated to be fully operational during November 2003.

3.7 Nutritional and Economic Studies

Within the ECAMAW network, draft research protocols and workplans were developed and refined in an iterative process with NARS colleagues at five research institutions within target countries (see summary table below).

Country and Partner Institution	Research Center and Principal Investigator(s)
Ethiopia, EARO	Bako and Debre Zeit ARCs (Dagne Wegary and Alemu Yayi)
Kenya, KARI	Embu RRC (Kangara and Mutinda)
Tanzania, MASF-DRD	Selian ARI (S.D. Lyimo and nutritionist from Hai)
Tanzania, MASF-DRD	Ilonga ARI (J. Assenga and S.D. Lyimo)
Uganda, NARO	Namulonge ARI (George Bigirwa and Cyprian Ebong)

The draft proposals were subjected to a thorough review process by a multi-disciplinary team of scientists—including nutritionists, breeders, agronomists and economists—to ensure a high quality end-product. With the exception of the proposal from Ilonga Agricultural Research Institute in Tanzania, all of the other research proposals received final approval. The feeding studies in Kenya and Tanzania were swine-based, while the studies in Ethiopia and Uganda were poultry-based.

Substantial quantities of QPM grain are being produced during the 2003 cropping cycle to provide the requisite raw material for the feeding trials to begin in 2004.

During 2002-03, ILRI-Ethiopia (at the Debre Zeit campus) conducted several ruminant feeding studies (with SG2000 funding)—based on whole plant silage with or without grain—with dairy cows and sheep. Preliminary reports indicate no differences between QPM and normal maize silage in the dairy cow study. However, significant differences were detected between QPM and normal maize silage in the sheep feeding studies.

In addition to the formal research activities detailed above, the Ugandan QPM Working Group (WG)—initiated under the auspices of the SG2000 country program—has established on-farm QPM pig feeding demonstrations, and plans to produce a documentary on the demonstrations for promotion of QPM as animal feed. Priority for hosting the pig feeding demonstrations has been given to vulnerable groups such as people living with HIV/AIDS, widows and orphans. The demonstrations have been established at strategic locations to serve whole communities.

A community health study in Ethiopia is being conducted by the Ethiopian Health & Nutrition Research Institute (EHNRI), and is supported financially by the SG2000 Ethiopia country program. The four principal objectives of this study are:

- Nutritional study on a family basis
- Laboratory analysis of whole diets
- Acceptability of QPM to farmers
- Functional (end-use) properties of maize-based products

Relevant details of the study include:

- 200+ farm families were randomly selected in East Wollega zone
- Prescreening and stratification were used to eliminate those better endowed with land and/or cattle and to focus on families with healthy children <5 years old
- Thus, a relatively homogeneous and representative sample of 160 families was obtained
- All 160 families received an SG2000 standard 0.5 ha maize production package
- Half received seed of normal maize hybrid BH-140 and the other half received the QPM hybrid BHQP-542. The study was conducted using a double blind approach—the field workers were assigned seed lots on the basis of a "secret," coded ID.
- To avoid ethical criticisms, no modifications were made to family farming operations, apart from the introduction of the improved maize seed and production package to all participating farmers.
- The farmers agreed to consume the maize produced on their 0.5 ha plots. Since the participants historically consumed a maize-dominated diet, the "experiment" basically consists of a substitution of QPM for normal maize in the diets of half of the families.

- SG2000 facilitated farmer cash flow and maize storage for the farmers by: (a) paying each farmer for any and all QPM (or normal) maize grain that they wished to market immediately post-harvest to meet cash needs, (b) storing each farmer's maize grain safely and clearly identified, and (c) "selling" the farmer his/her own grain as the season progressed—to avoid dietary contamination by purchased "outside" maize.
- Starting in October 2002 (i.e., pre maize harvest) and extending until October 2003, socio-economic characteristics and child health parameters were recorded on a family level through questionnaires and visits—including anthropometric measurements such as child height, weight, upper arm circumference, etc.
- Laboratory analyses of the grain samples of BH-140 and BHQP-542 are sponsored by a German-funded project.

The first annual cycle of this study was completed in Oct. 2003, and the Ethiopia QPM WG will disseminate the results by the end of 2003.

4. QPM ACTIVITIES IN WEST AND CENTRAL AFRICA

4.1 Collaborative Research Projects by the NARS

The Research Committee of WECAMAN met in the IITA Calavi Station in Cotonou, Benin, from April 10 to 12, 2003. Two of the three members of the committee, .M. Ouedraogo (OAU STRC-SAFGRAD), A. Menkir (IITA representative), Ousmane Coulibaly, an IITA economist who filled in for Kebbeh Mohamed (CORAF-WECARD representative), and B. Badu-Apraku were present at the meeting. During this meeting, the committee reviewed 32 research proposals submitted by the WECAMAN member countries for funding under the Nippon Foundation QPM Project. The committee used the criteria established by the steering committee of WECAMAN for the approval of collaborative research projects since 1994. The Research Committee approved a total of US$55500 for 22 projects in nine countries to support research, seed production and promotion of QPM activities for 2003 cropping season. Funds were released to nine countries in June to support the various activities of the approved Projects (Figure 5 and Table 3).

In West and Central Africa, harvesting of trials and seed multiplication is normally done between October and end of November. Every year, scientists from the NARS submit their progress reports as well as receipts for justifying the use of allocated funds to the coordinator of WECAMAN in April. For these reason, the progress reports dealing with the network activities by the NARS in West and Central Africa under the Nippon Foundation QPM project will be presented by May 2004.

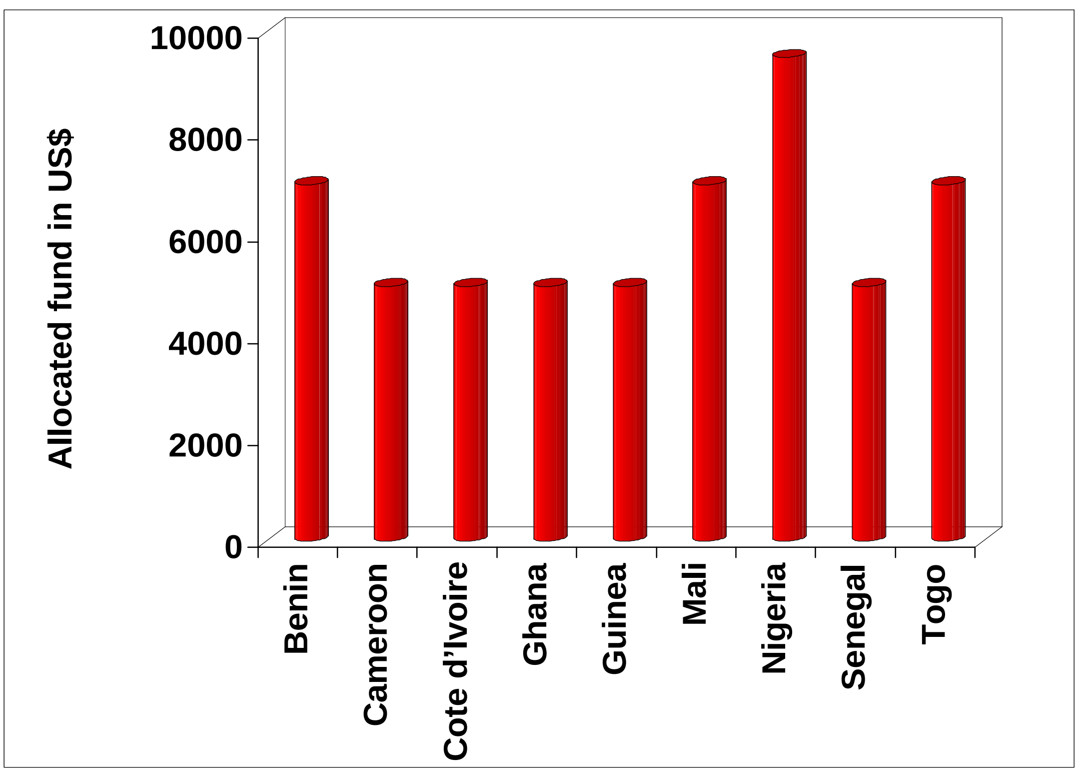


Figure 5. Funds allocated to support QPM research activities in nine countries in West and Central Africa in 2003

Table 3. Summary of fund allocations for 2003 QPM collaborative research Projects of WECAMAN member countries funded under the Nippon Foundation grant

Countries	Projects			
	QPM community-based seed production	Promotion of adoption of QPM varieties and crop management practices	Nutritional and utilization studies	Breeding for QPM varieties and hybrids
Benin	2500	2500	2000	
Cameroon	2500	2500		
Cote d'Ivoire	2500	2500		
Ghana	2500	2500		
Guinea	2500	2500		
Mali	2500	2500	2000	
Nigeria	2500	4000		3000
Senegal	2500	2500		
Togo	2500	2500		
Total	20000	21500	4000	3000

4.2 Germplasm Development

4.2.1 Upgrading the resistance to Maize Streak Virus Disease in elite QPM varieties

A collaborative program with SG2000 was initiated in 2002 in Cote d'Ivoire to upgrade the level of streak resistance in Obatanpa from Ghana and Susuma and DMRE-SR-W from Mozambique. Half-sib families of each variety were planted in the screen house under artificial infestation with maize streak virus. The plants were transplanted to the field about ten days after planting. The streak susceptible plants were removed and the MSV resistant plants were selfed at flowering. At harvest, the streak resistant plants with agronomically desirable characteristics were selfed. The S1 families from each material have been planted in Ibadan in 2003 under artificial maize streak virus infestation to recombine plants resistant to MSV. It is anticipated that the upgraded versions of these varieties will be provided to NARS by the beginning of the 2004-planting season for NF-QPM Project activities. In addition, seed increase of an extra-early QPM variety, EV 99 QPM, developed in Ghana is currently underway to make seeds available for on-farm testing in 2004. The EV 99 QPM had been tested for two years in WECAMAN member countries and proved promising.

4.2.2 Conversion of adapted germplasm to QPM

<u>Early and extra early normal populations and elite varieties</u>

A total of five early and two extra-early white elite varieties and populations were crossed to DMRE-SRW QPM and EV 99 QPM, respectively, in 2002 in Cote d'Ivoire for conversion to QPM. The F1 crosses have been planted in Ibadan and are being advanced to F2. Furthermore, two early and two extra-early yellow varieties and populations were crossed to Pool 18 SR QPM in 2003 at Ibadan for conversion.

Early maturing populations and elite varieties with increased micronutrient content

A total of five normal early maturing populations and varieties with higher levels of ß-carotene or iron content compared to the mean of all the varieties evaluated for two years in Nigeria were crossed to two sources of QPM (Pool 18 SR or Pool 15 SR) in the first season at Ibadan. The resulting F1 crosses have been planted at Ibadan for developing the first backcross generation.

Intermediate and late maturing populations and elite varieties

Nine selected intermediate and late maturing normal maize varieties and populations with resistance to Striga and diseases or with high bioavailable iron were crossed to two sources of QPM (POP66 SR and Obatanpa). The resulting F1 crosses have already been planted in the second season to generate the first backcross populations.

Late maturing elite inbred lines

We selected 15 lowland inbred lines with resistance to Striga and three elite normal lines and crossed them to two QPM lines (CML144 and CML181). The resulting F1 crosses have been planted at Ibadan for making backcross populations at the end of this year.

4.2.3 Extraction of QPM varieties and inbred lines

Extraction of early QPM varieties from existing QPM populations with resistance to MSV

Bulk seed of two pools, Pool 18 SR QPM and Pool 15 SR QPM, were planted at Ibadan for selfing to extract early white and yellow QPM varieties. The selected S1 with good agronomic traits at harvest will be evaluated in multi-location trials in 2004. The best lines selected based on the results of these trials will be screened under the light/laboratory analysis and recombined to form an experimental variety.

Extraction of S1 lines from crosses involving mid-altitude inbred lines

A total of 44 normal x QPM lines adapted to the mid-altitude have been planted in the main season at Jos. Several plants have been selfed from each cross to generate S1 lines, which will be evaluated under the light in 2004.

Evaluation of lines extracted from diverse sources of germplasm

A total of 55 lowland and 81 mid-altitude adapted lines derived from diverse QPM populations and crosses have been grown in the main season in single row plots for evaluation. Outstanding plants selected from the best lines will be screened under the light box/laboratory analysis in 2004. Based on the results of laboratory analysis, some of the lines will be used to form hybrids and/or synthetic varieties.

4.3 Germplasm Testing

A trial consisting of single and three-way cross hybrids between inbred lines developed from a QPM variety, Obatanpa, were grown at three locations in 2003. Results obtained in Saminaka show marked differences among hybrids for grain yield and other traits (Table 4). All hybrids involving the Obatanpa lines were as high yielding as or higher yielding than a normal commercial hybrid, marketed by Premier Seeds in Nigeria. Two single (A0303-2 and A0303-3) and two three-way (A0303-8 and A0303-9) cross hybrids out-yielded the normal commercial check by as high as one ton per hectare and had desirable agronomic features. Once the high lysine and tryptophan content of the parental lines of these hybrids is confirmed in the laboratory, the best hybrids will be multiplied and distributed to the NARS through regional trials.

The Research Committee of WECAMAN had approved funds for on-farm trials of QPM varieties in 10 countries. The results of these trials will be summarized and submitted in May 2004.

Table 4. Mean grain yield and other agronomic traits of single and three-way crosses of inbred lines derived from Obatanpa tested at Saminaka in 2003

Hybrid	Grain yield kg/ha	Days to silk	Plant height cm	Plant aspect (1-5) [b]	Ear Aspect (1-5) [c]
A0303-2	8128	58	217	2.0	2.2
A0303-9	**7457**	**58**	**203**	**2.2**	**2.2**
A0303-8	**7362**	**58**	**213**	**2.0**	**2.7**
A0303-3	7340	56	200	2.0	2.0
A0303-1	7133	57	212	2.8	2.3
A0303-6	7126	60	212	2.7	1.8
A0303-5	6975	57	195	2.2	2.3
A0303-4	6654	57	200	2.3	2.3
A0303-7	**6297**	**63**	**213**	**3.0**	**2.3**
Oba Super I	6153	64	215	2.8	2.7
MEAN	7063	59	208	2.4	2.3
SE	541	1	6	0.2	0.2
CV	13	2	5	11	12

b Plant aspect- A scale of 1 to 5, where 1=excellent plant type with good agronomic traits and 5= poor plant type with poor agronomic traits.

c Ear aspect- A scale of 1-5, where 1= excellent ear aspect and 5= poor ear aspect

4.4 Seed Production/Dissemination

Since the Nippon Foundation QPM project for West and Central Africa was initiated in 2003, we did not have enough time to produce adequate quantity of seeds of Obatanpa and EV99 QPM for on-farm testing and community-based seed production in WECAMAN member countries. We thus purchased one ton of Obatanpa seed from Ghana and made it available to all project member countries on request. Seeds of EV99 QPM, DMRE-SR-WQPM and the improved versions of Obatanpa and Sussuma for resistance to the maze streak virus disease will be multiplied in the 2004 dry season for use by the NARS for on-farm testing and/or community-based seed production.

4.5 Training Workshop on QPM Development and Seed Delivery System

A workshop on QPM development and seed delivery system was organised in Kumasi, 4-15 August 2003 by SG 2000 in collaboration with CRI, WASNET, CSIR, IITA and WECAMAN. The objectives of the workshop were to review the progress of QPM development and promotion in WCA and update knowledge of participants on breeding of QPM varieties, QPM seed production and varietal maintenance and strategies for promotion of, QPM in WECAMAN member countries. Thirty-one participants made up of breeders, agronomists, extensionists and seed producers drawn from both the private and public sectors in 11 countries attended the workshop. The course covered QPM development and promotion, the role of QPM in human and animal nutrition, QPM laboratory analysis and light box screening, seed industry in West and Central Africa, seed production, processing and storage.

4.6 Laboratory Facilities

During the Steering Committee Meeting of WECAMAN in May 2003, the members looked into laboratory facilities that are available for analysis of lysine and tryptophan in the region. It was agreed that the facilities in Ghana and at IITA could be upgraded and used to support the activities under the Nippon Foundation QPM project in the region. Two of the three countries selected to breed for QPM, Nigeria and Togo, were encouraged to send their samples to Ghana for amino acid analysis. Currently IITA is standardizing the protocol for amino acid analysis so that scientists from Ghana and other countries can come and work in the laboratory to upgrade their analytical skills. Funds are available from the Nippon Foundation QPM project to support amino acid analysis by the NARS at the end of this cropping season.

4.7 Nutritional Studies

The Research Committee of WECAMAN assigned responsibilities to Mali to carry out utilization of QPM for animal feed and to Benin for evaluation of the potential use of QPM in the preparation of different traditional food products consumed by the people in the country. The results of these studies will be summarized and submitted in May 2004.

4.8 Consultation Visit to the National Maize Program of Nigeria.

During the QPM training workshop, A. Menkir and B. Badu-Apraku had opportunities to visit the QPM breeding nurseries and seed multiplication fields in Kumasi, Ghana. The fields were managed very well and the seed production fields were adequately isolated form other maize production fields. Private seed growers of Obatanpa and a QPM hybrid were also visited. The seed growers maintain good quality seed production fields and have developed processing facilities to package seeds of the QPM varieties in small quantities to promote procurement of seed by small-scale farmers and growers. The Ghana Grains and Legume Development Board, which is also responsible for the production of QPM foundation seed for the growers, provides storage and processing facilities to growers for a fee.

We also paid a consultation visit to the national Maize Program of Nigeria at IAR on 30 September 2003. The objective of the visit was to monitor progress on collaborative research projects funded under the Nippon Foundation QPM project and USAID grant and to exchange experience with the scientists in the national system. Among the activities visited included community-based seed production of Obatanpa, on-station QPM trials, and on-farm QPM trials funded under the Nippon Foundation Project. The on-farm trials and community-based seed production plots had been well established and well managed. B. Badu-Apraku has planned to visit the QPM activities supported by NF-QPM project in Senegal in early November.

5. QPM ACTIVITIES IN SOUTHERN AFRICA

5.1 QPM Networking

A regional meeting of QPM partners and stakeholders was held in Harare in March[4]. Representatives of private seed companies, non-governmental organizations, nutritionists and economists presented the perspective of their institution or discipline to the group. This provided a foundation of mutual understanding of interests, expectations and potential contributions to the regional QPM effort by each type of partner.

Maize scientists also briefed the group about the status and outlook for QPM activities in each of their countries. Highlights of these country reports follow:

<u>Malawi</u>: Have been testing QPM for four years; have conducted extensive farmer-participatory variety evaluations in partnership with SG2000; have released a three-way QPM hybrid in 2002, but it has some production problems and disease susceptibility (MSV); will likely release Obatanpa and/or an Obatanpa topcross hybrid in 2003; have formed a QPM country working group; have established two "QPM villages"; have a very limited QPM breeding effort; are constrained by the lack of protein quality laboratory facilities and lack of training for technicians.

<u>Mozambique</u>: Have a very substantial QPM breeding effort, focused on early maturing, white flint OPVs with resistance to MSV and downy mildew; have released 'Sussuma' (improved Obatanpa); are working on developing a QPM version of 'Matuba'; significant amounts of seed of Sussuma have been produced; have formed a QPM country working group, but it is not working smoothly; are constrained by the lack of protein quality laboratory facilities, lack of seed storage facilities and lack of foundation seed processing equipment.

<u>South Africa</u>: There are three QPM projects in South Africa, which due to large distance between them, operate largely independently of each other. 1) Eco Link (in Mpumalanga) is producing seed of Obatanpa and is working with small-holder farmers to disseminate QPM. 2) Quality Seeds is developing QPM hybrids in Natal area; have released about 20 QPM hybrids; are now partnering with another company interested in QPM OPVs; have had good success using yellow QPM germplasm from Brasil and white QPM from Ghana; their goal is to see QPM meal on supermarket shelves, soon; constraints are lack of interest in QPM by most private companies and government, although it is a good sign that ARC has revived QPM work. 3) ARC was not represented at our meeting, but they have initiated a very small effort in QPM breeding; they are also evaluating QPM trials from CIMMYT.

<u>Swaziland</u>: QPM activities in Swaziland to date are nil. We recommended that they should evaluate small trials available from CIMMYT, and they should explore opportunities to form alliances with Mozambique and Eco Link to benefit from the success of those nearby QPM projects. We recommended against forming a QPM country working group until there are products ready for extensive testing and promotion.

[4] Detailed minutes of this meeting are available on request from CIMMYT.

Zambia: Started QPM activities in 2002; are evaluating CIMMYT regional trials at 2 sites; plan to link QPM testing to the existing Mother/baby trials; the National Council for Scientific Research has a program to fortify maize meal (could link with QPM activities); constraints are lack of resources, very few staff, and need for training in quality assessment.

Zimbabwe: AREX (government research and extension) and/or Midlands University are testing QPM under low-N and drought stress; selfing in early generation bulks provided by CIMMYT; would like to convert local yellow varieties to QPM; would like to conduct feeding demonstrations with dairy, chickens and pigs; will link QPM testing to ongoing Mother/baby trial scheme. Seed Co has a substantial QPM breeding research program and expects to have commercial QPM hybrids on the market soon. A University of Zimbabwe nutritionist is experimenting with protein quality analyses; is interested in working with nutrition studies. It was agreed to convene a first meeting of a QPM country working group for Zimbabwe.

During the regional SADLF (southern Africa drought and low soil fertility network) steering committee meeting held in September 2003, the steering committee approved funding of seven proposals: Angola, \$2,920; Malawi, \$5,570; Mozambique, \$5,800; Tanzania, \$1,570; Zambia, \$1,000; Zimbabwe(1), \$2,000; Zimbabwe(2), \$5,200.

5.2 Germplasm Development

The primary objective of the CIMMYT QPM breeding program for southern Africa is to develop stress tolerant QPM hybrids and open-pollinated varieties (OPVs) suitable for use by resource-poor farmers in the region. We are pursuing two broad strategies to achieve this objective: 1) Convert to MSV resistant the best Mexican QPM materials, and 2) develop new QPM germplasm by partially converting to QPM the best southern African materials.

5.2.1 Conversion to MSV resistant of best Mexican QPM

About 1,300 new experimental lines were evaluated for MSV resistance in Zimbabwe and sent to Mexico for laboratory analyses of protein quality. At the same time, a few of the most promising new lines were used to form hybrids to evaluate their yield and agronomic performance in comparison to the original hybrids (which were developed in Mexico and are susceptible to MSV). Table 5 compares the performance of the popular hybrid, CML144/CML159//CML176, which has been released in several countries, including Ethiopia and Tanzania, with experimental MSV-resistant versions of the same hybrid. Two of these MSV-resistant versions yielded 22% more grain than the original hybrid across four locations (6.9 versus 5.65 t/ha), and had acceptable MSV resistance in an artificially, severely infected field at Harare (symptom score of 3.1, versus 4.55 for the original hybrid).

From this project, new MSV-resistant QPM hybrids have been identified and have been included in trials that will be distributed throughout sub-Saharan Africa during 2004.

5.2.2 Development of new QPM southern African germplasm

Nearly 2000 experimental maize lines, developed from crosses between elite African germplasm and Mexican QPM lines, were selected for MSV resistance and advanced to further evaluation. These materials include about 12 elite lines from IITA and 30 elite lines from southern Africa. During winter 2003, a total of 243 experimental MSV-resistant QPM lines were used to make hybrids (testcross hybrids) that will be evaluated in multi-location yield trials during 2004. Results from those trials, plus laboratory data on protein quality, will identify the next generation of African, MSV-resistant, QPM lines.

Table 5. Grain yield (across four locations) and maize streak virus disease (MSV) symptom score (one site with artificial infestation) for selected QPM and normal check hybrids

Pedigree	Across Locations			MSV
	GrainYield	Rel GY	Rank	
		%	Avg	1-5
CML444/CML443//CZL00003 (normal)	7.7	134	3	2.6
GQL5/CML176//CML181	7.4	126	17	3.5
CML395/CML444//CML442 (normal)	7.3	126	10	1.7
GQL5/CML176//CML181	7.1	121	17	3.1
CML144/CML159//[CML389/CML176]-B-29-2	6.9	120	23	3.1
CML144/CML159//[CML176/CML395]-B-2-2	6.9	118	16	3.1
Normal Commercial Check:	6.6	115	15	2.3
CML144/CML159//[CML176/CML395]-B-1-1	6.6	115	16	3.1
CML144/CML159//[CML205/CML176]-B-2-1	6.5	113	22	3.1
CML144/[CML159/CML395]-B-17-2	6.2	108	27	1.2
CML144/CML159//[CML442/CML176]-B-8-1	6.2	107	30	3.3
CML144/CML159//[CML176/CML395]-B-6sx-1	6.1	106	29	2.8
CML144/CML159	6.1	105	31	4.4
CML144/CML159	5.8	102	37	4.4
CML144/CML159//CML176	5.7	100	38	4.5
CML144/CML159//CML176	5.6	97	47	4.6
Mean	**5.8**	**100**	**41**	**2.5**

Rel GY is the grain yield relative to the mean of the trial (100%, by definition)

Two QPM diallel mating designs were formed during winter 2003. One diallel, including 14 CIMMYT QPM lines (mostly experimental, MSV-resistant QPM lines), will be used by two students for their Master's degree thesis research projects. One student (Mr. Langa, from Mozambique) will evaluate performance of the QPM hybrids grown under low soil nitrogen fertility at four sites in Mozambique and Zimbabwe. The second student (Mr. Mawere, from Zimbabwe) will evaluate the hybrids under well fertilized conditions at four sites in Zimbabwe. The parent lines used to form the hybrids have been sent to the applied biotechnology center at CIMMYT (Mexico) for "fingerprinting", to enable analysis of genetic distance among the lines. The information from these studies will be crucial to identifying a few key, new QPM lines for extensive use in southern Africa during coming years.

The second diallel experiment includes QPM experimental lines mostly from Seed Co, a private seed company. The experiment also uses four CIMMYT QPM lines, which are common to both of the diallel experiments formed during 2003 (to enable comparison of results between experiments). As with the CIMMYT QPM diallel, the parent lines of this Seed Co QPM diallel have also been sent to the applied biotechnology center at CIMMYT (Mexico) for "fingerprinting." This diallel will form the thesis project of Mr. Tembo (maize breeder at Seed Co) and will greatly assist Seed Co to develop commercial QPM hybrids for Zimbabwe and the southern Africa region.

5.3 Germplasm Testing

5.3.1 Farmer-participatory QPM evaluations in Malawi

As follow-up to similar activities during 2001/02, more than 2000 Malawian farmers grew QPM hybrids and OPVs during 2002/03. Sasakawa Global 2000 (SG2000) and the Malawi Ministry of Agriculture coordinated this work. Similar to 2001/02, the QPM hybrid CML144/CML159//CML176 was the highest yielding of the four QPM entries evaluated in these trials (Table 6). This hybrid was released in Malawi, but problems with seed production have limited its commercialization. It is important to note that this is the hybrid being improved through efforts described above (Section 5.2.1 and Table 5), and that better versions of this hybrid will soon be available.

5.3.2 Regional QPM trials

Results of a QPM hybrid trial grown at 33 sites in eastern and southern Africa during 2001/02 identified four very promising hybrids (Table 7). One of these hybrids, labeled ‘A’ in Tables 3 and 4, had grain yield equal to the best experimental normal hybrid in 2001/02. Two of the four best QPM hybrids are double-cross hybrids, which means that four inbred lines are used to form each of these hybrids. During commercial seed production of double-cross hybrids, both parents are single-cross hybrids, which means that both parents have considerable vigor and associated stress tolerance. Double-cross hybrids may be a desirable option in regions where seed production often occurs in stress-prone environments (e.g. where irrigation is not available).

Preliminary results (14 sites) for regional QPM hybrid trials grown during 2002/03 confirm the good performance of the four hybrids identified as promising in 2001/02 (labeled as ‘A’, ‘B’, ‘C’ and ‘D’ in Tables 7 and 8). Based on the results from both years, National Programs in Malawi and Zambia have selected one or two hybrids among these four hybrids for inclusion in on-farm, farmer-participatory evaluations (“mother/baby trials”) during summer 2003/04.

Table 6. Summary results from 0.1-hectare plots grown by more than 2000 farmers in Malawi during summer 2002/03, coordinated by Sasakawa-Global 2000 and the Malawi Ministry of Agriculture

QPM Variety	Number of farmers	Average grain yield tons/ha
Obatanpa (OPV)	405	4.97
CML144/CML159//CML176	302	5.16
CML182/CML175/Obatanpa	770	4.58
CML144/CML159/Obatanpa	640	4.78

Table 7. Results of evaluation of Quality Protein Maize hybrids from CIMMYT and an OPV from Ghana across 33 sites in eastern and southern Africa, 2001/02.

Pedigree	Across		
	Rel GY	Rank	
	%	Avg	Stdev
Entries with anthesis date between 65 - 68 days			
CZL01006/CML176//CZL01005/CML181 **B**	110	9	5
CZL01006/CML176//CML181/CML182 **D**	108	10	5
CZL01006/CML176//CML182	105	11	7
CZL01006/CML175//CML182	105	12	6
CZL01005/CML182//CZL01006	99	12	7
CZL01006/CML176//CZL01005/CML182	99	14	6
CZL01006/CML176//CZL01005	96	14	6
CML182/CML175/OBATANPA	97	14	5
CML175/CML176/OBATANPA	89	16	6
CZL01006/CML176//PL15QC7-SRC1	85	18	4
CML175/CML176//PL15QC7-SRC1	79	20	7
Maturity group average	97	14	6
Entries with anthesis date > 68 days			
CZL00025/CML312//CML395/CML202 (normal)	120	4	4
CZL01005/CML181//CZL01006 **A**	122	5	4
CML444/CML395//CML443 (normal)	116	7	6
CZL01006/CML176//CML181 **C**	109	10	5
CML181/CML175/OBATANPA	106	10	5
CML181/CML182//CML176	105	10	5
Local Check 2	103	11	8
CZL01005/CML181//CML176	101	12	7
CML144/CML159/OBATANPA	100	13	6
Local Check 1	92	15	7
CML144/CML159//CML176	92	16	7
CML144/CML159/OBATANPA	91	16	6
OBATANPA	77	21	2
Maturity group average	102	12	6
Mean	**100**	**12**	**6**

Table 8. Preliminary results of evaluation of Quality Protein Maize Hybrids across 14 locations in southern Africa, 2002/03.

Pedigree	Across		
	Rel GY	Rank	
	%	Avg	Stdev
Entries with anthesis date between 65 - 68 days			
CML181/CML182//CZL01006	109	9	4
Local Check 1	105	9	7
CZL01005/CML182//CZL01006	107	10	6
CML181/CZL01005//CZL01006 **A**	107	10	5
CZL01006/CML176//CML181/CML182 **D**	105	11	6
CZL01006/CML176//CZL01005	100	12	7
CML144/CML159//OBATANPA	101	13	6
CZL01006/CML176//CML182	99	14	6
CZL01006/CML176//CZL01005/CML182	96	15	5
CML182/CML175//OBATANPA	91	16	6
CML175/CML176//CZL02011	90	17	9
CML175/CML176//PL15QC7-SRC1	88	18	6
CZL01006/CML176//PL15QC7-SRC1	85	19	4
Maturity group average	99	13	6
Entries with anthesis date > 68 days			
CML444/CML443//CZL00003	123	4	3
CML395/CML444//CML442	119	6	6
Local Check 2	111	9	6
CZL01006/CML176//CML181/CZL01005 **B**	105	10	6
02C3728	102	10	7
CML181/CZL01005//CML176	103	11	8
CML181/CML182//CML176	104	12	6
CZL01006/CML176/CML181 **C**	103	12	6
CML144/CML159//CML182	89	16	4
CML144/CML159//CML176	79	19	4
OBATANPA-ZMSRc1F2	81	20	5
Maturity group average	102	12	5
Mean	**100**	**13**	**6**

5.4 Seed Production

We do not have figures available for QPM seed production in southern Africa during 2003. Production of Sussuma, the Mozambican version of the QPM OPV Obatanpa, was surely quite substantial, as seed was exported to Malawi and elsewhere. QPM seed production by CIMMYT, in Zimbabwe, included 2 tons of topcross hybrid seed, 2.5 tons of Obatanpa, 1.5 tons of the hybrid CML144/CML159//CML176, and a total of one ton of seed of 7 QPM inbred lines (CML144, CML159, CML176, etc.).

The seed produced by CIMMYT has thus far been distributed as follows:

- SG2000 Tanzania, 500 kg of CML144/CML159//CML176 for on-farm testing in southern Tanzania
- SG2000 Malawi, 2,200 kg of hybrids for on-farm testing
- GTZ Zambia, 250 kg of Obatanpa for community-based seed production
- Anonymous seed company in Zimbabwe, 750 kg of Obatanpa for commercial seed production

5.5 Training

QPM partners and stakeholders participating in the regional QPM planning meeting held in Harare in March 2003 agreed that no special QPM training activities would be held in southern Africa during 2003. This was considered reasonable given the fact that several technicians from southern Africa attended a QPM and seed production training course in Ethiopia during 2002. Nevertheless, QPM training funds were used for two purposes during 2003:

- Several regional scientists were supported to attend the southern Africa plant breeding planning meetings in South Africa in September. At this meeting, the regional Steering Committee considered applications for QPM funding to National Programs for 2004. Seven proposals were approved and funded at a total cost of US$24,440. The successful proposals were from Angola, Malawi, Mozambique, Zambia and Zimbabwe.
- One participant, who is also a member of the Zimbabwe QPM country working group, was funded to attend the Arnel R. Hallauer International Symposium on Plant Breeding, 17-22 August 2003, Mexico City, Mexico.

5.6 Laboratory Facilities

In response to a widely distributed call for proposals, 10 laboratories submitted proposals to serve as regional QPM laboratory in southern Africa. The proposals were from: Malawi (2), South Africa (1), Zambia (2) and Zimbabwe (5). The proposals were reviewed by a panel of four scientists, who then selected a short list of three strongest candidate laboratories. A team of two scientists visited these laboratories before selecting Zimbabwe Laboratories (Pvt) Ltd to be awarded an agreement to serve as regional laboratory for the QPM project.

About US$12,000 of equipment and chemicals has been ordered and is gradually arriving for the regional QPM laboratory. It is expected that the lab will be operational by end of January 2004 and will be ready to process the required volume of samples (about 2000 per year) before harvest of the maize crop from summer 2003/04.

6. QPM FOR THE TROPICS WORLDWIDE

Since 1997, when the Nippon Foundation helped CIMMYT to reactivate research on quality protein maize (QPM), 17 developing countries have released dozens of QPM hybrids and varieties for use by farmers, while more than 30 countries annually request CIMMYT QPM trials.

In the 2003A season, experimental QPM was sown on 4,800 5-m rows at the CIMMYT research station near Agua Fría, Puebla, Mexico. In 2003B 7,500 rows were planted at Agua Fría and 2,500 rows at Cotaxtla, Veracruz, Mexico. All plantings were for the purposes of increasing seed for QPM hybrids, synthetics, pools, and populations; selecting inbred lines; evaluating hybrids and synthetics; or converting normal lines to QPM.

Research on QPM for the lowland tropics comprises the following components:

1. Incorporation of stress resistance
2. Pedigree breeding
3. Conversion of normal lines to QPM
4. Formation of synthetics
5. Hybrid development and testing
6. New releases and seed production

6.1 Incorporation of Stress Resistance in QPM

The lowland tropics is well known as very stressful environment, with many biotic and abiotic constraints. The incorporation of resistance for the most important ones could greatly improve the yield and dependability of QPM. As the Nippon Foundation is focused on Africa, we oriented our work in CIMMYT-Mexico to select for resistance the constraints prevailing in this part of the world, crossing tropical germplasm with material resistant to maize streak virus (MSV) and gray leaf spot (GLS) to form F2 pedigree breeding populations. We are also creating new heterotic populations with resistance to both stresses.

In 2003A we grew and selected at Agua Fría (a location favorable for different biotic stresses) among 210 white and 121 yellow S2 lines developed from QPM crosses with donors for resistance. Of these, 117 white and 85 yellow ears were selected for advancement. In all, 19 F2 populations (QPM x source of stress resistance) were grown at Agua Fría, and 510 (white and yellow) ears were selected based on tolerance to diseases, insects, and other important agronomic characteristics to be advanced in the next season. In addition 200 white new F1s and 70 yellow F1 crosses between elite QPM germplasm and stress resistant source material were planted at Agua Fría in 2003B season.

Another important way to incorporate stress resistance in QPM material is to create opposite heterotic populations. These populations should have as many resistance donors as possible, while maintaining a significant portion of elite germplasm. Crosses for making these populations were selected and advanced to F2 at Agua Fría in 2003B season.

6.2 QPM Pedigree Breeding

Pedigree breeding is important for developing new, lowland tropical QPM lines that result in high yielding and agronomically superior hybrids.

Based on carefully selected parents and to develop stress tolerant QPM, 500 rows of white and 200 rows of yellow F1s were grown in 2003 for pedigree selection. All F1s were screened for major diseases (maydis, rust, ear rot) and lodging. The susceptible ones were discarded. We then grew 816 rows of F2 plants at Agua Fría in 2003B. Selection was performed at flowering and based on plants free of diseases, with no lodging, with favorable ear placement, and with no silk delay. The best 30-40% of the plants were selfed and selected again at harvest time for ear rot resistance and good levels of QPM modifier genes.

In early generation (S2 to S4) QPM nurseries, 827 tropical, intermediate-to-late maturing, yellow and white endosperm lines were planted at Agua Fría in 2003B and selection performed first by row then by plants within rows. The most resistant rows were selfed and selection was done at harvest based on low incidence of root lodging and resistance to ear rot. The best lines will be advanced to the next generation and forwarded to CIMMYT offices in Africa for selection under local conditions and crossing to local testers. After evaluation, the best lines can be used to form hybrids and synthetics.5 Based on yield trial data from 2002B, the most promising S5 to S8 white and yellow lines were planted at Agua Fría in 2003B ear-to-row in 5-m plots at a density of 66,666 plants per hectare. All healthy plants were selfed. The best lines will be designated as "elite" and sent to Africa, Latin America, and Asia. We sent 245 S2-S3 lines to Harare.

6.3 Conversion of Normal Lines to QPM

As mentioned in the 2002 annual report for this project, the conversion of two elite CIMMYT lines (CML264 and CML273) is complete, and the subsequent results of crosses between these lines and other elite QPM germplasm are very encouraging. Converted line CML264Q in single-cross and three-way-cross combinations made hybrids with excellent performance and topped many yield trials. Protein quality data confirmed that conversion was successful.

Table 9 shows head-to-head analysis of CML264 x CML273 (a normal hybrid) versus CML264Q x CML273Q (QPM hybrid from converted lines) and the best local checks from 2001 and 2002 yield trials. There are no differences between the normal and converted version, except that the QPM hybrid outyielded the best local check by more than 800 kg/ha across 28 locations and had much better standability (that is, less stalk and root lodging) and plant scores.

Table 9. Head-to-head analysis of CML264Q x CML273Q vs. CML264 x CML273 and the best local check based on data from 28 locations in 2001B, 2002B and 2003

Hybrid	Yield (t/ha)	End Hard	ER %	RL %	SL %	Mo %	BH %	Silk	Poll.	PH cm	EH cm	EA asp.	Plt. asp.	Try %
CML264Q x CML273Q	6.68	2.20	6.1	10.9	3.7	20.3	5.2	56.0	56.3	235	120	2.77	2.70	0.083
CML264 x CML273	6.60	2.14	5.9	13.8	3.3	19.6	7.1	55.9	56.1	231	118	2.79	2.58	0.050
Local Check	5.85	1.82	6.2	31.2	10.8	20.2	5.5	54.4	54.4	232	124	2.78	3.40	0.050
Number of locations	28	24	28	24	28	28	25	27	28	28	28	28	22	
Prob. QPM vs. Normal	0.68	0.47	0.83	0.23	0.40	0.08	0.17	0.33	0.38	0.07	0.21	0.83	0.32	
Prob. QPM vs. Check	0.00	0.02	0.94	0.00	0.02	0.78	0.80	0.00	0.00	0.14	0.12	0.88	0.00	

Yield=Grain Yield t/ha; End Hard.= Score for endosperm hardness (1-5); ER= % of Ear Rot; RL=% of Root Lodging; SL=% of Stalk Lodging; Mo=% of Grain Moisture; Silk=Days to Silk; Poll.= Days to flowering; Plt= Plant height; EH=Ear Height; EA asp.=Ear Aspect (1-5); Plt. Asp.= Plant Aspect (1-5); Try=Tryptophan in the whole kernel (average of the parents)

[5] "Synthetics" are open-pollinated varieties (OPVs) formed by inter-crossing several inbred lines known to combine very well (i.e., their progeny are outstanding) among themselves. Synthetics offer yields superior to those of normal OPVs but, as with all OPVs, seed from the previous harvest can be sown the following season without significant loss of yield or desirable qualities. This is an advantage for poor farmers, who cannot afford to buy new seed year after year (a requirement in the case of hybrids, for example).

In 2003B cycle we planted 116 rows for conversion of another eight elite normal lines (R1, CML247, CML254, CL-RCW01, CML451, CL-02450, CML287 and CML312SRBC1). Based on the data from DNA analyses homozygous recessive (o2o2) plants were used for making backcrosses with recurrent parents. The selected ears (BC3F1) will be planted in next cycle and selfed to fix the QPM conversion. The QPM donors used in the conversion correspond to the same heterotic group of recurrent parents. The new converted lines to QPM will be used to form the QPM versions outstanding normal hybrids already planted in several hundred thousand hectares in the developing world.

6.4 Formation of QPM Synthetics

Development of quality protein maize synthetics with excellent yield, uniformity, tolerance to pests and diseases, and high levels of essential amino-acids is a very important task. Synthetics can be used directly by resource poor farmers for stable yields, as female parents in creation of non-conventional hybrids, as opposite synthetics in reciprocal-recurrent breeding schemes, and as source populations for inbred lines.

The best inbreds from 2002B yield trials were used to form 10 white and 6 yellow QPM synthetics. The lines were planted in 2003B and all possible crosses between selected lines were made. Series of single-cross hybrids will be planted next cycle to complete the formation of synthetics. In 2003B we increased seed of 18 QPM synthetics.

6.5 QPM Hybrids and Synthetics Development and Testing

Close to 850 new white and crosses between advanced and elite QPM lines were made in year 2003. Crosses made in season 2003A were grown in yield trials in 2003B. Total 25 new white and 10 yellow superior hybrids were grown in international (CHTTWQ and CHTTYQ) yield trials in 2003B. In addition other 300 hybrids, and 12 new QPM synthetics were evaluated in yield trials managed by tropical lowland subprogram on 4-5 locations. Trials from these locations are analyzed, data stored in database, and based on results we planned our new crosses and breeding nursery plantings for 2004A cycle.

Eight yield trials, including 851 QPM hybrids and varieties, were grown at six different locations—three in Mexico and one each in Colombia, Guatemala and India. Selected results are discussed below. In further discussion mean grain yield is expressed as "clean" yield (that is, total yield reduced according to the % of ear rot); in the tables, this is "Yield 1," unless otherwise stated. Trypthopan data for QPM hybrids were calculated using average values for tryptophan from inbred lines, parents of the observed hybrid. Given the expense of chemical analyses and the high correlation coefficient between tryptophan and lysine (0.954 in our case, based on more than 300 samples) only tryptophan content for QPM lines was requested from the laboratory.

6.5.1 TSCWQ02-21: Evaluation of advanced tropical QPM white single crosses

Crosses between late, white, CIMMYT QPM lines and advanced QPM lines were evaluated at six locations with two replications in a 4 x 8 a-lattice design to identify the best hybrids for CIMMYT hybrid trials (CHTTs). The 27 crosses between QPM lines, two QPM reference hybrids, one normal hybrid, and two commercial checks made total 32 entries sown on one-row plots 5 m long and 0.75 m apart. Scores and counts were taken for several important traits.

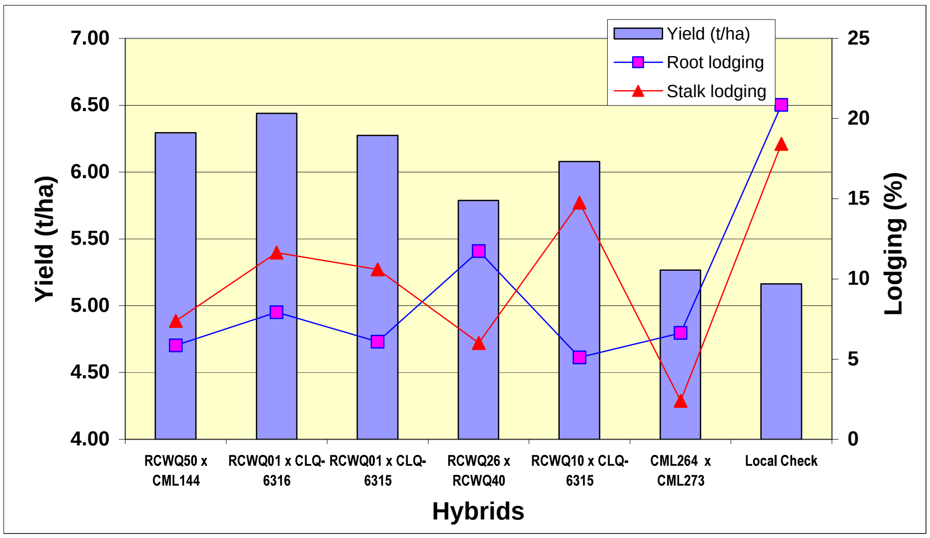
ANOVA showed no significant interaction between genotypes and environment, whereas at individual locations, significant differences were observed among entries for grain yield.

The highest mean grain yield for this experiment were achieved at Agua Fría (7.09 t/ha), following by Cotaxtla (6.99 t/ha), while New Delhi, India, had the lowest yield (3.08 t/ha.

The highest yielding hybrids were CLQ-RCWQ50 x CML144 (5.99 t/ha) and CLQ-RCWQ01 x CLQ-6316 (5.98 t/ha). These hybrids outyielded the best local checks by 24% percent and the QPM reference hybrid (CML144 x CML159) by more than 40%. The endosperm hardness, ear rot resistance, and standability of these hybrids were at high levels. Almost all advanced hybrids had higher yield performance than the QPM reference check, and 2/3 yielded more than the best normal endosperm local checks.

Besides the statistically significant yield performance of several top hybrids, all QPM hybrids had almost twice the content of tryptophan as the best local checks, with from 0.089% to 0.108%. The advantages of new generation of QPM hybrids over local check can be easily seen at Figure 6. The data clearly show that QPM hybrids can compete with the best normal hybrids for grain yield and most other quality traits. Based on this study the biggest concern in QPM material is root and stalk lodging.

Figure 6. TSCWQ02-21. Average grain yield (t/ha) and root and stalk lodgings (%) for top five QPM hybrids, the best normal hybrid, and local check across six locations in Asia and Latin America 2002-2003.



Partners in national programs are already requesting seed of the best hybrids, and seed will be increased to meet the demand. Seeds of the best hybrids across locations will be also increased and included in CIMMYT hybrid tropical trials (CHTT). The best lines will be used together with other very good advanced and early generations QPM lines to form synthetics.

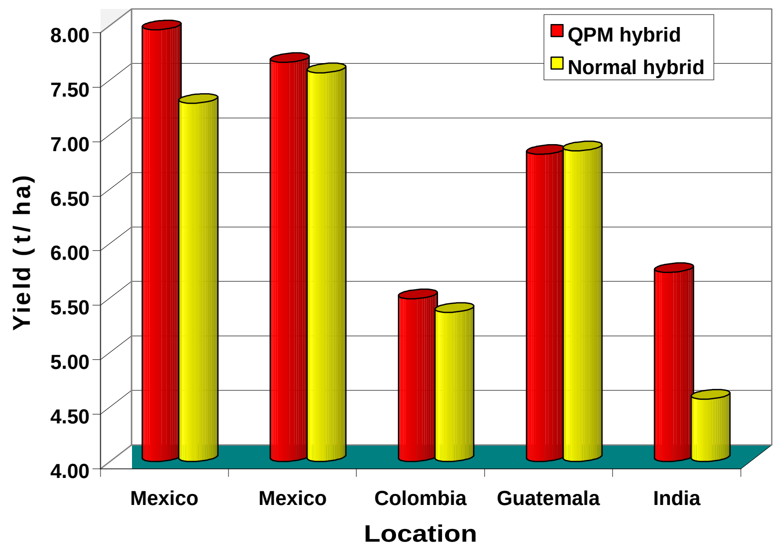
6.5.2 TSCYQ02-22: Evaluation of advanced tropical QPM yellow single crosses

Advanced generation, tropical yellow QPM hybrids were evaluated at five locations during 2003B. Thirteen QPM hybrids, a reference entry, and two local checks were grown in a 4 x 4 a-lattice in 5 m long rows with two replications per location to identify the best hybrids for CHTTs and females for three-way cross (TWC) hybrids. The best lines will also be used to form new sources for pedigree breeding.

ANOVA across five locations showed significant genotype-by-environment interactions (G x E) for grain yield, ear and plant aspect, lodging, helminthosporium maydis, and bad husk coverage. These findings will make general conclusions across locations less dependable.

Six out of thirteen hybrids outyielded reference the QPM hybrid CML161 x CML165 and will be sent to CHTTQ04. The highest yielding QPM hybrid CML161 x CLQG2404 produced 5.93 t/ha (11% higher than the reference entry) and showed excellent endosperm hardness scores, low incidence of ear rot, good resistance to observed diseases, and levels of lodging similar to those of reference entry. In addition to high yields, QPM hybrids CML161 x CLQ-S89YQ06 and CML161 x CLQ-RCYQ22 had the highest standability in the entire experiment, and showed more resistance to fusarium moniliforme, corn stunt, and general diseases than the reference entry. At individual locations, at least one QPM hybrid yielded more than the best local check. These findings are important where G x E is significant (Fig. 7). Additional advantages of QPM hybrids are their higher tryptophan and lysine content. The best QPM hybrids had tryptophan contents from 0.083 to 0.101% (normal endosperm hybrid grain contains around 0.050%).

Figure 7. TSCYQ02-22. The grain yields performance of the best QPM hybrids and the best local check hybrids across five locations 2002-2003.



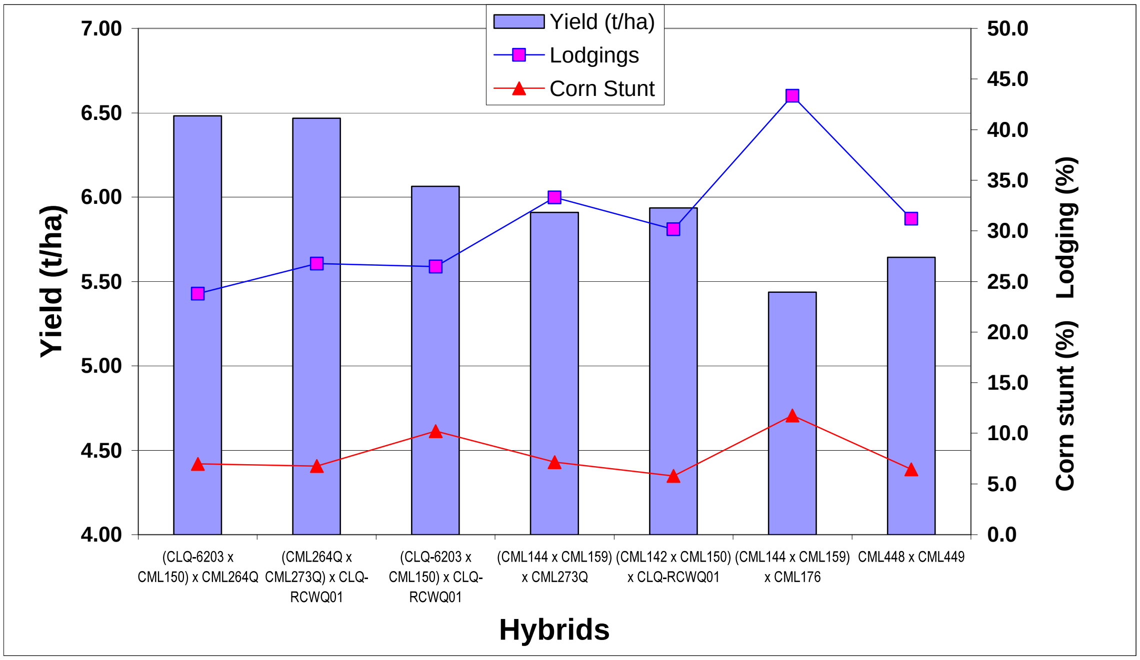
6.5.3 TTWCWQ02-23: Evaluation of tropical QPM late white three-way crosses

In this experiment 48 new developed three-way cross (TWC) hybrids were evaluated together with their female components (single-cross hybrids). The objective was to find the best TWC hybrids for CHTTs. Because it is easier to produce seed of TWCs than of single-cross hybrids, these represent a good option for farmers in developing country areas not yet served by effective seed industries. A total 64 entries were grown at six locations in an 8 x 8 a-lattice design with two replications per location.

ANOVA across locations revealed significant G x E for grain yield, ear rot, plant aspect, stalk lodging, bad husk cover, and endosperm hardness. At all individual locations significant differences were observed between entries for grain yield. The highest yield for this experiment was achieved at Cuyuta, Guatemala (6.73 t/ha), whereas New Delhi, India, had the lowest average grain yield (1.97 t/ha) due to severe drought conditions.

Two reference entry hybrids were used as standards to compare newly developed TWC hybrids. The QPM reference entry was (CML144 x CML159) x CML176, which has already been released in several developing countries, and the normal single-cross hybrid CML448 x CML449, which is a regular check in normal trials. The results from this experiment are very encouraging. More than half the new TWC hybrids outyielded the QPM reference entry—the best by more than 20%. The new TWCs were also superior for many important agronomic characteristics (Figure 8).

Figure 8. Average grain yields, aggregate lodgings, and corn stunt for the best five TWC hybrids and two reference entries across six locations in Asia and Latin America 2002-2003



Several TWC hybrids even outperformed and had better standability than the normal, single-cross tester. The highest yielding TWC hybrids across six locations were (CLQ-6203 x CML150) x CML264Q with 6.12 t/ha, (CML264Q x CML273Q) x CLQ-RCWQ01 with 6.09 t/ha, and (CLQ-6203 x CML150) x CLQ-RCWQ01 with 5.77 t/ha, which were 10, 9, and 4 % better than normal, single-cross hybrid (CML448 x CML449). All three hybrids also had the above average performance in drought conditions in India. The female parents of these hybrids also had high yield performance (4.38 t/ha and 5.13 t/ha), which would ensure inexpensive seed production. All lines in these three hybrids are unrelated and our guess is that the new hybrids could play an important role in developing countries and replace (CML144 x CML159) x CML176. Estimated tryptophan values for the top TWC hybrids ranged from 0.092 to 0.097%—much higher than in normal endosperm hybrids. All five new TWC hybrids include new QPM lines in their backgrounds and outyielded (CML144 x CML159) x CML176, the normal seed industry checks, and the reference entry checks. This confirms the potential of new QPM hybrids to increase maize productivity and alleviate malnutrition in Africa and Latin America, where maize is a staple food, and should be tested extensively.

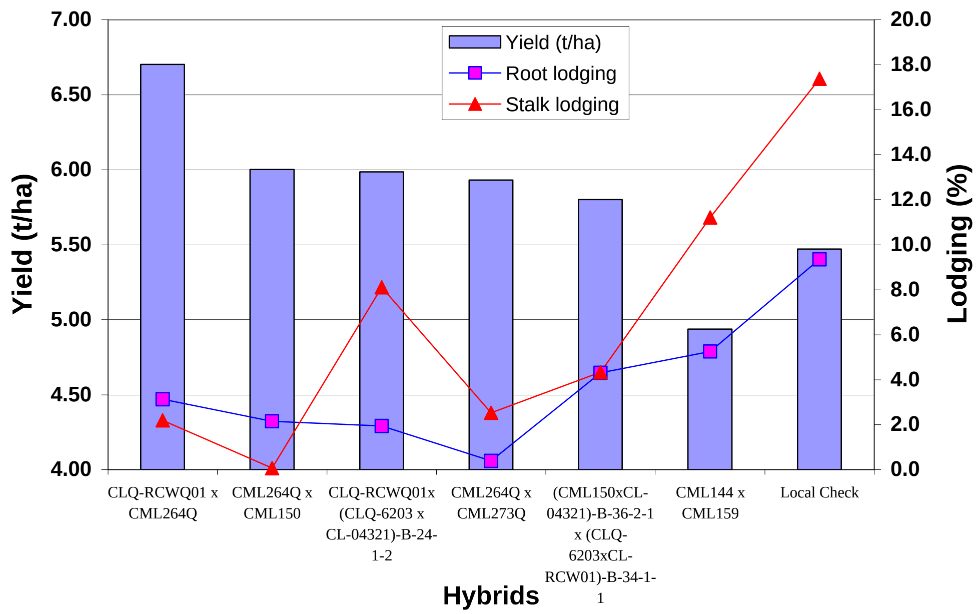
6.5.4 TSCWQ02-26: Evaluation of tropical QPM white single crosses

In all, 35 hybrids were evaluated at six locations using a 5 x 7 a-lattice design with two replications per location. The aim was to identify the best hybrids for advancement in CHTTs or advanced tropical trials. Several new crosses with advanced and released lines were evaluated; 16 entries were part of a small design II experiment (2 x 8) with S4 lines.

ANOVA across locations revealed no significant G x E for studied traits, while differences between entries at individual locations for grain yield were higher than LSD values. The highest average grain yield was recorded at Cotaxtla, Mexico (7.49 t/ha). The lowest mean yield (4.22 t/ha) was observed at New Delhi, India.

The highest yielding hybrid in experiment was CML491 x CML264Q with 6.70 t/ha across six locations. This hybrid outyielded the best local check and QPM reference entry by 23 and 36% and had better standability, corn stunt resistance, and much more attractive plant and ears. The hybrid topped the trial in Cotaxtla with a maximum grain yield of 11.73 t/ha and 0.0% ear rot. Seven other QPM hybrids outyielded the local check, while 14 had better performance than the QPM reference entry. The superiority of the top five hybrids is shown in Figure 9. Besides higher yield, the new QPM hybrids showed better standability than reference entries.

Figure 9. Average grain yields, stalk and root lodgings for the best five QPM hybrids, reference entry, and local check across six locations in 2002B



6.5.5 CIMMYT QPM hybrids and synthetics tested internationally

A new generation of QPM hybrids and synthetics was developed and international testing was initiated in 2002. 40 trials were shipped to 25 countries. Results from testing in 2002 and 2003 are presented separately for hybrids and synthetics.

<u>EVTWQ02-28: Evaluation of tropical QPM white synthetics</u>

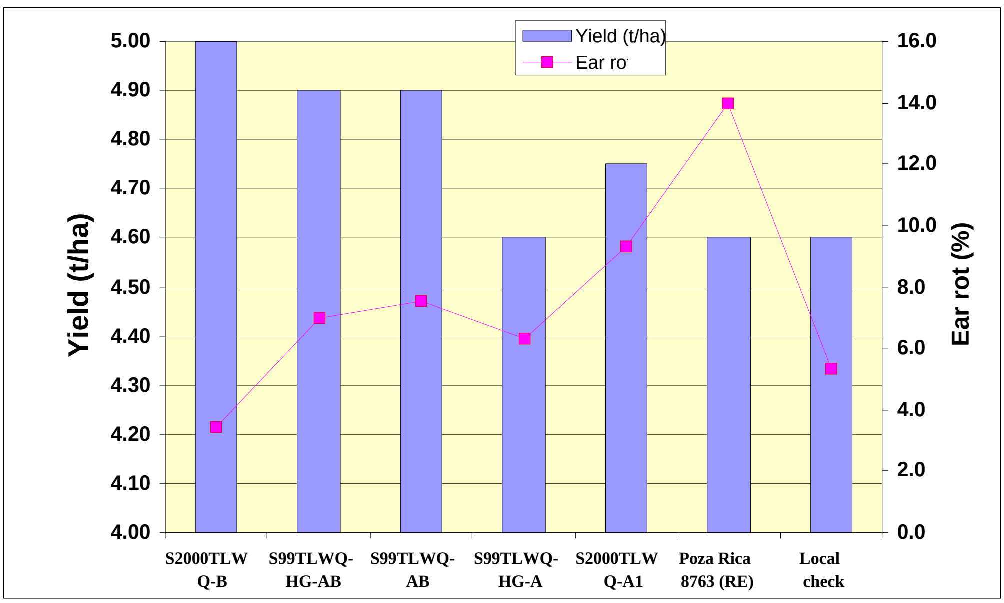
New synthetic varieties were tested at more than 30 locations in two different trials (EVT12S and EVTQ-28) in 2002-2003. The results shown here are from EVT-12S (9 sites) and EVTQ-28 (5 sites). At Harare, Zimbabwe, four white semi-flint QPM synthetics outyielded the best check, Otabanpa-ZMSR, by 1,500 kg/ha and showed better standability. These new synthetics also offer better protein quality. S00TLWQ-B and S99TLWQ-B yielded 6.6 and 6.5 t/ha, with 0.11, 0.53 and 10% tryptophan, lysine and protein in whole-grain, respectively, while Obatanpa yielded 4.9 t/ha and had 0.09, 0.43 and 9.5% tryptophan, lysine and protein in whole-grain, respectively. New synthetics should be tested extensively in Africa and, once adaptation is proven, seed production should start.

Twelve new white QPM synthetics, two reference QPM synthetics, and two local checks in EVTQ-28 were grown in a 4 x 4 a-lattice design with two replications per location. The lines that formed the new QPM synthetics were selected based on their GCA values and other good characteristics from yield trials in 1999 and 2000.

ANOVA showed that, except for corn stunt, there significant G x E. At each individual location significant differences were observed between entries. The highest mean grain yield (5.65 t/ha) was achieved at Cotaxtla, Mexico.

Seven of 12 new QPM synthetics yielded as much as or more than the best reference entry, POZA RICA 8763. The highest yielding synthetics were S2000TLWQ-B (5.0 t/ha) and S99TLWQ-HG-AB (4.9 t/ha) across 14 locations; both also had less ear rot (Fig. 5), and their other agronomic characteristics not significantly different from those of the reference entry. These synthetics also equaled or bettered the performance of the best normal, local OPVs and hybrids (Fig. 10).

Figure 10. Grain yield and Ear rot for the best five QPM synthetics reference entry and the best local check across 14 location in (EVTQ-28 and EVT12S) 2002-2003



CIMMYT tropical QPM hybrid trial

Newly developed QPM single and three-way cross hybrids were shipped to 60 locations in 2002 and 2003. Based on data from 25 locations in Latin America, Africa, and Asia, the new hybrids have better potential and stability than QPM hybrids released to date in the developing world. Three-way cross hybrid (CML142 x CML150) CML491 yielded 8.4 t/ha at Agua Fría 1.0 t/ha more than the normal check CML247 x CML254. At Turipana, Colombia, QPM hybrid CML491 x CML147 yielded 6.4 t/ha—40% more than the Monsanto hybrid C-343 (Fig. 11).

CML144 x CLQ-RCWQ26 topped the trial across 16 locations in 2002. At mid-altitude locations such as Zimbabwe, this hybrid yielded 8.1 t/ha 17% more than the normal hybrid check SC633. QPM hybrid check CML181/WW0140811 GQLS yielded 8.6 t/ha but with

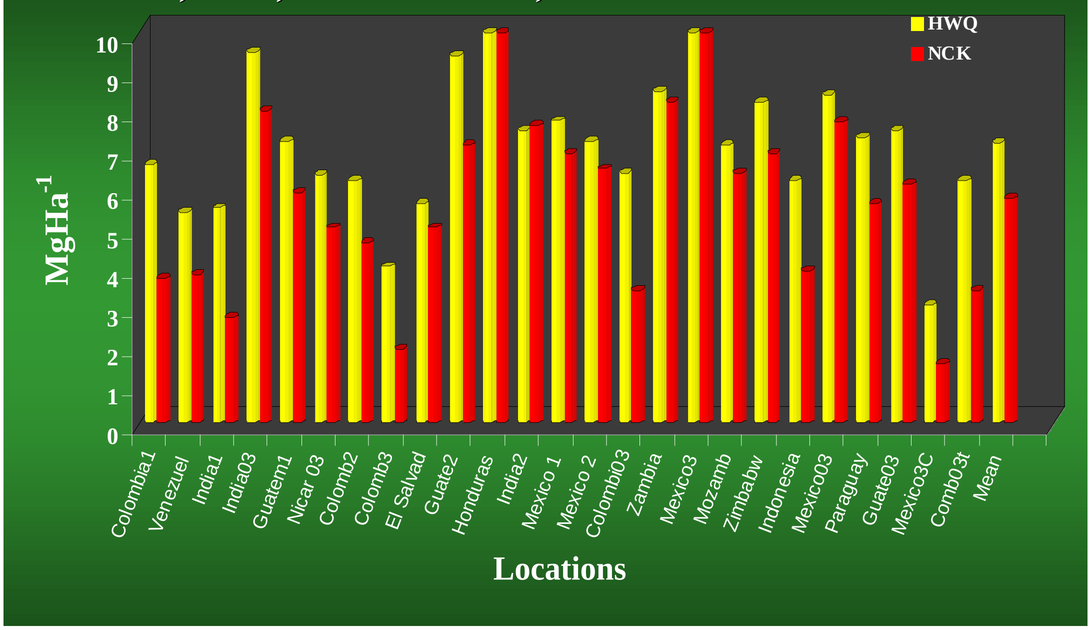
29% ear rot, therefore 2.47 t/ha of ear rot are deducted from the total yield, reducing the clean yield to 6.1 t/ha. At Mozambique, new QPM hybrid CML491 x CML492 (two new released lines) outyielded the best normal check, and both parents are highly resistant to ear rot.

At Campeche, Mexico, a drought-prone location, the best QPM hybrid CML491 x CML264Q yielded 3.0 t/ha, while Pioneer Hybrid P3086 yielded 1.5 /ha. Three QPM hybrids (CML144 x CML147, CML142 x CML147, and CML150 x CLQ-RCWQ31) had total lodgings of less than 10% (average for the experiment 17.3%), confirming that progress has been made in this direction. As CML147 was a parent in two out of three of these non-lodging hybrids, the line probably possesses favorable alleles for standability and should be used as donor in QPM breeding programs.

The mean yield across locations for QPM hybrids was 7.18 t/ha and that for normal seed industry check hybrids was 5.25 t/ha (Fig. 11), a 36% advantage in yield across 25 locations, 75 replications and two years. This reflects the recent progress in breeding QPM hybrids for the lowland tropics.

The new single and three-way cross hybrids will be tested in Southern Africa in 2003-2004. For this purpose 10 trials were shipped to Zimbabwe, Mozambique, Zambia, Malawi and Angola.

Figure 11. Best-yielding white QPM hybrids, 25 Locations in Asia, Africa, and Latin America, 2002 -2003



6.6 New Releases and QPM Seed Production

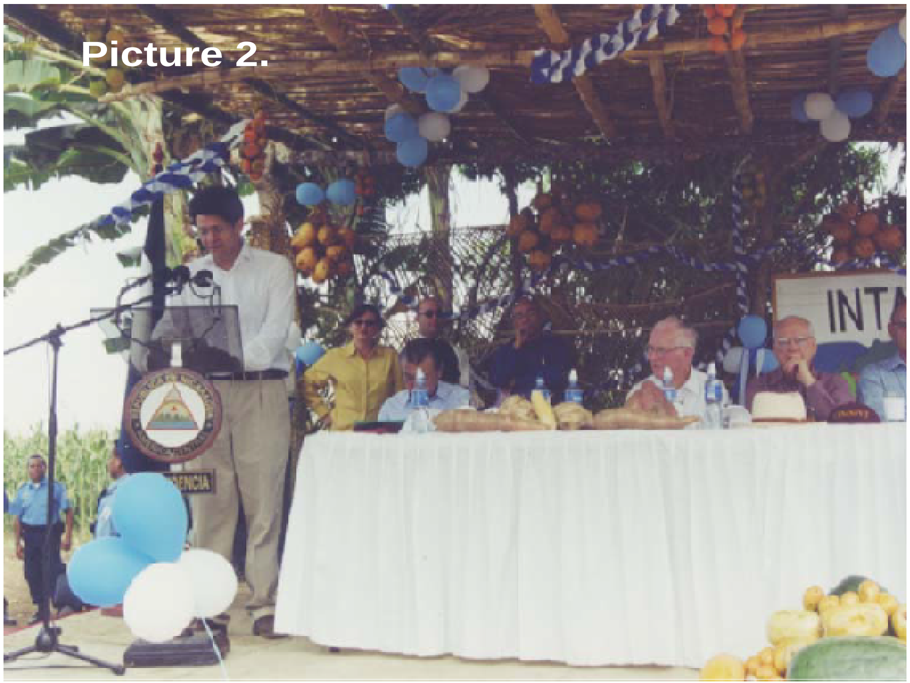
6.6.1 New tropical QPM line releases

Four new QPM lines (CML490 to CML493)—three white and one yellow—were released in June, 2003. The new lines possess special characteristics that make them superior to the old QPM lines: better yield potential in combination, resistance to ear rot and foliar diseases (particularly CML491), high yield potential per se (3.6 t/ha), standability, and resistance to ear rot, tropical rust, and Bipolaris maydis. In hybrid combinations, the lines gave yields of up to 11.6 t/ha at Cotaxtla, Mexico. The use of these lines by the public and private industry will contribute to form new hybrid combinations with elevated yield performance (Picture 1).

6.6.2 QPM in Nicaragua

In Nicaragua, Nutrinta Amarillo was released in February 2003 in a ceremony presided over by President Enrique Bolaños, Dr. Norman Borlaug, Mr. Yohey Sasakawa, Ing. Augusto Navarro (Minister of Agriculture), the Minister of Foreign Relations, Dr. Noel Pallais (Executive Director of the Instituto Nacional de Tecnología Agrícola), and CIMMYT maize breeder Dr. Hugo Cordova. Dr. Borlaug mentioned CIMMYT's dedication to reducing hunger and malnutrition in the developing world and encouraged Nicaraguan farmers to plant the new QPM variety to increase maize productivity and reduce poverty in Nicaragua. The Minister of Agriculture and INTA Director talked about the dedication of the present government to support agriculture and help maize farmers, as well as the long-time and fruitful collaboration with CIMMYT. President Bolaños also emphasized the dedication of his present government to support the rural and urban poor, and commended CIMMYT's Maize Program for its contributions to enhance agriculture research and development in Nicaragua in the past 25 years (Picture 2).

After the release ceremony President Bolaños awarded Dr. Borlaug the Order of Ruben Dario, the highest honor the Nicaraguan government can bestow upon a foreigner.



QPM Synthetic S99TLYQ-AB is a variety developed by CIMMYT in 2000-2001 through 20 replicated on-farm trials conducted by Nicaragua's Maize Program researchers. The variety outyielded local and improved checks and was sown in strip tests (a type of demonstration trial) in 2002 and evaluated at 60 on-farm locations. In the latter tests, it outyielded the improved variety NB-6 by more than 10% and had 0.10% tryptophan and 14% protein content in the grain. In winter season of 2002-2003, 10 tons of registered seed are being produced. INTA authorities say 10,000 hectares of three QPM cultivars will be grown in Nicaragua during 2003.

After the release ceremony, Ing. Alberto Espinosa, leader of Nicaragua's Maize Program, conducted a visit of a demonstration plot for NUTRINTA AMARILLO and reported on swine feeding trials similar to those that have been conducted in El Salvador, Guatemala, Honduras, Colombia, Ghana, Ethiopia and Kenya. In all such trials, use of QPM as opposed to normal maize in swine feeds results in healthier, faster-growing animals.

Together with maize breeder Daisy Ortega, Espinosa and Cordova spent two days visiting trials, both on-farm replicated and strip tests, as well as commercial plots with QPM NUTRINTA, both white and yellow. They also saw seed production and basic seed plots in the three-year, government financed "pound-for-pound" program, an initiative whereby farmers can pay for improved seed with grain from their harvests.

In 2000 President Bolaños (then Vice President) presided over the release of NUTRINTA, which is derived from CIMMYT germplasm. In 2002 the Ministry of Agriculture began wide-scale efforts to introduce NUTRINTA. INTA produces the basic seed and sells it to small seed companies, which in turn produces certified seed under the supervision of the seed unit. In 2002–03A, 200 tons of NUTRINTA seed were produced and in 2003B, enough seed was distributed to small farmers to sow 7,000 hectares. Prior to its release, NUTRINTA underwent two years of on-farm trials and strip tests—60 in all—in which it its average yield of 5.1 t/ha was 10% better than those of Obatanpa and NB-6. The variety's grain also contains 0.087% tryptophan, 0.402% lysine, and 10% protein.

Farmers in Masaya and Leon who grew NUTRINTA expressed expressed their satisfaction with the benefits it would bring to them and especially their children, whom daily consume a maize-based drink that will now be enriched by the QPM. They also mentioned that NUTRINTA AMARILLO has better price on the market because it improves the flavor of the drink.

6.6.3 QPM in India

In India, 300 tons of seed of white endosperm hybrid Shaktiman-1 were produced and sold—enough to sow 15,000 hectares in 2002. In 2003, 600 tons of seed will be harvested, which will allow 30,000 hectares to be sown in 2004.

The Directorate of Maize Research has released two new yellow endosperm QPM hybrids (CML161 x CML163 and CML163 x CML169) and another QPM hybrid will be released in Karnal Province. The release of yellow QPM hybrids was speeded up by the tremendous demand in the poultry industry for this product. Seed production of the new yellow hybrids will start in the winter 2003-2004.

6.6.4 QPM in Vietnam

In Vietnam, seed production of HQ-2000 continues to increase. All seed production in Vietnam is done by transplanting—a method whereby seedlings from nurseries transferred by hand to the field. In 2003 400 tons of seed were produced and more than 20,000 are being planted with QPM maize. A new hybrid HQ-2004 (CML161 x CML493) will be released soon and replace HQ-2000. Vietnam is also exporting hybrid technology. In 2003, 30 tons of HQ-2000 seed were exported to Bangladesh.

6.6.5 QPM in Bangladesh

In Bangladesh, on-farm testing of the QPM hybrid CML161 x CML165 began in 2002 and is now peaking. Bangladesh farmers were demanding more seed at the end of 2002. Ten tons of seed were imported from Vietnam last October and another 20 tons of HQ-2000 (CML161 x CML165) were imported again. The Bangladesh Agriculture Research Institute began to increase seed of the hybrid's parent lines in 2003, led by a seed production specialist trained at CIMMYT.

6.6.6 QPM in Bolivia

In Bolivia, QPM hybrid CML161 x CML165 was approved for release, making this the 23rd developing country in which QPM is sown.

7. QPM FOR THE SUBTROPICS WORLDWIDE

7.1 QPM Breeding Activities

During 2003, the QPM research activities for the subtropical environments was further strengthened and expanded compared to previous years. These included:

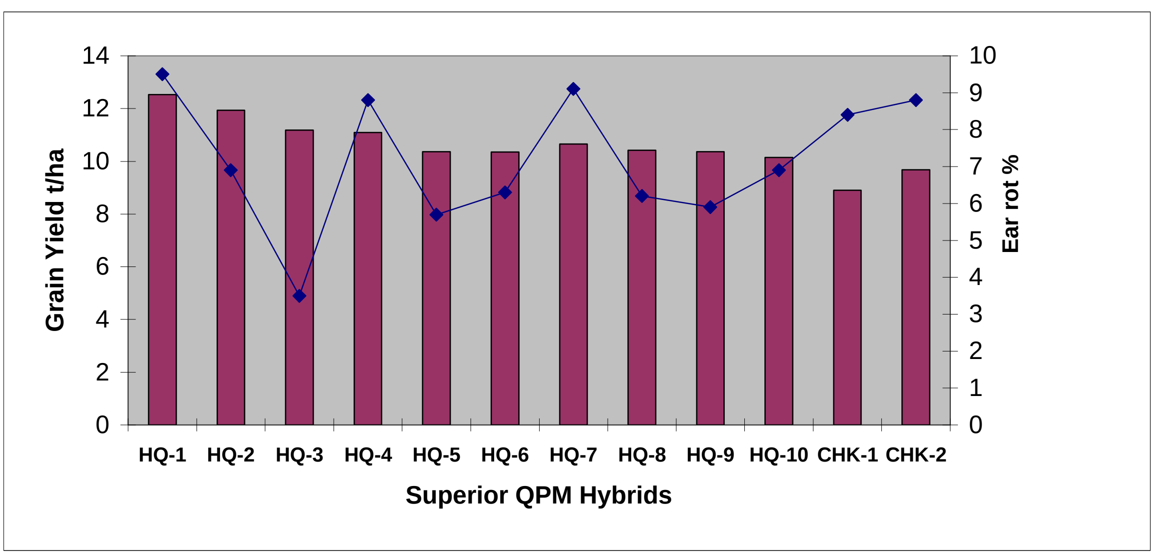
- Developing of new QPM white and yellow lines from subtropical intermediate to late maturity Gene Pools and broad base improved populations (Pool 31Q, 32Q, 33Q, 34Q, and Populations 67Q, 68Q, 69Q, 70Q) to further broaden the genetic base of QPM available for the subtropics.
- Pedigree breeding in QPM white and yellow germplasm involving elite lines from elite x elite F2 populations (QPM x QPM, QPM x Normal) at various stages of inbreeding.
- High GCA lines which were tested for their combining ability at S3 stage were advanced to S4 and S5 level of inbreeding. These lines were also screened for their reaction to the most important diseases and insect pests prevalent in the tropics.
- Advanced QPM white and yellow lines were planted at CIMMYT, El Batan, Mexico in highland environment and screened for common rust (Puccinia polysora) and northern leaf blight (E. turcicum) under artificial inoculation conditions.
- Elite QPM white and yellow lines at advance level of inbreeding were planted at Tlaltizapan (Subtropical environment) for seed increase. They were also evaluated under pressure of insect FAW (Fall Army Worm) and fusarium ear rot in line evaluation trials.
- Five white and three yellow QPM synthetics were formed by intermating selected lines with high GCA and better per-se performance. F1 seed was advanced to F2 seed, which will be evaluated in yield trials during 2004. Also other new QPM synthetics are being formed and are at F1 seed. Considerable emphasis was put on formation of synthetics and open-pollinated QPM varieties during 2003.
- High yielding QPM white and yellow hybrids identified from previous year's trials were formed to produce enough hybrid seed for testing in the international hybrid trials (CHTSWQ and CHTSYQ) for testing in 2004.
- During this year, we initiated the project on identifying superior QPM germplasm which also has high levels of Vitamin-A (B-Carotene) in the grain. Towards this objective over 200 entries involving lines, OPVs and hybrids were grown in Tlaltizapan, Mexico in replicated trial and sample plants were hand-pollinated to produce pure true to type grains for analysis of QPM and B-Carotene.
- The newly established QPM lab funded by Monsanto Foundation was inaugurated in October 2003 and will be fully operational before the end of the year.
- In the line conversion program involving normal x QPM lines, we aggressively continued to use molecular markers to accelerate the breeding cycle and reduce the number of generations.
- Exploited the heterosis between tropical and subtropical germplasm by crossing QPM lines between lines developed for these two mega-environments.

7.2 QPM Hybrid Yield Trials

During 2003, two international QPM hybrid trials, CHTSWQ (white) and CHTSYQ (yellow) were evaluated. These QPM trials included 16 white elite and 16 yellow hybrids, respectively. Preliminary results from the CHTSWQ trial showed that the single cross hybrid (P501 C1#-886-3-1-1-B x CML311)F2-19-1-BBB x CML175 had the highest grain yield 13.97 t/ha, followed by a three-way hybrid (CML186 x CML142) x CML176. In the case of the QPM yellow hybrids, the hybrid G34QC22MH135-4-2-BB-4-B*6 x G33QC25MH103-3-1-5-1-BBBB had the highest grain yield 10.58 t/ha, followed by (G34QC22MH135-4-2-BB-4-B*6 x G33QC25MH103-3-1-5-1-BBBB) x CML165, which yielded 10.66 t/ha. These preliminary information demonstrates the potential of three-way hybrids (TWC) that are the most popular type of hybrid in many developing countries.

About 250 S5 QPM, white, intermediate to late maturity lines derived from recycling elite x elite QPM x Normal F2 population (CML176 x CML384) and identified using molecular markers and subsequently confirmed through biochemical analysis for high levels of tryptophane and lysine were testcrossed with two testers lines CML186 (Subtropical) and CML149 (Tropical). These crosses were grouped in five different experiments and evaluated during 2002-2003 year in multiple environments. The top yielding hybrids from each of these trials out-yielded the best QPM reference hybrids used by more than 1 to 2 t/ha (Fig. 12). The best hybrid yielded 12.53 t/ha, which was 40 and 29 % better than the two reference QPM hybrids used as checks. All the QPM hybrids evaluated in these trials had very good endosperm modification, high levels of resistance to ear rot, tolerant to root and stalk lodging and enhanced levels of tryptophan content in endosperm.

Figure 12. Grain yield (t/ha) and percent ear rot in the best QPM hybrids across three locations during 2002-2003 in the S3 x tester testcross trial



Close to 100 S_3 QPM lines from a white early maturity gene pool, Pool27QPM were test-crossed to CML173 (Subtropical line) and S89G15 (Tropical synthetic) used as testers. The top-cross hybrid involving Pool27QPM c3-2-1-1 x S89G15Q had the highest grain yielding 8.58 t/ha, was nine days earlier than the best normal endosperm hybrid (P30640) (Table 10). The six superior yielding hybrids out-yielded the best early maturity normal endosperm hybrid used as check.

Table 10. Performance of five QPM white early maturity single hybrids across three locations during 2003 summer cycle

Pedigree	Yield	% of best check	FF	Ear rot (%)	End. Hard.	Try	Loc.	Trial
	t/ha		days		1-5	%		
Pool27QPMc3-2-1-1 x S89G15Q	**8.58**	**116**	74	17.7	1.8	0.076	3	SSCWQ0201
Pool27QPMc3-7-5-1 x CML173	**8.29**	**112**	72	16.9	1.6	0.060	3	SSCWQ0201
Pool27QPMc3-3-5-1 x S89G15Q	**8.19**	**111**	74	14.2	1.8	0.065	3	SSCWQ0201
Pool27QPMc3-45-2-2 x CML173	**8.52**	**115**	78	5.2	2.1	0.080	2	SSCWQ0225
Pool27QPMc3-14-1-3 x S89G15Q	**8.01**	**108**	83	12.4	1.8	0.070	2	SSCWQ0225
PSEW-HG-A-c0F8 x PSEW-HG-A-c0F39	**7.40**	**100**	76	12.2	1.8	0.037	3	
P30640	**8.56**	**116**	83	14.2	1.8	0.037	2	

End.Hardness =Score for endosperm hardness (1-5); Try=Tryptophan in the endosperm kernel (average of the parents); Loc=Number of locations tested; Trial=Name of each experiment.

Around 80 S3 QPM yellow early maturity lines derived from Pool29QPM gene pool were testcrossed with two tropical synthetics used as testers (S89G17Q and S86G18Q). The highest grain yield of 7.74 t/ha was recorded by cross Pool29QPM c9-48-1-3 x S89G17Q, which showed very low ear rot and was six days more early than the cross S89G17Q x S86G18Q used as reference check (Table 11). In general all six top yielding hybrids out-yielded the reference cross involving the two testers by 0.34 t/ha.

Table 11. Performance of five QPM yellow early maturity single cross hybrids across two locations during 2002-2003

	Yield	% over check	Days to	Ear rot	End. .Hard.
Pedigree	t/ha	%	silking	(%)	1-5
Pool29QPMc9-29-5-1 x S86G18Q	**7.35**	**106**	70	5.9	1.6
Pool29QPMc9-6-3-2 x S86G18Q	**7.16**	**103**	71	4.8	1.6
Pool29QPMc9-9-1-1 x S86G17Q	**7.10**	**102**	67	5.2	1.1
Pool29QPMc9-48-1-3 x S86G17Q	**7.74**	**111**	69	6.6	1.4
Pool29QPMc9-38-3-1 x S86G18Q	**7.21**	**104**	74	7.6	1.7
Pool29QPMc9-48-1-2 x S86G17Q	**7.19**	**103**	69	13.1	1.2
S86G17Q x S86G18Q	**6.95**	**100**	75	4.8	1.7

8. QPM FOR THE TROPICAL HIGHLANDS WORLDWIDE

Elite QPM germplasm adapted to the highlands does not currently exist at CIMMYT nor at other research institutes. At CIMMYT, we initiated two QPM highland projects in 1998. The first involves conversion of elite highland CML lines with normal grain type. In a second project we have made a series of crosses between subtropical, transition zone, and highland QPM and normal germplasm. Our goal is to develop white and yellow-grained source QPM germplasm adapted to the highlands including populations, synthetics and inbred lines.

8.1 Conversion to QPM of Elite Highland CIMMYT Maize Lines (CMLs)

The conversion of elite highland CML lines with normal grain type was initiated in 1998 by crossing 7 highland CMLs (239, 242, 244, 246, 349, 352, 354) (all white grained with early maturity) to an elite subtropical line (CML176). Through backcrossing and selfing, we are in the process of developing elite highland QPM inbred lines. In all segregating generations we use molecular markers (MM) to identify families with the opaque 2 allele and the light table to select grains with good kernel modification. During the 2003 growing season we tested elite BC4F2 both per se and in hybrid combination. We hope to release several highland early white QPM lines coming from this work in 2004.

Last year we expanded our QPM line conversion work to include elite lines of later maturity and with white and yellow-grain color. Eight elite lines were selected to begin this new conversion work.

8.2 Formation of Elite Highland Source Populations, Synthetics, and Lines

In a second highland QPM project we have made a series of crosses between subtropical, transition zone, and highland QPM and normal germplasm. Our goal is to develop white and yellow-grained source QPM germplasm adapted to the highlands including populations, synthetics and inbred lines.

We now have intermediate generation lines coming out of this highland QPM source population work. One encouraging example is shown in Table 12 where we evaluated a set of S4 white-grained QPM lines crossed with the subtropical tester line CML177. Combined over two Mexican environments, we identified several hybrids that were very competitive with the best normal check commercial hybrids. Most of these QPM hybrids also had superior agronomic characteristics such as shorter plant and ear height and less lodging as compared to the commercial checks. However, ear rot and grain modification were a problem in some combinations. Superior lines identified are being further inbred and used in synthetic formation.

We have now formed two highland white-grained QPM synthetics (one early and the other late maturing) which were tested for the first time in the 2003 season with encouraging preliminary results. Seed of these white-grained synthetics are currently being increased in our winter nursery with plans for more wide-scale testing in 2004. Additionally in our winter nurseries, we are making a first recombination of a yellow-grained QPM synthetic.

Table 12. Best highland late white S4 topcrosses with CML177 (2003-26 COMB)

Entry No.	Pedigree	Grain yield (t/ha)	% Best Check	Days to Flower (Male)	Plant Height (cm)	Root Lod (%)	Ear rot (%)	Grain Moist	Grain Modif. (1-5)	Plant aspect (1-5)
33	(2714-D x 2714-C-#-2-1 x 89[G23Q c25 H276 S6 / EWE 3056]-B-3-1-3-2-1-1)-B-1-1TL-2 x CML 177	8.5	110%	88	226	0.0	29.7	38.5	3.3	2.6
35	(2714-D x 2714-C-#-2-1 x 89[G23Q c25 H276 S6 / EWE 3056]-B-3-1-3-2-1-1)-B-1-1TL-4 x CML 177	8.1	105%	86	221	0.0	27.4	33.2	2.8	2.8
30	(COMP. O2 DURO DE ALTURA x G9A-#-1-4 x G31 c18 H#-96-1-2-1-B-5-1-B-1-B-1-B*4)-B-3-1TL-1 x CML 177	7.9	102%	89	243	0.0	12.8	34.3	2.0	2.8
37	(2714-D x 2714-C-#-2-1 x 89[G23Q c25 H276 S6 / EWE 3056]-B-3-1-3-2-1-1)-B-1-2TL-3 x CML 177	7.5	97%	83	225	0.0	14.6	33.5	3.5	2.6
	LOCAL CHECK'S									
43	HS-2	6.5		88	259	21.8	12.5	41.0	2.0	3.5
44	SAN ISIDRO	6.7		85	250	16.4	15.3	38.0	1.8	3.5
45	SAN JOSE	7.7		86	260	18.8	21.4	40.2	3.0	3.3
MEAN		6.3		87	218	1.8	30.3	34.9	3.7	3.0
C.V.=15.4										

8.3 Introgression of Subtropical QPM Germplasm into Highland Environments

A new project initiated last year involves extensive evaluations of CIMMYT's subtropical QPM germplasm in highland environments. While screening a small set of subtropical QPM synthetics in 2002, we were encouraged to find several materials that performed well with good resistance to common rust (*P. sorghi*), leaf blight (*E. turcicum*), and ear rot (*Fusarium*), diseases common in highland environments. During the 2003 major season we evaluated a larger set of elite subtropical QPM materials. We also initiated selfing in the most promising materials while also crossing them to elite highland populations and synthetics. In 2004 we plan to study the combining ability of this material while further advancing the early generation QPM lines.

8.4 Highland QPM – the Future

The next few years look exciting for our highland QPM research as we begin to make available elite highland QPM lines, synthetics, and source populations. At present we are investing about 25% of our highland resources into QPM research with an emphasis on white-grained materials. We expect our research allocation to grow up to about 50% in the next 2-5 years as we build our highland QPM germplasm base, increase yield trial evaluations of highland QPM, and devote more emphasis to yellow-grained QPM types which we expect will be increasingly demanded particularly by the feed industry. Links with CIMMYT outreach, national programs, private companies, and NGO's will be strengthened to help accelerate the adoption of improved highland QPM OPVs and hybrids.

APPENDIX 1

The Development and Promotion of Quality Protein Maize in sub-Saharan Africa

Workplan for 2004

The development and promotion of QPM in sub-Saharan Africa: Workplan for 2004

Core Project Component	Objective(s)	Plans for 2004	Milestones for 2004
1. QPM Networking	Develop and support national and sub-regional networks or working groups to guide and promote QPM research and dissemination	Regional steering committees will evaluate progress during 2003 and first half of 2004 and will recommend funding of proposals for QPM activities by partners in each of the three sub-regions of Africa	1) Progress reports from each country that received funding for 2003/04 will be included in the 2004 annual report for the project, and 2) a summary of approved grants for 2005 will be provided in the 2004 annual report
		QPM country working groups will meet in at least two countries of each sub-region to review progress and plan activities for QPM deployment	3) Country progress reports for QPM activities in at least 4 countries will be included in the 2004 annual report
2. Germplasm Development	Short-, medium- and long-term QPM germplasm requirements will be addressed for the major ecologies of sub-Saharan Africa	In Western Africa: 1) Conversion to QPM will be initiated for 6 normal maize populations with resistance to streak virus, resistance to *Striga,* and tolerance to drought, and 2) QPM lines and hybrids from CIMMYT will be evaluated and used to initiate breeding projects	4) Progress from two seasons of breeding activities will be reported in the 2004 annual report, and 5) The selected lines for use in forming QPM synthetics and hybrids will be identified in the 2004 annual report.
		In Eastern Africa: 1) New, improved streak virus resistant versions of at least four QPM populations will be formed, and 2) collaborative development of QPM lines will be continued with breeders of at least two national programs	6) Improved versions of at least 2 QPM populations will be included in regional trials, and 7) at least 200 experimental lines will be sent to the regional quality protein laboratory for protein content and quality analyses
		In Southern Africa: 1) Streak virus resistant versions of at least 10 elite southern African inbred lines will be advanced beyond S5, and will be evaluated in yield trials, and 2) At least 2 new QPM streak resistant synthetics will be formed using data from yield trials	8) Seed of at least 10 streak resistant QPM inbred lines will be widely distributed in trials for 2004/05, 9) streak (moderately) resistant QPM hybrids will be available for extensive testing in 2004/05, and 10) a new QPM MSV-resistant synthetic will be at F1 stage by October 2004.
		In Mexico: Experimental QPM OPVs, hybrids and inbred lines, will be developed to support QPM activities in Africa for each of the main ecologies (lowland, midaltitude and highland)	11) At least 6 distinct sets of material will be available for evaluation and use in Africa: OPVs, hybrids and inbred lines for lowland, subtropical and highland tropical adaptation.

The development and promotion of QPM in sub-Saharan Africa: Workplan for 2004 (Cont.)

Core Project Component	Objective(s)	Plans for 2004	Milestones for 2004
3. Germplasm Testing	Experimental QPM germplasm is evaluated at an adequate number of sites to establish its merit, and outstanding QPM varieties are included in on-farm evaluations and demonstrations.	1) International QPM trials will be distributed globally from Mexico, 2) regional QPM trials will be distributed from Harare and Nairobi, 3) research trials will be grown by breeders in each of the 3 major ecologies.	12) Trial results will be summarized and widely reported. 13) Best OPVs and hybrids will be identified for seed multiplication and further testing during 2005.
4. Seed Production/Dissemination	Seed of QPM varieties is produced and available in most countries of sub-Saharan Africa.	1) QPM varieties will be produced in each sub-region, 2) Community-based seed production of at least one QPM variety will be undertaken in at least two countries.	14) Seed of at least one QPM variety will be commercially sold in at least 4 countries, and 15) At least one seed company will be a member of each country-level QPM working group.
5. Training	Train researchers, technicians and support staff capable of sustaining QPM research and dissemination efforts in sub-Saharan Africa.	Training needs will be agreed at sub-regional level, and at least four scientists from each sub-region involved in QPM activities will receive professional training in a topic of relevance to QPM activities.	16) At least 12 African scientists working with QPM will have participated in relevant training activities
6. Laboratory Facilities	Ensure access to adequate laboratory facilities to sustain QPM research and dissemination efforts in sub-Saharan Africa.	1) The newly established or upgraded QPM laboratories in each of the three sub-regions will be used to evaluate protein content and quality of at least 1000 samples, and 2) a set of 25 maize samples will be sent to CIMMYT Mexico and each of the three regional laboratories for analyses and comparison of results	17) At least 1000 QPM materials will have been evaluated for protein content and quality at the regional QPM laboratories (at least 200 samples at each lab), and 18) results of evaluations of 25 common samples at all laboratories will be reported in the 2004 annual report
7. Nutritional and economic studies	Document the potential and actual nutritional and economic impact of QPM in selected countries of sub-Saharan Africa.	Develop links with the Harvest Plus (formerly biofortification challenge program) project and develop a plan for collaborative activities in the areas of nutritional advocacy and socio-economics	19) The opportunities for synergies between QPM and Harvest Plus projects will be reported in the 2004 annual report, together with an outline of the proposed strategy.

APPENDIX 2

Supplementary Data Tables A1 to A5

Table A1. Grain yield (t/ha), and other important agronomic characters of double topcross QPM hybrids, 2 pre-released 3-way hybrids and 2 commercial checks tested across 5 sites including low N, drought and optimum in Kenya, 2003A.

Entry	Pedigree	Across			DR	LN	OPT	Anth	ASI	Lodging	E.turc	Ear	Plant
		Rel GY	Rank		Kiboko	Across	Across	Date		Root		Aspect	Aspect
		%	Avg	Stdev	t/ha	t/ha	t/ha	d	d	%	1-5	1-5	1-5
1	CML153-B/CL-Q6203//CML173	88	12	1	0.4	0.8	6.8	69	1	0	3.4	2.4	1.9
2	CML154-B/CL-Q6203//CML173	94	9	4	1.3	0.8	7.5	69	2	61	3.3	2.4	1.8
3	CML176-B/CL-Q6203//CML173	79	14	8	0.6	0.5	7.4	70	1	75	3.1	2.2	2.0
4	CML178-B/CL-Q6203//CML173	83	14	7	0.7	0.9	5.2	67	2	69	3.4	2.7	1.8
5	CML180-B/CL-Q6203//CML173	77	17	2	0.6	0.7	5.8	67	3	51	2.5	2.7	1.7
6	CML181-B/CL-Q6203//CML173	118	8	2	0.5	1.4	7.1	69	1	2	1.5	2.8	1.8
7	CML182-B/CL-Q6203//CML173	88	11	2	0.6	0.8	6.9	70	3	53	1.8	2.5	2.0
8	Susuma/CL-Q6203//CML173	112	10	4	0.7	1.3	6.7	70	5	72	2.5	2.6	1.6
9	CML181/CML182/CL-Q6203//CML173	129	9	6	1.0	1.7	6.7	70	2	69	2.3	2.7	2.1
10	QPMSRSYNTH/CL-Q6203//CML173	80	13	11	0.7	0.5	7.7	71	3	86	2.8	2.4	2.0
11	NQPMSRSYNTH/CL-Q6203//CML173	84	14	0	0.1	0.7	6.6	72	3	66	2.5	3.1	2.0
12	POOL15QPMSR/CL-Q6203//CML173	76	17	1	1.0	0.7	6.0	67	2	39	3.0	2.9	1.9
13	CML144/CML159/CL-Q6203//CML173	96	9	2	0.9	0.9	7.4	72	1	65	2.4	2.4	2.1
14	CL-Q6203/CML173/CL-Q6203//CML173	37	21	0	0.6	0.3	3.1	71	2	37	2.8	3.2	1.6
15	OBATANPA-SRc1F3#	75	17	1	0.1	0.6	6.1	69	6	18	2.9	2.6	1.9
16	CML144XCML159//CML181	178	2	1	0.3	2.4	8.8	72	5	61	1.4	2.8	2.0
17	CML144XCML159//CML182	109	6	3	0.4	1.0	8.4	70	3	52	1.5	3.1	2.0
18	POOL15QPMSR	63	19	1	0.8	0.6	4.6	65	4	33	2.9	3.8	1.8
19	CG4141	134	9	9	0.2	1.8	6.1	72	3	90	2.1	3.5	2.2
20	Phb 3253	143	3	3	0.6	1.4	10.1	69	6	46	2.4	2.2	2.0
21	H513	160	3	1	0.9	1.8	9.7	72	5	69	2.1	2.8	2.6
Mean		**100**	**11**	**3**	**0.6**	**1.0**	**6.9**	**69.7**	**2.7**	**53.0**	**2.5**	**2.7**	**1.9**
LSD (0.05)					**0.8**	**0.8**	**1.1**	**1.5**	**2.8**	**17.3**	**0.7**	**0.5**	**0.3**
MSe					**0.1**	**0.1**	**0.2**	**2.0**	**1.5**	**117.0**	**0.2**	**0.2**	**0.0**
CV					**55.1**	**32.4**	**7.0**	**2.0**	**44.3**	**20.4**	**18.3**	**14.5**	**10.6**

Table A2. Grain yield (t/ha), disease (GLS, turcicum and ear rot) reaction and other agronomic characters of QPM OPVs along with QPM and normal OPVS and hybrids, tested across 4 sites including low N and optimum in Kenya, 2003A.

Entry	Pedigree	Across Rel GY	Across Rank Avg	Across Rank Stdev	OPT Across	LN Across	Anth Date	Plant Height	Ear Height	Ears/ Plant	Husk Cover	Ear Rot	GLS	E.turc	Ear Aspect	Plant Aspect
		%	Avg	Stdev	t/ha	t/ha	d	cm	cm	#	%	%	1-5	1-5	1-5	1-5
1	OBATANPA-SRc1F3#	95	7	3	5.4	2.7	70	247	123	1.06	11	22	1.9	2.6	3.3	2.8
2	CML144XCML159//CML181	130	3	2	7.5	3.5	72	248	126	1.05	39	35	1.7	1.5	2.2	2.6
3	CML144XCML159//CML182	132	3	1	8.6	2.8	72	261	122	1.35	52	12	1.6	1.4	2.4	2.7
4	CML181/CML175//OBATANPA	108	6	3	7.2	2.2	71	262	132	1.10	27	22	1.6	2.3	3.3	2.8
5	GQL5/CML176//WWO1408//CML181	99	8	3	6.0	2.4	72	252	119	1.02	32	39	1.6	1.9	3.3	2.7
6	POZARIC8763	81	10	4	5.3	1.8	72	256	107	1.03	28	25	2.0	2.7	4.1	2.5
7	ACROSS8762	78	11	4	5.3	1.6	73	233	128	1.06	25	11	1.9	2.8	4.0	2.4
8	S99TLWQ	86	9	1	5.5	1.9	75	241	100	1.02	28	27	2.0	2.3	4.0	2.3
9	S00TWQ-B	84	10	2	5.5	1.8	77	260	138	0.97	12	11	2.3	2.7	3.6	2.4
10	POOL15QPM-SR	61	13	1	3.4	1.8	65	211	109	0.99	27	35	2.1	2.7	4.4	2.0
11	QPMSRSYNTH	93	9	3	5.7	2.2	72	254	128	1.04	29	32	1.7	2.9	3.2	2.5
12	WH403 - Normal Hybrid	148	1	1	9.3	3.4	74	272	120	1.00	46	7	1.3	1.2	2.5	2.9
13	ECAVL-1 - Normal OPV	100	7	4	5.6	2.8	73	255	121	1.06	25	27	1.6	2.3	2.9	2.5
14	LOCAL CHECK - Normal OPV	106	7	5	6.5	2.5	77	306	178	0.98	14	20	1.6	1.5	2.8	3.9
Mean		**100**	**8**	**2**	**6.2**	**2.4**	**72.4**	**254.0**	**125.1**	**1.05**	**28.2**	**23.0**	**1.8**	**2.2**	**3.3**	**2.6**
LSD (0.05)					**1.2**	**1.0**	**1.7**	**19.3**	**19.9**	**0.12**	**11.2**	**13.7**	**0.3**	**0.4**	**0.9**	**0.3**
MSe					**0.8**	**0.3**	**3.3**	**105.2**	**111.7**	**0.00**	**106.4**	**52.6**	**0.1**	**0.2**	**0.3**	**0.0**
CV					**14.6**	**23.3**	**2.5**	**4.0**	**8.4**	**5.84**	**36.6**	**31.5**	**14.8**	**17.7**	**15.3**	**7.4**

Table A3. Grain yield (t/ha), and other agronomic characters of QPM hybrids, 2 normal checks and 2 commercial hybrids tested across 6 sites including optimum and low N conditions in Kenya, 2003A.

Entry	Pedigree	Across			LN	OPT	Anth	ASI	Ear	GLS	P.sorg	E.turc	MSV	Ear	Plant
		Rel GY	Rank		Across	Across	Date		Rot					Aspect	Aspect
		%	Avg	Stdev	t/ha	t/ha	d	d	%	1-5	1-5	1-5	1-5	1-5	1-5
1	CZH01029	89	14	7	2.8	6.9	76	2	28	1.5	2.4	2.4	0.7	2.5	2.6
2	CZH01031	117	8	5	3.7	8.0	75	2	13	1.5	2.8	1.7	5.3	2.4	2.8
3	CZH01030	81	16	8	2.4	6.7	74	2	26	1.5	2.5	2.5	2.7	2.4	2.6
4	CZH01025	106	11	4	3.2	8.0	73	2	7	1.6	2.2	2.2	1.3	2.8	2.6
5	CZH01027	87	17	2	2.7	6.4	75	1	22	1.5	2.1	2.1	4.7	2.6	2.5
6	CZH99051	119	7	4	3.6	8.7	74	3	3	2.6	1.8	2.2	1.0	2.8	2.9
7	CZH99052	80	20	3	2.4	5.9	78	2	8	1.8	3.7	2.3	4.0	2.1	2.7
8	CZH01021	98	13	1	3.0	7.1	75	2	16	1.5	2.8	2.1	1.3	2.4	2.9
9	CZH01023	94	14	4	2.9	7.1	74	0	6	1.5	2.5	2.3	2.0	2.7	2.6
10	CZH01033	60	23	2	2.0	4.2	73	4	14	1.9	2.9	2.9	3.3	3.1	2.3
11	CZH01034	74	18	5	2.2	5.4	72	2	13	1.5	2.8	2.7	4.7	2.5	2.5
12	CZH99055	80	18	5	2.4	6.7	75	4	8	2.0	2.7	2.6	0.7	2.7	2.8
13	CZH99061	81	18	4	2.4	6.6	74	1	23	1.5	2.6	2.2	2.0	2.9	3.0
14	CZH02016	70	20	5	2.0	5.0	71	2	16	1.9	3.2	3.0	2.0	2.7	2.3
15	OBATANPA-ZMSRc1F2	70	20	4	1.8	5.4	75	3	8	2.0	2.8	2.7	0.7	2.9	2.9
16	CZH01022	112	9	2	3.8	7.6	73	2	17	1.6	2.2	1.8	1.0	2.8	2.9
17	CZH01024	133	5	3	4.5	8.1	76	1	10	1.5	2.5	2.0	1.7	2.7	2.9
18	CZH01032	130	7	6	4.4	7.8	75	1	9	1.4	2.8	1.6	1.7	2.9	2.7
19	CZH01028	119	6	3	3.9	8.4	74	3	21	1.6	2.5	2.2	1.3	2.7	2.6
20	02C3728	124	8	5	3.8	7.3	75	2	18	2.7	2.7	1.9	2.7	2.6	2.6
21	CZH00026 (Normal Check1)	109	8	5	3.0	8.3	76	2	7	1.4	1.6	2.6	1.0	2.0	2.9
22	CZH01008 (Normal Check2)	128	4	2	3.9	9.4	73	3	3	1.4	2.3	1.8	3.0	1.8	2.9
23	Local Check 1	131	4	3	4.4	8.4	77	5	7	2.3	2.0	2.0	4.7	2.3	3.3
24	Local Check 2	108	14	8	3.3	6.4	76	6	5	2.3	2.4	1.4	4.0	2.0	3.6
Mean		**96**	**14**	**4**	**3.0**	**6.9**	**74.6**	**2.3**	**12.7**	**1.7**	**2.5**	**2.2**	**2.4**	**2.6**	**2.8**
LSD (0.05)					**0.9**	**1.1**	**1.2**	**2.2**	**13.5**	**0.3**	**0.5**	**0.4**	**2.4**	**0.5**	**0.4**
MSe					**0.6**	**0.8**	**3.0**	**1.7**	**65.3**	**0.1**	**0.1**	**0.2**	**2.0**	**0.2**	**0.1**
CV					**24.8**	**13.1**	**2.3**	**57.4**	**63.5**	**21.3**	**12.7**	**21.7**	**59.2**	**18.6**	**13.7**

Table A4. Grain yield (t/ha) and other important agronomic traits of QPM CMLs tested across 3 hot spot sites in Kenya, 2003A.

Entry	Pedigree	Across			- Grain Yields								Anth	ASI	Plant	Ear	Lodging		Ears/	Husk	Ear	GLS	E.turc	Ear	Plant
		Rel GY	Rank		Across		Alupe, Kenya		Kakamega		Embu		Date		Height	Height	Root	Stem	Plant	Cover	Rot			Aspect	Aspect
		%	Avg	Stdev	t/ha	Rank	t/ha	Rank	t/ha	Rank	t/ha	Rank	d	d	cm	cm	%	%	#	%	%	1-5	1-5	1-5	1-5
1	CML 141	89	24	10	1.7	24	0.4	34	1.5	23	3.2	15	81	1	147	78	0.0	1.2	1.37	32.4	25.9	2.4	2.2	3.3	2.0
2	CML 142	125	14	6	2.2	14	0.6	20	2.7	8	3.3	13	85	0	170	73	0.0	1.1	1.01	-0.2	3	1.7	2.2	2.9	2.1
3	CML 143	101	19	12	1.9	19	0.5	30	1.7	20	3.5	6	80	1	155	63	5.6	-2.2	0.96	0.7	6.6	2.5	2.0	3.2	1.9
4	CML 144	114	17	3	1.9	17	0.7	16	2.2	15	2.9	21	84	0	160	54	0.0	21.3	1.53	5.9	27	2.6	2.0	3.4	2.2
5	CML 145	56	28	23	1.6	28	0.0	42	-0.1	41	5.0	2	92	10	0	0				12.7	2.5	0.1	0.7	3.8	2.2
6	CML 146	47	37	3	1.0	37	0.2	40	0.4	38	2.3	34	88	6	154	52	0.0	-2.0	0.77	-0.4	40.0	2.5	2.5	5.0	2.8
7	CML 147	60	34	4	1.1	34	0.3	38	0.7	32	2.4	31	79	3	143	39	0.0	-1.2	1.28	12.6	5.0	2.7	1.8	3.1	1.4
8	CML 148	52	37	5	0.9	37	0.3	37	0.7	33	1.6	42	85	3	177	87	12.5	5.0	1.38	80.6	5.0	1.5	2.7	3.4	2.1
9	CML 149	69	32	2	1.2	32	0.4	33	0.9	30	2.3	33	82	4	157	60	10.0	8.5	1.09	23.5	25.0	2.4	2.3	4.1	2.6
10	CML 150	62	34	6	1.1	34	0.4	35	1.1	27	1.8	39	80	3	132	37	6.3	-1.0	0.58	18.1	30.8	2.1	2.5	4.2	2.0
11	CML 151	159	12	13	2.5	12	0.9	5	3.9	3	2.6	27	82	2	145	66	0.0	3.7	1.06	7.5	13	1.8	1.8	2.7	2.2
12	CML 152	130	15	8	2.2	15	0.6	21	3.0	6	3.0	17	84	3	166	73	3.5	6.2	0.90	25.9	18	2.3	2.0	3.1	1.7
13	CML 153	82	27	3	1.4	27	0.5	26	1.3	25	2.4	30	80	3	150	63	5.0	1.8	0.88	50.4	16.6	2.6	3.0	3.8	2.4
14	CML 154	72	26	16	1.5	26	0.4	36	0.6	34	3.5	7	81	7	147	54	5.6	9.3	0.48	-0.9	60.0	1.6	2.8	4.8	2.6
15	CML 155	115	15	9	2.1	15	0.6	25	2.3	12	3.4	8	79	4	122	40	6.7	3.8	0.96	2.3	0	2.3	2.1	3.5	1.5
16	CML 156	79	30	10	1.3	30	0.5	27	1.6	22	1.6	41	88	1	98	45	0.0	2.3	0.63	-0.8	3.2	1.7	2.2	3.3	1.5
17	CML 157	89	21	8	1.6	21	0.6	24	1.1	28	3.3	12	82	2	103	42	8.4	3.9	1.04	0.6	29.2	2.0	2.0	3.4	1.7
18	CML 158	76	27	9	1.3	27	0.6	22	0.5	37	2.9	22	82	3	157	67	5.6	0.1	0.92	59.6	34.3	2.7	2.6	3.4	2.1
19	CML 159	115	18	7	1.9	18	0.7	19	2.3	11	2.9	24	83	2	129	41	10.1	0.8	0.88	36.2	14.6	1.8	2.1	3.5	2.2
20	CML 160	121	16	14	2.4	16	0.5	28	1.7	19	5.1	1	81	6	67	28	0.0	0.0	1.28	-1.2	17	1.0	1.2	3.0	1.7
21	CML 161	90	22	15	1.8	22	0.3	39	1.8	17	3.3	11	81	2	144	62	0.0	-0.4	1.67	1.4	26.7	2.2	2.3	3.4	1.9
22	CML 162	70	25	19	1.4	25	0.4	31	0.1	40	3.8	4	78	8	160	32	0.0	9.8	0.52	5.1	9.4	2.4	3.1	2.1	1.4
23	CML 163	112	20	13	1.7	20	0.8	11	2.2	14	2.2	35	82	5	171	89	22.5	12.5	1.18	9.6	10.5	1.9	1.8	3.5	2.4
24	CML 164	86	25	7	1.4	25	0.7	17	1.1	29	2.5	28	79	2	170	87	0.0	9.2	1.03	0.4	12.4	1.9	2.0	3.3	2.2
25	CML 165	143	11	6	2.5	11	0.7	15	3.4	5	3.3	14	84	2	157	67	13.6	1.8	1.56	2.2	18	1.4	1.4	3.2	2.0
26	CML 166	87	25	6	1.6	25	0.4	32	1.4	24	2.9	20	81	3	162	66	51.5	3.4	1.11	56.8	31.4	2.4	1.6	3.0	1.6
27	CML 167	77	31	15	1.5	31	0.2	41	2.3	13	2.1	38	77	0	170	73	0.0	-1.4	1.16	71.8	20.7	2.0	2.4	4.2	2.1
28	CML 168	83	25	11	1.3	25	0.7	13	0.9	31	2.4	32	79	1	150	59	12.1	33.9	1.08	2.0	6.7	2.3	1.9	3.5	2.3
29	CML 169	96	18	8	1.7	18	0.7	18	1.1	26	3.3	10	80	4	141	50	4.6	2.6	1.26	15.6	31.0	2.5	2.1	3.8	2.1
30	CML 170	56	32	9	1.0	32	0.5	29	-0.1	42	2.7	26	80	2	122	59	0.0	1.8	0.70	12.4	14.9	3.1	2.5	3.2	2.0
31	CML 171	127	13	9	1.9	13	1.0	2	1.8	18	3.0	18	77	5	180	58	4.2	3.2	1.01	47.8	34	1.7	2.1	2.9	2.1
32	CML 172	138	8	2	2.2	8	0.9	6	2.4	10	3.4	9	78	3	163	62	12.5	1.7	1.06	49.4	32	1.8	2.2	2.9	1.8
33	CML173	62	33	9	0.9	33	0.6	23	0.5	35	1.6	40	73	2	110	35	0.0	9.1	0.96	10.0	39.2	2.5	2.5	4.3	1.5
34	CML154	119	16	13	1.8	16	1.0	4	1.9	16	2.4	29	83	0	149	65	15.7	17.0	1.09	0.1	26	2.3	1.8	2.8	1.9
35	CML181d	183	7	10	2.8	7	1.1	1	4.4	1	2.9	19	80	-1	161	69	0.0	-1.6	1.01	10.8	27	1.4	1.4	3.4	1.8
36	CML181f	146	6	2	2.5	6	0.8	7	2.7	7	4.0	3	84	-1	160	66	0.0	12.2	1.22	4.1	13	2.6	1.9	3.0	2.2
37	CML182	172	4	1	2.8	4	1.0	3	3.8	4	3.7	5	77	2	157	54	14.9	-0.6	1.17	5.9	14	1.1	1.4	3.0	1.4
38	CML175	79	27	16	1.1	27	0.8	8	0.5	36	2.1	37	81	1	128	55	4.6	14.6	0.85	2.0	38.2	1.6	3.0	3.6	2.0
39	CML176	105	19	6	1.7	19	0.7	12	1.7	21	2.9	23	80	1	157	57	3.2	2.4	0.85	1.4	16.1	2.2	1.6	3.7	2.3
40	WW011408-1-1-2-B*4	163	9	7	2.7	9	0.8	10	4.2	2	3.2	16	82	0	146	77	0.0	0.2	1.30	3.6	7	1.8	1.4	2.9	1.2
41	GQL5-B*3	68	30	14	1.0	30	0.7	14	0.2	39	2.2	36	81	3	105	48	0.0	7.1	0.59	9.7	68.4	1.8	2.5	4.2	2.1
42	CML202	125	14	9	2.0	14	0.8	9	2.5	9	2.8	25	83	0	139	56	0.0	8.3	1.16	0.1	6	1.5	1.2	2.5	1.2
Mean		**100**	**22**	**9**	**1.7**	**22**	**0.6**	**.**	**1.7**	**.**	**2.9**	**.**	**81.4**	**2.5**	**142.4**	**57.1**	**5.8**	**5.1**	**1.04**	**16.4**	**20.9**	**2.0**	**2.1**	**3.4**	**2.0**
LSD (0.05)					**0.6**		**0.5**	**.**	**1.3**	**.**	**1.2**	**.**	**2.5**	**2.5**	**41.0**	**29.3**	**15.4**	**10.8**	**0.36**	**26.7**	**17.8**	**0.6**	**0.5**	**0.9**	**0.7**
MSe					**0.3**		**0.1**	**.**	**0.4**	**.**	**0.3**	**.**	**4.5**	**4.4**	**401.0**	**205.5**	**56.2**	**56.0**	**0.06**	**341.2**	**151.4**	**0.2**	**0.1**	**0.6**	**0.3**
CV					**29.7**		**37.6**	**.**	**37.2**	**.**	**20.3**	**.**	**2.6**	**83.4**	**14.1**	**25.1**	**129.0**	**146.8**	**23.86**	**112.8**	**58.9**	**22.3**	**18.7**	**22.5**	**29.1**

Table A5. Grain yield (t/ha) and disease reaction of different versions of Obatanpa tested across 2 sites including optimum and low nitrogen in Kenya, 2003

Entry	Pedigree	OPT		LN		Anth	Ear	E.turc	Plant
				Alupe, Kenya		Date	Rot		Aspect
		t/ha	Rank	t/ha	Rank	d	%	1-5	1-5
1	SUSSUMA (Obatanpa-Moz)	6.6	2	1.7	4	71	4	3.1	2.8
2	OBATANPA (Ghana)	7.3	1	1.4	5	72	4	3.6	2.8
3	OBATANPA-SRc1F3#	6.4	3	1.8	3	72	4	3.3	2.8
4	S91SIWQc1F3	6.0	5	0.9	6	66	7	2.9	1.3
5	ZM611=[P501-SR/P502-SR] F2	5.6	6	2.4	1	71	16	1.9	1.5
6	ZM621-FLINT F2	6.3	4	2.0	2	71	10	3.0	2.0
Mean		**6.4**	**.**	**1.7**	**.**	**70.3**	**7.5**	**3.0**	**2.2**
LSD (0.05)		**1.4**	**.**	**2.0**	**.**	**1.8**	**0.5**		**0.9**
MSe		**0.2**	**.**	**0.4**	**.**	**0.3**	**0.0**		**0.1**
CV		**7.1**	**.**	**36.3**	**.**	**0.8**	**0.5**	**0.0**	**13.3**

APPENDIX 3

Tentative Workplan for 2004
QPM Research for the Lowland Tropics Worldwide

Tentative Workplan for 2004

QPM Research for the Lowland Tropics Worldwide

Training

Training activities will take place in Mexico and Southern and Eastern Africa.

Evaluation of QPM hybrids and OPVs in collaborating countries

9 different types of trials involving white and yellow QPM hybrids and synthetics will be distributed in several countries (see description of trials) during summer and winter 2004 (Table 1).

Seed increase of QPM hybrids, varieties and inbred line parents

1000 rows 5 meters long will be planted in 2002 at the Agua Fria in Mexico to increase seed of synthetics, hybrids and inbred parents and to form new hybrid combinations. This will include forming new synthetics, and increasing seed of new synthetics and new inbred parents of tropical hybrids.

Analysis of varieties and hybrids trials for quality traits

Data from international trials mentioned above will be put into the database of the CIMMYT international maize testing unit and analyzed by sites and across locations. Stability analysis will be performed for yield, endosperm hardness, and ear rot. Superior hybrids and synthetics will be identified for on-farm validation trials in 2004. Inbred parents showing stability for yield and endosperm hardness in hybrid combinations will be included in crossing blocks for pedigree breeding and recycling activities.

Breeding activities

QPM pedigree breeding selection

100 F1 QPM crosses that involve QPM lines and normal lines with resistance to insects, drought, low-N, corn stunt, downy mildew, and soil acidity, will be planted at Agua Fria, during the 2004 A cycle.

QPM F2 population

100 F2 QPM populations (S1 lines) that involve QPM lines and normal lines with resistance to insects, drought, low-N, corn stunt, downy mildew, and soil acidity, will be planted at Agua Fria, during the 2004 B cycle

QPM early generation nurseries S3 to S5

400 tropical, intermediate-to-late white and yellow QPM lines will be planted at Agua Fria during the 2004 A and B cycles.

QPM advanced generation nurseries S6 to S8

200 QPM lines, tropical white and yellow heterotic groups A and B selected by performance with testers, will be planted at Agua Fria during 2004 A and B cycles.

QPM elite inbred line nurseries S8 to S10

Approximately 20 QPM lines (10 white and 10 yellow) will be planted at Agua Fria during 2004 A and B cycles.

Conversion of elite line (normal hybrid parents) to QPM

BC1 and BC2 and BC3 line conversion QPM will be practiced in various tropical white and yellow normal lines, plants carrying the o2 o2 gene, will be identified using molecular markers light table. BC3 converted lines will be selfed further to fix the hard endosperm.

QPM hybrid development and testing

More than 300 new yellow tropical, intermediate-to-late maturity QPM hybrids were will be form in Agua Fria during the 2004 A cycle. In addition, 15 white and 15 yellow QPM elite hybrids will be form for seed increase in Agua Fria during the 2004 B cycle for evaluation in local and international yield trials (CHTT's)

A total of 8034 five meter long rows including tropical lowland materials will be planted at Agua Fria stations in 2003A and 2003B and 3000 at Campeche and Cotaxlta, Mexico, Guatemala, Colombia, India, Kenya .

Formation of QPM synthetics F1

15 QPM synthetics (10 white and 5 yellow) will be formed in Agua Fria during the 2004 A cycle to make F1 and advance to F2 in 2004B.

Four isolations will be planted at Agua Fria, at a ratio 2:1 female rows will be planted with early generation , advanced lines , and single crosses and male rows will be the testers.

Description of Lowland Tropical Maize Subprogram QPM Trials, 2004 B

TSCWQ04-1:	Includes the evaluation of 28 advanced tropical white late QPM single crosses, and two checks for a total of 30 entries, under 5x6 Alpha lattice design, 2 row, 5 meters long plot, 2 replications per location.
TSCYQ04-2:	Includes the evaluation of 23 advanced tropical yellow late QPM single crosses, and two checks for a total of 25 entries, under 5x5 Alpha lattice design, 2 row, 5 meters long plot, 2 replications per location.
TTWCWQ04-3:	Includes the evaluation of 28 new three-way tropical white late QPM hybrids, and two checks for a total of 30 entries, under 5x6 Alpha lattice design, 2 row, 5 meters long plot, 2 replications per location.
TTWCYQ04-4:	Includes the evaluation of 23 three-way tropical yellow late QPM hybrids, and two checks for a total of 25 entries, under 5x5 Alpha lattice design, 2 row, 5 meters long plot, 2 replications per location
TSCWQ04-5:	Includes the evaluation 100 single crosses among early generation tropical late white QPM lines heterotic group “A” and heterotic group “B”, under 10x10 Alpha lattice design, 1 row, 5 meters long plot, 2 replications per location.
TSCYQ04-6:	Includes the evaluation 70 single crosses among early generation tropical late yellow QPM lines heterotic group “A” and heterotic group “B”, under 10x7 Alpha lattice design, 1 row, 5 meters long plot, 2 replications per location.

CHTTWQ04: Includes the evaluation of 18 elite tropical white late QPM hybrids, and two checks for a total of 20 entries, under 4x5 Alpha lattice design, 2 row, 5 meters long plot, 3 replications per location.

CHTTYQ04: Includes the evaluation of 14 elite tropical yellow late QPM hybrids, and two checks for a total of 16 entries, under 4x4 Alpha lattice design, 2 row, 5 meters long plot, 3 replications per location.

EVTWQ04-7 Includes the evaluation of 18 tropical white late QPM OPV's, and two checks for a total of 20 entries, under 4x5 Alpha lattice design, 2 row, 5 meters long plot, 3 replications per location.

* Key Sites

Agua Fria	México
Cuyuta	Guatemala
Turipana	Colombia
Mtuapa	Kenya
Delhi	India
Harare	Zimbabwe

Table 1. Description of tropical QPM trials for 2004

Code Trial	Design Type	Ent/ Num.	Reps	Rows Plot	Total Rows	Loc	Trial Name
TSCWQ04-1	5x9	30	2	2	120	10	Tropical advanced generation SC late white.
TSCYQ04-2	5x5	25	2	2	100	10	Tropical advanced generation SC late yellow.
TTWCWQ04-3	6x6	30	2	2	120	10	Tropical three-way crosses late white.
TTWCYQ04-4	5x5	25	2	2	100	10	Tropical three-way crosses late yellow.
TSCWQ04-5	10x10	100	1	1	200	10	Tropical late white SC early generation
TSCYQ04-6	7x10	70	1	1	140	10	Tropical late yellow SC early generations
CHTTWQ04	4x5	20	3	2	120	40	Tropical late white hybrids
CHTTYQ04	4x4	16	3	2	96	40	Tropical late yellow hybrids
EVTWQ04	4x4	20	3	2	120	25	Tropical late white varieties