

Message from the Project Leader

NuME is a nutrition-sensitive agricultural R4D project aimed at generating quality protein maize (QPM) knowledge and technology and disseminating it to rural households in major maize-growing and -consuming areas to alleviate food and nutrition insecurity.

The NuME project is now in its final year of implementation. The final annual work plan is focused on activities that are useful for consolidating the project results achieved so far and sustaining its future impact. The project is in line with government policies and beneficiaries' needs, and the Government of Ethiopia (GOE) has decided to include QPM technology as a component of the regular extension program, and has carried out many field demos each year largely in non-NuME project woredas. QPM is recognized as suitable for enhancing nutrition-sensitive agriculture and has been included in major GOE nutrition-related initiatives like the National Nutrition-Sensitive Agriculture plan, the Sekota Declaration, Agriculture Growth Program II, etc.

In its seven years of implementation, the project has carried out a variety of interventions aimed at increasing the utilization and supply of QPM seed and grain in rural households and reaching the desired project goal. Alongside these direct interventions, side-by-side investments were made in areas where the project's impact will transcend its life and will be sustainable by strengthening individuals, communities and institutions surrounding the project and the ideas it promotes. One such activity has been capacity building. Although QPM, a variant maize type having superior nutritional and biological values than conventional maize, requires different technology transfer approaches and techniques, it can be developed through capacity building. Capacity building helps to have more robust social and technical arrangements to adapt the technology to local conditions that can lead to its adoption. As defined elsewhere, capacity development is the process through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time.



This issue of the NuME Newsletter is dedicated to giving a brief account of the project's capacity building efforts and presenting several MSc and Ph.D. thesis abstracts of students who were fully or partially supported by the project and who completed their studies by April 2018. We hope you find this issue of the NuME Newsletter useful.

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The Nutritious Maize for Ethiopia (NuME) project is implemented by CIMMYT in Ethiopia and funded by Global Affairs Canada. It is designed to help improve the food and nutritional security of Ethiopia's rural population, especially women and children, through the adoption of quality protein maize varieties and crop management practices that increase farm productivity.

NuME's institutional, physical and human resource capacity building activities

Recognizing capacity building as one of the most important interventions that increase a project's probability of success and sustainability, efforts were made to map capacities at individual and institutional levels during NuME's design phase.

Based on mapping exercises, NuME has undertaken different capacity building activities with farmers and local project partners involved in QPM research, seed production and dissemination. The capacity building activities covered three major areas: institutional, physical and human resource capacity building.

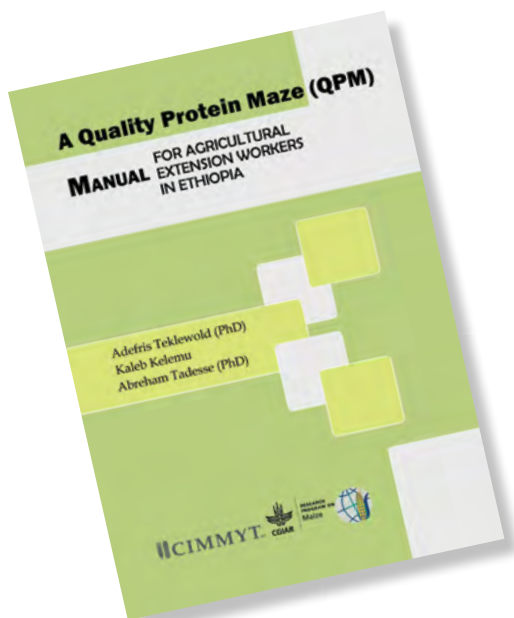
Institutional capacity building

Institutional capacity development was provided to project partners to enhance intellectual property that remains within the institution irrespective of human resource mobility. The project developed three types of intellectual properties: QPM germplasm; training and reference/informational materials; regulatory standards, protocols and procedures. Accordingly, several QPM inbred lines and breeding populations were developed; some of them are being used to develop varieties in Ethiopia. In accordance with CIMMYT policy, these inbred lines and breeding populations are freely available to public and private sector maize breeders globally. There has been a robust introduction of germplasm, both finished and



in pipeline. QPM varieties that have been released in Central and South America and Africa were introduced from CIMMYT-Mexico, CIMMYT-Colombia, CIMMYT-Harare and IITA through shortcut release. Other pipeline materials and various germplasm lines were obtained from CIMMYT-Zimbabwe and were tested at different locations. Some are likely to be released soon. Similarly, a

variety of training and informational materials including two printed bulletins and two manuals (both in four languages) and 41 training DVD videos (in five local languages) were produced and distributed to relevant partners and other institutions involved in teaching, research and extension. Most of these manuals and videos are freely available on the NuME webpage <http://nume.cimmyt.org/>. Because quality control is essential to protect QPM producers and consumers, quality standards for QPM seed and grain were defined. Protocols and procedures for monitoring quality were also developed to verify QPM quality for seed companies, producers and consumers. A technical bulletin with guidelines for the quality control of QPM seed and grain has been published in English and Spanish so that it can be used not only in Ethiopia, but also in Latin America. Based on the outcome of this work, in 2016, Ethiopia incorporated QPM quality stranded definition into the national maize seed quality standard specification.





The NIRS MACHine as installed in the AQRL of EIAR.

Physical capacity building

Most of the physical capacity building activities were meant to increase project implementation efficiency and included procuring and using a broad category of equipment and vehicles. Some of the most important activities have been: procuring and supplying digital green (DG) technology useful for audiovisual-based training of farmers in rural settings. More than 154 DG projectors and accessories were distributed through SG2000 to all project woredas to be used by both health and development extension agents to train farmers on QPM production, utilization and agronomic and nutritional/health benefits. To increase technical support and supervision and to bring development agents closer to the work and the farmers, focal people in project woredas were provided with 36 motorbikes, one for each woreda. Each regional coordinator was also provided with a double-cabin pickup truck to be used for supplying inputs, collecting samples and monitoring and supervising. In collaboration with other CIMMYT sister projects, NuME has also built a cold room for the Ambo Plant Protection Research Center of

the Ethiopian Institute of Agricultural Research (EIAR) to improve long-term germplasm storage and use. At a cost of CAD 91,800, NuME has also provided three double cabin Toyota vehicles for three EIAR research centers: Bako National Maize, Melkassa and Ambo Plant Protection Research Centers. Small equipment needed for field operations were also procured and supplied as required by EIAR and partner institutions like SG2000. The other significant physical capacity building activity of the project that guarantees future QPM research and development beyond the life of the project was the upgrading of the quality research laboratory (AQRL) of EIAR. By acquiring modern quality scientific equipment, the AQRL at EIAR HQ, Addis Ababa, was upgraded to handle larger numbers of samples to provide timely service to breeders, seed companies and the food/feed industry. A state-of-the-art near-infrared reflectance spectrometer [NIRS monochromator model FOSS 6500 (FOSS NIR Systems, Inc.)] and ancillary apparatus were purchased and installed by the FOSS company and has been functioning since 2015. The machine is fast, easy to operate and has transferable calibrations and

very user-friendly interface features. Besides promoting the already released QPM varieties, the NuME project set targets for developing productive QPM germplasm that are resilient to biotic and abiotic stresses and that can be adapted to specific project areas and beyond. EIAR is CIMMYT's main partner in coordinating and implementing NuME's breeding and seed and grain quality control activities. Hence, cheap, fast and reliable techniques for screening germplasm for quality protein traits were made available to EIAR's long-term QPM breeding program. The analytical service has been available to all QPM seed and grain producers and traders in a full cost recovery scheme during and after the termination of the project. FOSS company experts trained 10 researchers from local public and private institutions and CGIAR centers in different topics: NIRS introduction, installation, operation and calibration equation development. EIAR senior management expressed their appreciation to CIMMYT/ NuME for upgrading the laboratory, which increased EIAR's capacity to undertake quality research. ▶

Human capacity building

NuME's human capacity building was executed beyond expectations. On the job training, mentoring and long-term degree training aimed at building technical skills, sharpening problem solving and improving the knowledge bases were undertaken for farmers and staff of project partners. Besides increasing their knowledge and understanding of QPM and its benefits, these training activities are intended to help individuals, organizations and societies obtain, strengthen and maintain their capabilities to set and achieve their own social and economic objectives. Although the number of women trainees was not as high as expected, through affirmative/positive actions, efforts were made to give both women and men equal opportunity to participate. Provided below is NuME's performance under each of the above-mentioned human resource capacity building categories.

Short-term training

Without undermining the merits of degree-level training, short-term training directed towards

strengthening specific skills and strengthening specific knowledge areas is essential for dealing with new technologies and innovations like QPM. It provides opportunities for developing a group of team members who can effectively contribute to project implementation.

It is also vital for capturing the attention of the communities in the target woredas in regards to technology and showing them how to grow and use QPM. To this end, the NuME project has designed short-term trainings for farmers, extension workers (development and health) and professionals working in different partner institutions. The main component of NuME's short-term trainings were to provide field demonstrations for field demo farmers (female and male), staff of bureaus of



Training of trainers on video-based QPM dissemination for development agents and health extensionists.

agriculture [officials, MoARN Extension Services subject matter specialists (SMSs), project woreda supervisors and development agents (DAs)] and health extension agents. This type of short-term training was provided both in workshops and on-the-job training to 47,500 farmers (17,300 or 36.4% were women). As indicated in Table 1, audio-visual based training (DG technology) greatly contributed in reaching more people; 93% of the trainees attended audio-visual based training. Specifically, audiovisual-



Farmer trainings on QPM-based traditional food preparation.



based training has increased the number of women reached, as it offers the possibility of organizing the training closer to the women –

around their homes, in small groups or at the village level. The training topics covered were focused on QPM technology, establishment

and management of QPM field demonstrations, QPM-based traditional food preparation and video-based extension/training, etc.

Table 1. Number of trainees and type of training offered to farmers, staff of the bureau of agriculture and health extension agents.

Description	Number of trainees	Number of women participants	% of women participants
QPM-based food preparation, demonstration and utilization*	719	466	64.8
QPM technology, establishment and management of QPM field demonstrations*	2,549	441	17.3
Audiovisual-based training	44,250	16,400	37.1
Total	47,518	17,307	36.4

*based on conventional training

With regard to professional short-term training (excluding on-the-job training), 16 workshops and short courses addressing specific themes like gender, seed production, seed quality control, seed business management, radio broadcasting, audiovisual-based extension, and

participatory variety selection, production and utilization were offered to partners and allied institutions (Table 2). About 391 professionals were trained. Though the gender ratio varied from training to training, one training saw 44% female participation. Overall, however, female participation was limited, averaging only 17%. ▶

TTable 2. Description of short-term training offered to staff of project partners and other allied institutions.

Name of the event	Participants	No. of training sessions	No of participants	No. of women
QPM seed production, quality control and agronomic management training	Seed experts, researchers and staff of regulatory and quality control bodies	4*	125	7
Seed business management training	Seed company managers, deputy managers and senior researchers	2	39	4
TOT training on farmer and consumer participatory evaluation	Researchers	1	26	4
Gender strategy action plan development training	Gender focal persons of partners and woreda agriculture office	4	87	38
QPM production and utilization training	ATVET	2	72	6
Field layout, data management and analysis (breeding and agronomy)	Researchers	2	22	3
Project financial management training	Project finance focal persons	1	20	4
Total			391	66

*Two of the seed production training sessions were funded jointly by the Drought Tolerant Maize for Africa Seed Scaling and NuME projects.



Participants in one of the seed production and quality control trainings.

As indicated in Table 3, in the past six years, NuME trained 98 radio journalists, of which 32% were women, to enhance their ability to produce and broadcast engaging and effective participatory agricultural radio campaigns (PRC) on QPM. The topics included participatory radio program production techniques, style and format, developing core messaging, script development, interviewing skills, feedback methods, integrating ICT with radio, gender responsive radio production, etc.

Two specialized conferences on variety registration and plant variety protection (PVP) were organized. Participants were senior staff and officials from the ministry of agriculture and livestock, the bureau of agriculture and natural resources, federal and regional research centers, CG centers, seed companies, and NGOs involved in developing the country's seed sector, as well as reputed professionals from CIMMYT, ICARDA, Integrated Seed System Development (ISSD)-Ethiopia, Ethiopia Seed Association, EIAR and MOANR. The seminars focused on the following topics: what is PVP under the UPOV convention; variety registration and PVP and its relevance and importance in Ethiopia; principles and technical examination in variety registration and PVP; distinctness, uniformity and stability (DUS) definitions, principles and guidelines; the experience of DUS testing in south Asian and east African countries: India, Korea, Kenya, Tanzania and Uganda; national variety registration and the prospect of PVP in Ethiopia; and arrangement/organization of variety registration (DUS testing) in the Ethiopian context. To support

the development of robust plant breeders' rights, both conferences were organized when the old plant breeders' rights of Ethiopia were under revision and the topics were also selected to generate useful thoughts for the revision process.

Long-term training

Long-term degree training was offered to produce a critical mass of human resources in breeding, agronomy, socioeconomics, extension education and nutrition, as well as to achieve the project's mission and sustain QPM production and utilization in the future. The degree training was comprehensive and included different fields and levels needed to bring QPM technology generation and seed production to the next level of operational and developmental maturity. The long-term training included five Ph.D. and ten MSc level courses (Table 4) in five fields of study. Scholarship support was provided in different packages covering: full-funded scholarship in local university; a full-funded scholarship on a sandwich basis; partial or full thesis research support; and providing data for thesis writing. Three of the Ph.D. students (in agronomy, breeding and health economics) completed their studies and two (in breeding and nutrition) are now writing their theses. The female Ph.D. student specializing in health economics, matriculated at

the Harvard School of Public Health and received partial research support. She studied the effect of adoption and consumption encouragement on child nutrition by superimposing on the randomized control trial (RCT) of another Ph.D. student specializing in human nutrition sponsored by NuME. Seven of the MSc students completed their studies and went back to their mother institution. Two (in agronomy and breeding) are writing their theses and are expected to complete their studies before the end of 2018 or in early 2019.

Table 4. Recipients of NuME's long-term training sponsorship/support.

s.n.	Name	Level	Field of specialization	Types of scholarship
1	Addis Tadesse	MSc	Agronomy	Full scholarship
2	Haji Kumbi	MSc	Agronomy	Full scholarship
3	Worknesh Terefe	MSc	Breeding	Full scholarship
4	Lealem Tilahun	MSc	Breeding	Full scholarship
5	Beyene Abebe	MSc	Breeding	Full scholarship
6	Goshime Muluneh	MSc	Breeding	Full scholarship*
7	Lemelem Abebe	MSc	Socio-economics	Full scholarship
8	Samuel Diro	MSc	Socio-economics	Research support only
9	Ali Bianco	MSc	Human Nutrition	Use NuME data [§]
10	Anastasia Karakitsou	MSc	Human Nutrition	Use NuME data [§]
11	Masersha Tesema	Ph.D.	Human Nutrition	Full scholarship
12	Katherine Donato	Ph.D.	Health Economics	Partial research support [‡]
13	Tolera Abrea	Ph.D.	Agronomy	Research support only*
14	Gudeta Nepir	Ph.D.	Breeding	Research support only
15	Addis Alem Mebrahatu	Ph.D.	Breeding	Research support only

* Has not yet finished his/her studies.

§ Is using some aspect of the randomized control trial data collected by the Ph.D. (nutrition) student.

‡ In collaboration with the ATAI project.

Table 3. Radio journalists trained disaggregated by gender and radio stations.

Year	No of journalist trained									
	DWET*		AMMA		ORTO		SNNPRSRTA		Total	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
2013	4	3	3	2	6	2	5	1	18	8
2014	3	1	2	0	2	1	2	1	9	3
2015	4	3	1	1	3	1	2	1	10	6
2016	7	3	3	2	8	1	1	1	19	7
2017	4	1	2	2	3	1	1	2	10	6
2018	-	-	1	1	-	-	-	-	1	1
Total	22	11	12	8	22	6	11	6	67	31

*DWET= Dimtse Woyane; AMMA= Amhara Mass Media Agency; ORTO= Oromia Radio and Television Organization; SNNPRSRTA= State Radio and Television Agency.



Ph.D. and MSc thesis abstracts



Calibration of nitrogen fertilizer based on in-season estimated yield using handheld NDVI sensor for quality protein maize (*Zea mays* L.) in the Central Rift Valley of Ethiopia.

Addis Tadesse, Jimma University, 2015

Maize (*Zea mays* L.), a highly valued crop in the southern and southeastern regions of Ethiopia, is produced across various agroecologies of the country. However, maize productivity is constrained by blanket application of mineral nutrients, in particular nitrogen. Site-specific nutrient management supported by precision agriculture tools are expected to provide extension agents and farmers with better ways to manage nitrogen, increase net benefits and reduce environmental pollution. Radical rise in the cost of N fertilizer, environmental pollution and increased public scrutiny have encouraged development and implementation of improved N management practices. In this context, on-farm and on-station experiments were carried out during the 2014 main cropping season in the Adami Tulu district and

Melkassa Agricultural Research Center (MARC), respectively. The study was carried out on MHQ138, a newly released quality protein maize (QPM) variety, with the objective of calibrating nitrogen fertilizer rates using a hand held normalized difference vegetation index (NDVI) sensor for efficient nitrogen management and to optimize grain productivity. Both trials had seven nitrogen levels (0, 10, 25, 50, 75, 100, and 125 kgN ha⁻¹) with phosphorus applied uniformly in a randomized complete block design. In this study the relationship between QPM grain yield and the NDVI was evaluated using a handheld GreenSeeker sensor. There was a strong relationship ($r^2 = 0.82$ and $r^2 = 0.96$) in Adami Tulu and ($r^2 = 0.84$ and $r^2 = 0.93$) at MARC between in-season estimated yield (INSEY) and grain yield. Nitrogen rate also had a significant effect on plant height, leaf area index, number of ears per plant, ear length, stover yield, biomass yield, grain yield, harvest index and thousand-kernel weight. Economic analysis using a partial budget showed a higher net benefit of 40,444 Ethiopian Birr (ETB) at 100 kg N ha⁻¹ compared to 19,629.39 ETB obtained from the control treatment at Adami Tulu. Generally, all measured parameters as well as the marginal benefit from the economic analysis indicated that applying 75 kg N ha⁻¹ is economically feasible and recommended for Adami Tulu and MARC. This study shows that the handheld NDVI sensor can improve the management of N fertilizer application.



Heterosis and combining ability of mid-altitude quality protein maize (*Zea mays* L.) inbred lines at Bako, Western Ethiopia.

Beyene Abebe, Haramaya University, 2016

Quality protein maize is a type of maize whose nutritional value has been enhanced through conventional breeding. The production of hybrid QPM, which recently began in Ethiopia, requires extensive breeding work to exploit heterosis and increase crop productivity. Exploitation of heterosis through hybrid production is a proven breeding method that improves maize yield. Accordingly, the objectives of this study were to estimate the magnitude of heterosis and combining ability in crosses of 10 mid-altitude adapted QPM inbred lines and to determine the association among morph-agronomic traits. The experiment and crossing activities were conducted at Bako National Maize Research Center during

the 2014 and 2015 main cropping seasons, respectively. Forty-five F₁ hybrids obtained by crossing 10 inbred lines in diallel fashion (without parents and reciprocals), along with their parental lines and four standard checks, were planted in two separate trials on adjacent experimental blocks. The experimental design used was an alpha lattice for the hybrid trial and a randomized complete block design for inbred line trial with three replications. Each entry was planted on a one-row plot 5.1 m in length with 0.75 m and 0.3 m spacing between rows and plants, respectively, in each trial. Data on phenology, growth, grain yield and yield-related traits, and disease reaction were collected at the appropriate plant growth stages. The

mean squares due to hybrids and parents were highly significant for all traits except common leaf rust in the hybrid trial and stem lodging, poor husk cover and ear rot in the inbred line trials, indicating the existence of genetic variability for most traits. The highest positive intermediate and better parental heterosis was observed for grain yield and yield-related traits, indicating the possibility of increasing grain yield and yield-related traits via hybridization. Negative heterosis was observed for phenology and growth traits, and disease parameters as well. The mean squares due to general and specific combining abilities were significant for all the traits except days to silking, harvest index and total above-ground biomass, which indicates the importance of additive and non-additive gene action in the inheritance of these traits. In about 60% of the traits (including yield), however, the relative importance of general to specific combining ability was lower than unity denoting



the predominance of non-additive gene action. This study enabled the identification of two ideal parents that can be useful in increasing grain yield and yield-related traits. Two other inbred lines showed better resistance to foliar diseases. One of the 45 cross combinations was identified to be high yielding (11.5 t ha⁻¹) and thus has the potential to be released as a single-cross or three-way hybrid. Grain yield had significant positive association with plant height, ears per plant, ear

length and number of kernels per row and negative correlation with anthesis silk interval, plant and ear aspect, total above ground biomass, common leaf rust, phaeosphaeria leaf spot and ear rot at both the genotypic and phenotypic levels. Plant height, ears per plant, ear length and number of kernels per row had positive direct effects, while the anthesis-silking interval, plant aspect, phaeosphaeria leaf spot and ear rot had negative

direct effects on grain yield at both the genotypic and phenotypic levels. Total above-ground biomass and common leaf rust had negative direct effects at the genotypic level, and days to anthesis, ear height, root lodging and ear aspect had negative direct effects on grain yield at the phenotypic level. This indicated that, by increasing the positive and decreasing the negative direct effects of these traits, grain yield can increase considerably.



Determinants of intra-household gender differences in access to agricultural extension services on improved maize varieties: the case of Toke-Kutaye District, Oromia Regional State, Ethiopia.

Lemlem Abebe, Haramaya University, 2016

This study explored intra-household gender differences and their effect on accessing agricultural extension services with improved maize varieties. It assessed farmers' perception of the agricultural extension services received and analyzed women's empowerment in agriculture using a combination of multistage, purposive, random and probability proportional to size sampling techniques. The study was conducted in four kebeles randomly selected from the eight maize growing kebeles of Toke-Kutaye District, Oromia Regional Government. Data was collected from 120 respondents who were randomly selected based on the proportion

of beneficiaries in each kebele. Descriptive statistics, logistic regression, perception score and the women's empowerment index were used for analysis. Accordingly, the regression results revealed that age, education, family size, farming experience, frequency of listening to the radio, distance from a farmers' training center and the development agents' gender significantly affected women's participation in agricultural extension services. There was a disparity between women and men; women were less empowered than men. The women's empowerment index in agriculture was 73%, while the overall gender parity index was 68% and the empowerment gap was 32%. The perception score reveals that farmers' perception of the performance of agricultural extension was different for women and men farmers. The study suggests different areas of intervention that could bridge the gap and contribute to enhancing intra-household access to agricultural extension services and the level of women's empowerment in agriculture. Future work in the area of study is needed to consider and address the empowerment gap and enhance the reduced contributions of each indicator according to its priority.



Sensory acceptance of quality protein maize dishes and willingness to pay for its grain in districts around Gilgel Gibe Hydroelectric Power Project.

Samuel Diro, Jimma University, 2015

This study aimed to identify consumers' sensory preferences for traditional dishes made from quality protein maize (QPM) and from conventional maize (CM) and to estimate the willingness to pay for QPM in Jimma Zone. It used sensory evaluation techniques like the central location test, modified home use test and triangular test, as well as the Becker-De Groot- Marschak

method as an experimental auction mechanism. The treatment products used in the experiments were white and yellow QPM varieties and the control products used were white and yellow CM varieties. SPSS-20 was used for descriptive statistics, inferential statistics and ordinal logistic regression, while Stata 12.1 was the random effect model. The results of triangular test show significant

sensory differences between *dabo* (bread) made from QPM and from CM. The results of the central location test and modified home-use test showed QPM dishes to be significantly more appreciated than the CM dishes. The overall score of children also indicated QPM *genfo* (porridge) was more highly appreciated than CM *genfo*. The Becker-De Groot-Marschak mechanism results revealed that sample respondents were willing to pay more for QPM. The results also show that information has boosted bids for QPM grain and reduced the bids for CM grains. Finally, the study recommended using QPM sensory superiority and market potential to adopt and disseminate the technology.



Genetic variability and combining ability of highland quality protein maize (*Zea mays*) inbred lines.

Worknesh Terefe Gebre, Addis Ababa University, 2016

Information on the genetic diversity and combining ability of quality protein maize inbred lines is important for analyzing their potential to form superior hybrids and assess the gene action involved in the inheritance of traits. This study was conducted to assess genetic variability and relationships among elite QPM inbred lines using morphological data and single nucleotide polymorphism (SNP) markers and to estimate their combining ability in order to determine their usefulness in developing superior QPM hybrid combinations as well as heterosis. Twenty-six QPM inbred lines were assessed in twice replicated trials with alpha lattice design for evaluating morpho-agronomic traits at two locations in Ethiopia during the 2014 main season as Set-I experiment. The inbred lines were genotyped using single nucleotide polymorphisms (SNPs) at Biosciences eastern and central Africa (BecA). SNP markers and morphological distance estimates showed the inbred lines to be substantially distant from each other. Cluster analysis based on morpho-agronomic traits and SNPs

grouped the inbred lines differently. Based on morphological data, lines were clustered into five distinctive groups. Cluster analysis based on SNP markers produced four clusters which showed association of inbred lines that more reliably and efficiently concurred with pedigree data. The diversity study identified one promising inbred line (Line 20) with superior characteristics. Information generated by this study is important in the development of maize varieties with high grain yield and nutritional quality traits. In Set-II experiment, 24 of the QPM inbred lines were crossed using a line x tester mating design to estimate the combining ability and gene action on grain yield and its components. A total of 48 hybrids and two checks were evaluated in alpha-lattice design replicated twice at four locations (the Ambo, Holetta, Kulumssa and Adet Agricultural Research Centers) in 2014. Data on grain yield, agronomic traits and disease were recorded. The highest grain yield obtained was 8.74 t ha⁻¹ (Line 8 x Tester 1). Mean squares due to general combining ability (GCA) and specific combining ability (SCA) effects were also significant, except GCA for anthesis-silking interval (ASI), root lodging (RL) and ear position (EPO), which indicated both additive and non-additive gene actions are important in controlling these traits. However, in all traits, the proportion of GCA was higher than the proportion of SCA. Parent lines 1, 17 and 18 performed best for grain yield and most other traits as well. Best cross combinations were also identified as breeding pipelines. Based on this study, morphological distance was not important for predicting grain yield heterosis.



Study of the effect of plant density of parental lines on the production of BHQPY545 hybrid maize seed at Chagni, Awi Zone, Ethiopia.

Demelew Abebe, Bahirdar University, 2016

Maize (*Zea mays* L.) hybrids differ in their response to plant population density. The present study was conducted to evaluate the effect of different plant densities on growth and yield of quality protein maize hybrid parental lines. It was conducted during the main rainy season of 2015 in Chagni District, Awi Zone, Ethiopia. Factorially combined treatments including three inter-row spacing (80 cm, 75 cm and 55 cm) and three intra-row spacing (30 cm, 25 cm and 20 cm) to form nine plant densities (41,667, 44,444, 50,000, 53,000, 60,606, 62,500, 66,667, 72,727, 90,909 plants per hectare) of the parental lines [CML-161 (female line) and CML-165

(male line)] of QPM variety BHQPY545. The experiment was laid out in a randomized complete block design with three replications. Highly significant ($p < 0.01$) differences were observed among the nine population densities for most growth and yield parameters of the tested maize lines. The results indicated that plant densities of 53,333 plants/ha (75x25 cm) and 60,606 plants/ha (55x30 cm) produced maximum cob length of 16.03 cm and 15.43 cm, respectively. Plant density of 53,333 plants/ha (75x25 cm) produced the maximum and the highest number of grains per cob (296.3), 1000-grain weight (227.4 g), grain yield (2.5 t/ha), biomass (4.28 t/ha), leaf height

(83.3 cm), plant height (250 cm) and leaf width (11.9 cm). The weight of ears per plant was significantly affected by increasing the plant population. The results showed that increasing the plant population beyond 53,333 plants/ha (75x25 cm) significantly decreased the weight of ears per plant. There was no significant difference observed between treatments for days with 50% emergence, disease scores and lodging. Based on this study, 53,333 plants/ha using 75x25 cm spacing is the optimum plant density for obtaining maximum seed yield of variety BHQPY545 from the crossed parental lines, followed by 60,606 plants/ha with 55x30 cm spacing, whereas 90,909 plants/ha with 55x20 cm spacing and 41,667 plants/ha with 80x30 cm spacing showed minimum yield and other agronomic parameters. Since the experiment was carried out only at one location for one cropping season, the study should be repeated with the same or modified treatments at different locations to reach a valid conclusion.



Effects of soil with incorporated faba bean (*Vicia faba*) and soybean (*Glycine max*) biomass on yields of subsequent maize in Ethiopia.

Tolera Abera, Sokoine University of Agriculture, Morogoro, Tanzania 2016

Different experiments were conducted as components of this PhD work, including soil characterization, determination of soil rhizobium population, nitrogen (N) fixing capacity of faba bean and soybean genotypes, effect of legume residue incorporation on N requirements and maize grain yield, and in-season N prediction for maize in farmers' fields in Bako-Tibe and Toke-Kutaye districts of Ethiopia. Among these, the NuME project supported sensor-based in-season nitrogen prediction for quality protein maize (QPM) varieties in farmers' fields in Bako-Tibe district. In this experiment a GreenSeeker sensor reading of normalized difference vegetation index (NDVI), which is highly related to leaf N content, was used for in-season estimation of yield (INSEY) during the 2013 and 2014 cropping seasons. Results of

the study indicated that yield components of QPM varieties (AMH760Q and BHQPY545) were significantly affected by the rate of N fertilizer applied. Increasing the N rate from 0-100 kg ha⁻¹ significantly increased maize grain yield and yield components. Taller plant height, higher leaf area and higher leaf area index were recorded when 50-100 kg N ha⁻¹ were applied. A strong positive correlation was observed between the NDVI reading and leaf area, with correlation coefficients (r) of 0.46 and 0.47 at the four- and six-leaf stages, respectively. Similarly, significantly higher mean grain yields of both varieties were observed at an N rate of 50-100 kg ha⁻¹. A good level of correlation was recorded between INSEY and the actual mean grain yields in 2013 (r = 0.36) and 2014 (r = 0.60) cropping seasons, indicating the prospect of predicting the grain yield of QPM varieties with INSEY. The NDVI readings at four- and six-leaf stages had 5% and 1% positive meaningful correlation with grain yield (r=0.72 and r=0.65), indicating that NDVI readings at four- and six-leaf stages positively influenced QPM grain yield. Based on the promising results of this study, validation of the N rate for side-dressing and N use efficiency of QPM varieties is required for their commercial recommendation.



Genetic analysis of agro-morphological traits and molecular diversity study (ISSR and SNPs) of quality protein maize (*Zea mays* L.) inbred lines in drought stressed areas of Ethiopia.

Lealem Tilahun, Addis Ababa University, 2017

Genetic studies and characterization of elite breeding lines provide understanding of the genetic diversity and relationships among inbred lines. They also offer information on the type of gene action controlling the inheritance of desirable quantitative traits. This information enables breeders to define a systematic breeding strategy and select suitable parents and hybrids for further breeding activities and commercialization. Thus, this study aimed to estimate combining abilities and heterosis, and determine the genetic variation, correlation, heritability and expected genetic advance of elite quality protein maize inbred lines for grain yield and other agronomic traits, as well as to investigate their genetic diversity and relationship using SNP and inter simple sequence repeat (ISSR) markers. A total of 116 QPM

test cross hybrids developed by crossing 58 QPM inbred lines with two QPM testers was evaluated for 17 morphological traits, along with two conventional maize (CM) and two QPM standard checks in drought stressed areas of eastern Ethiopia – Melkassa Agricultural Research Center (MARC), Edo Gojola and Mieso experimental sites. The inbred lines were also evaluated separately, adjacent to the hybrid trial at each site, and genotyped by SNP and ISSR markers. Significant differences were observed among the inbred lines and hybrids for grain yield and most of the agronomic traits considered, indicating that there are genetic variations among the genotypes that can allow good progress from selection for improvement. Across sites, the highest mean grain yield (GY) was observed for hybrid L52/CML159 (5.38 t ha⁻¹) followed by L18/CML159

(5.07 t ha⁻¹) and L35/CML159 (5.02 t ha⁻¹) in the hybrid trial, while inbred line L52 showed the highest mean GY (3.15 t ha⁻¹), followed by L38 (2.94 t ha⁻¹) and L47 (2.88 t ha⁻¹). The combining ability analysis showed that the lines' general combining ability (GCA) was significant, while their specific combining ability (SCA) was non-significant for grain yield, anthesis date, plant height, ear height, plant aspect, ear length and thousand-kernel weight, indicating that the variability observed among the hybrids was attributable to additive gene effects for most traits. The contribution of the lines' GCA was found to be higher than the contribution of tester GCA and line × tester SCA for all traits, except thousand-kernel weight. Inbred lines L35, L45, L53, L4, L21, L52 and L32 had significant positive GCA effects for grain yield. Hybrid combination L52/CML159 had the best SCA effects for grain yield and other important agronomic traits and the maximum standard heterosis over MH140 and MH130 was 19.7% and 21.4%, respectively. Grain yield had positive and highly significant genotypic and phenotypic correlations with plant height, ear length and thousand-kernel weight,

but negative and highly significant correlations with days to 50% anthesis, anthesis-silking interval, ear position, shoot lodging and ear aspect. Root lodging was not an important trait to consider, while shoot lodging played an important role in determining grain yield. It also showed that ear height is more important than plant height for developing high yielding hybrids and that it is possible to select high yielding

varieties which are early but tall with low ear placement. The ISSR markers were found to be as effective as SNP markers in clustering inbred lines into seven sub-groups which are in agreement with pedigree information. All three multivariate analyses compared to cluster analysis, model-based population structure analysis and principal component analysis using SNPs consistently identified the

same seven distinct populations and revealed similar membership of inbred lines in each population. In general, the results of this diversity study based on SNP and ISSR markers will be useful to breeders in selecting the best parental combinations for starting new breeding populations, mapping populations and marker-assisted breeding.



Genetic analysis and genotype x environment interaction in quality protein maize (*Zea mays* L.) genotypes in Ethiopia.

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Holding superior nutritional and biological values, quality protein maize varieties released in Ethiopia are few in number and limited to a few agro-ecologies. Pushing to reach more farmers and agro-ecologies with varieties that have higher or at least equal agronomic advantage to the conventional maize (CM), this study was conducted with the objective of generating genetic information and genotype x environment interaction (GEI) in QPM, and establishing the relationship between genetic and phenotypic characteristics of inbred lines and F_1 performance and heterosis. Two separate experiments were conducted. In the first experiment, 10 inbred lines were crossed following diallel method II to produce 45 single-cross hybrids (SCs), and a total of 57 genotypes (10 inbred lines, 45 SCs and two standard checks) were evaluated using an alpha lattice design with two replications at Ambo and Bako in 2014. Seed samples of the parental lines were sent to CIMMYT to obtain SNP-based distances (SNPdis). In the second experiment, 12 inbred lines were diallel-crossed following Griffing's method IV to produce 66 single crosses that were evaluated at eight locations (Ambo, Kulumsa, Hawassa, Jimma, Adet, Ginchi, Bako and Pawe) using an alpha lattice design. In both experiments, data on yield and yield components were collected and subjected to an analysis of variance (ANOVA) using SAS software. The ANOVA showed highly significant ($P \leq 0.01$) variations among hybrids for grain yield and yield components. The study indicated higher probability of producing superior QPM SC hybrids from the present set of parental lines. Values as high as 292.7% for mid-parent heterosis (MPH), 248.4% for better-parent heterosis (BPH) and 71.7% for standard heterosis (SH) were recorded for grain yield, implying the presence of sufficient genetic distance among parents

and desired dominant alleles with relative differences in gene frequency in the parents. The GCA mean squares were highly significant for the traits, whereas the SCA mean squares were significant for all traits except gray leaf spot and common rust. The mean squares due to environment (E), SC x E and both GCA and SCA x E were significant for grain yield and related traits, except for the SCA x E for some traits. Six of the parents showed predominant GCA effects for most traits in the desired direction and could therefore be used for synthetic and hybrid variety development. Four SC hybrids that have P12 as a male parent had positive SCA for yield, surpassing both QPM and CM checks by 17.7 to 23.5%, respectively. This result demonstrated the usefulness of P12 (CML159) for future QPM breeding in Ethiopia. Both additive and non-additive gene actions controlled grain yield and its components, with major roles of additive genes, implying a higher chance of obtaining superior synthetic varieties and good hybrids from these parental lines. With regard to GEI, the AMMI model identified 16 hybrids as the first four selections in eight locations. The GGE biplot identified Jimma as an ideal and favorable environment for assessing the yield potential of QPM hybrids, whereas Adet and Ginchi are unfavorable environments. Cross P5 x P12 was identified as an ideal and winner genotype. Due to the presence of significant GEI and the variable performances of most QPM SCs in varying locations, the results suggested location-specific QPM variety development. Hybrid grain-yield was positively correlated with PDis, SNPDis, absolute better-parent heterosis (ABPH) and absolute mid-parent heterosis (AMPH), GCA and SCA effects, GCAsum and parental *per se* performance (PMV). SC grain yield was positively correlated with phenotypic distance (PDis), SNPDis, absolute better-parent heterosis (ABPH) and absolute mid-parent heterosis (AMPH), GCA and SCA effects, GCAsum and parental *per se* performances and/or parental mid-values (PMV). Grain yield showed strongly significant positive ($P \leq 0.01$) correlation with ABPH, AMPH, GCA-and-SCA effects, GCAsum and parental *per se* performance. This indicates that PDis and SNPDis were capable of sorting distant parents, and that hybrid combinations among relatively divergent lines are highly useful. Concomitantly, parental performance, GCA effects, GCAsum and SNPDis of inbred lines could be used as reliable predictors of MPH, BPH and performance of F_1 SCs for yield and component traits.



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This is a quarterly newsletter produced by the NuME project, a seven-year project that aims to contribute significantly in reducing malnutrition, especially among young children, and increase food security and household income of resource-poor smallholder farmers in Ethiopia through the widespread adoption, production and utilization of QPM.

Supported by Global Affairs Canada, NuME is implemented by CIMMYT in collaboration with the Ethiopian Institute of Agricultural Research, Ministry of Agriculture, Ministry of Health, Ethiopian Health and Nutrition Research Institute, Sasakawa Africa Association, Sasakawa Global 2000, other NGOs as well as universities and public and private seed companies.

The contents of this newsletter revolve around the day-to-day activities that the project and its stakeholders undertake by focusing on strategies such as demonstrating to farmers new QPM technologies, improved crop management practices, post-harvest handling and processing as well as improving their knowledge and skills.

Comments and articles from our readers, particularly the staff of stakeholders, are welcome.

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

