CIMMYT - Kenya

Annual Report 2002

International Maize and Wheat Improvement Center (CIMMYT)
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CIMMYT® (*www.cimmyt.org*) is an internationally funded, non-profit scientific research and training organization. Headquartered in Mexico, the Centre works with agricultural research institutions worldwide to improve the productivity, profitability, and sustainability of maize and wheat systems for poor farmers in developing countries. It is one of 16 similar centers supported by the Consultative Group on International Agricultural Research (CGIAR, *www.cgiar.org*). The CGIAR comprises of about 60 partner countries, international and regional organizations, and private foundations. It is co-sponsored by the Food and Agriculture Organization (FAO) of the United Nations, the International Bank for Reconstruction and Development (World Bank), the United Nations Development Program (UNDP), and the United Nations Environment Program (UNEP). Financial support for Comet's research agenda also comes from many other sources, including foundations, development banks, and public and private agencies.

CIMMYT supports Future Harvest®, a public awareness campaign that builds understanding about the importance of agricultural issues and international agricultural research. Future Harvest links respected research institutions, influential public figures, and leading agricultural scientists to underscore the wider social benefits of improved agriculture-peace, posterity, environmental renewal, health, and the alleviation of human suffering (*www.futureharvest.org*).

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Abstract: Maize is the most important staple cereal grain in eastern and Central Africa (ECA) providing more than half the daily calorie and protein intakes of most of the population. It is largely used directly for human food but increasingly for animal feed. CIMMYT activities in ECA are implemented through special project funds and in close collaboration with national programs and regional networks. This report presents achievements obtained in 2002 under the following projects: African Maize Stress (AMS); Insect Resistance Maize for Africa (IRMA); Strengthening Maize seed Supply Systems for small-scale Farmers in Western Kenya and Uganda; Engineering Striga Resistance Maize; and Enhancing the Nutritional Quality of Locally Adapted Maize cultivars in Eastern and Southern Africa by incorporating Quality Protein Maize (QPM) traits. It also described the work of the CIMMYT Economics Program in eastern Africa, and lists CIMMYT staff in the region as well as key partners. Among these are the donor agencies that generously support the above work: the Rockefeller Foundation, BMZ-Germany, the Nippon Foundation, the OPEC Fund for International Development, CIDA-Canada, and the Syngenta Foundation for Sustainable Development.

> ***"The greatest brake on a people's progress and health is food security and production. Without these, any society lives a nasty struggle between starvation and hunger."***

Contents

Abbreviations and Acronyms

AMS	African Maize Stress
ARC	Agricultural Research Centre
ARI	Agricultural Research Institute
ASARECA	Association for Strengthening Agricultural Research in East and Central Africa
ASI	Anthesis-silking interval
BMZ	Bundesministerium für wirtshaftliche Zusammenarbeit und Entwicklung (German Federal Ministry for Economic Cooperation and Development)
Bt	*Bacillus thurigiensis*
CIAT	Centro Internacional de Agricultura Tropical
CIDA	Canadian International Development Agency
CIMMYT	International Maize and wheat Improvement Center
CML	CIMMYT maize lines
CMLT	CML testers
CMRT	Crop Management Research Training
CORAF	Conférence des Responsables de Recherche Agronomique Africains
Cry	Crystalline protene
EACP	East Africa Cereals Program
EARO	Ethiopian Agricultural Research Organization
ECA	East and Central Africa
ECAMAW	Eastern and Central Africa Maize and Wheat Research Network
EU	European Union
FPB	Farmer Participatory Breeding
FPR	Farmer Participatory Research
GIS	Geographical information system
GLS	Grey leaf spot
GTZ	Gesellschaft für Technische Zusammenarbeit, Germany
ICIPE	International Centre of Insect Physiology and Ecology
ICRAF	International Center for Research in Agro forestry (World Agro forestry Centre)
ICRISAT	International Center for Research in Semi-Arid Tropics
IFAD	International Fund for Agricultural Development
IFDC	An International Center for Soil Fertility and Agricultural Development
IITA	International Institute for Tropical Agriculture
IR	Imidazolinone resistant
IRAD	Institute de Reserche Agronomique et de Development
IRMA	Insect Resistant Maize for Africa
KARI	Kenya Agricultural Research Institute
MoU	Memorandum of Understanding
MSV	Maize Streak Virus

Abbreviations and Acronyms

NAARI	Namulonge Agricultural and Animal Research Institute, Uganda
NARO	National Agricultural Research Organization, Uganda
NARS	National Agricultural Research Systems
NBC	National Biosafety Committee
NDFRC	National Dryland Farming Research Center
NGO	Non-Governmental organization
OPV	Open pollinated variety
PAMA	Pan-African Maize Association
PASCON	Pan-African *Striga* Control Network
PRA	Participatory Rural Appraisal
QPM	Quality Protein Maize
RRC	Regional Research Center
SADLF	Southern African Drought and Low Soil Fertility
SARI	Selian Agricultural Research Institute, Arusha, Tanzania
SC	Steering Committee
Sida	Swedish International Development Agency
SSA	Sub-Saharan Africa
TSP	Triple super-phosphate fertilizer
UNDP	United Nations Development Program
WCA	West and Central Africa
WECAMAN	West and Central Africa Collaborative Maize Network

Acknowledgments

We would like to thank the Government of Kenya for hosting CIMMYT and facilitating its research and training activities in the eastern and central Africa region.

We are grateful for the financial support from our donors: the Canadian International Development Agency (CIDA), the Syngenta Foundation for Sustainable Agriculture, the Rockefeller Foundation, BMZ and OPEC.

We would like to express our appreciation for the collaboration we have received from the center directors, scientists, technical officers, technical assistants and field workers in the national agricultural research systems (NARS) of eastern Africa, including universities, and for the collaboration of the development and extension officers of the Ministry of Agriculture, the non-governmental organizations and community based organizations in the region. We thank the Association for Strengthening Agricultural Research in East and Central Africa (ASARECA) for the regional framework through which we collaborate with NARS. We appreciate the collaboration of the region's seed companies who test and use our stress tolerant maize, thus helping deliver it to farmers.

We would like to thank several other Future Harvest centers for their collaboration, in particular the World Agroforestry Center (ICRAF), the International Institute for Tropical Agriculture (IITA), the International Centre of Insect Physiology and Ecology (ICIPE), and the Centro Internacional de Agricultura Tropical (CIAT). We are also grateful to the International Center for Soil Fertility and Agricultural Development (IFDC), which has attached a Senior Scientist to the Kenya office.

Special thanks go to our staff for their dedication and hard work, and the support from our headquarters in Mexico. In particular, we appreciate the help of CIMMYT science writer Mike Listman in editing and formating this report.

Finally, we thank the thousands of farmers who have participated in testing new varieties and technologies on their farms, and who sat with us through numerous meetings and interview sessions, for their wisdom, enthusiasm, and appreciation. That's what this is all about.

CIMMYT-Kenya's Activities in Eastern Africa – An Overview

A. Diallo, D. Friesen, H. de Groote, S. Mugo, F. Kanampiu and D. Kirubi

Maize in Eastern and Central Africa

Maize is the most important staple cereal grain in eastern and Central Africa (ECA) providing more than half the daily calorie and protein intakes of most of the population which now numbers more than 270 M and is growing at an annual rate of > 2.5% (FAO, 2002). It is largely used directly for human food but increasingly for animal feed. Average per capita consumption in ECA is 50 kg/yr and ranges from 12 kg/yr to 103 kg/yr (Pingali, 2001). During 1997-99, approximately 7.6 M hectares of maize were harvested in ECA with an average yield of just 1.3 t/ha, compared to an average yield of CIMMYT cultivars in trials in the region of > 5 t/ha. Maize is planted on about 38% of the cultivated area in ECA on mainly small-scale farm holdings with a high proportion of women performing much of the farm labour. With the notable exception of Ethiopia where an active dissemination program of improved maize hybrids with inputs sponsored by the SG2000 operates, maize productivity (yield per ha) was negative during the period 1988-99. The largest producers in the region (Ethiopia, Kenya and Tanzania) are also the largest net importers of maize.

Our Clients

CIMMYT's clients in ECA are the millions of resource poor farming families—who constitute >75% of the population in the region (FAO, 2002) and who cultivate maize in stressed environments—and the urban masses that depend on their excess produce. Maize production, processing and utilization provide vital employment and income generation activities for a much of the population. CIMMYT-ECA works primarily with NARS in the region under the framework of the Eastern and Central Africa Maize and Wheat (ECAMAW) Research Network, which is one of some 16 similar networks under the umbrella of the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA). The ASARECA mandate area comprises 10 NARS in Burundi, Congo, Ethiopia, Kenya, Madagascar, Rwanda, Somalia, Sudan, Tanzania and Uganda. In addition, CIMMYT-ECA collaborates with NGOs operating in the region with experience in agricultural development, as a means of evaluating its technologies directly with farmers and disseminating those that are useful and of interest to farmers. NGOs with whom we are collaborating include CARE-Kenya, the Catholic Relief Services (CRS), and SG2000.

Limiting Constraints to Maize Production in ECA

Maize is grown almost entirely under rainfed conditions in ECA, and farmers have limited cash for purchased inputs. Yields are well below their potential of 4.5-7.0 t/ha, due to a combination of low-yielding varieties, suboptimal agronomic practices, and multiple abiotic and biotic stresses. ASARECA has identified maize as the number one priority crop for regional research and has endorsed a list of priority researchable constraints identified by NARS as the principle limitations to improved maize productivity and production in ECA. These major limiting factors include drought, low soil fertility (particularly nitrogen [N]), insect pests (especially stem borers, termites and storage pests), weeds including *Striga*, diseases (*E. Turcicum* leaf blight, gray leaf spot [GLS], maize streak virus [MSV], ear rot) and low yield potential (especially in the highlands).

In addition to the biophysical constraints that limit maize production, the capacity of national agricultural research and extension systems to develop and disseminate new technologies that address these constraints has to be improved. In many ECA countries, the infrastructure and facilities needed for research and technology transfer are not in place. It is not unusual to find that the most popular maize cultivars have been in the market for more than 20 years and are susceptible to diseases and pests that were not prevalent when they were developed.

Finally, resource poor small farmers often have little or no access to improved technology. Seeds of improved varieties are frequently unavailable to small farmers since seed companies usually target larger commercial farmers in more favourable environments. In many cases, small farmers do not even know of such varieties, as there are few testing schemes that systematically evaluate newly developed maize cultivars under conditions representative for resource-poor smallholders or ensure efficient feedback of farmers' preferences to public and private maize breeding programs.

Despite these constraints, it is important to recognize that during good years with adequate rainfall, farmers especially in higher potential ecologies in ECA are able to produce surplus maize that they are then unable to sell at reasonable prices. Moreover, poor roads limit the movement of produce to needy areas elsewhere in the country. Unable to repay the loans they received for seed and inputs, farmers are discouraged from investing in production in subsequent years. Thus, wide market fluctuations and poor infrastructure and support further constrain adoption of new technologies.

As a consequence of these many constraints, annual imports of maize are high and growing in many ASARECA countries. Increasing production to replace imports is biologically feasible and makes economic sense. CIMMYT's goal in the ECA region is to work with our partners in the NARS, NGO community and private sector to reduce or eliminate some of the priority constraints that currently limit increased production.

Our Approach

CIMMYT activities in ECA are implemented through special project funds and generally focus on specific constraints of particular interest to the particular donor. These constraints have been identified in consultation with our NARS partners as well as through CIMMYT's long-term experience in the region, which extends back to 1975. Almost all CIMMYT projects in the region are implemented in close collaboration with NARS scientists through the ECAMAW Research Network or, in specific cases, through bilateral arrangements with specific NARS. Despite the project based character of CIMMYT's regional activities, projects are often complementary and our research program is implemented in a highly collaborative and integrated manner.

CIMMYT is mostly a crop improvement institute and most of its scientists are plant breeders or agronomists. Their research is, however, also supported by a small team of social scientists, primarily agricultural economists, working in the CIMMYT Economics Program (CEP). CEP's principal role is to ask and answer questions about the focus, organization, and impacts of CIMMYT's maize and wheat research activities, CIMMYT economics analyses the elements of success, from farmers' fields to the global market place.

This report presents achievements obtained under the following projects:

- African Maize Stress Project (AMS)
- Insect Resistance Maize for Africa (IRMA)
- Strengthening Maize seed Supply Systems for small-scale Farmers in Western Kenya and Uganda
- Engineering Striga Resistance Maize
- Enhancing the Nutritional Quality of Locally Adapted Maize cultivars in Eastern and Southern Africa by incorporating Quality Protein Maize (QPM) traits.
- CIMMYT Economics Program in Eastern Africa.

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Africa Maize Stress Project: Breeding Activities

Alpha O. Diallo

Background

The overall goal of Phase II of the African Maize Stress (AMS) project remains as stated in the original Phase I proposal: to increase the food security and income generation of African farm families by increasing the productivity and sustainability of maize-based cropping systems subject to drought, low and declining soil fertility, and infestation by *Striga spp.* and stem borers. UNDP, IFAD and Sida funded the initial phase of the Project from 1998-2001. The Rockefeller Foundation assumed co-funding of the AMS project activities with BMZ, NIPPON and OPEC in mid-2002. RF, BMZ, NIPPON and OPEC funds support continued participation of NARS scientists working within the framework of the ECAMAW network to (i) develop and test stress (streak, *Striga*, drought and low-nitrogen) tolerant maize germplasm, adding to the activities the incorporation of the QPM trait; (ii) develop and/or evaluate and disseminate cultural practices to enhance the productivity of stress tolerant maize varieties; (iii) develop seed production and distribution systems that improve the availability and affordability of improved maize varieties to resource-poor maize farmers, and (iv) provide training to NARS scientists to develop stress-tolerant maize germplasm.

Stress Tolerant Germplasm Development

In 2002, the collaborative breeding activities resulted in the identification of: a series of (1) early stress tolerant hybrids (single cross, 3-way and double top cross); (2) disease (GLS, streak and *E.turcicum*) resistant double top cross hybrids; (3) top cross and QPM synthetics; (4) herbicide resistant single and top cross hybrids; (5) single cross and OPV testers; and (6) early stress tolerant and streak resistant inbred lines with good combining ability when tested under optimum, drought and low nitrogen conditions. These breeding activities have resulted in the release of: 14 stress tolerant varieties including 8 extra-early OPVs, 4 normal and 2 QPM hybrids. Twenty-three new hybrids and OPVs including QPM were nominated for the National Performance Trial (NPT) in Kenya. In addition, more than 20 promising varieties were identified in Ethiopia, Tanzania, Rwanda, and Burundi.

Testing

Partners tested 2,255 genotypes of different origin (CIMMYT- Kenya, Harare, and HQ) under optimum conditions and different biotic and abiotic stresses in Kenya and other sites in eastern Africa. Four sets of Line Evaluation Trials (LET) were planted under managed drought and hot spot disease conditions at Kiboko and Alupe; 900 S_4 lines developed jointly by the scientists of ECAMAW member countries were evaluated and 167 disease tolerant/resistant lines were identified; 19 small projects related to seed increase, line development and germplasm evaluation were funded for execution by NARS scientists.

The yield performance and disease reaction of the best selected genotypes are presented on Tables 1-8. Twenty two QPM hybrids from CIMMYT Harare were evaluated across 4 sites including stressed and unstressed conditions in Kenya (Table 8). Two hundred single cross hybrids and 33 OPVs were crossed with 2 testers and the crosses were evaluated under both unstressed and stressed environment in order to determine their combining ability and identify single cross and OPVs testers (Table 9).

153 QPM segregating lines from Harare and 55 from CIMMYT HQ were screened for disease at Alupe, and 4 sets of CHTSW involving QPM and normal hybrids were tested in 4 locations including one under managed drought site in Kenya.

Breeding Nursery

Herbicide resistant (IR) maize

Eight single and 4 three-way hybrids were formed; 11 herbicide resistant lines were advanced to BC2F1; 10 S2 herbicide resistant bulks were advanced to S3.

QPM Germplasm Development

New stress tolerant QPM population development

Early and extra-early populations. (1) Twenty nine extra-early stress tolerant normal populations were crossed and backcrossed to Pool15QPM-SR. The resulting crosses are being subjected to successive light table selection and sibbing to fix the opaque 2 genes and modifiers and develop 2-5 extra-early stress tolerant QPM populations and early inbred lines. (2) Eight hundred early Full Sib (FS) families were generated from Pool15QPM-SR. These FS are being tested using unreplicated design under low nitrogen, drought and optimum conditions in Kenya. The selected 20% will be analyzed for quality protein (tryptophan). The best families will be selected to form new extra-early QPM-SR population and 3-4 extra-early QPM synthetics for the midaltitude dry ecology of eastern and Southern Africa.

Intermediate stress tolerant QPM populations. Twenty one locally adapted normal CMLs were crossed with the QPM single cross (CML144/CML159) and the resulting F1 were crossed to Pool15QPM-SR. These crosses are being subjected to successive light table selection and sibbing/selfing/recombination for 2 to 3 generations to develop new 2-3 QPM populations, and inbred lines.

QPM population improvement. Two QPM lowland adapted OPVs: PR8763 and Across8762 were self pollinated to develop 230 S1 from each OPV. The S1 bulks will be screened for streak resistance to upgrade the streak resistance level and improve them for local adaptation.

QPM streak lines development. 95 QPM F2 populations (QPM crossed to normal) developed at Harare were planted in 3 sites in East Africa for selfing and 90 S2 bulks were generated. These bulks will be distributed to NARS in 4 countries for further selfing and QPM line development.

QPM hybrids/synthetic formation and seed production. One new QPM synthetic was formed and advanced to F2 for testing during 2003. Seventeen QPM top cross hybrids were developed for testing in 2003. Two QPM (BC0) F1 synthetics under streak conversion were advanced to F2. Seed of two three-way hybrids being evaluated in the Kenyan National Performance Trial (NPT) and their parental lines were multiplied.

Seed Production and Distribution

Two hundred kg breeder seed of 122 genotypes were produced and distributed. Two hundred ninety two sets of trial (about 500 kg seed) were distributed to 12 countries.

Training

Sixteen national scientists from the region have been trained and/or have attended various training workshops within and/or outside of Africa.

Grain Yield Performance and Other Important Characters of Selected Hybrids/Varieties in 2002

Table 1. Grain yield (t/ha) and days to anthesis of selected early streak and abiotic stress tolerant OPVs tested across 15 sites including optimum, Low N and drought in East Africa, 2002A.

Entry	Pedigree	OPT	LN	DR	RDR	AD
		t/ha	t/ha	t/ha	t/ha	d
10	ECAVEE2	4.1	4.1	2.3	2.1	65
14	ECAVEE6	4.1	3.7	2.5	2.5	66
18	ECA-EE-POP1	4.1	3.4	1.3	1.9	60
19	KATUMANI-Local Check1	2.9	2.7	1.3	1.9	60

OPT = optimum, DR = drought, LN = low nitrogen, RDR = random drought, AD = Anthesis date

Table 2. Grain yield (t/ha) and days to anthesis of selected early streak and abiotic stress resistant double topcross hybrids tested across 10 sites including optimum, low N and drought in E. Africa, 2002A.

Entry	Pedigree	OPT	LN	DR	RDR	AD
		t/ha	t/ha	t/ha	t/ha	d
17	LLSYNTH1/[CML312/CML265]	5.5	3.8	*	4.2	80
28	Phil DMR61-2-#-#1-8-B-B/CML78/ZEWAC1F2	5.6	4.4	1.1	2.7	73
62	P300C5S1B-2-3-2#-#1-2-B-B/CML78/ZEWAC1F2	5.6	4.8	1.0	2.8	72
37	P100C6-26-1-2-#-#1-6-B-B/CML78/ZEWAC1F2	5.5	4.5	0.7	2.7	72
29	P300C5S1B-2-2-3-#-#1-1-B-B/CML78/ZEWAC1F2	5.7	4.4	0.9	2.4	74
6	Locsyn4/[CML312/CML265]	5.1	3.5	*	3.6	79
76	Local Check1- PIONEER3253	6.3	3.7	0.4	2.3	78
74	Local Check2 - Various	5.3	4.9	0.4	3.1	79
45	Local Check3- CG4141	5.6	3.6	*	4.6	83

***=This entry was not included in this environment**

Table 3. Grain yield (t/ha) and days to anthesis of selected early stress tolerant 3W hybrids tested across 13 sites including optimum, drought and low nitrogen in East Africa, 2002A.

Entry	Pedigree	OPT	LN	DR	AD
		t/ha	t/ha	t/ha	d
1	CML445/CML78/CML212	6.9	4.1	1.1	76
20	P43C9-56-1-1-2-B*4/TUX-45/CML212	6.1	4.6	1.3	77
22	TS6C2-32-1-1-1-1-B-B-B/TUX-45/CML212	6.3	4.2	1.2	76
23	Local Check1- PIONEER3253	4.7	3.5	0.4	77

Table 4. Grain yield (t/ha), and disease reaction of selected streak and abiotic stress tolerant intermediate OPVs tested across 12 Sites including optimum, Low N and drought in East Africa, 2002A.

Entry	Pedigree	OPT	LN	DR	GLS	*E. turcicum*
		t/ha	t/ha	t/ha	1-5	1-5
4	ECAVL11	4.9	2.3	2.9	2.1	1.5
14	ECAVL20	4.7	2.4	2.4	2.0	1.6
22	Local Check1- PIONEER3253	4.8	1.8	2.1	2.9	1.6

GLS=Gray leaf spot

Table 5. Grain yield (t/ha), and disease reaction of selected disease resistant intermediate double topcross hybrids tested across 9 Sites including Optimum and Low N in East Africa, 2002A.

Entry	Pedigree	OPT	LN	GLS	*E.turcicum*
		t/ha	t/ha	1-5	1-5
47	P43SR-4-1-1-2-3-1-3-B/CML202/Z97SYNGLS(B)	5.6	1.6	1.5	2.6
3	CML379/CML312/Z97SYNGLS(A)	7.5	4.2	2.2	2.0
6	CML379/CML444/Z97SYNGLS(A)	5.6	3.3	1.9	2.1
14	[EV792/EV8449-SR(PR84A116)]]C1F2-329-X-/CML395/Z97SYNGLS(A)	5.6	4.7	2.1	1.6
27	CML379/CML212/Z97SYNGLS(B)	6.4	4.8	2.4	1.9
36	[EV792/EV8449-SR(PR84A116)]]C1F2-329-X-1-2-X-X-1-B-B/CML212/Z97SYNGLS(B)	6.3	3.8	2.3	1.7
53	Local Check1- PIONEER3253	6.0	3.3	2.7	2.1
54	Local Check2- Various	5.6	2.9	2.4	2.1

Table 6. Grain yield (t/ha) and disease reaction of selected intermediate double topcross hybrids tested across 9 sites including optimum, low nitrogen and on-farm conditions in East Africa, 2002A.

Entry	Pedigree	OPT	LN	On-F	GLS	*E.turcicum*
		t/ha	t/ha	t/ha	1-5	1-5
47	ECAVL1/CML395/CML312	10.5	3.9	6.9	1.8	1.9
50	ECAVL4/CML395/CML312	9.7	4.0	6.6	1.5	2.0
55	ECAVL4-STR(flint)-#/CML395/CML312	9.8	3.7	6.8	1.8	2.0
62	ZEWAC1F2/CML395/CML312	9.5	3.7	5.4	2.3	2.0
69	Local Check1- PIONEER3253	9.7	2.3	2.9	3.3	2.0
70	Local Check2-Various	8.4	2.6	4.0	3.1	1.8

Table 7. Grain yield (t/ha) and disease reaction of selected intermediate stress tolerant 3 way hybrids tested across 12 sites, including optimum, low nitrogen and drought in East Africa, 2002A.

Entry	Pedigree	OPT	Low N	DR	GLS	*E.turcicum*
		t/ha	t/ha	t/ha	1-5	1-5
4	[[TUXPSEQ]C1F2/P49-SR]F2-45-5-1-2-B/CML202/CML78	6.1	4.3	4.9	2.1	2.3
11	CML442/CML202/CML395/CML312	6.6	3.4	6.2	1.8	2.5
14	MSRXPL9]C1F2-176-4 /CML312/CML442/CML444	6.1	3.5	5.3	1.6	2.2
19	Local Check1- PIONEER3253	4.5	3.7	4.4	2.6	2.4
20	Local Check2-Various	5.1	4.5	2.9	2.4	2.2

Table 8. Grain yield (t/ha), and disease (Gray Leaf Spot and *E. Turcicum* reaction of 6 selected QPM hybrids compared to 2 commercial checks tested across 4 sites in Kenya, 2002A.

Entry	Pedigree	OPT	DR	GLS	*E. turcicum*
		t/ha	t/ha	1-5	1-5
1	CZL01006/CML176//CZL01005/CML181	6.2	0.6	1.0	1.7
2	CZL01006/CML176//CML181/CML182	5.8	0.9	1.3	1.4
6	CZL01006/CML175//CML182	6.8	0.3	1.1	2.2
8	CML144/CML159/OBATANPA	6.1	0.6	1.6	2.2
16	CML181/CML175/OBATANPA	5.9	1.0	1.5	2.9
22	CZL00025/CML312//CML395/CML202 (normal)	6.3	0.4	1.2	1.9
23	Local Check 1-H513	4.2	0.5	3.4	1.3
24	Local Check 2-Various	6.4	0.6	2.2	1.5

Table 9. List of single cross hybrids and OPVs with high positive general combining ability under both optimum and low N conditions. 2002A.

Line	Pedigree	GCA-LN	GCA-OPT	GCA-Across	GCA Across Rank
3	CML379/CML312	0.250	0.128	0.168	5
6	CML312/CML373	0.242	0.3	0.281	7
8	CML312/CML254	0.416	0.305	0.342	5
14	CML395/CML384 +	0.312	0.573	0.486	1
24	CML204/CML384 +	0.202	0.378	0.319	6
1	CML204/CML445 *	0.262	0.418	0.366	1
15	P329-X/THG-B-95/EV8725SR-2-2-#1-B1-1-B1 *	0.269	0.515	0.433	2
16	LPSC3-36-1-1-2-1-B-B/CML395 +	0.248	0.467	0.394	3
23	CML373/CML384 +	0.315	0.763	0.613	1
OPV					
21	ECAVL3-STR(dent)-#	0.288	0.954	0.720	1
25	P501-SRCOF2	0.359	0.349	0.322	4

*** Streak resistant – SR; + Streak tolerant - ST**

Improving Crop Management Practices for Enhanced Productivity of Maize Systems

Dennis Friesen, CIMMYT/IFDC Regional Maize Systems Agronomist

Introduction

Agronomic research is implemented through the Eastern and Central Africa Maize and Wheat (ECAMAW) Research Network via a competitive small grants program. In 2002 work was supported by BMZ, the Rockefeller Foundation, and the CIDA-Canada Eastern Africa Cereals Program (EACP). There were 25 projects focusing on crop and natural resource management and the on-farm evaluation of elite drought and low-N tolerant maize varieties with farmers through mother-baby trials.[1] Agronomic research projects involved a substantial number of on-farm trials.

Agronomic and on-farm trials in all agro-ecologies in eastern and Central Africa were affected by moisture stress during 2002, due to severe drought in much of the region. Even the Ethiopian highlands, which normally receive > 7 months of well-distributed rainfall, received less than 50% their annual average within a 3-4 month foreshortened season. Trials in the Rift Valley of Ethiopia, eastern Province of Kenya, and the eastern and northern zones of Tanzania were lost or severely affected by the drought conditions which prevailed in the area during the major rainy season. Trials were replanted with adequate rain during the minor season in eastern Kenya. Agronomic research objectives and activities carried out during 2002 are summarized as follows:

1. Evaluation of superior drought and low-N tolerant maize varieties and hybrids with farmer participation in 'mother/baby' trials.

A total of 44 mother trials with 394 baby trials were planted in Ethiopia, Kenya and Tanzania.

Materials	Mother trials				Baby trials			
	ET	KY	TZ	Total	ET	KY	TZ	Total
EE-OPVs	4	11	4	19	6	204	48	258
Int-OPVs	8	2	2	12	23	24	24	71
Early hybrids	0	2	0	2	0	24	0	24
Int. Hybrids	9	0	2	11	17	0	24	41
TOTAL	**21**	**15**	**8**	**44**	**46**	**252**	**96**	**394**

2. Determination of the economically optimal levels of soil N fertility on different soil types and different agroecological zones for less demanding low-N tolerant varieties, integrating inorganic and organic nutrient sources.

A regional *trial* comparing N response of 'normal' and NUE- or QPM varieties was implemented at 11 sites in Ethiopia, E. Kenya and N. Tanzania.

[1] A "mother" trial comprising 20-30 varieties and different treatments is grown by partners in a conspicuous and easily accessible location in a participating village; "baby" trials containing small subsets of mother trial varieties are grown by farmers in their fields. Farmers' observations and researcher data are shared among farmers, researchers, NGOs, extension, and seed companies. The approach has been a great success and is being used throughout eastern and southern Africa.

3. Evaluation of the N contribution of organic sources including manures, and leguminous intercrops, relays and rotations to low-N tolerant maize in systems.

Thirteen researcher managed mother trials were planted on-station or on-farm, and 60 farmer managed baby trials were planted on-farm in the humid lowland ecology of eastern Tanzania (Mlingano), the moist midaltitude ecology of Ethiopia (Bako and Jimma) and Uganda (Tororo), and the dry midaltitude of northern Tanzania. All used a common design: maize grown in large plots in monoculture or intercropped with 3 legumes, the selection of which varied among the sites.

4. Determination of optimal sowing date and densities for extra-early maturing maize varieties in different environments.

Seven trials were planted in the dry midaltitude ecology of Ethiopia (2), Kenya (2) and Tanzania (3) to evaluate the effect of increasing plant density on 'normal' and drought tolerant cultivars (EE-OPVs and early hybrids).

5. Evaluation and adaptation of various soil moisture conservation strategies, including tied-ridges and surface mulches on-farm using farmer participatory methods.

Large-scale trials comparing planting on tied ridges with farmers' practice using a commercial extra early-OPV and early hybrid and a drought tolerant EE-OPV and early hybrid were planted on farmers' fields at 2 sites in Ethiopia, 2 in Eastern Kenya and 4 in Northern Tanzania.

Participatory Evaluation of Superior Drought and Low-N Tolerant Maize Varieties in 'Mother/baby' Trials

Ethiopia

This work was reported by Tolessa Debele and Girum Azmach (Bako ARC); Leta Tulu (Jimma ARC); Gelana Soboqsa and Hussen Harrun (Melkasa ARC).

Dry midaltitude ecology (Melkasa). Two sets of mother-baby trials were planted in the dry midaltitude ecology in Ethiopia in 2001: an extra early OPV set and an intermediate OPV set (Table 10). The set of extra-early OPVs was harvested at 3 sites while the set of intermediate OPVs was harvested at 2 sites. Due to severe drought, none of the baby trials was harvested. Maize grain yields in the all mother trials were very low with no signficant differences among entries (Table 10).

Table 10. Mother trials of early and intermediate OPVs planted in Ethiopia in 2002.

Entry	Extra early OPVs	Intermediate OPVs
1	ECA-EE-6	ECA-VL-14-STR
2	ECA-EE-8	ECA-VL-15-STR
3	ECA-EE-9	ECA-VL-16-STR
4	ECA-EE-13	ECA-VL-17-STR
5	ECA-EE-16	ECA-VL-1
6	ECA-EE-18	ECA-VL-2
7	ECA-EE-21	ECA-VL-3
8	ECA-EE-31	ECA-VL-4
9	ECA-EE-33	ECA-VL-5
10	ECA-EE-34	FAW/NON TUX(W)
11	ECA-EE-45	ECA-VL-7
12	ECA-EE-42	NIP 25
13	ECA-EE-49	SYNTH-NUE
14	ECA-EE-29	SADVIB#-#
15	ECA-EE-38	SADVEB#-#
16	ECA-EE-36	OBATAMBA
Mean yield	421 ns	314 ns
ASI	9.0 *	5.4*
EPP	0.31 *	0.23 ns
CV (yield)	73%	83%

Moist midaltitude ecology (Bako and Jimma). One set of intermediate OPVs was planted in a total of 4 mother trials and 16 baby trials (10 harvested) around Bako and around Nada and Kersa in the Jimma zone. A set of intermediate hybrids was planted in a total of 3 mother trials and 16 baby trials in the same areas. The mother trials were replicated 3 times; baby trials each consisted of one complete replicate of all entries. Overall yields in mother-baby trials in the moist midaltitude ecology were affected by moisture stress during the grain filling period in both areas. Strong winds also caused late-season lodging in some trials in Jimma. Nevertheless, clear differences among varieties were observed across sites and N levels (Tables 11 and 12). Among the hybrids, two entries stood out in both areas and were identified by both researchers and farmers, based on ear size, closed tips, disease resistance and agronomic performance. At Bako, the local check BH540 was most favored by farmers (based largely on ear size) and did not yield significantly less than the best entry; however, its performance was poorer at Jimma. At Bako, the QPM hybrid BHQP542 was the poorest yielder and had the poorest plant and ear aspect. Selections among the intermediate OPVs were less consistent between sites than was found with the hybrids. Differences in grain yield were not significant at Bako and only marginally so at Jimma (Table 12). At Jimma, the check Kuleni was the top performer in the mother trials, followed by ECA-VL-2, while ECA-VL-4-STR and ECA-VL-16 STR also performed well in the baby trials. Farmers also selected Kuleni at both Bako and Jimma and their selections of the test entries generally agreed with the researchers' selections (Table 12). Bare tips was a general problem identified among the majority of test entries at both sites.

Table 11. Grain yield of intermediate hybrids in mother-baby trials at Bako and Jimma, Ethiopia, in 2002.

Entries	Bako		Jimma	
	Mother	Baby	Mother	Baby
LPSC3 H-144-1-2-2-4-#-B-B-B x CML-202 x CML-384	6.8	4.8	5.1	5.3
CML-373 x CML-202 x CML-384	7.6	5.1	5.1	6.1
P_{21} MRRSC$_2$ -19-1-2-2-B-B-B x CML 202 x CML -384	**7.8 f**	**5.9 f**	**5.8 f**	6.5
LPSC$_4$ F273-2-2-1-B-B-B x CML 202 x CML-384	7.4	5.8	**5.3**	**6.8**
[TUXPSEQ]C_1F_2/P_{49}-SR/$F_2$45-5-12-B x CML-202 x CML-384	7.5	5.8	**6.1**	6.0
CML-444 x CML 202 x CML-384	7.2	5.4	5.6 f	6.5
CML-444 x CML 445 x CML-384	**7.9**	5.7 f	**5.1 f**	6.2
CML-388 x CML 202 x CML-384	7.0	5.1	5.3 f	5.9
BH 540	7.2 ff	4.6 ff	3.7	4.3
BH QP542	6.6 x	4.4 x	4.1	5.5
CV%	8.3	14.6		
LSD (0.05)	0.7	1.0		

* Yields of bold and boxed entries selected by researchers; those identified by 'f' and 'x' selected or rejected, respectively, by farmers.

Table 12. Grain yield of intermediate OPVs in mother-baby trials at Bako and Jimma, Ethiopia, in 2002.*

Entries	Bako		Jimma	
	Mother	Baby	Mother	Baby
1. ECA-VL-3	6.0	2.9	6.1	4.8
2. ECA-VL-5	**6.4 f**	3.4	5.8	4.9
3. ECA-VL-16STR	5.7 x	3.2	5.7	**4.5**
4. ECA-VL-2	6.1	2.8	**6.4 f**	**4.9**
5. ECA-VL-17STR	5.8 f	2.4	5.0	3.7
6. ECA-VL-1	**6.7 f**	3.8	6.3	5.2
7. ECA-VL-14STR	5.8	2.9	6.2	4.3
8. ECA-VL-15STR	5.2	2.7	5.6	4.2
9. ECA-VL-4STR	6.2	4.4	6.2	**4.8**
10. SYNTH NUE	6.1	3.2	5.1	4.7
11. Kuleni C_1F_1-#	6.2	4.1	**6.6 f**	5.7
12. Gibe 1	**6.4**	3.2	6.4 f	4.3
13. Kuleni	6.2 f	4.0 f		
CV%	12.2	28.0		
LSD (0.05)	NS	NS		

* Yields of bold and boxed entries selected by researchers; those identified by 'f' and 'x' selected or rejected, respectively, by farmers.

Kenya and Tanzania

This work was reported by A. Njaimwe (KARI-Katumani); F. Manyara, J. Ouma, and C. Mutinda (KARI-Embu);MB Muli (KARI-Mtwapa); J Irungu (CRS-Kenya);TE Mmbaga, Z Mduruma and PR Matowo (SARI).

Dry midaltitude ecology (eastern Kenya, northern Tanzania): 1. Extra-early OPVs. Early, drought tolerant OPVs were planted in mother-baby trials at two sites in northern Tanzania and two sites in eastern Tanzania during the long rains of 2002 (March-August). The trials in E. Tanzania failed due to drought while those at one site in N. Tanzania (Rundugai) were evaluated by farmers who ranked ECA-EE-6 followed by ECA-EE-POP1 as best, based on yield, kernal characteristics, and tolerance to drought, pests and diseases.

Three mother-baby trials were planted in eastern Kenya in the long rains but failed due to drought. The trials were re-planted in the short rains. In addition, eight mother trials each with 24 baby trials were formed for evaluation by farmers in collaboration with the Catholic Relief Services (CRS) in eight Districts in E. Kenya during the short rains. These trials comprised four entries of pre-released extra early OPVs from the CIMMYT/KARI-Kiboko program, which were compared to two local commercial checks and the farmers' local variety. Varieties were evaluated in field days organized by CRS at each site to evaluate various crops and technologies, usually attracting more than 100 farmers. Results from Gachoka Division are shown in Table 13. All varieties yielded better than the farmers' check, and ECA-EE-21 and ECA-EE-29 produced significantly more grain than the commercial checks (DLC1 and KCB). Farmers ranked ECA-EE-21 together with KCB and ECA-EE-6 as the best based on earliness, drought tolerance, and yield potential.

Table 13. Performance and farmers' evaluation of extra-early drought tolerant maize OPVs in mother-baby trials in Gachoka Division, Mbeere, Kenya, managed through CRS.

Varieties	Days to tasseling	Grain yield (t/ha)	Averages scores by farmers' in variety selection*				
			Earliness	Drought tolerance	Yield potential	Overall mean	Overall rank
ECA–EE-18	48	2.2	3.3	3.5	3.5	3.4	5
ECA- EE-21	47	2.7	3.8	3.8	4.3	4.0	1
ECA-EE-29	46	2.5	3.3	2.8	4.0	3.4	5
ECA-EE-6	47	1.9	3.8	4.0	4.0	3.9	3
DLC1	46	2.0	4.0	3.8	3.5	3.8	4
KCB	46	2.1	4.0	4.5	3.5	4.0	1
Local	49	1.6	2.7	2.7	3.3	2.9	7
No. of Farms	4	4	4	4	4		
SE_{mean}	0.8	0.17					

*Scores from participatory evaluations: 1 = very poor, 2 = poor, 3 = average, 4 = good, 5 = excellent

Dry midaltitude ecology (eastern Kenya, northern Tanzania): 2. Early hybrids. Early hybrids were evaluated at Kikatiti and Weruweru in N. Tanzania. Moisture stress at these sites also limited yields, although they were generally satisfactory, ranging from 2.6-6.3 t/ha under optimal fertilization and 0.6-2.7 t/ha under sub-optimal fertilization. There were no significant differences among entries under suboptimal conditions whereas, under optimal conditions at Kikatiti, the best performers were CKT126021, CKT026023 and CKT026027. Farmer evaluations ranked CKT026027, CKT026005 and CKT026001 as the most preferred based on yield, drought tolerance, grain quality (white and heavy), disease and insect resistance, milling quality, husk cover, stalk strength (lodging resistance), and biomass production (animal feed).

Moist midaltitude ecology (Embu, Central Kenya). Two sets of mother-baby trials were planted near Embu in the moist midaltitude ecology during the long rains of 2002. Each mother trial comprised 10 elite drought and low-N tolerant early hybrids plus two local checks (EMCO and H513) planted in four replicates, two of which received optimal fertilizer and two of which received only basal fertilizer. Farmers evaluated the materials at physiological maturity and at harvest according to several criteria (Table 14). Three entries (CKT026001, CKT026029 and CKT016011) were consistently ranked as the top three hybrids according to all criteria except grain size. Only CKT026001 was among those ranked best by Tanzanian farmers (see above), whose other two choices were found only to be average, among those evaluated by Kenyan farmers. For grain size, the check H513 as well as two other test entries were ranked highest. The other check entry, EMCO, was ranked last according to all criteria and H513 also was among the poorest except for cob size and grain size. One QPM entry was included among the test entries (Entry No. 5, Table 14). It generally ranked mid-scale or lower among all entries in the trial.

Table 14. Farmer evaluations of early maize hybrids in mother trials at two sites at physiological maturity and at harvest near Embu, 2002.

Entry No.	Pedigree	Average rank based on farmers' evaluations*					
		Overall ranking[1]	Pests and diseases[2]	Husk cover[1]	Cob size[3]	Cob filling[3]	Grain size[3]
1	CKT026001	**1.75**	**3**	**1.25**	**3**	**1**	5
2	CKT026005	5.25	7	5	7	4.5	9.5
3	CKT026011	**4.5**	**3**	**3.5**	**2**	**2.5**	7.5
4	CKT026015	5.75	5	5.5	10	6	6
5	CMTQ016001	6.75	10	8.5	8.5	6	7.5
6	CKT026021	7.5	8	10.25	5	8	**3**
7	CKT026023	6.75	7	8	6.5	7.5	**2.5**
8	CKT026025	10.5	5.5	6.75	11	8	10.5
9	CKT026027	6.75	6	8	5	10	6
10	CKT016029	**1.75**	**1.5**	**2**	**3.5**	**2.5**	5
11	EMCO	11.75	12	10	12	12	12
12	H513	9	10	9.25	4.5	10	**3.5**

* bold values shaded in grey are the three top ranked entries for each criterion.
[1] average of evaluations at physiological maturity and harvest across sites.
[2] average of evaluations at physiological maturity across sites.
[3] average of evaluations at harvest across sites.

Tropical Lowland Ecology (Mtwapa). Advanced low-N and drought tolerant tropical lowland OPVs were evaluated in mother-baby trials at two locations in coastal Kenya. Drought also adversely affected maize yields in this ecology during 2002 with maximum grain yields in the mother trials not surpassing 2.2 t/ha (Table 15). As a consequence, differences among varieties were not large and only marginally significant. Three entries (nos. 1, 2 and 6; Table 6) were superior. The checks, PH1 and PH4, gave similar yields.

Table 15. Yield and number of rotten ears in mother trials in Kilifi and Malindi sites.

Entry	Pedigree	Rotten ears	Grain yield
1	ECA-VL-16-STR	1.1 bc	2.0 a
2	SYNTH25ACF1-#	1.4 bc	2.1 a
3	SYNTH24EARLYF1-#	1.1 bc	1.9 ab
4	SYNTHDRLNF1-#	3.2 a	1.3 c
5	SYNTH24ACF1-#	2.5 ab	1.9 ab
6	STRIGA SYHT2000F1-#	1.9 abc	2.2 a
7	SYNTHHSRF1-#	2.1 abc	1.4 bc
8	SYNTHHA2000F1-#	1.8 abc	1.8 abc
9	SYNTHB2000F1-#	1.2 bc	1.9 ab
10	ECA-VL-20	2.8 ab	1.8 abc
11	PH1	0.8 c	2.2 a
12	PH4	1.1 bc	1.9 ab
CV		92.6	27.3

Comparative Nitrogen Requirements of N use Efficient and QPM Varieties

This work was reported by Tolessa Debele (Bako ARC); Tesfa Bogale (Jimma ARC); MB Muli (KARI-Mtwapa); A Njaimwe (KARI-Katumani).

Four out of five participating centers implemented this regional trial at eleven sites during 2002. However, drought conditions affected maize growth in eastern Kenya and Tanzania during the main season and several trials were lost. The trial in at Kiboko (E. Kenya) was re-sown during the minor season. In general, N use efficient (NUE) maize varieties responded marginally better to N rates than 'normal' varieties in the trial at Mtwapa, Kenya (tropical lowland ecology), although the interaction was not significant (Figure 1). Similarly at Emali, Kenya (dry midaltitude), N fertilizer significantly increased yield by >50% up to 30 kg/ha N (Figure 2), but the NxV interaction was not significant. In both trials, NUE cultivars yielded more than normal varieties. Neither trial was sufficiently sensitive to detect differences between the responses of NUE and normal maize to fertilizer. At Jimma, Ethiopia, trials were conducted to determine the optimal N rates and planting density for the recently released QPM variety, BHQP542. Yield increased significantly with N fertilizer up to 69-92 kg/ha, whereas populations in the range of 44,000 to 66,000 plants/ha had no significant effect on yields (Table 16).

Figure 1. Effect of N rate on yields of NUE and normal maize varieties at Mtwapa.

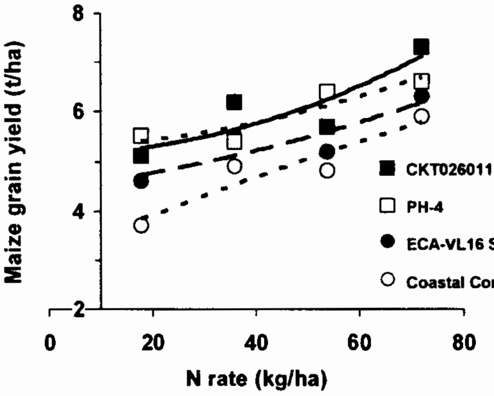


Figure 2. Mean response of maize varieties to N rates at Emali in 2002.

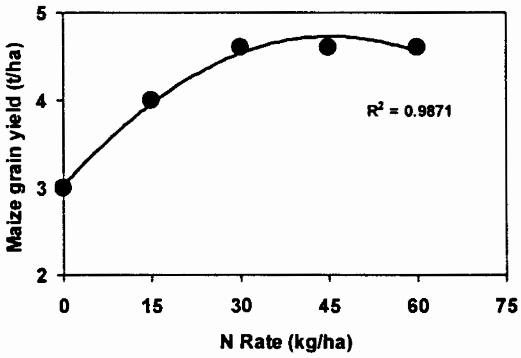


Table 16. Grain yield (t/ha) of QPM as affected by plant density and N-levels on station of Jima Center in season, 2002.

Nitrogen levels (kg/ha)	Plant density (D) (×1000/ha)				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	

Best-bet maize-legume systems with N use efficient varieties

This work was reported by Tolessa Debele (Bako ARC); Tesfa Bogale (Jimma ARC); R Assenga (ARI-Mlingano); TE Mmbaga and PR Matowo (SARI); J Kikafunda (NAARI).

Mother-baby trials/demonstrations were planted in the humid lowland ecology of eastern Tanzania (Mlingano), the moist midaltitude ecology of Ethiopia (Bako and Jimma) and Uganda (Tororo), and the dry midaltitude of northern Tanzania. A total of 13 mother trials were planted on station or on farm with researcher management, and a total of 60 baby trials were planted on farm and managed by farmers. The common design for these regional trials consisted of maize grown in large plots in monoculture or intercropped with three legumes, the selection of which varied among the sites. Plots will be divided in Year 2 (2003) of the trials and planted with 'normal' and NUE maize varieties fertilized with 0 or ½ the recommended N rate.

Work in 2002 served to establish the maize-legume green manure systems. The early cessation of rains and drought conditions at some sites affected biomass production and, at some sites, survival of the green manure intercrops. In the latter case, around Mlingano, Tanzania, good rains in August through November enabled replanting of the green manures and substantial biomass accumulation: 5.2 t/ha for mucuna (mean of 12 trials), 4.8 t/ha of canavalia (10 trials), 3.6 t/ha of cowpea (5 trials), and 3.0 t/ha of Dolicos lablab (5 trials).

Legumes in general did not compete with maize except in eastern Uganda (Tororo), where maize was frequently dominated by crotalaria. Biomass yields of both crotalaria and canavalia were high (5.5-6.4 t/ha) but maize grain yield was less than 0.25 t/ha, due both to competition from legumes, moisture stress and, at some sites, *Striga* infestation.

At Bako and Jimma, intercrops sown 30-40 days after maize did not compete with maize or reduce maize yields (Table 17). Early cessation of rains at both sites resulted in generally low green manure biomass production. Crotalaria was more easily managed than mucuna; it was easy to sow, proliferated well, and smothered weeds, whereas the creeping climbing habit of mucuna made it difficult to harvest maize.

Table 17. Legume biomass and maize grain yield in legume-maize systems at Bako and Kersa district, Jimma, in 2002.

Maize system	Bako				Jimma			
	Mother trials		Baby trials		Mother trials		Baby trials	
	Maize grain	Legume biomass	Maize grain	Legume biomass	Maize grain	Legume biomass	Maize grain	Legume biomass
	----------- (t/ha) -----------				----------- (t/ha) -----------			
Maize monocrop	5.4		5.3		5.6		5.7	
Maize+mucuna	6.2	1.24	5.4	0.26	5.9	1.27	4.7	1.09
Maize+lablab	5.5	0.92	5.3	0.37	6.3	0.46	5.3	0.16
Maize+crotalaria	5.6	0.45	5.4	0.18	5.7	1.63	5.0	1.45
Lsd (0.05)	ns	0.30	ns		ns		ns	
CV (%)	9.9	13.6	9.4					

Optimal Plant Populations for Drought Tolerant Maize Varieties

This work was reported by Hussen Harrun (Melkasa ARC); A Njaimwe (KARI-Katumani); PR Matowo and TE Mmbaga (SARI).

A total of 7 trials were planted in the dry midaltitude ecology of the region (2 in Ethiopia, 2 in Kenya and 3 in Tanzania). The design involved a comparison of 4 cultivars (2 EE-OPVs and 2 early hybrids, one of each being a new drought tolerant AMS entry) at 3 planting densities on tied ridges. As with the other trials planted in this ecology, these were also severely affected by drought; trials in Ethiopia were completely lost; trials in eastern Kenya were lost but re-planted with the short rains in November; trials in northern Tanzania produced very poor yields.

In eastern Kenya at Kiboko, maize grain yield was not affected by plant density in the range of 45,000-57,000 ha^{-1} but declined at the highest density (71,000 ha^{-1}) (Figure 3). At Katumani, yield was not affected by increasing density in the range of 48,000-72,000 ha^{-1}. At both sites the density × variety interaction was not significant. At Rundugai, Tanzania, yields were severely reduced by drought. Yield decreased with increasing density in the range of 44,000 to 66,000 ha^{-1} and there were no significant differences among varieties in their response to increasing population (nonsignificant density × variety interaction). However, differences among varieties were significant with the drought tolerant extra early OPV or early hybrid generally yielding more than the corresponding check variety (Table 18). Under more limiting rain, the extra early OPV produced more grain than the early hybrid. In the same dry midaltitude ecology at Melkasa, Ethiopia, severe drought conditions resulted in no grain production in a trial comparing three varieties of different maturities at increasing densities on tied ridges versus flat planted land preparation. Biomass (stover) production was significantly affected by land preparation (tied ridges < flat planting) and variety (Melkasa- 1 < ACV-6 < A-511). The density × variety interaction was significant with earlier materials producing more biomass at higher density while the later maturing variety produced less at higher density (Figure 4).

Table 18. Yield of normal and drought tolerant extra-early OPVs and early hybrids at three sites in Northern Tanzania and Eastern Kenya.

Maize variety	Grain yield (t/ha)		
	Rundugai, TZ	Kiboko, KY	Katumani, KY
KCB	1.87	3.9 a	3.3 a
GATE2001B	2.61	4.6 b	3.9 a
Early hybrid check*	1.02	3.9 a	2.2 b
CKT026015	1.64	4.7 b	2.5 b

* CG4141 in TZ; PHB3253 in KY

Figure 3. Effect of plant density on yield of maize at two sites in E. Kenya.

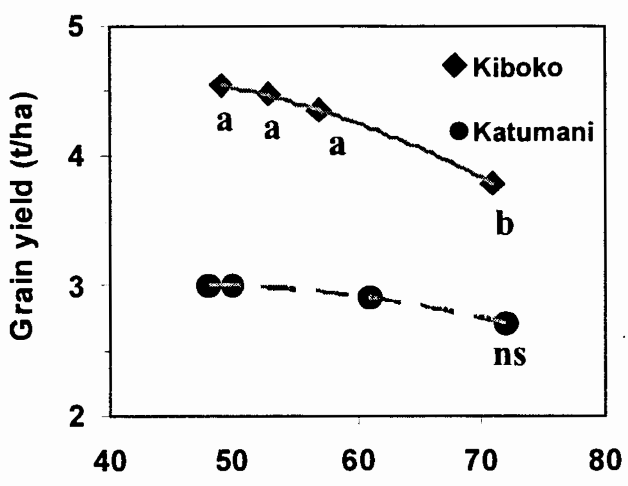
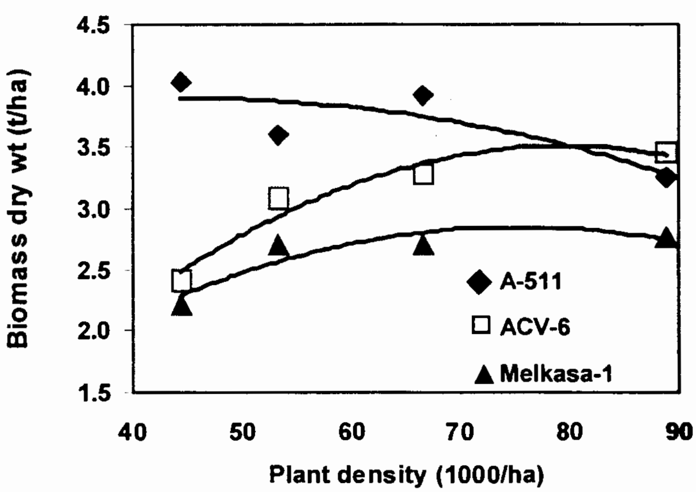


Figure 4. Effect on plant density on biomass yield of extra early, early and intermediate varieties at Melkasa.



As noted earlier, at Jimma, Ethiopia (moist midaltitude), increasing plant population from 44,000 to 66,000 ha^{-1} did not significiantly affect yield of the QPM hybrid, BHQP542, grown under comparatively less moisture stressed conditions during this abnormal season (Table 16). These results suggest that the earlier maturing BHQP542 will not be able to compete with BH660 even if planted at higher densities. This hypothesis will be tested in 2003 when rainfall hopefully will be adequate.

On-farm Evaluation of Tied Ridges with Drought Tolerant Maize Varieties

This work was reported by TE Mmbaga & PR Matowo (SARI); A Njaimwe (KARI-Katumani); Hussen Harrun (Melkasa ARC).

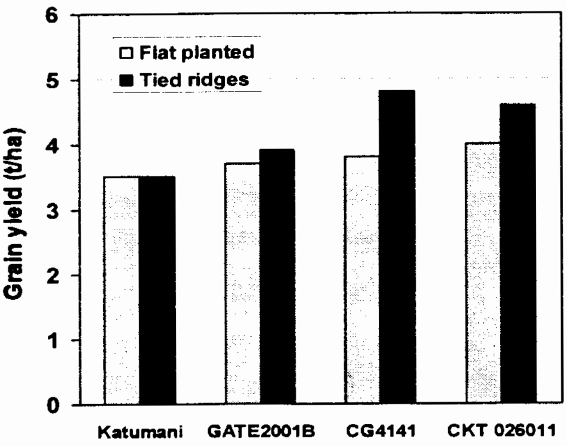
Large-scale trials were planted on farmers' fields at two sites in Ethiopia, two in eastern Kenya and four in northern Tanzania. The design involved a comparison of a commercially available EE-OPV and early hybrid with a drought tolerant EE-OPV and early hybrid planted on flat seed beds and tied ridges. Plot sizes of 1000 m^2 were used and ridges were formed with an ox-drawn implement where possible. The severe drought throughout the dry midaltitude ecology of the region greatly impacted the trials at all sites. Trials at Meiso in Ethiopia were completely lost; trials in eastern Kenya sown in the long rainy season were also lost but were re-sown during the short rains in November; 3 of the 4 trials in northern Tanzania were lost to drought. In the surviving trial, tied ridging did not affect the yield of EE-OPVs but increased that of the early hybrids by about 1 t/ha (Figure 5). Differences between varieties were not significant.

In eastern Kenya, trials at two sites sown in the short rains in October/November benefitted from good and well-distributed rainfall. At Emali, tied-ridges and flat planting were superimposed on chisel treatments (single or crossed) with 4 varieties. There was no significant difference between chisel treatments, possibly because the implement did not successfully break through the hardpan. Flat planted maize yielded mariginally (but significantly) more than maize on tied ridges (Table 19). At Tawa, tied ridges produced slightly greater yields than flat planted maize (Table 10).

Table 19. Effect of tied ridges and chiselling on yields of extra-early OPVs and early hybrids in E. Kenya.

Treatment	Maize grain yield (t/ha)	
	Emali	Tawa
Variety (main effect):		
KCB	4.2 b	3.8
GATE2001B	5.4 ab	4.2
PHB3253	6.1 a	5.4
CKT026015	6.2 a	4.5
Land prepn. (main effect):		
Flat plant	5.6 b	4.3
Tied ridges	5.3 a	4.7
Chisel method (main effect):		
Single pass	5.5 a	--
Crossed passes	5.4 a	--
Interactions:		
Variety × Land preparation	ns	--
Variety × Chisel method	ns	--
Variety × land prep × chisel	ns	--
CV (%)	19	

Figure 5. Effect of tied ridges on yield of extra early OPVs and early hybrids at Rundugai, Tz.



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Insect Resistant Maize for Africa (IRMA) Project

Stephen Mugo (Coordinator) and Hugo De Groote

Introduction

The Insect Resistant Maize for Africa (IRMA) Project is a joint venture between the International Maize and Wheat Improvement Center (CIMMYT) and the Kenya Agricultural Research Institute (KARI), with financial support from the Syngenta Foundation for Sustainable Development. It responds to the need to feed Africa's rapidly increasing population by reducing the damage incurred by the continent's major insect pest of maize, the stem borer. IRMA is being implemented initially in Kenya, but the results and experiences gained through the project will be made available to other willing African countries.

The overarching goals of the project are to develop insect resistant maize varieties for the major Kenyan maize growing environments and to establish procedures to provide insect resistant maize to resource poor farmers in Kenya. During the implementation of the IRMA project, relevant technologies will be transferred to KARI and continuously evaluated. The specific objectives of the project are as follows:

(1) Product development:	Develop insect resistant maize varieties for the major insect pests found in Kenyan maize production systems.
(2) Product dissemination:	Establish procedures for providing insect resistant maize to resource poor farmers in Kenya.
(3) Impact assessment:	Assess the impact of insect resistant maize varieties in Kenyan agricultural systems.
(4) Technology transfer:	Transfer technologies to KARI and Kenya to develop, evaluate, disseminate, and monitor insect resistant maize varieties.
(5) Documentation and communication:	Plan, monitor, and document processes and achievements for dissemination to the Kenyan public and developing countries.

Product Development

Development of sources line for *Bt* cry genes

Development and full molecular characterization of 2nd generation (clean events) *Bt* events (*6 ubi:cry1B, 2 ubi:cry1Ab* and *1 act:cry1Ab*) were accomplished. Clean events carry only the gene of interest and do not carry unnecessary selectable marker genes (such as the *bar* gene). Clean events are developed through co-transformation. While requiring additional laboratory work, we believe such products represent the state-of-the-art achievable at the time the events were produced and address many of the concerns associated with these types of products. Estimation of protein expression in different plant tissues (roots, expanded leaf, and whorl) was also accomplished for nine clean events. Mapping of all 9 clean events was initiated.

Two new synthetic *Bt* genes were acquired, *cry2A* from Canada and *cry1C* from CIRAD. These new *Bt* genes will be combined with the maize Ubiquitin and the rice Actin promoters to produce transformed events to evaluate against African insects. The *cry2A* is of special interest because it may target *B. fusca* better than other CIMMYT *cry* genes. Negotiations to acquire commercial events like *cry1F* for evaluation against African insects will continue in 2003.

A greenhouse is essential for evaluations to verify results obtained in a biosafety laboratory and for initial crossings and production of *Bt* maize seed in Kenya. Hence, an architectural design for the greenhouse was developed and an architect and a contractor were identified. Actual construction of the level-2 biosafety greenhouse complex and head house will commence in early 2003. Some components of the complex not available in Kenya were outsourced abroad.

An application was made to the National Biosafety Committee (NBC) for a plant importation permit to introduce *Bt* maize leaves from first generation events and combinations of these events to test the efficacy of two-gene combinations in controlling Kenyan stem borers. This was an effort to seek control of *B. fusca* not adequately controlled by straight events. Permission was granted, leaf samples were imported, and leaf bioassays were carried out. In bioassays with the five major, maize stem borers—*Chilo partellus* (Swinehoe), *Busseola fusca* (Fuller), *Sessamia calamistis* (Hampson) and *Eldana saccharina* (Walker)—cross combinations provided more control than straight events alone. Event 176 *(cry1Ab)* and its crosses with event 5207 (*cry1Ac-ubi*) provided up to 82% control of *Busseola fusca*, a stem borer difficult to control using straight events (Figure 6). This indicated that adding another *Bt* gene to Event 176 seems to enhance the level of control for *B. fusca* and doesn't decrease the effect on the *Chilo* species. This could be due to more *Bt* protein being produced and/or complementarities of the two proteins.

An open quarantine site (OQS) was developed at Kiboko and became operational. The facility will be used to verify, under field conditions, the results obtained from bioassays carried out at the level-2 biosafety laboratories. Meantime, mock trials were planted to calibrate the fields for growing maize and to train staff and collaborators on management of OQS facilities. An application for registration of the site was made to the Kenya Standing Committee on Imports and Exports (KSTCIE) as a quarantine site, with intention to upgrade it to handle genetically modified plants. The inspection process was done and it is hoped that the permit will be granted in early 2003.

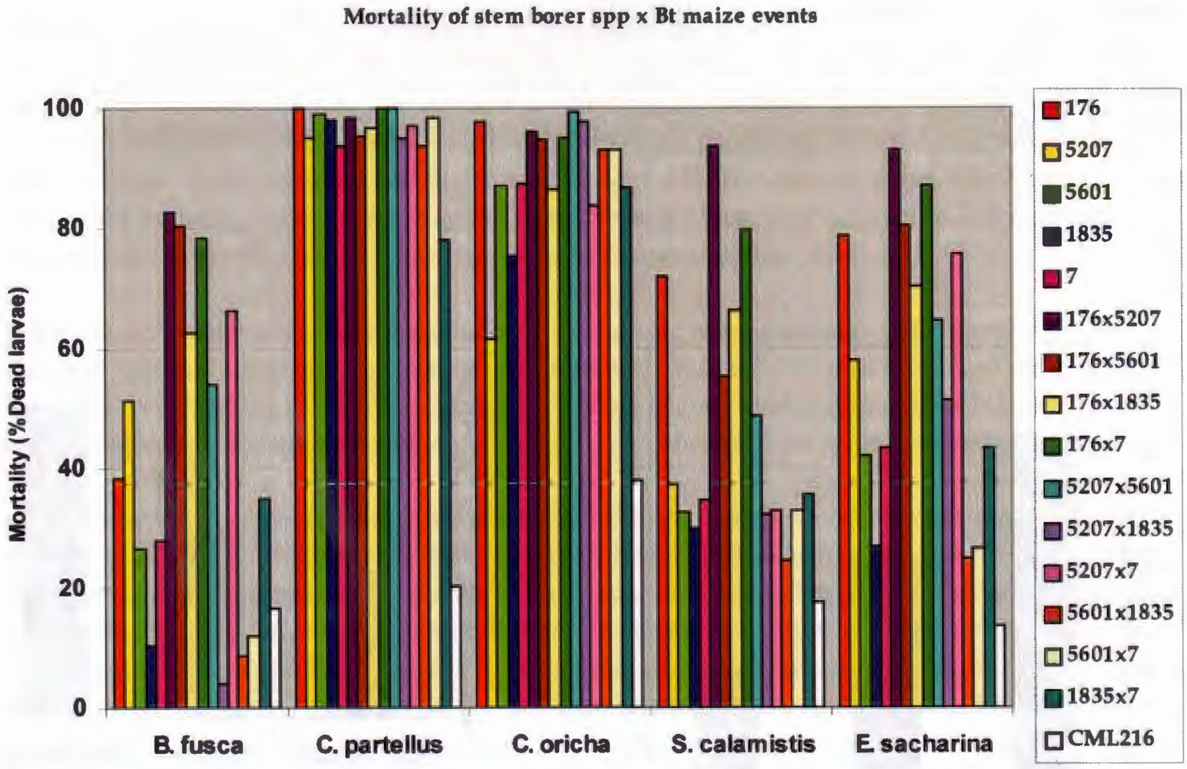

Figure 6. Mortality of stem borer species after feeding on *Bt* maize from *Bt* events and crosses of events.

Development of insect resistant maize through conventional breeding methods

Development of insect resistant germplasm continued with emphasis on identifying insect resistant maize germplasm through screening putative source germplasm from CIMMYT Mexico, Zimbabwe, and Kenya. To develop putative sources of insect resistant maize, a total of 862 maize inbred lines were evaluated and advanced. Screening of insect resistant maize germplasm is continuing and resistant inbred lines and OPVs have been identified and are being used to develop resistant germplasm to stem borers. The breeding program has identified 40 S6 insect resistant inbred lines from MBR group to be used for developing insect resistant germplasm including hybrids and open pollinated varieties. Combining ability studies of these inbred lines were initiated with formation of three sets of complete diallels, each involving 12 inbred lines.

One hundred and eighty (180) single cross and 60 3-way cross hybrids were developed from elite insect resistant maize inbred lines using CML78 and CML444 as testers. They were evaluated for resistance to insects, diseases, random drought and low nitrogen stresses, as well as for yield potential and general adaptation at five KARI centers. Data from Kiboko site are encouraging and there is possibility of identifying good three-way cross (TWC) hybrids to nominate to the maize national performance trials in Kenya. Some TWC hybrids were much better than the checks in grain yield and stem borer resistance as measured by both stem borer damage scores and leaf toughness (Figure 7).

More than 400 elite maize hybrids from CIMMYT maize international trials were evaluated at KARI centers for insect resistance, grain yield potential and general adaptation. These are for adaptation at various locations: (2001 EVT14B (IEWV0103), CHTTEW 2001 (IEWH0107), CHTTWQ 2001 (ILWQ0109), and CHTTWQ-NCH/S 2001 (ILWQ0111) for humid tropical lowlands at Mtwapa). Others were EPOP01, ECA-EE-VT, ECA-DTLN-VT-50, ECA-DTLN-HTA, and ECA-DTLN-HTB for midaltitude dry at Kiboko. Others included ILPOP01 (FIWV0182), EIHYB01EA (FEWH0184), and ILHYB01E (FIWH0185) for midaltitude moist and transitional areas at Embu and Kakamega.

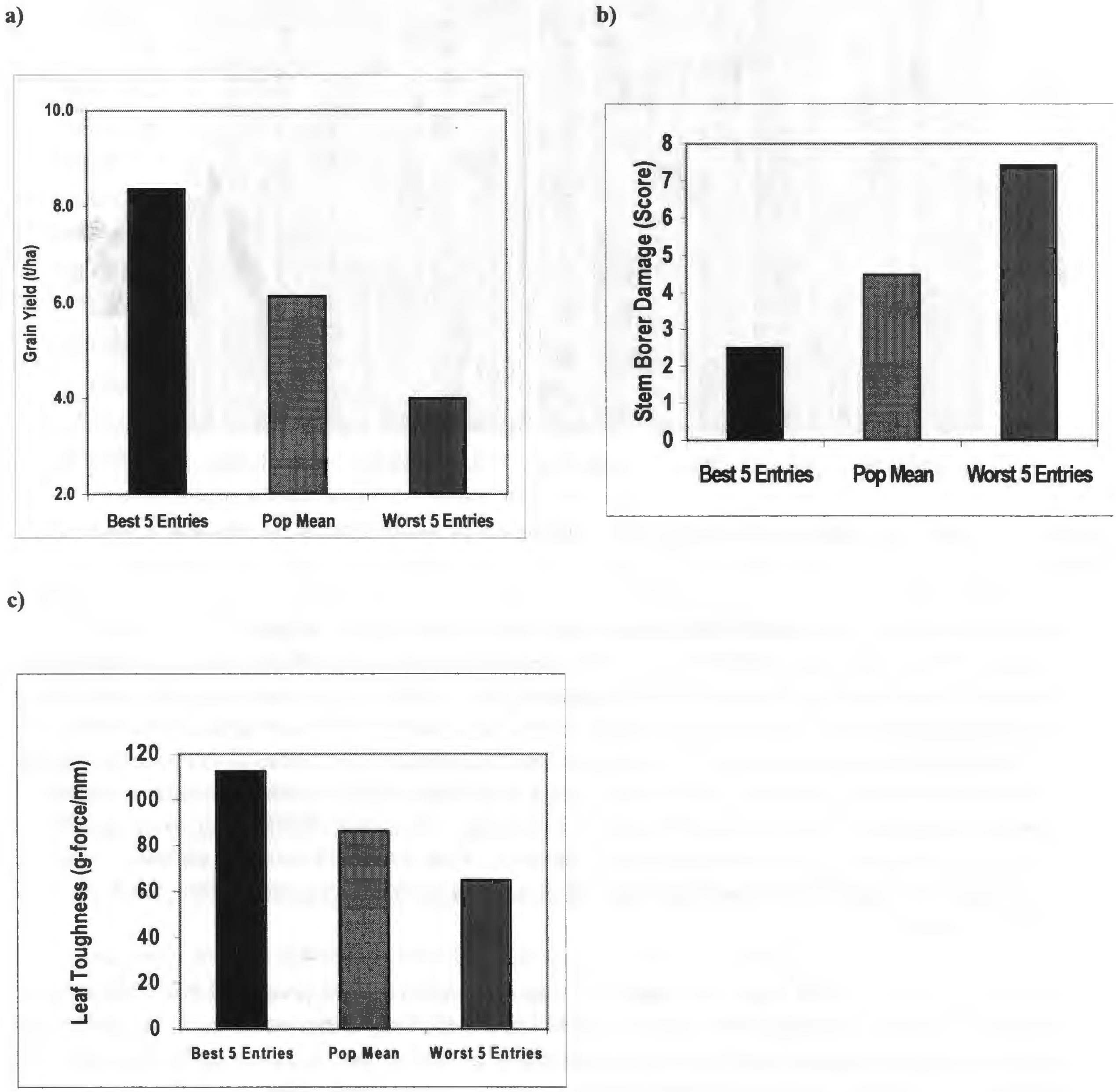

Figure 7. Grain yield (a), stem borer damage (b), and leaf toughness (g-force) (c) for three sets of 3-WC hybrids grown at Kiboko during 20002B season

Product Dissemination

Development of insect resistance management strategies for Kenya

Development of appropriate insect resistance management strategies for resource poor farmers in Kenya continued, with evaluation of putative crop species for refugia at Mwapa, Embu, Kakamega, and Kitale. Sorghum varieties were the best alternate host for stem borers, generating 2.5 times as many moths per unit area as maize. Wild Columbus and Sudan grasses were effective refugia, generating 4 and 2.5 times as many moths as maize, respectively. Napier grasses attracted moths for oviposition but were not productive hosts, generating only 15% as many moths as maize per unit area.

Bioassays were conducted to assess the suitability of alternate hosts for maize stem borers. Larval development time and fitness of moths were measured when the stem borers were reared on 16 different alternate hosts representing sorghums, maize, wild grasses groups. Results from these bioassays have important implications for the synchrony of emerging adults between the refugia and *Bt* maize.

A vegetation survey protocol for insect resistance management (IRM) was developed to quantify the distribution and abundance of alternate hosts for maize stem borers in Kenya and also to estimate the percent area planted to maize relative to alternate host species for stem borers and their proximity to each other. With this information, we can identify regions where natural refugia are sufficient to o*Bt*ain the 20% maize equivalents recommended by IRM specialists. The survey questionnaire was tested with both commercial and small-scale farmers in the Trans-Nzoia district, and the humid coastal lowlands (Kilifi district). In Kilifi district, there were 21% refugia within the existing cropping system (Table 20). However, in the Trans-Nzoia district, maize is grown predominately as a monoculture and the natural refugia was not adequate. Structured refugia will be required in that region. Surface maps will be generated to identify areas that pose a high risk of resistance development, to ensure that these areas are surveyed.

Potential effects of non-target arthropods

To characterize target and nontarget arthropods of *Bt* gene-based resistance in four major maize growing regions in Kenya, baseline studies were continued to establish the diversity and relative abundance of target and nontarget organisms associated with maize cropping. Field collections were completed and the samples sorted to facilitate identification of family and genus (Table 21). Digital photos were taken of a representative number of specimens; these were entered into a database for easy access by regional offices. A core and reference insect collection has been established at KARI-Katumani. Collection data are now being formatted for use in a GIS to facilitate future monitoring efforts, once *Bt* maize has been introduced. This database will enable targeted monitoring of regions where insect species may be adversely affected by *Bt* maize and enable efficient and effective monitoring of any adverse impacts at an early stage of release.

There was significant progress at the insectary at Katumani in synchronizing insect production with field infestations to ensure high quality infestation to screen maize germplasm. Artificial infestations at Kiboko, Mtwapa, and Embu functioned well with *C. partellus* and *B. fusca*.

A study was conducted on the nontarget effects of a *Bt* biopesticide (Thuricide™) and conventional insecticides (Dimethoate) on arthropods in a maize/bean cropping system. Using a RCB design, the experiment was repeated over two seasons at the KARI-Katumani research station and showed that Thuricide provided more effective stem borer control than Dimethoate. Dimethoate had a more adverse impact on nontarget arthropod diversity (families) and abundance. Both Dimethoate and Thuricide reduced the range of parasitoids that were recovered, compared to the untreated control, which in part could be explained by the absence of hosts.

In screening trials using two *Diatraea spp.*, the stem borer have not developed resistance to *cryIAb* after 30 cycles of selection. This study indicates that for pyralids (i.e., *C. partellus*), resistance has held up well under an ideal selection regime. However, for geometrids (i.e., *B. fusca* and armyworms) this may not be the case, and screening trials similar to those done in Mexico will be initiated once the biosafety greenhouse in NARL is operational.

Screening for resistance to storage pests

To characterize maize cultivars for resistance to post harvest pests in Kenya, candidate germplasm for receiving the *Bt* gene was evaluated for storage pest resistance under artificial infestation. Germplasm from five trials were evaluated during 2002, with several hybrids and varieties being identified with moderate levels of resistance against the maize weevil, *Sitophilus zeamais*. The most promising materials were (hybrids) CKT015015, CKT015017, SYNTH-NUE, CKT016017; (varieties) NIP25, FAW/NON-Tux, SYNTH-DR, CMTQ016001, PL15QPMc7-, POOL16SE, DTP C1 Zambia, KATUMANI-S, POOL16SR.

Gene flow studies

Gene flow studies were planted with white and yellow endosperm maize cultivars grown in four directions to estimate distances and directions to which the xenia effect will be detected in the white endosperm cultivar, as a measure of distance and directions that pollen moves. About 120 plants of the yellow endosperm variety were planted as source of pollen. Plants of the white endosperm variety were grown in three rows at right angles, each of the three extending to 50 m in the four directions. The yellow and white varieties were of similar maturity. Measurements were made on the distance to which xenia effect was observed from the source of yellow pollen. The percentage of grains showing xenia effect was observed in all four directions. The trial was replicated at two locations.

Table 20. Vegetation survey results for Mombasa/Kilifi district to assess the availability of natural refugia within the existing cropping system.

Location	Total area (ha)	Area planted	% maize	% loss due to borers: No control	% loss due to borers: Control	Natural refugia (%): by farm	Natural refugia (%): by area
Chilulu	3.0	1.6	44	64	19	12.9	10.1
Kaloleni	2.7	2.5	36	62	27	37.2	50.3
Dzombo	4.5	4.0	52	76	25	13.2	10.6
Mtwapa	4.0	2.4	18	53	12	22.1	19.1
Township	1.8	0.9	28	62	15	41.0	35.4
Ziani	3.7	2.5	40	63	19	10.5	12.2
Means	**3.3**	**2.3**	**36**	**63**	**20**	**22.8**	**22.9**
				Estimate of district			**18.2**
				Desired refugia (minimum)			**20.0**

Table 21. The most abundant and beneficial arthropods recovered from the major maize cropping systems in Trans-Nzoia District during the year 2001.

Abundant	Potential biological Control Agents: Parasitoids	Potential biological Control Agents: Predators	Pollinators
Ants	*Cotesia sesamiae*	Ants	Honey bees
Crickets	*Dentichasmias busseolae*	Spiders	Hoverflies
Long-legged flies	*Flesh flies*	Ground beetles	
Muscid flies	Muscid flies	Ladybird beetles	

Impact Assessment

Baseline data collection was initiated, and support was received from IPGRI to add a biodiversity component to the baseline data. Biodiversity analysis of the PRA data show that the high potential areas are richer in maize biodiversity than the dry areas, and that in the dry areas the most popular varieties are also more dominant. From the maize seed industry data, liberalization has largely increased the number of seed distribution points and, to a lesser degree, the number of seed producers. New companies and varieties have made most progress in the moist midaltitudes, but not so in the highlands and low-potential areas.

A study of informal credit groups in Siaya district showed that members who borrowed from the group use significantly more inorganic fertilizer (19.4 kg vs 6 kg), and improved maize seed (4 kg vs. 2 kg), and so obtained a significantly higher output (845 kg vs. 616 kg). These figures are from the parcels planted with maize.

At the Kenyan coast, an inventory was made of NGOs working in agricultural activities, and found out that although they can complement conventional agricultural extension and be important at the local level, they are limited in comparison to conventional extension. A study was made of consumer awareness about the GMO issue. Very few urban consumers have knowledge of GMOs, and it would not, at the moment, influence their consumption pattern. To capture the opinion of highly educated groups, university professors were also interviewed. Most were informed about GMOs, but many perceived them as risky.

Technology Transfer

In technology transfer, training in biosafety facilities was emphasized in 2002. A small team of KARI and CIMMYT scientists benefited immensely from interacting with Diego Gonzalez de Leon, a biotechnology consultant, and Dave Hoisington, on greenhouse designs and functions. Christopher Ngichabe, Head of Biotechnology in KARI, visited CIMMYT-Mexico to further study the design and functions of the biosafety greenhouse facilities of the CIMMYT ABC.

Training in the field and laboratory activities of entomology took place in Kenya. A schedule was elaborated mainly for training in biosafety operations. One KARI scientist started six month training at CIMMYT-ABC in Mexico in transformation and molecular analysis, while a second one will start in early 2003. Three scientists from KARI and KEPHIS were trained on the management of biosafety facilities at CIMMYT-Mexico. KEPHIS and KARI scientists trained 10 Kenyan researchers on the management of open quarantine field facilities. Six management-level scientists from KARI, KEPHIS, the Ministry of Agriculture and Rural Development (MOARD), accompanied CIMMYT scientists in visits to institutions dealing with the development and regulation of biotechnology and biosafety facilities in USA and Mexico in October 2002. One entomologist from KARI visited CIMMYT-Zimbabwe to learn about the maize weevil resistance breeding project underway there.

Among facilities developed were the open quarantine site at Kiboko, and designs were completed for a greenhouse at KARI biotechnology center. Equipment purchased included a computer for NARC Kitale, and a water purifying system and standby power generator for the Katumani entomology laboratory. Cameras were obtained for socioeconomists and a PCR system for the biosafety laboratory at KARI biotechnology center.

Documentation and Communication

In documentation and communication, emphasizes was laid on reaching extension service of MOARD, farmers and other stakeholders. Seminars were held for about 120 lead extension staff of the MOARD in the major maize growing regions of Kenya. The seminars were to inform extension staff about *Bt* technology and the IRMA project. They were also meant to identify (1) additional information areas the project needs to address, (2) good communicators among extension staff, and (3) effective messages for possible use in video and/or radio productions. The latter will likely comprise low-cost, straightforward productions for direct use with farmers. Other objectives were to refine a series of fact sheets on *Bt* maize through feedback and suggestions from extension workers.

Six fact sheets were developed on various aspects of *Bt* maize and its management. Three rounds of reviews (the last by five different panels) were made to develop a format and appropriate language for use at the extension level. Final production awaits synthesis of the input and production of more suitable graphics.

Seminars were presented to various groups. The major ones were (1) the ABSF Inter-institutional Seminar held at KARI NARL in March 2002; (2) the symposium "Perspectives on the Evolving Role of Private/Public Collaborations in Agricultural Research," organized by the Syngenta Foundation for Sustainable Agriculture, Washington, D.C., USA, the Syngenta staff in Greensboro, NC, USA, and the Syngenta staff in Basel, Switzerland, all in June 2002; (3) the World Summit on Sustainable Development (WSSD) for Regional Parliamentarians and Policy Makers, with participation of 35 MPs from Kenya, Uganda, Malawi, Ethiopia, Zambia, Tanzania, and Zimbabwe; (4) a seminar to the RECONCILE Monthly Public Forum at Nakuru, Kenya, in September 2002; and (5) a seminar at the MOARD Rift Valley Province, Nakuru, October 2002.

Documents produced included: (1) the 2001 Annual Report (No. 6); (2) the 2001 Stakeholders Meeting (No. 7) technical report, which was presented to the Syngenta Foundation; (3) three IRMA Project quarterly reports; (4) three issues of the IRMA Updates quarterly newsletter circulated to about 200 recipients and posted on the IRMA website; (5) an article describing the work on refugia in the CIMMYT Annual Report; and (6) scientific papers presented in various fora and/or published.

Monitoring of the print media continued through the clipping service and periodic review of the reports. Approximately 100 articles and 30 editorials related to agricultural biotechnology, mostly on maize, appeared in the major Kenyan newspapers during 2002. Five feature type articles had an IRMA focus. Slightly less than half of the total articles and editorials were related to GM maize and the food crisis in southern Africa.

Concluding Remarks

We are confident that, through these activities, the purpose of the IRMA project—putting improved maize varieties with insect resistance into the hands of the Kenyan farmer—will be achieved. We hope that this project will serve as a positive example to other nations on how to develop partnerships between projects and institutions in the region to safely and responsibly put this technology to work for the betterment of our people and our nations.

IRMA Publications in 2002

De Groote H. 2002. Maize yield losses from stem borers in Kenya. Insect Science and its Application, 22 (2): 89-96.

De Groote H., C. Bett, L. Mose, M. Odendo, J. O. Okuro, and E. Wekesa. 2002. Direct measurement of maize crop losses from stem borers in Kenya, preliminary results from the 2000-2001 season. Paper prepared for the 7th Eastern and Southern Africa Regional Maize Conference, Nairobi, Kenya, 11 - 15 February 2002

De Groote H., B. Overholt, L. Macopiyo, J. O. Okuro, S. Mugo. 2002. Guiding technology development through a GIS based Ex Ante Impact Assessment model: the Case of Insect Resistant Maize in Kenya. Poster presentation prepared for the International Conference on Impacts of Agricultural Research and Development: Why has Impact Assessment Research Not Made More of a Difference? 4-7 February 2002, San José, Costa Rica. International Maize and Wheat Improvement Center (CIMMYT).

De Groote H., J. O. Okuro, C. Bett, L. Mose, M. Odendo, E. Wekesa. 2002. Using participatory methods to quantify functional biodiversity in maize and to measure the effect of by biotechnology on biodiversity. Poster presented at the 10th Congress of the European Association of Agricultural Economists (EAAE) Congress, Zaragoza, Spain, August 28-31, 2002.

De Groote H. 2002. Comparing and integrating farmers' and breeders' evaluations of maize varieties in East Africa. Presentation prepared for the workshop on "Quality of Science in Participatory Plant Breeding", IPGRI, Rome September 30- October 4, 2002.

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Strengthening Maize Seed Supply Systems for Small-Scale Farmers in Western Kenya and Uganda

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Introduction

Other CIMMYT projects in ECA have recognized and addressed in a limited way a key constraint faced by poor, smallholder farmers: a lack of access to quality seed of improved maize varieties. In 2000, CIMMYT-ECA initiated a project that focuses on strengthening maize seed supply systems in western Kenya and Uganda.

The project "Strengthening Maize Seed Supply Systems for Small-scale Farmers in Western Kenya and Uganda" (hereafter referred to as the Seed Project), was initiated by CIMMYT, the Kenya Agricultural Research Institute (KARI), and Uganda's National Agricultural Research Organization (NARO), with funding from the Rockefeller Foundation. The aims are to improve food security and reduce poverty by increasing farmers' access to affordable, quality seed of improved, locally adapted varieties of maize. To accomplish this, project participants are working to improve the local capacity for seed production and distribution. The project covers midaltitude Uganda and the Lake region, mainly the Nyanza Province of Western Kenya. Maize is important for Kenya and Uganda, as evidenced by the large area under production of this crop. It is the major staple in Kenya and increasingly important in Uganda. In both countries, per capita consumption of maize is high, maize grain provides around 40% of inhabitants' calories, and the demand for maize is increasing by 3.0–3.5% annually, due among other things to rising populations. Despite the importance of maize as a source of food and livelihoods in the region, maize yields average only 1.5 t/ha.

Seed is a strategic input—the most important and least expensive one—and provides a high rate of return on investment, sets the upper limit on productivity, is the easiest technology for farmers to adopt, and its availability often determines whether or not farmers sow. The constraints to seed availability include the lack of any or all of the following: (1) effective seed production and distribution systems; (2) a suitable testing system, whereby farmers can help evaluate maize cultivars and which ensures effective feedback; (3) interest on the part of private seed companies in resource poor farmers as a market; (4) inappropriate choice of seed by non-government organizations (NGOs) working in agricultural development or disaster relief programs, mainly because they lack of reliable information.

A team of three scientists; an overall coordinator, and a country coordinator in each of Kenya and Uganda manage the project.

Objectives

The project seeks to: (1) strengthen the capacity of breeders to produce breeders seed; (2) identify improved maize cultivars for testing through mother and baby trials; (3) work with farmers to develop a sustainable system for seed production and distribution; and (4) help assure quality control in all phases of seed production.

Achievements 2000-2002

Strengthening capacity of breeders to produce breeder seed

The capacity of KARI and NARO national programs to produce breeder and foundation seeds has been increased through the provision of infrastructure, including improved seed storage, irrigation, and small processing equipment.

Identify improved maize cultivars for testing through mother and baby trials

Improved maize cultivars preferred by farmers have been identified through evaluation of more than 100 improved cultivars grown under optimal and sub-optimal fertility conditions, with researcher and farmer management, and using the mother and baby trial designs that enables wide exposure of technology and includes dialogue and feedback among farmers and researchers. Data from the on-farm mother and baby trials have been used to support release of varieties after testing in the national performance trials. As examples, Kakamega Synthetics 1 and 2 were released in Kenya in 2002.

Results of multi-location trials and farmer evaluations from the nearly 200 mother and baby trials in 6 districts in western Kenya and 2 districts in Uganda indicated that the approach greatly enhanced farmers' knowledge base and generates information that complements breeders' efforts to develop well-adapted and acceptable maize varieties.

Work with farmers to develop a sustainable system for seed production and distribution

Individual farmers and farmer groups are participating in on-farm seed production varieties of their choice involving the quality control authorities in Kenya and Uganda. Experiences with farmer associations—mainly women's groups—have showed that farmers can produce good quality seed if offered training and assured of markets. Farmer associations improved production of seed in northern Uganda and western Kenya (where these are less developed than in eastern Uganda). Sustainability has been built into the associations by ensuring availability of improved maize varieties and seeds as well as establishment of business approach and markets within the seed producing communities.

Assuring quality control in all phases of seed production

The capacity to produce quality seed has been built in through the training of more than 120 KARI, NARO, government extension, seed companies, and NGOs staff, and farmers in Kenya and Uganda in maize seed production and management.

Others achievements

An unexpected output was the use by local extension staff of the mother and baby trials and the on-farm seed production plots as demonstration plots and for farmer field days on agronomic practices, especially soil fertility management in Uganda.

CIMMYT Economics Program, East Africa: Activity Report for 2002

Hugo De Groote

Introduction: The CIMMYT Economics Program

CIMMYT is primarily a crop improvement institute and most of its scientists are plant breeders or agronomists. A small team of social scientists, however, primarily agricultural economists working in the CIMMYT Economics Program (CEP), supports their research. The socioeconomists' principal role is to ask and answer questions about the focus, organization, and impacts of CIMMYT's maize and wheat research activities. Are our research programs targeting the right set of technologies? Are the products of our research programs reaching poor farmers in developing countries? If they are reaching poor farmers, are they contributing to our mission of improving productivity, alleviating poverty, and increasing the sustainability of the natural resource base? Are we being efficient in the way we conduct our research? Does our portfolio of research activities require adjustments? Should we undertake new research activities that are not currently on the agenda? Should we abandon some existing activities? CIMMYT socioeconomists analyze the elements of success, from farmers' fields to the global marketplace. The CEP's activities fall into five broad categories: (1) assessing impact and technology adoption, (2) economic analysis and participatory evaluation of emerging technologies, (3) economics of genetic diversity, (4) sector and policy analysis, and (5) setting research priorities.

In Africa, CEP has two agricultural economists, covering Southern Africa (from the Harare office) and Eastern Africa (from the Nairobi office), and working in collaboration with social scientists from NARS, universities, and other research institutes. In East Africa, CEP contributes to a number of projects, including insect resistant maize, IR maize against *Striga*, quality protein maize, stress tolerant maize, and the seed systems project. The social scientists contribute to economic analysis and impact assessment of these projects, but also conduct studies from a larger perspective, studying the maize sector as a whole, or particular institutions such as maize markets, informal credit groups, and market information systems. This section presents an overview of the activities of CEP in East Africa, with summaries of the results and a list of publications.

Impact Assessment

This section covers the estimation of the demand for new technologies, studies of their adoption, and ex-post impact assessment.

Adoption studies
The results of the adoption studies concerning maize technologies (improved seed and fertilizers) were discussed in last year's report. This year the studies from the Coast (Wekesa, 2002) and Embu (Ouma et al., 2002) were finalized and edited. A synthesis of all eastern African adoption studies was also produced (Doss et al. 2002).

IRMA crop loss assessment
A first paper analyzed secondary data based on farmers' estimates of crop loss (De Groote, 2002a). The yield loss was estimated to be 12.9%, amounting to 0.39 million tons of maize with an estimated value of US$ 76 million. High-potential areas have relatively low crop loss levels (10–12%), while the low-potential areas have higher losses (15–21%). Taking into account the higher yield of the former areas (more than 2.5 t/ha), the loss per hectare is remarkably constant, between 315 and 374 kg/ha, except for the dry midaltitude zones, where losses total approximately 175 kg/ha.

The direct estimates from the 2000-2001 seasons were analyzed and presented in a second paper (De Groote et al., 2002c). The final estimate of crop loss (Table 22) is 14.1% for the long rains, 8.4% for the short rains, and 13.5% for the whole year. This is within less than 1% of the previous estimate, calculated from farmers' perceptions. Total loss is then estimated at 0.42 million tons of maize.

Table 22. Estimation of crop losses based on field observations.

	Long rains			Short rains			Total			
	production	loss		production	loss		production	loss		
	1000 ton	%	1000 (ton)	1000 ton	%	1000 (ton)	1000 ton	%	1000 ton	Farmers' estimate*
Lowland Tropics	45	9.0	4.4	8	6.1	0.5	53	8.5	5.0	20.3
Dry Midaltitude	122	17.0	25.0	40	8.4	3.7	162	15.0	28.7	14.6
Dry-Transitional	45	26.0	15.8	32	8.4	2.9	76	19.8	18.8	20.7
Moist Midaltitude	170	13.1	25.7	62	5.6	3.7	231	11.3	29.4	12.3
Moist-transitional	1,170	16.6	232.7	64	16.6	12.7	1,234	16.6	245.4	9.9
Highlands	893	9.0	88.0	16	9.0	1.6	909	9.0	89.6	20.7
Total	2,395	14.1	391.7	276	8.4	25.1	2,671	13.5	416.8	12.9

*Based on a farmers' survey (Hassan, 1998), for calculation see De Groote (2002).

The economic analysis of stem borer control is presented in third paper (Wanyama et al., 2002). The value of the loss in the long rains is estimated at 3,661 Ksh/ha, while the treatment cost is estimated at 1,847 Ksh/ha (Table 23). The average net benefit of the treatement in the long rains is calculated at 1,814 KSh, or slightly less than the cost. The marginal return (marginal benefit/marginal cost) is therefore just below 1. It is generally assumed that for a technology to be interesting to farmers, the marginal return should be more than 1.5. We conclude that, on average, stem borer control is cost effective but the marginal return is too low for general application. Therefore, an economic injury level needs to be determined.

Table 23. Economic analysis of stem borer control.

	Long rains	Short rains	Total
Yield loss (kg/ha)	390	186	576
Revenue loss (Ksh /ha at Ksh. 11 per kg)	3,661	2,244	5,905
Cost of insecticide application (Ksh/ha)	1,847	1,847	3,694
Net Revenue from stem borer control (Ksh/ha)	1,814	397	2,211
Marginal return (marginal benefit/marginal cost)	0.98	0.22	0.60

Source: Wanyama et al. (2002)

IRMA impact assessment

The average price of maize in Kenya during 1997-2000 was $193/ton. The 0.42 million tons of maize lost yearly to stem borers can thus be valued at US$ 80 million.

To estimate the economic impact of maize for different agroecological zones and resistance against different species, a model was developed in collaboration with ICIPE to combine crop loss estimates with production data, species distribution, and efficacy of particular genes (De Groote et al., 2002b). The results show that *Busseola fusca* is the major cause of economic loss due to stem borers (82% of all losses), followed by *Chilo partellus* (16%), while losses from other species are negligible (Figure 8). More than half the losses occur in the moist transitional zone, followed by the highlands, which are also the zones with the highest adoption rates. It follows that a *Bt* gene effective against *B. fusca* and incorporated into varieties for these two zones would be most likely to bring high returns.

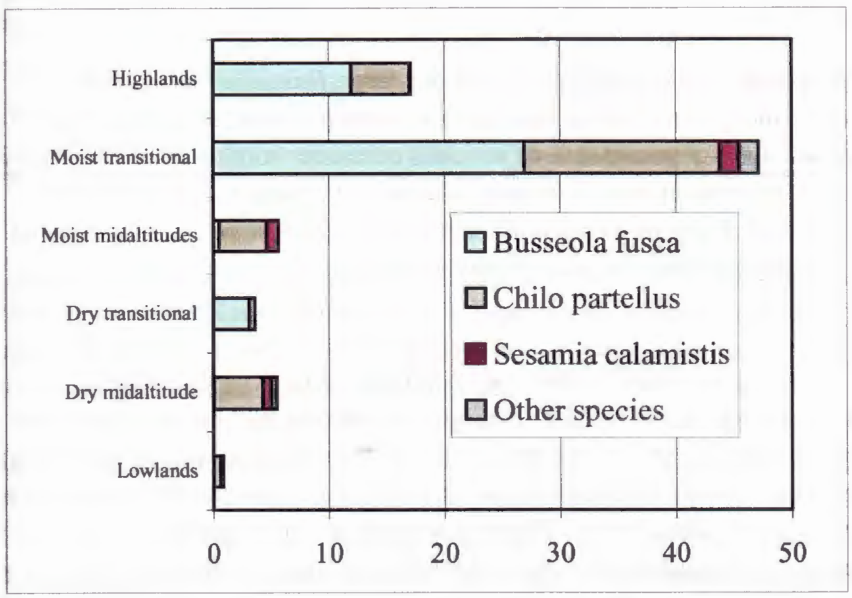

Figure 8. Crop loss by species and agroecological zone (US$ million).

A reduction of crop loss through the adoption of new resistant varieties will lead to a shift in the supply function. At the same time, this will reduce prices, leading again to a supply reduction. In the new equilibrium of demand and supply, not only do the farmers profit, but also the maize consumers. To calculate the benefits, an economic surplus model (Alston et al. 1998) with standard assumptions (supply elasticity=0.8, demand elasticity=-0.4, discount=10%, closed economy, adoption is linear and starts at 5 years) was used. The cost of the project, which started in 1999, is US$ 1 million, and is expected to last 10 years. In a first scenario with full resistance to all stem borers, the yearly benefits reach $49 million per year, two-thirds of which go to consumers (Table 24). Discounted benefits over 25 years reach $ 208 million, compared to discounted costs of $ 6.8. This produces a benefit/cost ratio of 31:1 and an internal rate of return of 83%. In the second scenario, no resistance to *B. fusca*, yearly benefits reach only $ 5 million. Total benefits over 25 years reach $24 million, with a B/C ratio of 3, and an IRR of 30%.

Table 24. Impact assessment - Economic Surplus Model (using 10% discount rate, 0.8 supply elasticity, -0.4 demand elasticity).

Scenario	Period	Economic surplus (benefits) Producer	Consumer	Total	Costs (discounted)	Benefit/ cost ratio	Internal Rate of return (IIR)
Resistance to all stem borers	1 year	16.3	32.7	49			
	25 years	69.5	139	208.5	6.76	31	83
No resistance to *B. fusca*	1 year	1.9	3.8	5.7			
	25 years	8.1	16.1	24.2	6.71	3.6	30

Source: De Groote et al. (2003).

If the project manages to find a *Bt* gene that is effective to the fifth stem borer, *Busseola fusca*, adoption rates are likely to be high, and therefore the returns. Under standard assumptions the economic surplus of the project is calculated at $ 208 million over 25 years (66% of which is consumer surplus), as compared with a cost of $5.7 million. In this case, the project should focus on the moist-transitional zone. However, if such a gene cannot be found, adoption of *Bt* maize would only take place in the low potential areas, and adoption rates would be fairly low, although benefits would still exceed costs.

IRMA baseline survey

Although the Participatory Rural Appraisals, executed in 1999 and 2000, give a first overview of the demand of insect resistant varieties, a more quantitative study is needed to confirm the results and to offer a baseline against which to compare the adoption of the new varieties. The baseline survey was initiated in the moist transitional zone around Embu. A stratified two-stage sampling design was used to select 150 farmers from 15 sub-locations in the agro-ecological zone. The agro-ecological zones formed the strata, and sub-locations the first stage, while farm households the second. Optimization was done based on Kenya Maize Data Base (KMDB), to obtain a precision of 5-10% root mean square error (RMSE) for each Agro-ecological zone for key maize variables, maize area, yield, household size and acres under major three varieties.

KARI enumerators administered a structured questionnaire to the selected farmers. The baseline data survey consisted of an update of the maize database, employing more extensive data on the actual use of different varieties, farmers' preferences, pest history, and farmers' assessment of crop losses.

The preliminary results (only 75 farmers) show that the H614, a late maturing hybrid is the most popular, grown by majority of farm households in the three districts of Nyeri, Muranga and Maragua (Table 25). The next two popular varieties are the shorter duration hybrids H511 and H512. The varieties imported by international companies, Pioneer's PHB3252 and Cargill's CG4141, are not that popular, and are grown by less than 6% of the farmers. The local variety seem to do better during the short rains season 2, thus has a higher number of farmers growing it during this season. The overall domination of improved varieties in the sample relative to the landrace points at the high adoption rate and willingness of the farmers in trying newly developed varieties.

Table 25. Number of farmers growing different varieties in the moist-transitional zone, (3 districts, 75 farmers).

	Long rains		Short rains	
	Number of farmers	%	Number of farmers	%
H614	37	52.9	13	18.6
H512	20	28.6	6	8.6
H511	17	24.3	4	5.7
H625	17	24.3	1	1.4
H513	7	10	9	12.9
Pioneer PHB3252	4	5.7	4	5.7
CG4141	2	2.9	1	1.4
Githigo (local variety)	2	2.9	3	4.3
Total	106	100	41	58.6

Concurrently with the baseline survey, IRMA is also describing, and characterizing all local varieties encountered. The Kenya National Gene Bank is collaborating and has agreed to conserve a sample of all varieties, and the International Plant Genetic Resources Institute has agreed to collaborate on the morphological and molecular characterization.

IRMA consumer survey

A maize consumer survey was initiated in collaboration with the University of Nairobi in October 2002. Over a hundred consumers were interviewed in supermarkets and at posho mills. Initial results indicate that very few consumers are aware of the existence of genetically modified organisms (GMOs). Supermarket clients buy their maize as pre-packed flour, and they do express brand loyalty and trust in those companies. Assuming awareness of GMOs increases with education, 20 lecturers of the Universities of Nairobi and Egerton were interviewed. Most expressed knowledge of GMOs, but many were not comfortable with their safety.

Participatory plant breeding

CIMMYT and KARI economists have been working with different projects to develop methodologies for participatory variety selection (Siambi et al. 2002). These methods have been adapted by scientists in other countries and are now being used in Kenya, Uganda and Ethiopia. The major purpose of participatory variety selection is to incorporate the farmers' perspective into breeding programs. This approach is expected to bring breeders' and farmers' evaluation closer together, since research found a substantial difference between the two (De Groote et al., 2002d). In the example of a trial from the semi-arid region of Kenya, the relationship between the farmers' order of preference and that of that of the breeder is analyzed by mapping each evaluated variety in a two-dimensional diagram, where the horizontal axis represents the farmers' rank and the vertical axis represents the breeders' rank (Table 26). It shows, for example, how variety EE-EAC-31 was selected first by farmers, but came only 6th in the breeders' evaluation. Varieties acceptable to both groups can be found in the top left corner. There are clearly three varieties appreciated by both: EE-EAC-31, EE-EAC-33, and EE-EAC–21. Two other acceptable but not outstanding varieties are EE-EAC-16 and EE-EAC–46. The breeders' top choice, EE-EAC-21, is ranked third by the farmers, but their second and third choices do not even show up in the farmers' top ten.

Table 26. Order of varieties as ranked by farmers (horizontal axis) and breeders (vertical axis).

	Farmers' Rank									
Breeders' Rank	1	2	3	4	5	6	7	8	9	10
1			EE-EAC-21							
2										
3										
4		EE-EAC-33								
5							EE-EAC-16			
6	EE-EAC-31									
7						EE-EAC-46				
8										
9										
10										EE-EAC-9

The Economics of Emerging Technologies

Imazapyr resistant maize against *Striga*

In PRAs carried out in the moist midaltitudes in the Lake Victoria basin, *Striga* was identified by farmers as their first constraint (Odendo et al., 2001). A new technology developed by CIMMYT uses a natural mutation in maize that makes it resistant to the herbicide imazpyr (Kanampiu et al., 2002). A coating of the seed with the herbicide (equivalent to 30 g/ha), results in an almost complete suppression of *Striga* (Figure 9). On-farming testing showed an increase in yield from 1 ton to 3.5 ton (Figure 10), and the economic analysis showed an increase of net benefits of 513 $/ha, for a cost of $4/ha.

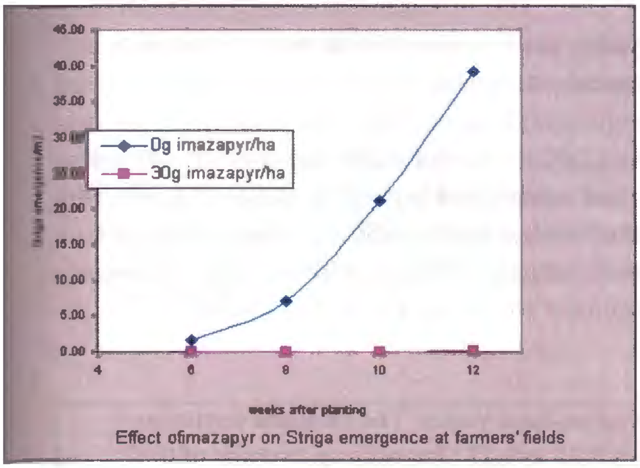

Figure 9. Effect of IR maize on *Striga*.

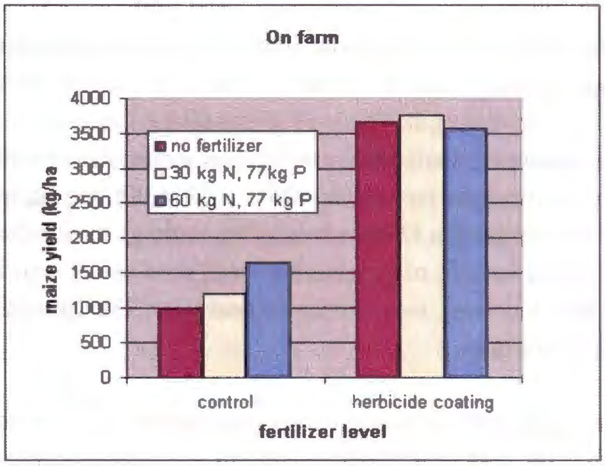

Figure 10. Maize yield with and without IR.

Economic analysis of quality protein maize for feed

CIMMYT scientists have developed a type of maize whose grain contains much higher levels of the essential amino acids, lysine and tryptophan, significantly increasing the quality of the grain protein. Nitrogen retention in the body—the biological value for those who consume this quality protein maize (QPM)—is about 80%, compared with only 40-57% for normal maize and 86% for eggs. It is also estimated that the protein of normal maize has a biological value of about 40% that of milk (often used as a reference for protein quality), whereas QPM has about 90%. An analysis of the economic value of QPM for the feed industry, using linear programming methods, showed that broiler feed of the same quality can be produced 5% cheaper with QPM. The calculated ratios, one with regular maize and one with QPM, were then produced by a local feed miller in September 2002. The two mixes were used in a comparative feed trial with batches of 100 broilers each, on-station and on three farms. Statistical analysis found no differences in feed intake, growth rate, or taste between birds raised with the different feeds. Since feed costs make up about 70-80% of production cost, a 5% reduction in feed costs through use of QPM could bring down the cost of broiler production by 5% x 80% = 4% (Nyanamba et al., 2003).

The economics of recycling hybrids

The IRMA PRAs revealed that Kenyan farmers frequently recycle maize hybrids—that is, they sow seed saved from previous harvests, rather than purchasing fresh seed. Farmers said there was a decrease in yield, but not a large one. Consequently, given the high cost of seed, recycling hybrids is often economical, especially when the farmer faces a cash constraint. To understand the economics of hybrid recycling, on-farm yields were measured in Embu and Kitale. In Embu, farmers recycled two hybrid varieties: H513 (an older variety from the Kenya Seed Company) and PHB3253 (more recently introduced by Pioneer). Yields of plots with fresh seed were measured, as well as with once and twice recycled seed (Figure 11). Fresh H513 seed produces 3.5 t/ha, but the yield decreases to 3.0 t/ha after recycling, and stays the same after twice recycling. The yield of PHB3253, on the other hand, does not change much between fresh seed and once recycled, 3.2 and 3.1 t/ha respectively. At the second recycling (or third generation), however, it drops dramatically to 1.0 t/ha. The OPV also had a yield of 3.0 t/ha, but the farmers could not recall the number of times this variety had been recycled. These results should be interpreted with caution, given the limited number of farmers involved (N=35). Moreover, the comparisons are not pair-wise in an experimental setting: yields were measured in farmers' fields, and type of variety and the number of recycling noted from farmers' interviews.

The economic analysis shows that, at a current price of KSh 8,000/ton (about $100), the economic loss of recycling ranges from KSh 400 to KSh 4,000 per ha in the first season, and between Ksh 40 and 8,000 for the second season. This needs to be compared with the cost of seed, currently KSh 2,750/ha. Clearly, the economic benefit of purchasing fresh seed every year is small compared to the cost in the first year and, for H513 at least, even in the second year. The limited data do not encourage a recycling of PHB3253 more than once.

The statistical analysis shows a high variance in the observed on-farm yields. The standard deviation within the different variety x generation classes ranges from 0.21 to 1.72 t/ha, with an average of 0.67 t/ha. This implies that to measure an average yield with a confidence interval of +/- 100 kg/ha (with 5% precision), a sample size of more than 170 plots is required, and for a conficence interval of +/- 100 kg/ha, 42 plots are required. Clearly, to obtain accurate estimations, much larger sample sizes are required than was possible in this study. Alternatively, the experiments could be more controlled or include more control variables such as soil fertility, rainfall and date of planting.

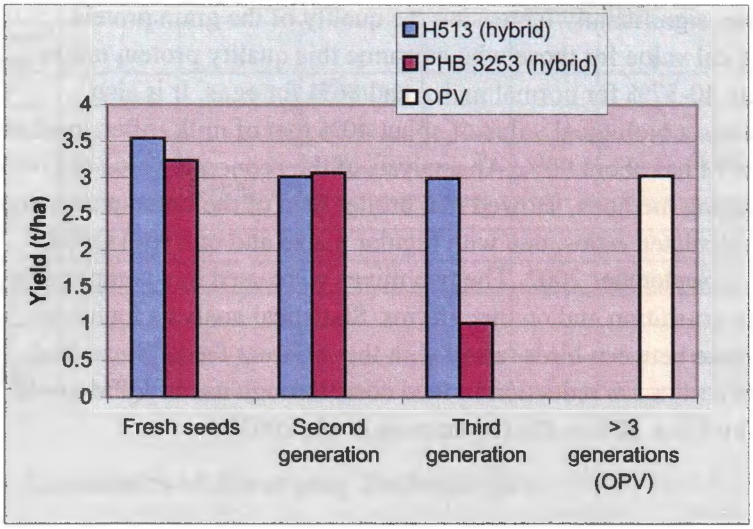

Figure 11. Yields of recycled maize hybrid varieties.

The results in Kitale (21 farmers so far entered from a total of 60) are similar. Three groups of farmers were distinguished, depending on management level. Farmers with low management level saw their yields reduced from 1.58 t/ha for fresh hybrid seed to 1.02 t/ha for recycled seed. For farmers with medium management skills the difference was very small (1.65 vs. 1.57 t/ha), and in high management farms the yield of fresh seed was actually slightly less than the recycled (2.20 vs. 2.25).

Economics of genetic diversity

The data from PRAs were further analyzed regarding maize biodiversity (De Groote et al. 2002). The number of local and improved varieties is presented in Figure 12. Five indices were calculated for each site: the Margalev index (richness) and the Berger-Parker index (dominance). From average indices across sites by zone, dry areas are clearly less rich in biodiversity than wetter areas and the high potential areas are richer than the low-potential areas. In the dry areas the most popular varieties are also more dominant. The highlands clearly face more dominance (caused by the very popular H614 variety) than the other high potential area, the moist transitional zone.

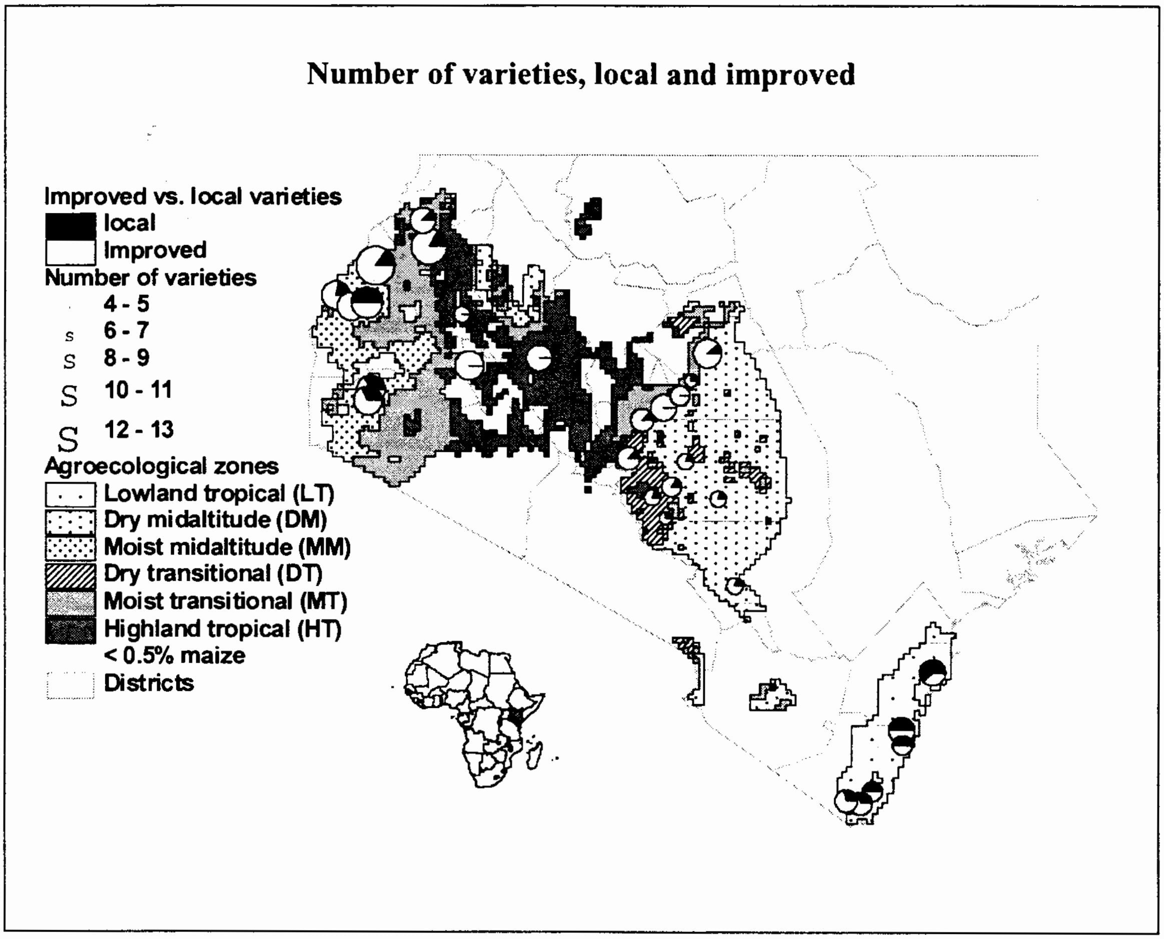

Figure 12. Number of varieties grown at each site.

Sector and Policy Analysis

Maize seed sector in Kenya

After analyzing the maize seed sector of the semi-arid area of eastern Kenya (Muhammad et al., 2002), the study has moved to the national level. An inventory of all 35 registered seed producers was established, and all 7 registered maize seed companies and some of the regulatory offices (such as KEPHIS) were visited. Seed companies were very hesitant to share information, especially sales and production data (they fear competitors might use the information to gain an advantage), so data on two major companies are still lacking. A first paper was written (Ely et al., 2002) and an overview document of the maize seed industry with the existing laws and regulations is being prepared. During the next phase, case studies will be undertaken to understand current practices.

Maize seed sector in Tanzania

Another study analyzed the seed sector in Tanzania (Lyimo et al., forthcoming). Since the mid-12970s, the National Maize Research Program (NMRP) has released about 15 improved OPVs and hybrids. The foundation seed produced on State Foundation Seed Farms is sold to the government's Tanzania Seed Company (TANSEED) to produce certified seed. TANSEED was the major supplier of improved maize up to the liberalization of the mid-90s. Many new companies have entered the market, such as Dekalb/Monsanto, Pannar, Kenya Seed Company, Pioneer and Seed-Co, selling mainly hybrids. At the same time, several non-governmental organisations (NGOs), churches, individual farmers, farmer groups and other organisations have started community based seed production of OPVs. The seed produced does not qualify as certified, but is called quality declared seed (QDS). These new entries in the seed markets have not been able to make up the shortfall in seed production by TANSEED, especially for OPVs. While sales of hybrid seed decreased slightly from 4,806 to 4,545 tons during 1997-2000, sales of OPV seed decreased from 4,689 to 2,114 tons. Estimating the maize area in Tanzania at 2 million ha and assuming a seed rate of 15 kg/ha, we can calculate that the area planted in fresh maize dropped from 32% to 24%. If we consider once or twice recycled OPVs as improved varieties, the area under improved maize varieties can be estimated at 46%.

Maize production trends in East Africa

A study of the maize production trends in eastern Africa (Ethiopia, Kenya, and Tanzania) shows that maize yields increased substantially (from 1.0 to 1.5 t/ha during the early 1960s to mid-1980s). This increase can be attributed partly to the increase in use of improved maize seed varieties and fertilizer, which many farmers have adopted over the years. Adoption has stalled, however, in Kenya and Tanzania. Despite the liberalization of the seed and fertilizer sectors in these countries, sales have not increased. In Ethiopia, the maize sector is still largely under government control, and strong extension and credit programs increased the use of improved maize seed and fertilizer in the late 1990s. Maize production increased during the same period, which was also influenced by an increase in area. Maize prices collapsed though in 2001, leading to a decrease in adoption in 2002.

Maize markets in Kenya

Results of a study on the liberalization of maize markets showed that private sector participation at all levels in the marketing system has increased substantially, and there is easy maize movement and supplies to all parts of Kenya (Wangia et al., 2002). However, the liberalization was implemented without the formation of alternative marketing institutions, and maize price fluctuations increased substantially, due to competitive market forces with only limited moderation by the government through open market interventions and import tariffs. Real maize prices have increased slightly over the last 10 years, shielded from international prices by the import tariff. The rules of regional and worldwide trading organizations, however, will make this protection difficult in the future.

Informal credit groups in western Kenya

A survey in western Kenya studied the impact of informal credit groups on seed and fertilizer use and found it to be significantly positive (Owuor et al., 2002). Table 27 shows that group members who borrowed used more improved inputs (fertilizer and hybrid seeds) and obtained significantly higher output than farmers who did not belong or members who did not borrow. The use of fertilizer of borrowing members was 19 kg/ha, as compared to 8 kg/ha for non-members and 4 kg/ha for non-borrowing members. Similarly, borrowing members used 4 kg of hybrid seed per ha, as compared to 2 kg/ha for the other groups. As a result, the yield of borrowing members averaged 0.84 t/ha, compared to 0.67 for non-members and 0.52 t/ha for non-borrowing members. Lack of credit appears to be a major constraint to the use of improved maize production technology, and informal credit groups can alleviate that constraint. The groups face some difficulties: lack of training in management or access to external capital.

Table 27. Comparative analysis of three groups of farmer and their use or not of credit from informal credit groups.

Input/output	Non-members (G1)	Non-borrower members (G2)	Borrower members (G3)	t-test G2 vs G3	t-test G1 vs G3
Fertiliser/farmer (kg)	9.13	7.06	32.68	2.038**	2.313**
Hybrid seeds/farmer (kg)	2.83	3.36	6.58	3.029***	4.271***
Hired labour/farmer (person-days)	7.02	9.72	10.13	1.136	1.982*
Farm labour/farmer (person -days)	99.9	106.2	109.39	0.241	1.145
Pesticides (liters)	0.68	0	0.24	0.74	-0.758
Fertiliser/hectare (kg)	8.13	3.84	19.39	3.954***	2.450**
Hybrid/hectare (kg)	1.75	2.08	3.98	2.012**	2.568**
% maize hectares/ farmer	48.99	63.36	78.47	2.054**	4.124***
Maize production (kg/farmer)	897.15	834	1395	3.636***	3.973***
Maize yield (kg/hectare)	670.67	520.34	844.9	3.330***	2.468**

**** *= Significant at 0.01, ** = Significant at 0.05, *=Significant at 0.10.**

Potential role of NGOs in agricultural extension

To identify NGOs active in agriculture and assess their potential role in the dissemination of *Bt* maize and related technologies, an inventory of NGOs in the coastal region was assembled. A complete list of all NGOs was obtained from the MOARD and those active in agriculture were visited and interviewed. The study concluded that several NGOs are available as agricultural technology disseminators, but that their impact is likely to be small. Their number of technical staff (15 for all the NGOs) is small compared to agricultural extension agencies, and they lack technical skills and reach relatively few farmers (5,320). As a result, the NGOs can complement the classical agricultural extension but are unlikely to replace them in the near future.

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Engineering Striga-Resistant Maize

F. Kanampiu , A. Diallo, S. Mugo, H. De Groote and D. Friesen

Introduction

Of all the *Striga* species, *S. hermonthica* is considered to be the most important parasitic weed on a world scale. *S. hermonthica* is distributed throughout the semi-arid tropics of Africa. Estimates of grain loss due to *Striga* typically range from 15-50%, however, total crop failure has been observed under conditions of heavy infestation. This weed results in US$1 billion in lost yield and has deleterious impacts on the welfare and livelihoods of over 100 million people. *Striga* plants have a high reproductive capacity, producing 50,000 to 200,000 seeds per plant. *Striga* seeds are small, light, and easily dispersed by wind, water, animals and agricultural practices (e.g. transmitted by implements such as ploughs and unclean seed). The seeds can remain viable in the soil seed bank for at least 5 to 10 years—indeed, 20-year life spans have been reported. The large capacity for seed production coupled with lengthy viability creates conditions of high numbers of *Striga* seed in the soil seed bank in areas where the plant is endemic. This parasitic weed is not only spreading into new areas but also increasing in severity in areas already infested. The areas badly affected by *Striga* are also the areas where many of the poorest people use the highest percentage of maize in their diet. Farmers in areas where *Striga* is endemic need new approaches to contain it, for them to benefit from genetic gains made in maize improvement and crop management practices. As an alternative to agronomic and conventional breeding approaches, CIMMYT and the Weizmann Institute of Science have developed and demonstrated a highly promising technology with potential for high and immediate impact for controlling *Striga* in maize.

Activities during 2002 focused on herbicide formulations and application methodologies for effective *Striga* control and development of adapted imidazolinone-resistant (IR) maize cultivars. These studies are necessary to fine-tune seed-coating practices for the diverse soil and cropping conditions in the major *Striga*-infested agro-ecologies of sub-Saharan Africa and bringing the IR-trait into maize germplasm for those environments.

IR-Maize Germplasm Development

The initial phase of the project focused on testing the concept. Breeding efforts proceeded at a relatively low level: sufficient to provide IR materials for preliminary agronomic and formulation experiments. The IR source, PHB3245-IR developed by Pioneer Hi-Bred, was crossed to the ZM 503 (INTA/INTB) population by CIMMYT-Zimbabwe to put the gene into tropical maize germplasm for use by CIMMYT agronomist working at Kibos, Kenya. This material required heavy fungicide treatments to prevent crop loss from northern leaf blight (*Exerohilum turcicum*) and gray leaf spot (GLS; *Cercospora zeae-maydis*).

Having established proof of concept and the viability of the technology under Phase I, a full-scale breeding effort was launched under Phase II at Kibos and Kiboko, Kenya, to develop IR hybrids and OPVs fully adapted to prevailing biotic and abiotic stresses. Two approaches were used. In one, 283 segregating lines developed by selfing crosses between adapted lines and the IR source were sent from CIMMYT-Harare to CIMMYT-Nairobi and subjected to successive selfing under artificial infestation with *E. turcicum*. Currently the combining ability of 30 S5-S6 lines is being studied to identify the best for development of hybrids and synthetics. Fifty-four three-way cross (TWC) hybrids involving CML 78, CML 444 testers, and the converted CML 202 IR and CML 204 IR are being evaluated for resistance to herbicide, *E. turcicum,* and for adaptation in Western Kenya. Also, conversion to IR of one *Striga* tolerant and *E. turcicum* resistant synthetic was initiated and is now at the level of second backcross (BC2).

The second approach began with the conversion of three elite CIMMYT maize lines adapted to the region (CML 202, and CML 204) to IR by CIMMYT's Applied Biotechnology Center in Mexico. These were received by CIMMYT-Kenya in September, 2000, and used in the following activities:

- Formation of hybrids for multi-location and on-farm testing; 12 single-cross and top-cross hybrids were formed and evaluated across 25 sites including 4 in West Africa, and 2 single cross hybrids were tested on-farm with farmers in 78 *Striga* hot-spots in Western Kenya.
- Conversion of the best adapted CMLs to IR using the converted lines as sources of resistance; 10 lines are now at the BC2F1 level.
- Conversion of the best stress tolerant OPVs to IR; 25 *Striga* tolerant and drought and low N stress tolerant OPVs, as well as 1 adapted QPM variety and 4 lowland materials (all with MSV resistance) are now at the BC1F1 level of conversion.
- Development of new IR lines; in the CML conversion process, 804 new IR lines were developed and are currently at the S3 level.

The large breeding effort of Phase II and data from the multi-location evaluations and on-farm testing of single cross and top-cross hybrids during 2002 culminated in nomination of five hybrids bearing the IR-gene to the national performance trials (NPT) in 2003, the release procedure in Kenya, and use with the refinements of the seed coating technologies. These materials have the same genetic background, hardness, color and are within 4 days of the maturity period of the most popular local hybrid, H513, of the target region.

IR-Maize On-Farm Testing

This effort has demonstrated that the delivery of imazapyr on the IR maize seed as a coating can provide highly efficient and season-long control of *Striga* emergence. Indeed the evidence indicates that herbicide delivered in this manner acts at the time of *Striga* attachment to the maize root and so prevents the exertion of the phytotoxicity effect of *Striga* on the maize plant, damage to the host that usually occurs even before emergence of the *Striga* from the soil. The approach combines low doses (ca. 30 grams per hectare) of imazapyr, a systemic acetolactate synthase-inhibiting herbicide as a seed coating with IR maize seed. The treatment leaves a field virtually clear of emerging *Striga* stalks up to harvest, and allows intercropping with legumes as long as the legume is interplanted between the maize rows at least 12 cm from the treated maize seed. Since the maize seed is treated, there is no added cost of the spraying equipment and no possibility of off-target application. The herbicide is compatible with commonly used fungicide/insecticide seed dressings, and is applied with them. With effective *Striga* control, the potential for returns on inputs such as fertilizers and other pest control products is greatly improved. When herbicide is delivered in small quantities as a seed treatment, this technology can provide African farmers with an affordable, cost-effective solution for *Striga* control as well as improve the potential for returns on other inputs such as fertilizers and other pest control products.

On Farm Technology Evaluation

Over 188 farmers have participated in testing the material and assisting us in its evaluation. They and their neighbors have provided the feedback necessary for us, the seed companies, herbicide producers, and the regulators, indicating that the products are ready for bulking and commercial scale evaluation in areas where *Striga* infestation is most severe—areas where yields are more than doubled when this technology is used (Table 28).

Table 28. Effect of imazapyr on *Striga* emergence and grain yield in 78 on-trials in western Kenya, long rains 2002.

Entry	Imazapyr rate (g ha^{-1})	*Striga* emergence (m^{-2})* Weeks after planting					Grain yield* (kg ha^{-1})
		6	8	10	12	Average	
H513	0	1.45 a	8.6 a	25.3 a	50.4 a	21.4 a	1,493 a
Nyamula	0	1.1 a	5.4 b	16.5 b	36.7 b	14.9 b	1,907 b
IR-single cross-1	30	0.0 b	0.3 c	2.0 c	4.1 c	1.6 c	3,247 c
IR-single cross-2	30	0.0 b	0.3 c	2.8 c	5.1 c	2.1 c	3,571 c
	LSD	0.4 N=78	2.0 N=78	5.5 N=78	9.5 N=78	4.0 N=78	349 N=68

* Means followed by a same letter do not differ significantly

Socio-economic studies with participating farmers and their neighbors show that IR-maize has an untapped potential market in Kenya, and similar potential is expected in other African countries where *Striga* is a pest. Farmer participatory trials conducted during Phase II clearly demonstrated that the IR-maize herbicide seed coating technology gives season-long *Striga* control, reduces the *Striga* seed bank in the soil, increases maize yields by more than four-fold (Figure 13) at an additional cost of less than $ 4 per hectare. It is compatible with small-scale cropping systems practiced by African farmers, and has a large potential for commercialization. Work is needed to broaden the socioeconomic data and enlarge sample sizes to obtain more precise estimates of crop losses, the geographic distribution of those losses, and farmers' willingness to pay for the technology. This in turn will provide a proper idea of potential markets and possible impact.

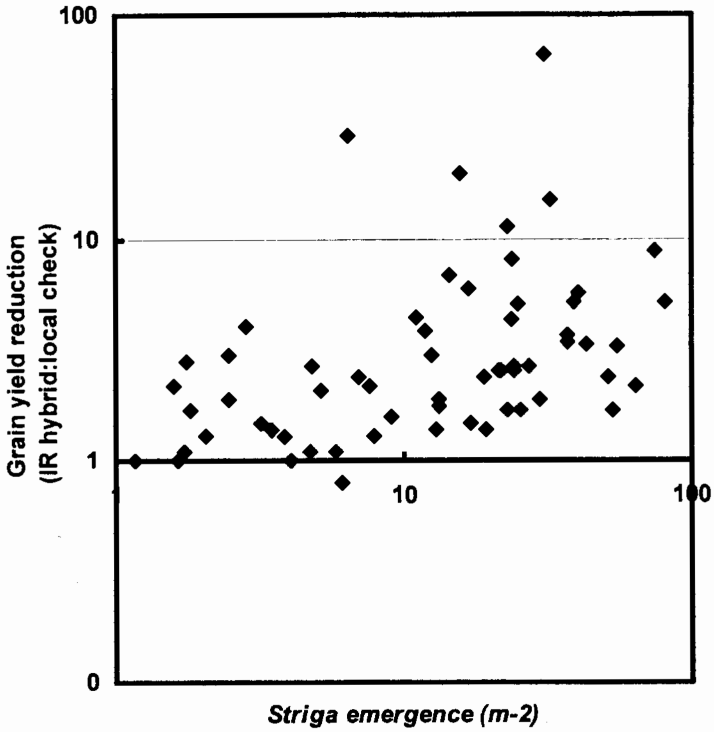

Figure 13. Yield increments with two CIMMYT adapted IR varieties (averaged) compared to the local hybrid (H513) and landrace (averaged), as a function of Striga infestation with > 70 farmers participating farms in western Kenya. Even with low infestations, most farmers reported significantly higher yields. IR/local check (landrace and H513, averaged) infested 10 weeks after planting. Yield increments above the colored band are economically and statistically significant.

Having successfully developed and demonstrated the effectiveness of the technology in midaltitude areas of western Kenya, with limited testing for both *S. hermonthica* and *S. asiatica* in southern Africa), CIMMYT, BASF, and local seed producers would like to complete development of the technology and help local seed companies make it available to farmers. This would involve: (1) widespread testing and farmer participatory evaluations of IR-maize seed coating technology together with seed companies and other collaborators; and (2) with seed companies, BASF, and other partners, developing various deployment strategies for the seed coating.

Potential Assessment of Seed-Coating to Control *Striga*

Striga has been a cropping constraint in Kenya for over 50 years and adds to poverty. Data from a *Striga* survey in the Vihiga and Siaya Districts of western Kenya were used to establish the potential usefulness of herbicide-coated maize seed, across three clusters of farmers whose fields had low, moderate, and heavy *Striga* infestations. Results show *Striga* is still a problem and included figures on *Striga* coverage. Current control measures include use of inorganic and organic fertilizers, hand weeding and pulling of *Striga,* and fallowing. Hand pulling, late fallow, and hand weeding were associated with decreased incidence of *Striga*, while non-use of fertilizers, lack of cash, and no hand pulling before flowering were associated with an increase in the *Striga* incidence. Nine-tenths of the farmers interviewed expressed their willingness to try herbicide-coated seed and pay an extra cost to have *Striga* controlled.

Coating seed with herbicide is a near-term strategy. In the long term, breeders will be expected to come up with *Striga* resistant varieties. What is worth noting is that *Striga* is gradually creeping into the high potential areas of Kenya.

Economic Analysis of Herbicide Coated Maize to Combat *Striga*

The results show that the herbicide is very efficient in suppressing *Striga*, even at the early stages, with 0 and 30 g/ha of seed coating giving about 1.0 and more than 3.5 t/ha, respectively. Under the conditions of the trial, the technology is therefore highly profitable. Partial budget analysis calculates the benefits and costs that differ between treatments (Table 29). The value of the maize yield was $ 193/t, costs of herbicide $ 4/ha, and fertilizer application $ 70 and $ 112/ha (for the respective doses). Use of the herbicide results in high increases of net benefits per ha, even without fertilizer: from $ 190 to $ 703 (a gain of $ 613) on-farm, and from $ 26 to $ 236 on-station. On-farm, the herbicide without fertilizer is therefore the most profitable treatment. On-station, it is profitable to use the herbicide in combination with the lower fertilizer application (30 kg of N, 77 kg of P), since it increases net profits from $ 236 to $ 410/ha. The use of fertilizers without herbicide is never profitable: their cost is higher than their benefit.

Further analysis using production function estimation, marginal and sensitivity analysis, confirmed the high profitability of the new technology. *Striga* infestation leads to substantial reductions in maize yields, in particular the *Striga* appearing earlier in the season, so control methods need to work on the *Striga* plants that are emerging early. Coating of maize seeds with imazapyr clearly showed the ability to suppress *Striga* emergence, even at the early stages. This result is confirmed in the production function analysis, where the herbicide showed a much larger increase in the yields than the use of fertilizer. The economic analysis showed that the use of fertilizer, even on-station, is not profitable at current prices when *Striga* is not controlled. Moreover, the economically optimal level of fertilizer use needs careful consideration. Increasing fertilizer levels even after suppressing *Striga* does not always improve yields. This means that optimal fertilizer rates for different sites should be determined first and used with imazapyr as an integrated management practice that improves both yields and net returns.

Table 29. Partial budget analysis for herbicide seed coating control of *Striga* and use of fertilizer.

Herbicide rate		No herbicide			With herbicide (30 g/ha)		
Fertilizer rates (kg/ha)		0	30N, 77P	60N, 77P	0	30N, 77P	60N, 77P
Average yield (kg/ha)	On-farm	985	1,200	1,644	3,663	3,761	3,575
	On-station	137	495	459	1,246	2,507	2,236
Gross field benefits	On-farm	1,901	232	317	707	726	690
	On-station	26	96	89	240	484	432
Cost of herbicide ($/ha)		0	0	0	4	4	4
Cost of fertilizer ($/ha)		0	66.2	104.7	0.0	66.2	104.7
Cost of labor, fertilizer ($/ha)		0	3.9	7.8	0	3.9	7.8
Total costs that vary ($/ha)		0.0	70.1	112.5	4.0	74.1	116.5
Net benefits	On-farm	190.1	161.5	204.8	703.0	651.7	573.5
	On-station	26.4	25.4	-23.9	236.5	409.7	315.0

Slow Release Herbicide Seed Coat Formulations

This is approach calls for the development of slow release formulations and fine-tuned agronomic recommendations for enhanced *Striga* resistance management. Slow release formulations were initiated to overcome two shortcomings of the present IR-maize seed treatment systems: (1) the rapid movement of the herbicide away from the seed in water, necessitating higher rates of herbicides; (2) the presence of late germinating *Striga*, which in 12-14 week maturing maize will not flower, but may set seed in 16-20 week maize. Initial ionically bound slow release formulations have been tested providing sufficient information for a provisional patent application. More work will be needed to perfect the technology by synthesizing a variety of covalently and statically electro-bound herbicide to a variety of substrates for field comparisons to ascertain the best, cost-effective method of providing slow release formulations. Beyond overcoming the above shortcomings of the present technology, slow release formulations will have additional benefits: less herbicide means fewer environmental problems; slow herbicide release can delay evolution of herbicide resistance if done correctly; IP protection affording better control over technology stewardship; spin-offs to licensing/royalties from the use of the technology especially in the developed world where it could have uses beyond seed coating for *Striga* control.

Seeds have been considered as carriers for herbicides, but were not been used extensively until the advent of mutant or transgenic crops with high levels of resistance to the herbicide. The first generation CIMMYT-bred germplasm for use with this technology is being released to seed companies. Our recent research indicates that the dressings used represent an inefficient use of herbicides, despite the excellent successes in the field. In soil column experiments, the herbicides, imazapyr and pyrithiobac, move more rapidly through the soil profile than maize roots grow through the same profile. Thus, much of the herbicide is lost, allowing the parasites to attack late in the season when crop roots grow into soil devoid of herbicide, due to rapid leaching. As the herbicide moves systemically through the crop roots, there is reason to have it slowly available throughout the season in a smaller volume of soil, with the herbicide cycling through the maize plants, and exuded from young roots, killing remaining *Striga*. If less herbicide can be used, there is less potential for leaching of unused herbicide into ground water. Two formulations of imazapyr and pyrithiobac were synthesized where the matrices had different affinities for the herbicides, and one was potentially easily biodegradable. These were mixed 1:1 with free herbicide so that the coating would have half the herbicide immediately available and the rest released over time. These formulations were applied to CIMMYT IR-maize in Kenya using PVP as the sticking agent. Preliminary experiments with imazapyr and pyrithiobac indicate that the formulation CE52 and DX1 had similar effects, both when used with free imazapyr and when used alone. They were as good as the herbicides used alone; that is, no activity was lost by having all or half of the herbicide present in the slow release formulation.

Product Stewardship

This seed-coating technology for *Striga* control, along with new, locally adapted, herbicide-resistant, open pollinated and hybrid maize varieties, was described by CIMMYT and partners in a meeting at Kisumu, Kenya, 2002, attended by seed and chemical companies and pesticide and seed variety regulators from eastern and southern African. Participants visited two experiment stations and farmers' fields in heavily infested areas of western Kenya. Delegates who had been unconvinced after the first day of presentations were largely convinced when they saw the practical results of the seed-coating technology. Huge differences between the treated and non-treated plots were seen at the Kibos experiment station, the first stop of the tour. In farmers' fields, *Striga*-infested plots were almost totally devastated, whereas stands of IR-maize treated with herbicide were clean.

CIMMYT and Rockefeller Foundation staff believe that IR maize seed should be industrially coated prior to making it available to farmers (1) to avoid farmers treating non-IR maize varieties with herbicide and inadvertently killing the seed, and (2) to facilitate monitoring of fields to best understand farmer needs, obtain feedback, and monitor available resistance strategies and their outcomes.

Local seed companies need assistance in taking the varieties and the technologies through the release and registration procedures. Talks are under way between key players to assess intellectual property rights issues, discuss licensing fees, and identify potential markets. The CIMMYT IPR counsel is in negotiations with BASF and will advise on issues related to criteria of selection of seed companies and proper arrangements (exclusivity, royalties, licensing etc). Four companies—Lagrotech, Western, Kenya Seed (Kenya), and Harvest Farm Seed (Uganda)—have indicated their interest. All work with small-scale farmers, have distribution networks where *Striga* is endemic, and—with the exception of Kenya Seed Company—are relatively small.

Integrated Management for *Striga*, Stem Borers and Soil Fertility

During 2002 CIMMYT, ICIPE, TSBF, KARI, and the Ministries of Agriculture of Uganda and Tanzania developed a 2.5-year project to address the problems of *Striga*, stem borers. and soil fertility in the Lake Victoria basin. Sites in each country (Vihiga and Siaya, Kenya; Busia, Uganda; Ukiriguru, Tanzania) were chosen to represent different agro-ecological, social, economic and biotic constraints. Informal diagnostic surveys using participatory methods were conducted to rank the production constraints maize farmers face, to ascertain farmers' knowledge about those constraints, and to learn about farmers' coping strategies. We are also conducting PRAs in Kenya, Tanzania, and Uganda to understand the problems and indigenous coping strategies for managing *Striga*, stem borers and soil fertility.

We have begun synthesizing information on interactions between pest and soil fertility management, with a special focus on stem borers and *Striga*, and identification of a range of potential soil management options. By the first cropping season of 2003, Best-Bet IPSFM strategies for the suppression of stem borers and *Striga* and improved soil fertility management, including "push-pull', herbicide-resistant and stress-resistant maize will be identified, adapted, and tested in farmer-participatory trials, taking into account the overall biophysical and socio-economic factors that influence farmers' decisions.

Increasing Food Security and Improving Livelihoods

During 2002, in collaboration with the Silsoe Research Institute and Ministry of Agriculture and Food Security, Tanzania, CIMMYT devised a 2.5-year project to reduce the impact of pests on poor peoples' crops and to improve the quality and yields of maize-based systems in the lowlands of northern Tanzania. Maize yields in the region average less than 500 kg, compared with a potential of 3-4 t/ha, due to low soil fertility, drought, foliar diseases, stem borer, and weeds (including *Striga),* among other constraints. On-station trials have indicated that yields can be increased significantly through use of stress tolerant OPVs and hybrids, along with incorporation of leguminous crops. Beginning in December 2002, project partners have worked with local communities, sharing local and scientific knowledge in designing farmer-managed trials that will address local constraints. These will be monitored over two years, providing opportunities to use the trials in promoting further adoption. The project will address the non-availability of inputs, linking with input suppliers and promoting community-based seed production. Regular stakeholder meetings, development of suitable extension material, and journal publications are planned, as part of promotion for project outputs.

Participants have also clarified the roles of partner organizations, consolidated local scientific knowledge, and held a series of community workshops aimed at mobilizing local farmers. These workshops confirmed that most people derive their livelihoods from crop production, with maize being the most important crop for both food security and cash income. Maize production constraints were prioritized, with *Striga*, low soil fertility, stem borer, and lack of improved seed being key concerns. Local coping strategies were identified and agreement reached to building on these in on-farm trials. Full community participation and ownership of farmer implemented and managed trials will be initiated in late March or early April 2003, dependent on the onset of rains. On-station trials using CIMMYT supplied maize varieties will be undertaken for testing under local conditions.

Enhancing the Nutritional Quality of Maize Cultivars in Eastern and Southern Africa

Duncan Kirubi (Coordinator)

Introduction

Normal maize is the principal staple food, dominating the diets of rural and urban populations in eastern and southern Africa. It often provides well over 50% of staple calories in most countries and as high as 80% in Malawi. In some countries maize is a primary weaning food for babies, putting them at risk of malnutrition and poor growth and development, because normal maize is deficient in two essential amino acids namely, lysine and tryptophan. Demand for maize as animal feed is also rising in the region.

During the last few decades, CIMMYT scientists have developed quality protein maize (QPM), which looks and tastes like normal maize and has similar yield and agronomic performance but whose grain contains 50-100% more lysine and tryptophan than normal maize, significantly increasing the nutritional quality of its protein. Given the large area and the number of farmers involved in maize production, the development and adoption of QPM has a significant potential to elevate incomes and help eastern and southern Africa attain self-sufficiency in maize and meat products. Developing QPM versions of locally adapted, widely used maize cultivars might speed the spread of QPM, bringing its nutritional benefits to those who most need them.

Goal, Objectives, Outputs, and Activities

The project aims to improve the nutrition, food security, and incomes of families in eastern and southern Africa by developing and deploying QPM versions of popular maize cultivars. Objectives comprise the following:

- Develop QPM versions of at least 10 eastern and southern African maize varieties.
- Train at least 10 scientists from eastern and southern Africa on various aspects of QPM breeding and associated technologies (e.g. use of Marker Assisted Selection).
- Identify at least 4 communities who will grow and use QPM varieties through projects with government extension services, NGO's or other partners.

Activities in 2002

Maize germplasm to be converted was identified in consultation with staff in the respective maize improvement programs in Kenya, Tanzania, Mozambique, CIMMYT-Zimbabwe, and CIMMYT-Kenya (Table 30). The conversion protocol was discussed with partners. Donor lines of the *opaque-2* gene were sourced from CIMMYT-Mexico and sent to NARS collaborators in Kenya and Tanzania. F_1 crosses between the normal germplasm (OPVs and lines) and the QPM donors were successfully made at Kitale, Kibos and Kiboko in Kenya and SARI in Tanzania during the short rains season in 2002 (Tables 31-34).

The F_1 crosses will be advanced to F_2 progeny in the main season in 2003. Selection for modifiers in F_2 progeny will be carried out before seed is sent to the project coordinator for planting in Kenya. Leaf samples will be collected and sent to the biotechnology facility at KARI, Kenya, for DNA extraction and identification of plants with homozygous recessive *opaque-2* alleles. The BC1 generation will be formed by the project coordinator using results from the laboratory, and BC1F1 seed will be sent to the national program scientists to continue the breeding process.

Table 30. Popular maize varieties being converted to QPM and countries participating in the QPM conversion project.

Entry #	Material	Origin	Remarks
1	Kakamega Pool A	Kenya	OPV
2	Kakamega Pool B	Kenya	OPV
3	Tuxpeno C_1	Kenya	Exotic OPV adapted to Kakamega
4	Kitale Synthetic II ($R_{11}C_{10}$)	Kenya	OPV
5	Ecuador 573 ($R_{12}C_{10}$)	Kenya	OPV
6	Inbred line A	Kenya	Line from Kitale II
7	Inbred line F	Kenya	Line from Kitale II
8	Inbred line 82	Kenya	Line from Ecuador 573
9	Inbred line 93	Kenya	Line from Ecuador 573
10	UCA	Tanzania	OPV
11	Staha-MSV	Tanzania	OPV
12	POP 105	Tanzania	OPV
13	Kilima ST	Tanzania	OPV
14	TMV1	Tanzania	OPV
15	Matuba	Mozambique	DMR-SR – OPV
16	P501-SRC0-F2 (BAL. BULK	CIMMYT-Zimbabwe	Heterotic Group A
17	P502-SRC0-F2 (BAL. BULK)	CIMMYT- Zimbabwe	Heterotic Group B
18	99SADVLA-#	CIMMYT – Zimbabwe	Heterotic Group A
19	ECAVL-2	CIMMYT - Kenya	Drought and Low N tolerant Mid-A

Table 31. List of germplasm from RRC- Kakamega, Kenya, and *Opaque-2* donor lines used in conversion.

Entry #	Germplasm	*Opaque-2* donor line
1	Kakamega Pool A	CML 144
2	Kakamega Pool A	CML 185
3	Kakamega Pool B	CML 154
4	Kakamega Pool B	CML 176
5	Kakamega Pool B	CML 153
6	Kakamega Pool B	(CML 384 X CML 176 (F3)98-2-1-2
7	Tuxpeno C1	CML 159
8	Tuxpeno C1	CML 144
9	Tuxpeno C1	CML 185

Table 32. Germplasm from CIMMYT-Kenya and CIMMYT–Zimbabwe and *Opaque-2* donor lines used in the conversion.

Entry #	Germplasm	*Opaque-2* donor line
1	ECAVL2	CML 173
2	ECAVL2	CML 152
3	ECAVL2	CML 144
4	P501-SRC0-F2 (BAL. BULK)	CML 153
5	P501-SRC0-F2 (BAL. BULK)	CML 159
6	P501-SRC0-F2 (BAL. BULK)	CML 150
7	P502-SRC0-F2 (BAL. BULK)	(CML 384 x CML 176)(F3) 4-1-1-2
8	P502-SRC0-F2 (BAL. BULK)	(CML 384 x CML 176)(F3) 11-6-3-1
9	P502-SRC0-F2 (BAL. BULK)	(CML 384 x CML 176)(F3) 98-2-1-2
10	P502-SRC0-F2 (BAL. BULK)	(CML 384 x (CML 384 x CML 176)(F3) 135-2-2-2
11	P502-SRC0-F2 (BAL. BULK)	(CML 384 x (CML 384 x CML 176)(F3) 147-1-5-1
12	SADVLA	CML 176
13	SADVLA	CML 144
14	SADVLA	CML 154

Table 33. Germplasm from NARC Kitale, Kenya and *Opaque-2* donors lines used in the conversion.

Entry #	Germplasm	*Opaque-2* donor line
1	Kitale Synthetic II ($R_{11}C_{10}$)/CML 159	CML 159
2	Kitale Synthetic II ($R_{11}C_{10}$)/CML 175	CML 175
3	Kitale Synthetic II ($R_{11}C_{10}$)/CML 185	CML 185
4	Inbred line A	CML 159
5	Inbred line A	CML 175
6	Inbred line A	CML 185
7	Inbred line F	CML 159
8	Inbred line F	CML 175
9	Inbred line F	CML 185
10	Ecuador 573 ($R_{12}C_{10}$)	CML 144
11	Ecuador 573 ($R_{12}C_{10}$)	CML 176
12	Ecuador 573 ($R_{12}C_{10}$)	CML 186
13	Inbred line 82	CML 144
14	Inbred line 82	CML 176
15	Inbred line 82	CML 186
16	Inbred line 93	CML 144
17	Inbred line 93	CML 176
18	Inbred line 93	CML 186

Table 34. Germplasm from SARI, Tanzania and *Opaque-2* donors lines used in the conversion.

Entry #	Germplasm	*Opaque-2* donor line
1	UCA	CML 173
2	UCA	CML 144
3	UCA	CML 142
4	UCA	CML 150
5	POP 105	CML 159
6	POP 105	CML 144
7	POP 105	CML 142
8	POP 105	CML 173
9	Staha	CML 144
10	Staha	CML 153
11	Staha	CML 150
12	Staha	CML 142
13	TMV1	CML 186
14	TMV1	CML 144
15	TMV1	CML 173
16	TMV1	CML 142
17	Kilima	CML 159
18	Kilima	CML 144
19	Kilima	CML 173
20	Kilima	CML 150
21	Kito	CML 186
22	Kito	CML 159
23	Kito	CML 150
24	Kito	CML 144

CIMMYT Staff in Kenya

Internationally Recruited Staff

Alpha Diallo-Principal Scientist is a maize breeder, project coordinator for Africa Maize Stress (AMS), and National Liaison Officer and for CIMMYT-Kenya and Team Leader, East Africa. His work focuses on developing maize varieties suitable for East Africa, especially with built-in tolerance to stresses such as drought, low-nitrogen, stem borers, *Striga*, and quality protein maize.

Dennis Friesen is a soil scientist and the CIMMYT/IFDC Regional Maize Systems Agronomist for eastern and central Africa. He coordinates the maize activities of the Eastern Africa Cereals Program (EACP). Within AMS Project, he is responsible for the development, evaluation and dissemination of agronomic practices that enhance the productivity of stress adapted maize germplasm including integrated management of inorganic and organic nutrients in maize-based cropping systems, soil moisture conservation technologies for maize cropping systems in dry areas.

Hugo de Groote is an agricultural economist with the Insect Resistant Maize for Africa (IRMA) project, who's work focuses on farmer participatory research, economic analysis of the maize sector and the technology transfer. He also assists the Africa Maize Stress (AMS) Project, *Striga* and other projects in participatory methods and economic analysis.

Fred Kanampiu is an agronomist with the Engineering Maize for *Striga* Resistance Project, who's work focus on devise, plan and conduct strategic on-station and on-farm research focused on control of *Striga* species through herbicide applications to herbicide-resistant maize, collaborate with NARS scientists in Zimbabwe, Malawi, Ethiopia and Tanzania to evaluate and adapt *Striga* control methods to other AEZs and develop and implement deployment strategies for herbicide-resistant maize technologies for *Striga* control. He also assists in managing resources and facilitating CIMMYT research activities in western Kenya.

Stephen Mugo is a maize breeder and coordinator of the Insect Resistant Maize for Africa (IRMA) project. His work focuses on the development of germplasm for use in combining *Bt*-gene based maize stem borer insect resistance as well as project management. He also assists the Africa Maize Stress (AMS) Project in development of germplasm and technologies for tolerance to drought and low nitrogen, and the Engineering Maize for *Striga* Resistance Project.

Duncan Kirubi is a maize breeder with Quality Protein Maize Project, who joined CIMMYT-Kenya from headquarters in July 2002.

Wilfred Mwangi is Principal Scientist, Economist, but currently on leave of absence.

Nationally Recruited Staff

Alfred Imbai, Accounts Clerk

Carolyne Adhiambo, Skilled Labourer

Ebby Irungu, Administrative Assistant

Haron Mwangi Ndiritu, Driver

Isaac Mutabai, Principal Driver

Joseph Kasango, Research Technician

Linda Alondo-Ackel, Administrative Secretary

Muthoka Mailu, Field Technician

Peter Okoth Mbogo, Field/Lab Technician

Vincent Eget, Skilled Labourer

KARI Staff on Joint Appointment with CIMMYT

Archbold Mwashumbe, Technical Assistant, KARI Mtwapa

Fred Manyara, Technical Officer, KARI Embu

Grace Ambajo, Technical Assistant, KARI Mtwapa

Jacob Guteta, Technical Assistant, KARI Embu

Paul Mmtoni, Field/Computer Technician, KARI Katumani

Wilson Muasya, Technical Officer, KARI Katumani

Partners

ACD/VOCA-FOSEM Project, Kampala, Uganda

Adet Agricultural Research Center (EARO), Adet, Ethiopia

African Biotechnology Stakeholders' Forum (ABSF), Nairobi, Kenya

Agricultural Development Center/IDEA, Kampala, Uganda

Agricultural Research Corporation (ARC), Wad Medani, Sudan

Agricultural Research Institute (ARI) – Mlingano, Tanga, Tanzania

Agricultural Research Institute-Ilonga, Kilosa, Tanzania

Alupe Agricultural Research Sub-Center, Kenya Agricultural Research Institute (KARI), Busia, Kenya

Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), Entebbe, Uganda

Aventis Crops Science, Nairobi, Kenya

Awassa Agricultural Research Center (EARO), Awassa, Ethiopia

Bako Agricultural Research Center, Ethiopian Agricultural Research Organization (EARO), West Shoa, Ethiopia

Biotechnology Trust Africa (*BT*A), Nairobi, Kenya

CARE-Kenya, Homa Bay, Kenya

Catholic Diocese of Homa Bay, Homa Bay, Kenya

Catholic Relief Services, Nairobi, Kenya

Central Bureau of Statistics, Ministry of Finance, Nairobi, Kenya

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Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia

Faida Seeds Company, Nakuru, Kenya

IFPRI, Washington DC (USA)

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Institut des Sciences Agronomiques du Rwanda (ISAR), Butare, Rwanda

Institut National pour l'Etude et de la Recherche Agronomiques (INERA), Kinshasa, D.R.Congo

International Centre of Insect Physiology and Ecology (ICIPE), Nairobi, Kenya

International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Nairobi, Kenya

International Fertilizer Development Center (IFDC), Muscle Shoals, Alabama, USA

International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria

International Service for the Acquisition of Agribiotechnology Applications (ISAAA) Africentre, Nairobi, Kenya

Jimma Agricultural Research Institute (EARO), Jimma, Ethiopia

Jomo Kenyatta University of Agriculture and Technology (JKUAT), Nairobi, Kenya

Kakamega Regional Research Centre, Kenya Agricultural Research Institute (KARI), Kakamega, Kenya

Katumani National Dry Land Research Centre, Kenya Agricultural Research Institute (KARI), Katumani, Kenya

Kenya Agricultural Research Institute (KARI), Headquarters, Kenya

Kenya Industrial Property Office (KIPO), Nairobi, Kenya

Kenya Plant Health Inspectorate Service (KEPHIS), Kitale, Kenya

Kenya Plant Health Inspectorate Service (KEPHIS), Nairobi, Kenya

Kenya Seed Company, Kitale, Kenya

Kenya Sugar Research Foundation (KESREF), Kibos, Kenya

Kiboko National Range Research Centre, Kenya Agricultural Research Institute (KARI), Makindu, Kenya

Kitale National Agricultural Research Centre, Kenya Agricultural Research Institute (KARI), Kitale, Kenya

Kulumsa Research Center, Ethiopian Agricultural Research Organization (EARO), Addis Ababa, Ethiopia

Lagrotech Consultants, Agribusiness Development Support Project (ADSP) Company, Kisumu, Kenya

Makerere University, Kampala, Uganda

Maseno University, Maseno, Kenya

Melkasa Agricultural Research Center (EARO), Nazreth, Ethiopia

Ministry of Agriculture and Rural Development, Nairobi, Kenya

Ministry of Agriculture and Rural Development, Nyanza Province, Kenya

Monsanto Kenya Limited, Nairobi, Kenya

Mtwapa Regional Research Centre, Kenya Agricultural Research Institute (KARI), Mtwapa, Kenya

Muguga National Agricultural Research Centre, Kenya Agricultural Research Institute (KARI), Mtwapa, Kenya

Namulonge Agriculutral Research Institute (NARI), National Agricultural Research Institute (NARO), Uganda

National Council for Science Technology (NCST), Nairobi, Kenya

Njoro National Breeding Research Centre, Kenya Agricultural Research Institute (KARI), Njoro, Kenya

Perkerra Regional Research Centre, Kenya Agricultural Research Institute (KARI), Marigat, Kenya

Pioneer Seed Company, Nairobi, Kenya

Royal Tropical Institute, Bamako (Mali)

SCODP, Sega, Kenya

Selian Agricultural Research Institute, Arusha, Tanzania

The Agriculture Program, Texas A & M University System, Texas, USA

Tropical Pesticides Research Institute (TPRI), Arusha, Tanzania

Tropical Soil Biology and Fertility Programme (TSBF), Nairobi, Kenya

University of Florida (USA)

University of Nairobi, Nairobi, Kenya

University of Sussex (UK)

University of Wageningen

Weizmann Institute of Science, Rehovot, Israel

Western Seed Company, Kitale, Kenya

Winrock International

Yale University (USA)